ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING FRAMEWORK FOR THE ATTITUDINAL CHANGE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES

By

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

Construction workers are constantly faced with several hazards due to the nature of their work environment. Head traumas and eye injuries on construction sites are of great concern to industry stakeholders in the efforts to improve health and safety performance of the construction industry. Like most PPE, Safety helmets and goggles are a statutory requirement in most countries to protect the head and face regions which are the most vulnerable in the event of an accident. Safety helmets protect the head against the impact of lateral objects or the impact of falling objects on construction sites. Similarly, safety goggles protect the eyes and the face region from severe injury from flying particles and or other hazards encountered during construction work when used appropriately. Despite their importance, construction workers are reluctant to use safety helmets and goggles due to several discomforts experienced and thus are continuously faced with exposure to several hazards at the workplace. While using these PPE may prevent injury and or fatalities on the construction site, providing workers with poor fitting PPE may introduce other forms of strain that may contribute to avoidable incidents on site. This research employed a combination of adaptive selection and behavioural conditioning principles to remedy the discomforts associated with safety helmets and goggles to improve their use on construction sites. A preliminary investigation was initially conducted through the personal administration of questionnaires to one hundred and twenty-three (123) construction operatives to find out why construction workers do not use given PPE. Data for the main study was obtained through semi-structured interviews and a physiological strain field experiment (using physiological indicators of heart rates and body temperatures) involving sixteen (16) male construction workers, a comparative analysis of linear anthropometric head and face measurements of one hundred and twenty-seven (127) male construction workers and dimensions of construction helmets and goggles available in Ghana within a multiple case study. A questionnaire survey of seventy – four (74) large construction firms in the country was also conducted to identify selection considerations made in the procurement of helmets and goggles. A content analysis on interviewee data indicated that hotness and poor fit are the top two discomforts associated with safety helmets while blurred vision and poor fit are prevalent among safety goggle users. Workers were found to experience little or no physiological strain while using uncomfortable safety helmets in hot weather, when values of physiological indicators were entered into a physiological strain equation and interpreted on a universal scale. A two-sampled T-Test indicated statistically significant differences between helmet and head dimensions, as well as safety goggles and face measurements. Descriptive analysis of the likert data indicated that construction firms consider several factors aimed at ensuring the procurement of comfortable safety helmets and goggles. The study recommends a behaviour-based framework with a three – tier intervention plan, that combines a selection criteria consisting of anthropometric characteristics, ambient temperature, consideration of standards (aimed at improving the comfort experience of users), with activities such as user-involvement in the procurement process, safety inductions with audio-visuals, participatory toolbox meetings and selection of safety champions to stimulate the preferred behaviour of appropriate use of the PPEs. The conditioning theory is then applied in Tier three of the framework to maintain the acceptable behaviour. The proposed framework is intended to ensure the procurement of comfortable safety helmets and goggles for construction work and simultaneously improve the attitude of workers towards these PPE.

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DEDICATION

As iron sharpens iron, so one person sharpens another. (Proverbs 27:17, NIV).

This thesis is dedicated to my husband

David Adade-Boateng,

Throughout the years, you have done nothing but to ensure that I am sharpened,

and

My children,

David Ivan, Enoch, Jeremy and Jaden.

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Now unto Him who can do exceedingly, abundantly above what we ask for, according to his power that is at work within us, be all the praise and all the honour and all the glory forever.

LIST OF PUBLICATIONS

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Adade-Boateng, A.O., Fugar, F.D.K., and Adinyira, E., (2017). Investigating Physiological Strain as a result of Safety Helmet Use and Exposure to Ambient Heat on Construction Sites. In Proceedings of Joint CIB W099 and TG59 International Safety, Health, and People in Construction Conference held in Salvador, Brazil, August 1st - 3rd 2018, pp. 249-256.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background to the Study

According to the International Labour Organisation's (ILO) global estimates, occupational injuries account for about 14% of work-related mortality (Hämäläinen et al., 2017). It is estimated that more than 7,500 people die daily, and of this figure, 1,000 deaths occur as a result of occupational accidents (Hämäläinen et al., 2017). Statistics from the World Health Organisation (WHO) indicate that 20-50% of employees worldwide are faced with several hazards at their workplaces, with significant proportions of the figures emanating from developing and newly industrialized countries (El-Menyar et al., 2016). The continual increase in occupational accident statistics across the globe is a cause of grave concern.

According to the ILO, 380,500 fatal occupational accidents were recorded in 2014, an increase of 8% compared to 2010. Non-fatal occupational accidents also increased significantly from an estimated 314 million in 2010 to 374 million in 2014 (Hämäläinen et al., 2017).

The impact of occupational accidents is felt by the individuals, their families and the society at large. Apart from the loss of lives and injuries to persons which may sometimes result in permanent disabilities or debilitating conditions (Ceylan 2012; Lingard, 2013), the economic impact of occupational accidents cannot be overestimated. About £15million was spent on work related injury and ill health by Britain in 2016/2017 alone (HSE, 2018). According to Smith (2016), data from the World Monetary Fund suggests that "the annual cost to U.S. businesses of lost-time workplace injuries is greater than the gross domestic product (GDP) of 91 countries". The economic costs of work-related illness and injury have been shown in several studies to be equivalent to a range of 1.8% to 6% of GDP (Takala et al., 2012; ElMenyar et al., 2016).

Available literature indicates that the construction industry is one of the most significant contributors to global GDP. The industry is responsible for about 10% and 17% of the United Kingdom and Japan's GDP respectively while in many developing countries, it falls among the fastest growing areas of the labour market, continuing to provide a traditional entry point for labourers (ILO, 2015). Despite its contribution to global economies, the industry is classified amongst the most hazardous occupations (Varacallo and Knoblauch, 2019).

Construction workers are faced with a wide variety of hazards at the workplace including contact with harmful chemicals, the risk of electrocution, risk of being struck by equipment, and the risk of falls from heights. Even more worrying is the frequent increase in accident statistics considering that several efforts are continually being made to improve this narrative.

The ILO reported in 2005 that the industry was responsible for a staggering 25 - 40% of common occupational accidents. Ten years down the line, about 108 thousand construction workers (representing 30% of fatal occupational injuries) are killed on-site annually, with many others dying later because exposure to hazardous substances (ILO, 2015).

The construction industry recorded sixty-five thousand (65,000) self-reported workplace injuries and thirty-five (35) fatal accidents, between 2014 and 2015 in the United Kingdom (UK). In 2014, the construction industry's "fatal four" (falls, electrocution, struck by an object, caught-in/between objects) also accounted for 18.7% of all occupational fatalities recorded in the United States, the highest recorded since 2008 (BLS, 2015).

Even though many developing countries do not have reliable information on their occupational accidents due to a lack of proper recording and notification systems resulting in under-reporting of accident frequencies, statistics available serve as standard for occupational safety work (Hamalainen et al., 2017; 2006). In Malaysia alone, construction accidents increased in frequency by 55.7 per cent between 1993 and 2014, with an increase in fatality rate by 74% within the same period (Hamid et al., 2019). Between 2004 and 2010, the mining, metal and construction industry were accountable for 46.4% of occupational accidents and 41.1% of resulting fatalities in Turkey (Ceylan, 2012). Tadesse and Dagnachew (2016), also report that accidents are more prevalent in the Ethiopian construction industry than other industries within the country and the construction industry recorded an injury rate of 38.3%.

Among the several accidents that occur on construction sites, head injury is one of the severest (Li et al., 2017). Head injuries occur through a sudden blow to the head, a terrible fall from a ladder, or a scaffolding accident. These can result in traumatic brain injuries (TBIs) and death. TBI damages the brain and causes it to malfunction and depending on the severity, TBI can cause death or have debilitating effect in the form of residual cognitive impairment, emotional disturbances, and behavioural changes (Daughton, 1990), on the

individual for the rest of that person's life.

Unfortunately, the construction industry is reported to have the highest TBIs when compared with other industries in some countries. Tiesman et al. (2011) report that the construction industry had the highest number of traumatic brain injuries in the United States (US). Also in 2016, the National Institute for Occupational Safety and Health (NIOSH) reported that among US industries, the construction industry had the highest number of both fatal and nonfatal traumatic brain injuries.

Apart from injuries to the head, eye injuries are widespread at the workplace, and construction workers are not exempted from this canker. Over 2,000 workers in the US injure their eyes at work every day, and one-third of this number are treated in hospital emergency departments (CDC.gov, 2013). Most eye injuries occur as a result of small particles such as dust, cement or wood chips, and metal slivers striking, scraping or even penetrating the eye. Workers may also sustain eye injuries when they are struck in the eye or face causing trauma to the eyeball or socket. In addition, workers may sustain thermal or industrial chemical burns that can damage the eyes and their surrounding tissues (CDC.gov, 2013). Traumatic eye injuries are often the major cause of unilateral blindness across the globe, particularly in developing countries (Cheng and Li, 2016). The rate of blindness due to eye trauma in developed countries is about 9/100,000 while for developing countries, it is about 75/100,000 (Cheng and Li, 2016).

Eye injuries are notoriously popular in the construction industry, accounting for 20% of statistics (Welch et al., 2010). Even though eye injuries are very common, studies show that they are preventable with the proper use of eye protection (Welch et al., 2010).

Efforts to make the workplace safe requires a continual review of the work environment and work practices to control or prevent accidents due to existing hazards, and many such interventions have been suggested to mitigate the inherent risks on construction site. The hierarchy of controls is widely accepted as an effective means of ensuring employee safety at the workplace. It outlines five significant steps to ensure that work is done in a safer manner, namely, elimination of the hazard, substitution of the hazard, the use of engineering controls, administrative practices and personal protective equipment (PPE) use.

The system is based on the premise that protecting an employee's safety requires controlling his/her exposure to measurable risks in the form of exposure sources or harmful factors that cause accidents. At the topmost point of the hierarchy is the elimination of the risk of accident.

Eliminating an identified risk is widely accepted as the most effective means of safety protection. This involves removing the risk, so the employee does not interact with it or substituting it with another that is less harmful. In practice, it may not be possible to eliminate or substitute a risk except at the project inception stage; otherwise any attempt at this would require significant equipment and procedural change to function correctly.

Employers may also resort to the use of engineering controls to mitigate the risk of accidents occurring. This process involves introducing a barrier between the hazard and the employee i to prevent or minimise direct contact. Another method of risk mitigation involves the use of administrative controls. This involves separating persons from harmful factors either by utilising special working methods or by separation in time or space. Examples of administrative control tools are reduced exposure time, preventive maintenance programmes, and expedient organisation of work.

The use of PPE is indicated at the bottom of the pyramid as a final option in occupational risk mitigation. Examples of standard PPE used in the construction industry are safety helmets, safety goggles, high visibility jackets, hand gloves, among others. Even though the options higher up the pyramid are preferred to PPE use and are often described as more effective, it is practically impossible for them to afford complete protection to the employee in instances such as exposure to corrosive material that may harm the skin, exposure to harmful gases that may be inhaled, the risk of falling objects hitting the head, the risk of lateral impact to the head from equipment and even the risk of flying particles hurting the eyes just to mention a few.

Extant literature, for example, shows that safety helmets are useful in reducing the risk of traumatic brain injuries and fatalities resulting from impact to the head from flying or falling objects. Research indicates that safety helmets are essential in preventing intracranial injury occurring from work-related fall within a 4m height and calls for the development of safer helmets and regulations for its appropriate use as a risk-mitigating strategy against fall-related head injuries at the workplace (Kim et al., 2016). According to OSHA, thousands of people go blind each year because of work-related eye injuries that could have been prevented with the proper selection and use of appropriate eye and face protection (Asmatulu et al, 2014).

The injury statistics presented is an indication that irrespective of any measure that is taken on-site to mitigate risks, the use of PPE is imperative to protect or minimise the effects of direct physical contact between construction workers and unavoidable hazards that exist on the site.

1.2 Problem Statement and Justification

Despite the importance of Personal Protective Equipment to employee safety, several studies have indicated a persistent negative attitude by construction workers to comply with PPE protocols (Laryea, 2010; Tanko and Anigbobu, 2012). This matter is of great concern to industry players and the world at large due to the enormous social and economic impact of construction accidents.

The construction industry is notorious for high incidences of head injuries (Tiesman et al., 2011) as well as eye injuries (Welch et al., 2020). Research indicates that head and eye injuries are amongst the severest of construction accidents (Li et al., 2017). This assertion is in support of Jeong's (1998) assertion that the head and face area are usually more vulnerable to severe injury in the event of an occupational accident. The construction industry is noted for extremely high cases of traumatic brain injuries that result from impact to the head area (Tiesman et al., 2011). According to Laryea (2010), there are instances where construction workers must be compelled to use given PPE, meanwhile, the lack of use of PPE often results in needless injuries and fatalities on construction sites. Yilmaz (2014) identified the second most common cause of construction accidents, (i.e. 12%) in the Turkish construction industry, as the lack of use of PPE by site workers. In a preliminary investigation conducted to identify reasons for the lack of use of given PPE on Ghanaian construction sites, construction workers indicated their refusal to use these PPE was due to the several discomforts they experienced with them (Adade-Boateng et al., 2016). Safety helmets and goggles have been found effective in protecting against head and eye injuries, however typical discomforts that discourage workers from using them include build-up, poor fit and interruption of work (Lombardi et al., 2009; Ueno and Sawada, 2019).

Although several modifications have been proposed to improve the user experience with safety helmets and goggles, construction workers maintain that these PPE are uncomfortable and do not use them as required. Research indicates that people are more likely to use a clothing item when it is comfortable (Li, 2001). As such, McPherson (2008) proposes that the selection of personal protective equipment should satisfy comfort, fit and style requirements of users to encourage its use. Even though construction workers perform unsafe acts by not using safety helmets and goggles, an unsafe condition is also created when workers have to endure constant discomfort with their use while attending to their tasks, and both situations (i.e. unsafe acts and conditions) provide an enabling environment for the occurrence of an accident with resultant injuries to workers.

Construction workers are highly susceptible to traumatic brain injuries (TBIs), eye injuries and even fatalities due to the nature of hazards encountered in their work environments, and safety helmets and goggles are very essential equipment that are needed to protect workers against some of these occurrences. Safety helmets and goggles are particularly important for construction workers in the study location because Tanko and Anigbobu (2012), purport that personal protective equipment is often the only available mitigation strategy against occupational accidents in Africa and many other developing areas.

The study realises it is essential that an appropriate strategy is used to ensure total compliance with the use of safety helmets and goggles to protect construction workers from the risk of head and eye injury on site. However, it is not known if the selection and procurement procedures of safety equipment for construction workers make sufficient considerations that would ensure a user-friendly experience for safety helmets and goggles users Ghana. Again, it is not known if construction workers in Ghana experience physiological strain as a result of the consistent use of uncomfortable helmets or goggles.

This study investigates discomforts associated with the use of safety helmets and goggles within the Ghanaian construction industry and to identify relevant considerations and strategies that would improve the use of these PPE on construction sites through answering the under listed research questions;

1.2.1 Research Questions

1. What discomforts do construction workers experience in the use of safety helmets and goggles?
2. What accounts for the discomforts experienced by construction workers in the use of safety helmets and goggles?
3. What considerations are made in the selection and procurement of Construction safety helmets and goggles?
4. How can the user-experience of construction workers regarding safety helmets and goggles use be enhanced?

1.3 Research Aim

The aim of this study is to develop a framework for enhancing construction workers' experience with the use of safety helmets and goggles through the combination of behavioural conditioning and a comprehensive selection and procurement process that considers their anthropometric characteristics and physical environment.

1.3.1 Research Objectives

To achieve the stated aim, the study addressed the following objectives:

1. To identify discomforts that construction workers experience in using safety helmets and goggles.
2. To identify the factors that account for the discomforts that construction workers experience in using safety helmets and goggles.
3. To examine considerations that are made in the selection and procurement of construction safety helmets and goggles.
4. To develop and validate a framework for the procurement of safety helmets and goggles that enhance the user-experience of construction workers.

1.4 Scope and Limitations of the Study

This study focuses on the Ghanaian construction industry, although lessons are drawn from construction industries in other countries. The research delved into issues of discomfort associated with only safety helmet and goggles use on construction sites, and considerations made by construction companies in the procurement of same. Findings are limited to the procurement and use of construction safety helmets and goggles only, focusing on improving the user-experience of workers and an improvement in their attitudes towards safety helmet and goggle use. These two PPE were selected because the head and face region are the most susceptible to injury in the event of an accident (Jeong, 1998) and workers in the construction industry are highly susceptible to both eye and traumatic brain injuries.

The field experiment aspect of the study was limited to three cases in the southern part of Ghana, due to the concentration of construction workers in this part of the country. Participants for the field study comprised of sixteen male workers who work in the warm humid region of the country.

Data for the field experiment was taken over 5 days. This duration was the limit provided by the construction firms as they could not afford for work to be continually interrupted. It is unknown if different results may be acquired if the test is performed on workers in the hotdry climatic region or within a longer duration of study.

Additionally, although core body temperatures (oral or anal temperatures) are preferred for physiological strain tests, it is intrusive, expensive and impractical to take readings such as oral, oesophageal, intestinal and rectal temperatures, on a construction site. Body temperature readings were taken by way of a non-intrusive and comparatively economical method with the use of non-contact infra-red thermometers.

Finally, the information presented in this study was obtained from adult males only. This was not deliberate as women were not encountered in the data collection.

1.5 Summary of Contribution to Knowledge

Research conducted into minimising discomforts associated with the use of safety helmets and goggles have often targeted an improvement in the design and manufacture of these safety equipment to improve comfort and the use of these safety equipment. However, despite of the modifications made over time, construction workers continue to experience discomforts with their use. This study addressed the issue of discomforts with safety helmets and goggles by targeting an improved procurement process of these PPE through an adaptive selection process that actively involves users and considers their physical characteristics as well as the weather conditions in their physical environment. The improved procurement process, coupled with scheduled activities (based on the Operant Conditioning Theory, The Social Cognitive Theory and Behaviour Based Safety) aimed at improving the safety behaviour of construction workers is presented in a framework to improve the attitude of construction workers towards safety helmets and goggles to improve its acceptance and use on the site.

The successes achieved in the testing of the behaviour-based safety (BBS) Intervention framework is an indication that BBS intervention processes are successful in improving safety helmet and goggles use within the construction industry and supports research that BBS can be applied to improve the performance of the construction industry.

Literature available on physiological strain with reference to helmets are often obtained from laboratory experiments, however, this study presents physiological strain results from a field experiment obtained from workers in their natural environment. According to results obtained, in spite of the discomfort claims by construction workers, workers experience little or no physiological strain while they use uncomfortable helmets in hot weather. That notwithstanding, the study contributes to knowledge, a procedure for improving the attitude of construction workers towards safety helmets and goggles through the consideration of the three dimensions of comfort, i.e. physical, physiological and psychological factors.

The study has contributed to the industry by identifying that, the incorporation of relevant comfort concerns, specific to Ghanaian, and perhaps West African indigenes, such as anthropometric features and weather conditions within the proposed BBS framework will aid as a practical guide in the procurement of more comfortable safety helmets and goggles and simultaneously improve the attitude of workers towards them, resulting in improved safety behaviour and use of these PPE. It is hoped that safety helmets and goggles procured using the framework, will address the comfort concerns of construction workers resulting in users being more comfortable with their use.

1.6 Dissemination of Research Findings

Findings from this research were disseminated to academia through doctoral workshop papers, conference papers and peer-reviewed journal papers. In industry, the research findings were disseminated to practitioners during the process of validating the framework.

1.7 Organization of the Thesis

Chapter one (1) represents an introduction to the study. It includes research background, problem statement, theoretical and empirical justification and the importance of the study to knowledge and industry.

Both Chapter Two (2) and Chapter Three (3) consist of a literature review of the health and safety performance of the construction industry, with a focus on the research objectives. Existing literature on the use of safety helmets and goggles, construction site procurement practices and comfort factors for clothing use are contained in the review.

Chapter Four (4) describes and justifies the methods used in obtaining solutions for the research problem. A preliminary investigation preceding the study identified the main reasons for non-use of PPE amongst 123 construction workers. This investigation was conducted through a questionnaire survey presented to construction operatives. Subsequently, the results of the preliminary study led to the use of;

- Semi-structured interviews to elaborate on discomforts felt by workers with helmet and goggles use,
- An anthropometric study of heads and face regions of 127 construction workers, and an open market survey to obtain dimensions of helmets and goggles in the country.
- A field experiment to investigate physiological strain with helmet users with the help of body temperatures and heart rates of users
- A questionnaire survey was also conducted amongst construction firms to identify considerations made in the procurement of safety helmets and goggles.

The chapter also describes the ethical considerations made in obtaining data for this study.

Chapter Five (5) contains a presentation of valid findings obtained from an analysis of data from both the survey and case studies. A content analysis was applied to data obtained from the semi-structured interviews to identify critical discomforts associated with both helmets and goggle use. Data obtained from the anthropometric study was compared to helmets and safety goggles on the market through a two-sample T-test at a 95% confidence interval. Measurements obtained from participants of the field experiment were tested in a physiological strain equation and results translated from a universal scale. Survey results were taken through a descriptive analysis to identify the primary considerations made by construction firms in the procurement of safety helmets and goggles.

Chapter Six (6) contains a discussion of the findings with respect to the literature review and proposes a framework for the procurement of safety helmets and goggles that considers the physical characteristics of users, includes them in the procurement process and also suggests ways of ensuring their effective use. Chapter Seven (7) presents a report on the validation process of the proposed framework including suggestions for its improvement.

Chapter Eight (8) consists of the conclusion of the study and recommendations for further studies. The study's contribution to the industry and the body of knowledge is also indicated in this chapter.

The Appendix contains relevant supplementary data arising from the study.

1.8 Chapter Summary

The construction industry is notorious for a high prevalence of occupational accidents, injuries and illnesses. Many of these incidents involve impact to the head and the face region, resulting in irreparable damage to victims in some cases. The use of safety helmets and goggles is an important way of mitigating the risk of such injuries and illnesses to workers; however, safety helmet and goggle use can be impaired by discomfort experienced by workers, hence the need to delve into issues around their use by construction workers to improve their use. Results of data obtained in this study have culminated in the design of a framework that is aimed at improving the attitude of construction workers towards the use of safety helmets and goggles through a consideration of physical, physiological and psychological factors.

This chapter has presented the background leading to the aim, objectives and questions addressed by this study. The chapter has also presented the research scope and limitations and well as the main contributions made to knowledge. The next chapter presents a review of literature on the nature of the construction industry and the status of health and safety performance in the industry

CHAPTER TWO

LITERATURE REVIEW-THE NATURE OF THE CONSTRUCTION INDUSTRY

2.1 The Nature of the Construction Industry

Many studies have highlighted the significant contribution of the construction industry to both global and national economic development (Khan, 2008; Ofori, 2012; Oladinrin et al., 2012; Myers, 2013; ILO, 2015). The industry employs millions of skilled and unskilled human resources, contributing significantly to employment, household income and economic growth (Mosenogi, 2014).

The importance of the construction industry is unique regardless of whether the country is underdeveloped, developing or developed. The industry makes significant contributions to Gross Domestic Product, Gross National Income and Gross Fixed Capital Formation. According to Ofori (2012), apart from construction entities being capable of enticing foreign investments into the country, buildings produced by the industry form the arteries that enable goods and services to be distributed within and outside the country enhancing the efficiency of productive activities thus stirring economic activity within the country. The provision of shelters by the industry fulfils one of the basic human needs of protection from physical elements. The industry further stimulates the other sectors through reliance on their materials for production (Ofori, 2012). It is evident that the role played by the industry in national development cannot be over emphasized.

In the urbanization process, the construction industry provides a traditional entry point into the labour market for migrant workers from the rural areas in many countries. For example, within the period of rapid urbanization in Brazil between 1960 and 1980, about 30million people migrated into urban areas, where over 90% of these migrants got employed in construction. Similar occurrences were identified in India and China. (ILO, 2001). In Africa, able young people in search of greener pastures usually secure jobs in construction upon migration from the rural areas into urban towns. Construction is usually a good choice for people with little or no skill. For young people in Ghana, construction projects such as ‘lowcost housing’ projects create an ideal entry point into the industry as these dwellings tend to be built by artisans (Darko and Lowe, 2016). The construction industry has been described as able to “absorb the excluded”. Many people would usually be employed as unskilled workers and may learn some specialized skills with time on the job.

The industry played a similar role in the developed economies, drawing on labour in likewise manner in their urbanization process also. When the employment pools in the rural areas dried up, international migrants from countries far or near filled up the positions required. The countries of the Arabian Gulf and the United Arab Emirates are particularly important countries in the search for construction work by international migrants due to their small populations and big oil-financed construction programs (ILO, 2001). The Republic of Korea, Malaysia, Brazil and China also recorded rapid increase in employment within the construction sector during the urbanization period.

2.2 Construction Industries in Developing Countries

The construction industry in developing countries is dominated by small and medium sized firms, which operate mainly within the domestic market. Construction contributes five to ten percent of gross domestic product (GDP) in all countries, employs about 10 percent of the working population, and accounts for about half of the gross fixed capital formation (Lopes, 2012). The industry contributes 35% of the total gross domestic fixed investment and employs up to 240,000 people in South Africa (Mthalane et al, 2008). Despite its continual significant contributions to economic development, the construction industry in developing countries continues to face several challenges just like their counterparts in developed countries. However, the construction industry in developing countries deal with their challenges amidst a general situation of socio-economic stress, chronic resource shortages, institutional weaknesses and a general inability to deal with the key issues and these problems have increased in extent and severity in recent years (Ofori, 2000).

Ofori, (2012), however, identifies the sporadic development of the construction industry in local areas as a means of alleviating poverty in the country and encourages the need to integrate issues regarding sustainability into the construction industry practice.

2.3 The Ghanaian Construction Industry

The construction industry of Ghana is an important element of the national economy (Laryea, 2010) and is promoted largely by the Ghanaian government, as in many countries (Eyiah and Cook, 2003; Kheni et al., 2006). The construction industry in Ghana is dominated by physical infrastructure and asset-based-lending as a means for growth and development (Songwe, 2014). The industry's contribution to GDP increased steadily from 8.8% in 2009 to 11.8% in 2013 (GSS, 2014) and employs nearly 10% of the working population. Construction activity contributed US$3.8bn to GDP in 2014 at current prices, according to the Ghana Statistical Service. The Ministry of Water Resources, Works and Housing responsible for the housing infrastructure and construction throughout the country, classifies building contractors into four groupings, namely D1K1, D2K2, D3K3, and D4K4. These classifications are based on the contract sum limit of projects they can undertake. Projects worth up to $75,000 are awarded to D4K4 construction firms, projects ranging from $75,000-250,000 to D3K43 firms and projects worth $250,000-500,000 to D2K2. D1K1 construction firms are awarded projects over $500,000.

According to Kheni et al., (2006), the Ghanaian construction industry is dominated by small local businesses that hardly employ more than two hundred and fifty workers, hence most of the companies in Ghana fall under D4K4 and D3K4 classification (Oxford Business Group, 2014). The Chartered Institute of Building in Ghana estimates that there are over 1,600 building contractors working in Ghana since October 2012 (Oxford Business Group, 2014)

2.4 Health and Safety Performance of the Construction Industry

Health can be defined as "the protection of the bodies and minds of people from illness resulting from materials, processes or procedures used in the workplace" (Hughes and Ferrett, 2008). The authors define safety also as "the protection of people from physical injury" (Hughes and Ferret, 2008). The terms health and safety (H&S) are commonly used together in research and Occupational health and safety can be defined as protecting people from illnesses and injuries (i.e. harm) triggered by work-related conditions or activities (HSE, 2003).

The health and safety (H&S) performance of an entity entails compliance with H&S standards, procedures, policies, goals and or regulations as well as participation in H&S programmes or initiatives. It is determined by knowledge, skills and motivation of an individual (Griffin & Neal, 2001).

Workers' health and safety is constantly at risk either due to conditions within and outside of their workplace or their inability to recognize and handle the risks.

Construction workers typically encounter the risk of physical (e.g. noise, radiation, heat, cold, inadequate lighting, lack of oxygen, etc.), physiological (e.g. heavy loads, bad work postures or repetitive work) and psychological exposures (e.g. work in isolation, threat of violence, changing working hours, unusual job demands, etc.), making them highly susceptible to accidents in their workplaces.

In 2014, United States recorded that the construction industry's "fatal four" (falls, electrocution, struck by an object, caught-in/between objects) accounted for 18.7% percent of all occupational fatalities recorded, the highest recorded since 2008 (BLS, 2015). The UK construction industry consistently records high injury rates. In 2018, the industry recorded 30 fatal injuries occurring largely as a result of falls from a height and impact from being struck by objects (HSE, 2019).

In Singapore, the construction industry appears to have a similar record. Although the construction sector in 2005 contributed less than 10% to the gross domestic product it accounted for more than 37% of all industrial accidents (Teo et al., 2005).

Just like other developing countries, the Ghanaian construction industry has a poor health and safety performance record (Laryea, 2010). Accident statistics obtained from the National Labour Department indicated that the number of construction industry accidents recorded in Ghana increased from 8 to 28 in 2004 to 2009, an increase of 250 per cent over a period of 5 years (Akomah et al, 2010).

Although China has the highest world records of work-related fatalities, high accident fatality figures are also seen in the other places such as Asia and Sub-Saharan Africa. The regions where fewest people are killed at work are the Established Market Economies, the Former Socialist Economies and the Middle Eastern Crescent (Pearson, 2009).

It is often difficult to obtain approximate statistics from developing countries, due to poor accident reporting systems. Figures obtained are however used as a basis for discussions and indicate that developing countries comparably have a poor health and safety record (Kheni et al, 2006, Hämäläinen et al, 2006, 2017). It is estimated that construction workers in developing countries are more prone occupational fatality than their counterparts in developed countries. According to data available to the ILO, construction workers in developed countries are 3 to 4 times more likely to be killed at work compared to workers in other industries, however, this risk ranges between 3 to 6 times higher for those working in developing countries (ILO, 2015).

The poor safety performance of developing countries, which accounts for high risks found therein have been attributed to several reasons. While some studies blame a low use of labour-intensive methods, low workforce participation and technology in issues of health and safety (Kheni et al, 2006), others attribute this phenomenon to political instability and financial crises in some countries (El Kholt et al, 2018). In his study of the Ghanaian construction industry, the poor enforcement of policies and procedures on health and safety, and the absence of stringent institutional framework for the governance of construction activities were identifies by Laryea (2010) as the reasons for the poor state of the existing health and safety on the

Ghanaian construction industry. Other contributors to the industry's poor H&S performance include a lack of effective mechanism to implement laws (Cotton et al, 2005) and a lack of concerted effort by policy makers to address H&S issues (Kheni et al, 2007).

2.5 Causes of accidents in the construction industry

The question of why accidents happen is very important to Health and Safety researchers, as the process of answering this question helps in the design of models and theories to predict and prevent their occurrence.

Many theories of accident causation have evolved that attempt to explain the occurrence of accidents. The ensuing discussion will focus on some major theories of accident causation.

2.5.1 Heinrich's Domino theory of accident causation

Heinrich (1931), an early pioneer in accident causation theories and industrial safety, purports in his classical study, that industrial accidents are a result of an unfortunate conjunction of a human error and a chance event. Heinrich (1931) indicates from his study of 75,000 industrial accident reports that 88 percent of all accidents are associated with human error, 10 percent with unsafe conditions and the remaining 2 percent are attributable to 'Acts of God'.

Heinrich (1931), defines accident as 'an unplanned and uncontrolled event in which the action or reaction of an object, substance, person, or radiation results in personal injury or the probability thereof '(Abdelhamid and Everett, 2000).

Heinrich, formulated in ten statements, facts he felt should be known to health and safety decision makers, in what is usually referred to as Axioms of industrial safety outlined below:

1. Injuries occur as a result of a complete series of factors, including the accident itself.
2. Accidents occur purely as a result of an unsafe act by a person and/or a physical or mechanical hazard.
3. Most accidents occur as a result of unsafe behaviour by people.
4. An unsafe act by a person or an unsafe condition does not always result in immediate accidents or injury.
5. The reasons behind people committing unsafe acts serve as helpful guides in the selection of corrective actions.
6. Accidents are largely preventable, and their severity is largely fortuitous.

7. The best accident prevention techniques are comparable to the best quality and productivity techniques.
8. Management should assume responsibility for safety because it is in the best position to get results.
9. The supervisor is the key person in the prevention of industrial accidents.
10. In addition to the direct costs of an accident (for example, compensation, liability claims, medical costs, and hospital expenses), there are also hidden or indirect costs.

According to Heinrich (1931), an accident prevention programme that encompasses all the axioms was more likely to be effective than one which does not. He established the 'Domino theory' which is based on five sequential factors as cited in (Taylor et al, 2004)

i. Ancestry and social environment; this refers to the processes of acquiring knowledge of customs and skills in the workplace. Lack of skills and knowledge of performing tasks, inappropriate social and environmental conditions will lead to fault of person. ii. Fault of person/Carelessness; these are undesirable features of a person's personality, some of which may even be acquired. Carelessness results in unsafe act or creates unsafe conditions. iii. Unsafe act and /or mechanical or physical condition; accident –causing mistakes or technical errors.

iv. Accident; accidents are caused by dangerous acts and can lead to injuries.
v. Injury; injuries occur as a result of accidents.

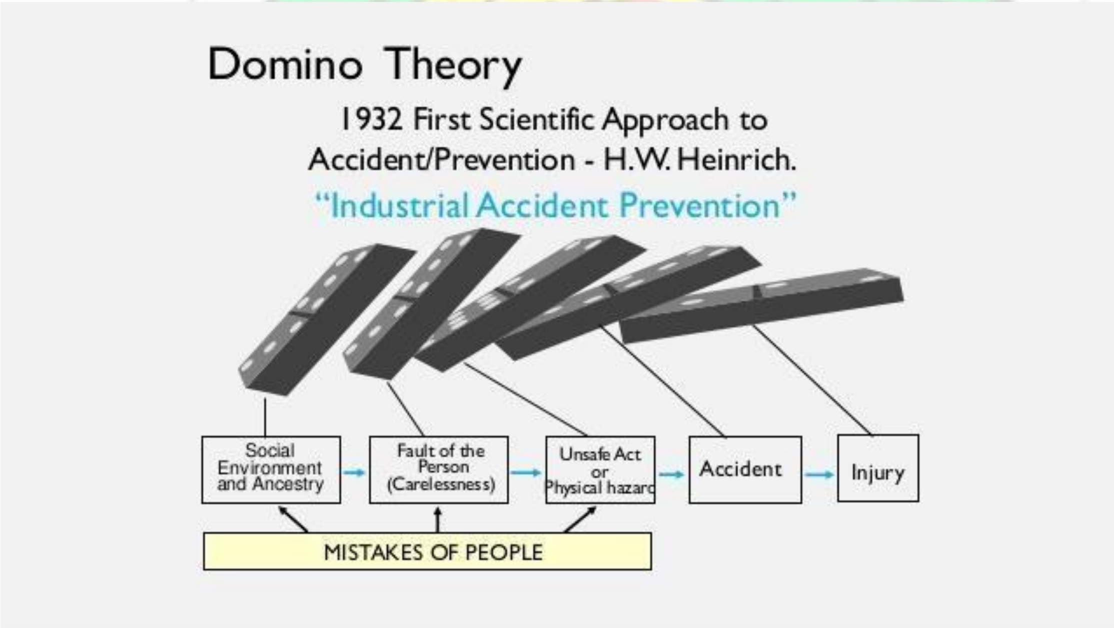


Figure 2.1: Heinrich's Domino Theory (Adeniran, 2017)

Heinrich's domino theory comprises of five standing dominos which will fall concurrently if the first domino (Ancestry and social environment) falls. According to the theory, accidents can only be avoided when the sequence chain is broken. For example
to prevent accidents and related injuries the hazardous act /condition can be removed (Seyyed and Zahra, 2012).

Heinrich's efforts on accident causation theory can be summed up into two points, People (Human), who are the main causes of accidents and Management which has the responsibility of preventing the accidents (having the power and authority) (Jhamb and Jhamb, 2003).

2.5.2 Management Based Theories

Even though Heinrich's Domino theory has been severely criticized for its simplistic nature and seeming over-reliance on the human component of accident causation, his axioms of industrial safety serve as the basis for many other studies and theories on accident causation particularly management-based theories or Updated Domino theories which places the blame on management for accidents. Management based theories attempt to identify failures within the management systems as causes of accidents (Hosseinian and Torghabeh, 2012). Two types of management based theories exist, namely Domino based theories, for example; Bird's Updated domino sequence, the Adams updated sequence and the Weaver updated dominoes Other management-based theories which are not domino-based are the Stair step model by Douglas and Crowe and the Petersen's multiple causation model (Hosseinian and Torghabeh, 2012).

2.5.3 Weaver updated dominoes

Weaver's theory of accident causation was based on the Domino theory. According to Weaver, the third, fourth and fifth dominoes in Henriech's theory represented a grave misgiving or critical error on the part of management. He reasoned that it was necessary to investigate what and how much safety knowledge management members had and why unsafe acts are ignored until the occurrence of an accident. Weaver purported that answers to these questions would help to eliminate underlying operational errors that facilitate the occurrence of accidents.

2.5.4 Bird's Updated domino sequence Theory

The updated Domino sequence theory reviewed the dominoes in Henreich's theory to reflect the role of management in the accident causation process. The reviewed dominoes/sequence of events are;

i. Lack of control/management (inadequate program, inadequate program standard, inadequate compliance to standard) ii. Basic causes/origins (basic causes: 1-personal factors, 2-job factors) iii. Immediate causes/Symptoms (sub-standard act and condition) iv. Incident (contact with energy and substance)

v. Loss (property, people, process) (Hosseinian and Torghabeh, 2012)

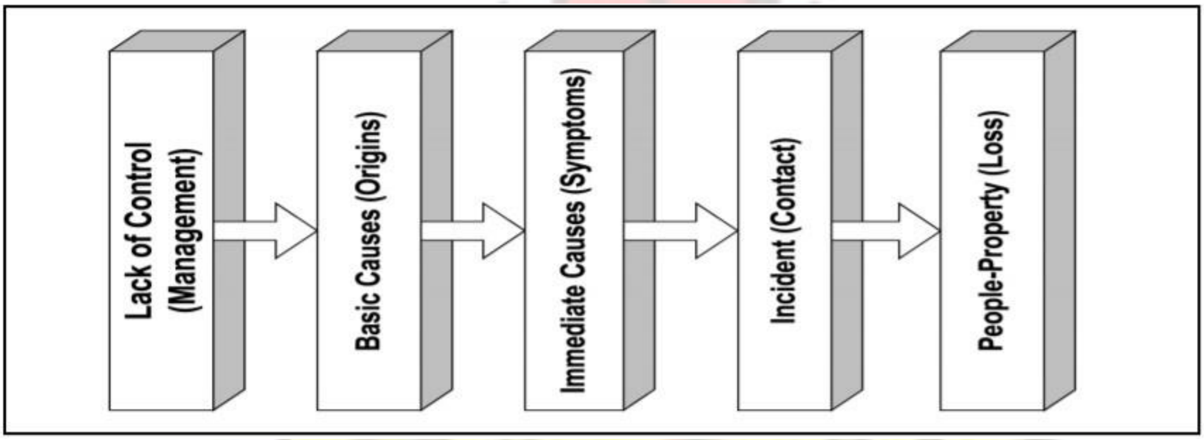


Figure 2.2: The Updated Domino Sequence Theory
Source: (Hosseinian and Torghabeh, 2012)

2.5.5 Peterson's Multiple Causation Theory

Peterson developed the Multiple Causation Model (Figure 2.3) on the basis that accidents occur as a result of unsafe acts and unsafe conditions. He believed that several factors give rise to both unsafe acts and conditions, resulting in accidents and the effects thereof. According to Peterson, identifying and dealing with the factors that give rise to the unsafe acts and conditions is the way to go in eliminating accidents.

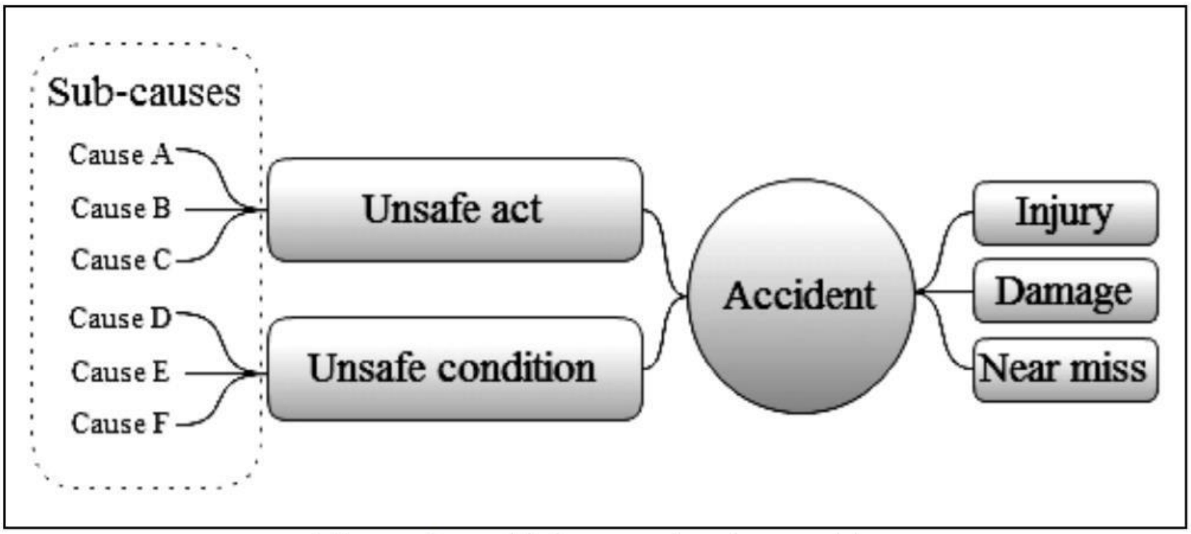


Figure 2.3: Multiple Causation Model (Hosseinian and Torghabeh, 2012)

2.5.6 Behaviour Models of Accident Causation

These models were based on the theory of Accident Proneness (Hosseinian and Torghabeh, 2012), which was coined by psychological workers in 1926 (Froggatt and Smiley, 1964) to suggest that some people, by virtue of their peculiar characteristics are more likely to experience accidents than others even though exposed to the same risk (Hosseinian and Torghabeh, 2012). Behaviour models blame human acts for the accidents that occur. Examples of behaviour models of accident causation are the 'Goals freedom alertness theory' and the 'Motivation reward satisfaction model'.

2.5.7 Goals freedom alertness theory

The 'Goals freedom alertness theory' purports that a psychologically pleasant work environment will result in higher alertness in workers leading to higher quality of work and an accident-free work environment (Hosseinian and Torghabeh, 2012). Attributes of a psychologically pleasant work environment includes, the involvement of workers in setting goals and allowing innovation in the achievement of goals, and the availability of encouragement to spur workers on when they have achieved set targets (Hosseinian and Torghabeh, 2012).

2.5.8 Ferrel Theory

According to the Ferrel theory (1997), accidents occur when there is a mismatch between a person's physical environment and his mental capabilities. This results in feelings of anxiety, pressure and fatigue. Subsequently, this person exhibits wrong responses leading to improper activity (unsafe acts) and finally accidents. Figure 2.4 below illustrates the Ferrel theory.

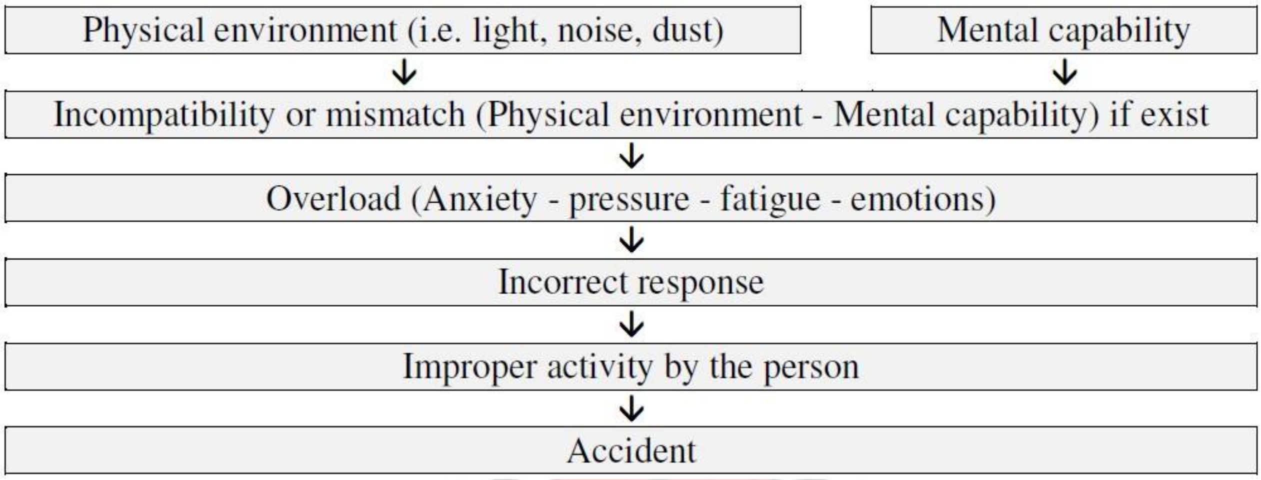


Figure 2.4: The Ferrel Theory of Accident Causation, (Hosseinian and Torghabeh, 2012).

2.5.9 The Accident Root Causes Tracing Model (ARCTM) (Abdelhamid and Everett, 2000)

The various accident causation theories indicate unsafe acts and or conditions are the immediate causes of accidents in workplaces. However, these unsafe acts and conditions often have underlying causes or triggers initiated by the actions or inactions of both employees and management. The ARCTM basically identifies and classifies causes of accidents into causal factors and root causes. Causal factors are the group of factors that contribute to an accident (thus unsafe acts and conditions). Root causes are however the underlying factors that give rise to the causal factors, thereby resulting in accidents. It is possible to reduce the severity or frequency of accidents when causal factors are identified and dealt with. However, dealing with the root causes results in total elimination of the accident and the protection of life and property from construction accidents.

2.6 Managing Workplace Safety

Workplace safety is usually managed by government institutions across the globe. The National Institute for Occupational Safety and Health (NIOSH) of the United States, the Health and Safety Executive (HSE) of the United Kingdom and the Department of Occupational Safety and Health (DOSH) of Malaysia are examples of statutory authorities that regulate health and safety at the workplace to reduce occupational injuries, diseases and fatalities. These institutions ensure workplace safety through the provision of advice, information and guidance, operating permissioning and licensing activities, and the enforcement of Acts (HSE, n.d).

Health and Safety Acts are legislation passed by parliament that set out broad legal or policy principles to protect the health, safety and welfare of all workers at work as well as other people who may be affected by the work. Some popular Health and Safety Acts include the Health and Safety at Work Act 1974 of the United Kingdom (UK), The Occupational Safety and Health Act of 1970 of the United States (US) and the Work Health and Safety Act (WHS) 2011 of the Australian government. In Ghana, the regulation of occupational health and safety falls under the auspices of the Factories , Offices and Shops Act 1970, PART XV of the Labour Act, 2003 (ACT 651) and the Workmen's Compensation Law, 1987 (PNDC LAW 187).

Regulations are that which determine how the provisions of the Act should be applied, they can also be described as the implementation details of the Act. Regulations are legally enforceable when they have been published in the government's gazette. Health and safety regulations are mandatory and require employers to maintain a safe working environment. The Health and Safety at Work Act 1974 of the United Kingdom has several regulations emanating from it, however, the six-pack regulations, were framed together in 2003 due to their relevance to a majority of workplaces irrespective of the industry. These regulations also cover everyday issues that would usually be experienced at work.

According to the Health and Safety Executive of Britain, a safety policy, demonstrates a company's commitment to workplace health and safety. Safety policy documents spell out clearly how a company intends to go about protecting the safety of employees, and usually indicates officers responsible to uphold this commitment. In Malaysia, the Department of Occupational Safety and Health (DOSH) and other government agencies have regulations that set down the legal requirements to ensure the safety and health of all the workers at the place of work.

2.7 Legal Framework for Occupational Health and Safety Management in Ghana

The management of health, safety and welfare administration of Ghanaian workers is currently under the auspices of the Factories, Offices and Shops Act 1970, PART XV of the Labour Act, 2003 (ACT 651) and the Workmen's Compensation Law, 1987 (PNDC LAW 187) (Adinyira, 2016).

2.7.1 Factories, Offices and Shops Act, 1970 (ACT 328)

The mission of the Factory Inspectorate Department is to promote measures that safeguard the health and safety of persons employed in premises which fall within the preview of the Factories, Offices and Shops Act, 1970 (Act 328). The department executes its mandate through activities such as inspection of workplaces to ensure that reasonable standards of Safety and Health of workers are maintained, registration of Factories and Renewal of Certificates of Registration and Investigation of reportable Occupational Accidents and Dangerous Occurrences to enhance identification of the contributory factors in the series of events that lead to an accident. Other functions include supervision of the Statutory Examination and or Test of potentially hazardous plant and equipment to ensure that they are safe to operate, prosecution of offences under the Factories, Offices and Shops Act. (Act 328, 1970) and approval of building plans for premises which are intended to be used as factories, so as to ensure that the provisions for health and safety of persons intended to be employed are adequate and satisfactory, having regards to the requirements of the Factories, Offices and Shops Act and its related regulations.

2.7.2 The Labour Act, 2003 (ACT 651)

The Labour Department is responsible for administering both the Labour Act, 2003 (ACT 651) and the Workmen's' Compensation Act, 1987.

The Labour Act requires employers to ensure satisfactory health and safety conditions, protect employees from imminent exposure to hazards and to report occupational accidents and diseases to the appropriate government agencies. Employees are required to report unsafe situations to their immediate supervisors, remove themselves from that situation and to use personal protective equipment provided by the employer in the discharge of their duties.

The Workmen's Compensation Act of 1987 provides for the payment of compensation to employees in the event of injury and or death resulting from an accident on the job. This compensation is payable to his dependants through the courts in the event of the loss of his life. As to whether compensations paid commensurate the pain of loss of use of body parts (whether temporarily or permanently) or the loss of loved ones is debatable.

According to Kheni, (2006) both the Factory Inspectorate and Labour departments are plagued with human and logistical constraints, which impede their operational efficiency. Laryea (2010) re-echoes this through his identification of lack of stringent institutional framework governing construction activities and poor enforcement of policies and procedures of H&S of Ghanaian construction site as the primary reasons for the existing poor state of health and safety. These circumstances are an indication that the management of H&S on Ghanaian construction sites is usually subject to the decisions of site management personnel and these decisions are not monitored for efficiency. The above Regulations and Acts are not only outdated but inadequate in scope to address the emerging trend of workplace H&S issues particularly in the Ghanaian construction industry. There is the need for these regulations to be looked at again in the light of globalization and the increased use of technology anticipated in the industry in Ghana.

2.7.3 The Safety Pyramid

Figure 2.5 illustrates a widely accepted system of hazard control employed at the workplace to guide health and safety performance.

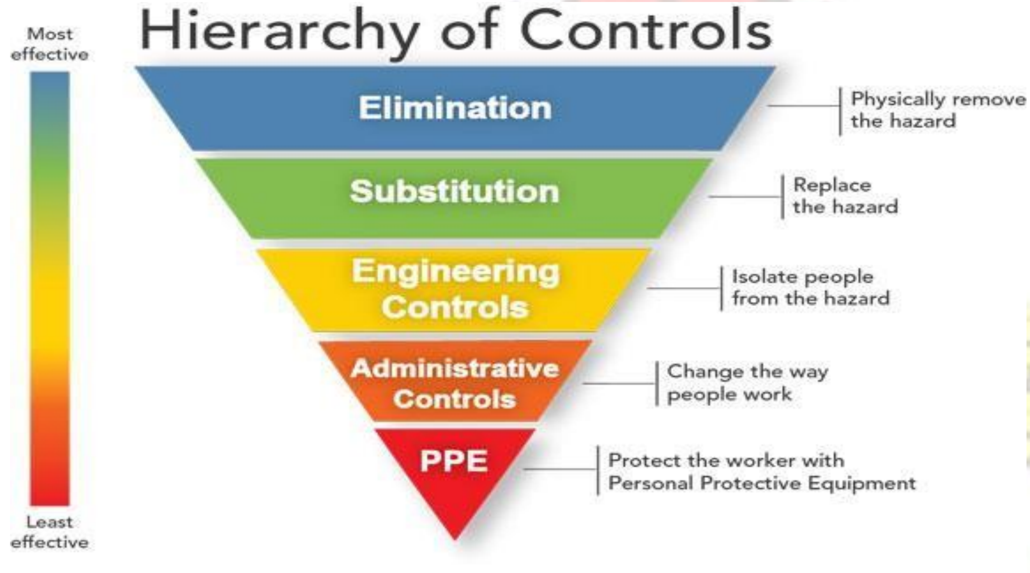


Figure 2.5: Hierarchy of hazard controls, (Cdc.gov, 2018).

At the topmost part of the pyramid is elimination or substitution, which is purported as the best way of dealing with safety hazards. Elimination operates by preventing exposure to the hazard before its occurrence while substitution replaces materials or tasks with less hazardous options. Although considered the most effective way of dealing with hazards, they are more easily implemented at the design stage rather than project implementation stage. Engineering controls appear in the next level below Elimination or Substitution. This method of safety protection requires the work environment and the job tasks to be designed in such a manner as to eliminate hazards at the source or reduce its severity before contact with workers

The next level, which is the use of Administrative & work practice controls as a means of controlling workplace hazards, requires that workplace rules and other operation-specific rules are designed to avoid or minimize employee exposure to hazards.

Examples of these rules are the inclusion of additional relief workers, exercise breaks and rotation of workers. This practice helps by minimizing exposure to long working hours and stressful work conditions.

At the base of the safety pyramid is the use of Personal Protective Equipment (PPE). Personal Protective Equipment (PPE) is defined as "all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects him against one or more risks to his health or safety, and any addition or accessory designed to meet that objective" (The Personal Protective Equipment at Work Regulations 1992 of the UK). Examples of PPE are hard hats/safety helmets, safety goggles, fall protection equipment, respirators, and safety boots.

According to OSHA, when exposure to hazards are completely out of normal operations or maintenance works, or cannot be reengineered, and when sufficient additional protection cannot be provided by other forms of administrative controls and safe work practices, it is necessary to provide Personal Protective Equipment (PPE) as a supplementary method of control. The HSE while admitting that engineering controls and safe systems of work are very necessary however mentions that PPE is ultimately required to minimize the risk of certain hazards. Examples of such hazards are injuries to the lungs, (e.g. from breathing in contaminated air) the head and feet, (e.g. from falling materials), the eyes, (e.g. from flying particles or splashes of corrosive liquids), the skin, from contact with corrosive materials and the body, (e.g. from extremes of heat or cold). In effect, PPE is actually a worker's foremost point of call in his safety protection in the event of an accident.

According to Tanko and Anigbobu (2012), in Africa and many other developing countries, the first personal line of defence against hazard at the workplace is the PPE. In fact, no most construction sites, the only line of defence against hazard is often the PPE.

2.7.4 Personal Protective Equipment (PPE)

There are several types of PPE with varying functions, which includes hearing protection, eye protection, respiratory protection, protection of the skin, and general protection in the form of

protective clothing, and safety helmets, harnesses and lifelines. Personal protective equipment has limitations. It does not eliminate a hazard if the PPE fails, therefore, it is imperative that the equipment is selected appropriately according to its use and maintained properly during its use through processes such as good housekeeping and tool inspection.
Additionally, workers are required to be trained before using any type of safety equipment.

2.7.5 Housekeeping

Good housekeeping is a vital function at any construction site that can improve overall safety performance by reducing the chances of accidents. This is a continuous process which involves everyone in the workplace. Many accidents occur due to causes such as tripping or slipping which are results of unsafe condition created by poor housekeeping. A good housekeeping program should be well planned, coordinated as well as regularly practiced.

2.7.6 Tool Inspection

One way of ensuring that PPE used on site is efficient is to facilitate the inspection of such equipment before coming into operation. Subsequently, routine equipment inspection should be carried out to ensure proper maintenance and or replacement of faulty ones. According to the guidelines established by the OHS regulation (2001), inspection and testing should be done by a qualified person. A safety officer and site supervisor can be tasked to conduct regular tool inspections on construction sites.

2.7.7 Safety Inductions

A safety induction is a process that allows a firm to educate workers or visitors to the workplace on safe working practices. Topics such as hazards present in the workplace, workplace behaviour, necessary actions to take in the event of an incident etc. are usually discussed in safety inductions.

When safety inductions are not performed, organisations may experience increased risk of incidents/accidents or even fatalities through avoidable contacts with existing hazards. In order to ensure a successful safety induction, the HSE recommends using a suitable location (away from excessive noise and distraction), allowing ample time for delivery, while maintaining good sensory contact and keeping presentations simple. A record of attendees and topics discussed should be kept for future reference (HSE, 2009).

2.8 Chapter Summary

This chapter reviewed literature regarding the nature of the construction industry, its health and safety performance as well as its significance to global economic development.

Information obtained in this review indicates that the construction industry employs a large number of people, stimulates other industries and is a major contributor to global economic growth. However, the prevalence of accidents with attendant injuries and fatalities in the industry however, is still a major cause of concern to industry players due to the socioeconomic impact of these occurrences.

Some theories regarding the causes of occupational accidents as well as interventions that have been designed over the years to improve workplace health and safety, have also been presented in this review. The theories outlined in this chapter indicate a relationship between human actions, their environment and the causation of accidents. In the researcher's opinion, it is important to identify the underlying reasons why unsafe conditions are created and why people commit unsafe acts that can lead to accidents to make any planned intervention effective to improve safety performance.

The next chapter focuses on the use of personal protective equipment, particularly safety helmets and goggles in the mitigation of risks that exist in the construction industry.

CHAPTER THREE

LITERATURE REVIEW – SAFETY HELMETS, GOGGLES AND THE CONSTRUCTION INDUSTRY

3.1 Occupational Injuries on Construction Sites

The construction industry remains one of the most hazardous considering the high accident rates that it churns out (Li et al, 2017). Institutions like the Health and Safety Executive (HSE) of the United Kingdom, the Bureau of Labour Statistics (BLS) of the United States and the International Labour Organisation (ILO) continually report high injury and fatality rates associated with the Industry (Li et al, 2017)

Among the several accidents that occur on construction sites, head injury is one of the severest (Li et al, 2017). Head injuries can occur through a sudden blow to the head, a terrible fall from a height, or a scaffolding accident. These can result in traumatic brain injuries (TBIs) and death. Several studies show that construction workers are at a very high risk of sustaining TBIs. A 2016 report by the National Institute for Occupational Safety and Health (NIOSH) indicated that the industry recorded the highest number of both fatal and traumatic brain injuries among workplaces in the United States. The industry had earlier on recorded 2,200 TBI fatalities between 2003 and 2010, representing a quarter of all construction fatalities.

TBI damages the brain and causes it to malfunction and depending on the severity TBI can cause death or have debilitating effect in the form of residual cognitive impairment, emotional disturbances, and behavioural changes (Daughton, 1990) on the individual for the rest of that person's life.

Apart from head injuries, construction workers are also at high risk of sustaining various degrees of eye injuries in the line of duty. According to the Centre to Protect Workers' Rights of the US, construction has a much higher rate of eye injuries than any other industry with inherent hazards such as flying nails, tiny pieces of metal, splinters, and cut wire ends, dust and grit produced from mixing of cement, sawing, grinding, and chipping. The centre reports that chemicals and welding can also burn the eyes, resulting in injuries or even loss of vision (CDC.gov, 2018).

Several interventions have been designed to enhance safety at the workplace and protect employees from occupational injury however, the use of Personal Protective Equipment (PPE) is the only measure that offers protection against serious workplace injuries or illnesses due to physical personal contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards as well as protection from hot and cold temperatures (Tanko and Anigbogu, 2012; Kwarteng, 2015). According to NIOSH, safety helmets or hardhats are the first line of defence against TBIs for construction workers. However, workers lose the protection when they do not wear them, alter its appropriate use or when the hats are damaged. Similarly, many eye injuries could be avoided if the appropriate safety goggles are used on site.

3.2 Personal Protective Equipment (PPE)

PPE is equipment that will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses (HSE, 2013).

The Labour Act, 2003 (Act 651) of Ghana mandates workers “to use safety appliances, firefighting equipment and personal protective equipment provided by the employer and in compliance with the employer’s instructions” (Section 118:3).

Studies on PPE, initially focused on protecting the worker but have in recent times shifted focus to worker comfort, functionality, performance issues and finally to style issues. Sometimes PPE is considered the most boring of all the facets of health and safety (Hands, 2010). According to Tanko and Anigogbu, (2012), in most developed countries PPE is considered a moot point in construction safety discourse due to well-developed safety regulations and a legal framework for their enforcement. For developing countries however, the first line of defence against hazard encountered at the workplace is use of the PPE. This makes discourse on PPE especially important for developing countries.

According to Joel (2007) protective devices are designed to interpose an effective barrier between harmful object environments. Personal protective devices should meet the following requirements before it is considered adequate.

- It should provide maximum comfort and minimum weight compatible with the protective efficiency.
- It should ensure adequate production form the hazards to which the workers will be exposed
- It should be durable
- It should impose no restriction on essential movements at work.
- It should have maximum attractiveness in appearance.
- It should be constructed in accordance with acceptable standards for performance and for the materials.

3.3 Safety Helmets

Human heads are both fragile and prone to collision (Long et al, 2015). As a result, head injuries are among the severest kinds of injuries encountered on construction sites (Li et al, 2017). Head injuries occur because of being 'struck by' materials and equipment (laterally) and falling objects (vertically). Victims may suffer lacerations to the head, concussions, severe brain injuries or even a fatality. Jeong's (1998) study on occupational injuries and deaths in the construction industry indicates that the head, face and neck regions are the most vulnerable in fatal accidents (Jeong, 1998). In non-fatal accident cases involving the head, victims have to be aided through residual cognitive impairment, emotional disturbances and behavioural changes that occur after the injury and which tend to continue long after the physical disabilities have resolved (Daughton, 1990).

Safety helmets are designed to protect the head area from the impact of contact with hazards, withstand penetration and in some cases protect against electric shock. Safety helmets should be worn whenever a person is on site, particularly in an area where overhead work is ongoing. The safety helmet provides head protection through two key components; the shell and the suspension system illustrated in Figure 3.1.

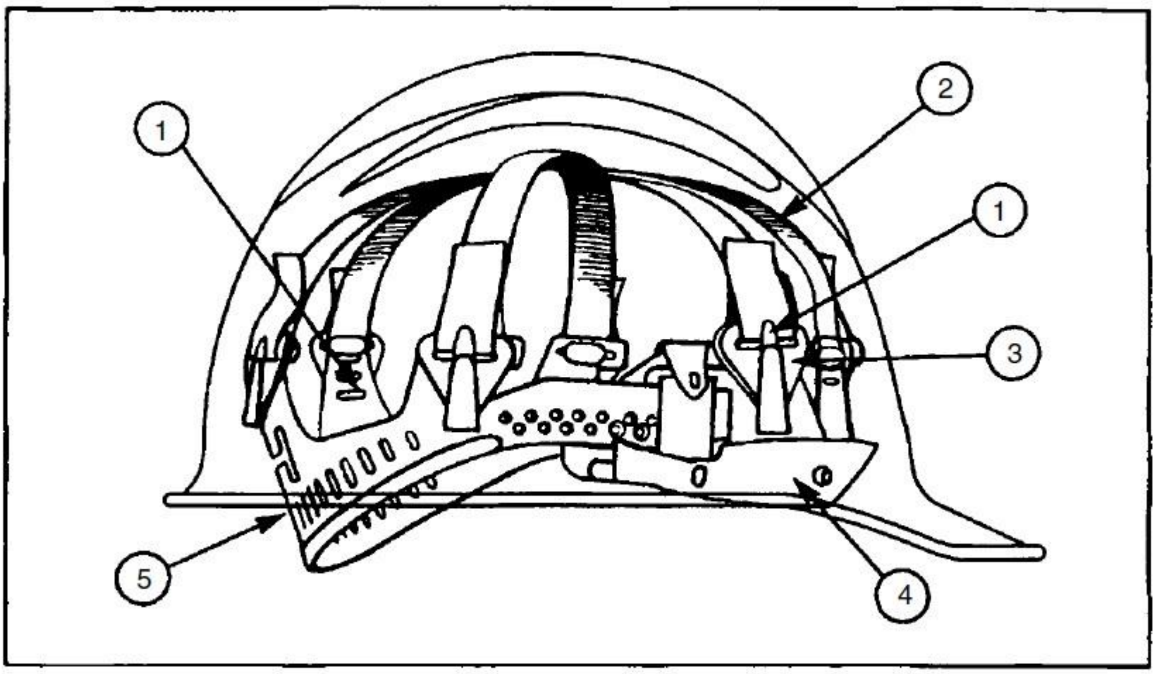


Figure 3.1: Hard Hat Suspension Design (Source: Nill, 2019)

Key:

1. Vertical Adjustment

2. Nylon crown strap

3. Hanger key

4. Absorbent brow pad

5. Sizing buckle

The smooth shell of the helmet deflects falling objects. The shell may also flex or deflect upon impact to the area between the skull and the suspension system. Additionally, the suspension system stretches slightly to absorb impact energy and distribute same over a large area while still maintaining the suspension-to-shell space.

The most common material used for the shell is high-density polyethylene, however other materials used include polycarbonate, polycarbonate glass, polyester glass, and aluminium.

For high-temperature applications, polycarbonate or polyester is more appropriate than polyethylene, and the suspension should be a woven material (Nill, 2019).

There are many different designs available, made for specific purposes. For example, many trades -such as scaffolders -find that helmets with a very short peak are easier to wear because they do not get in the way. Some helmets contain Kevlar fibres giving them great resilience and resistance to impact. All forms of head and scalp protection must be suitable, correctly fitted and have an easily adjustable headband, nape and chin strap where appropriate.

Several standards exist to regulate the manufacture and use of industrial helmets and provide guidance to aid their selection and use. For example, the British Standard (BS) is applicable in the United Kingdom while the Occupational Safety and Health Administration (OSHA) of the United States requires most PPE to conform to standards set by the American National Standard Institute (ANSI). PPE within the European Union is guided by the new Regulation (EU) 2016/425) which came into effect in April, 2018 (CSA Group UK., 2018). Standards are set as a result of performance tests carried out on PPE and are a helpful guide in their selection and importation. The American National Standard Institute (ANSI), for instance, classifies each type and class of head protector with respect to specific hazardous conditions thus a helmet user should be able to identify the type of helmet by looking inside the shell for the manufacturer, ANSI designation and class.

The Hong Kong government in its head protection program identified that safety helmets must have some constructional features or key characteristics that satisfy international requirements to ensure comfort (labour.gov.hk, 2018). These requirements are listed below.

- Helmets must have an elliptical shell configuration on horizontal sections above the headband.
- The vertical clearance between the harness and the inside of the shell shall in general be not less than 25 mm and not more than 50 mm.
- The horizontal clearance between the headband and the inside of the shell shall in general be not less than 5 mm and not more than 20 mm.
- Provision shall also be made by ventilation gaps between the shell and the headband.
- The length of the headband or the nape strap shall be adjustable in increments of not more than 5 mm.

3.4 Safety Goggles

Eye injuries in the workplace are very common. Many eye injuries occur as a result of flying material, dust or radiation through workplace tasks such as:

- Breaking, cutting, drilling, dressing or laying of stone, concrete and brickwork with hand or power tools
- The chipping and dressing of painted or corroded surfaces
- Cutting off or cutting out cold rivets and bolts
- Dry grinding of surfaces with power grinders
- Welding and cutting of metals

In some industrial processes, there may also be a risk from the spillage, leakage or splashing of hot or corrosive liquids. Some of these hazards can be removed permanently by proper machine guarding, exhaust ventilation or work design. For many hazards, however, personal eye protection is the only practical solution.

The National Institute for Occupational Safety and Health (NIOSH) of the United States reports that every day about 2,000 US workers sustain job-related eye injuries that require medical treatment. However, safety experts and eye doctors believe the right eye protection can lessen the severity or even in some cases prevent these eye injuries.

Workers at risk of eye injury should be provided with and wear the prescribed personal protective equipment such clear or coloured goggles, a screen, a face shield or other suitable device when the worker is likely to be exposed to risks of injury to the eye (Example; Fig. 3.2).

Safety goggles provide protection to the entire eye from hazards coming from any direction (such as dust, flying particles, sparks, or chemicals) by serving as a seal around the entire eye. Eye protection must be suitable, comfortable and available to encourage workers to wear it.

The selection of safety goggles should consider the lens, frame and ventilation openings. For industrial purposes, most goggles are made from Hi-Vex lenses (materials). According to CSA Standard Z94.3.1-16, the Hi-Vex is

- More impact resistant than CR39 plastic
- Available with all surface treatments (coatings)
- 100% UV filtering
- Light weight
- Material is very clear

Table 3.1 presents different types of goggles to protect against possible hazards employees encounter during industrial operations.

Table 3.1: Types of Goggles

Nature of Hazard	Hazard activities involving but not limited to	Recommended Goggle
Flying Objects	Chipping, scaling, stonework, drilling, grinding, buffing, polishing, hammer mills, crushing, heavy sawing, planning, wire and strip handling, hammering, unpacking, nailing, punch press, leatherwork	Class 2A and 2B Goggles
Flying particles, dust, wind, etc.	Woodworking, sanding, light metal working and machining, exposure to dust and wind, resistance welding (no radiation), sand, cement, aggregate handling, painting, concrete work, plastering, material batching and mixing	Class 2A and 2B Goggles
Heat sparks, and splash from molten materials	Babbiting, casting, pouring, molten metal, brazing, soldering, spot welding, stud welding, hot dipping operations	Class 2C goggles
Acid splash, chemical burns	Acid and alkali handling, degreasing, pickling and plating operations, glass breakage, chemical spray, liquid bitumen handling	Class 2B Goggles
Abrasive blasting materials	Sand blasting, shot blasting, shotcreting	Class 2B Goggles
Glare, stray light	Reflection, bright sun and lights, reflected welding flash, photographic copying	Class 2 A and 2B Goggles
Injurious optical radiation	Torch cutting, welding, brazing, furnace work, metal pouring, spot welding, photographic copying	Class 2C Goggles
Laser radiation	Laser cutting, laser surgery, laser etching	Class 2D Goggles
Electric arc flash	Electrical installation, electrical maintenance, trouble-shooting of electrical systems, disconnecting live electrical systems	Class 2E Goggles

Source: CSA Standard Z94.3.1-16

Sample of safety goggles

Figure 3.2: Example of ANSI Approved safety glasses (Amazon.com, 2019)

3.5 Non-Use of Safety Helmets and Goggles by Construction Workers

Non-compliance with safety requirements including the non-use or improper use of PPE results in occupational accidents in a wide range of industries as agreed by literature. Construction workers either use PPE wrongly or do not use them at all while working resulting in construction accidents (Haslam et al, 2005; Ahmed et al., 2015; Laryea, 2010; and Yilmaz, 2014). Research suggests a rising trend in non-conformance to PPE protocols in which construction workers attribute this non-compliance to several discomforts experienced with their use (Haslam et al., 2005; Ahmed et al, 2015; Tanko and Anigbobu, 2012).

While some study indicates a lack of knowledge with regards to PPE, resulting in a cavalier attitude (Taylor, 2011), others indicate that construction workers are fully aware of their benefits but do not use them as required due to discomforts experienced (Tanko and Anigbogu, 2012; Adade-Boateng et al, 2016).

Safety helmet users indicate several discomforts such headaches, hotness and dizziness while wearing them (Adade-Boateng et al, 2017). Users of safety goggles bemoan discomforts such as poor fit, poor visibility and interference with work as factors that prevent their efficient use on site. Perhaps this explains why workers sometimes have to be coerced to use PPE on some construction sites (Laryea, 2010).

According to Tanko and Anigbogu, (2012), in a Nigerian study, majority (90%) of workers understand the need for PPE and want to be protected against accidents, injuries and illnesses. However, the workers emphasized the need to address issues of comfort frequently experienced with PPE use to ensure that it does not interfere with their productivity taking into account the work environment. The workers indicated that the supervision, proper maintenance and replacement of PPE would improve the practice of PPE use on construction sites. They also raised a concern that policies and regulations with respect to PPE need to be developed and implemented. Similarly, Lombardi et al., (2009) identify three main areas as important factors that affect the use of protective eyewear in the workplace. Firstly, the authors identified 'perceptions of hazards and risks' as an important factor. Respondents in their study (especially younger workers) admitted they would usually skip the use of eye protection because they forgot or took the risk for granted. Safety training and having older workers constantly urging them towards the PPE use mitigated this factor. The second factor identified was "barriers to PPE usage'' such as a lack of comfort/fit and fogging and scratching of the eyewear. Workers experienced discomfort with eye wear that did not fit properly and would not stay on. Thirdly, 'enforcement and reinforcement' was identified as important in encouraging safety eyewear use. The authors suggested that workers are more likely to use given eyewear when their supervisors ensure its use and provide positive reinforcement when they are used appropriately.

Kimura (2011), affirms that the two basic problems with the use of eye and face protectors are the availability of effective protection for use over long hours of work without associated discomfort and restriction of vision. Usually users of eye protection equipment have their vision limited by the side frames and the nose bridge. The nose bridge may disturb binocular vision; and misting is a constant problem with safety goggles particularly in hot climates.

If the items of protective clothing are uncomfortable and slow down workers, then they are likely to get injured. On the other hand, if clothes fit properly and do not impede the wearers' ability to do their job, they are much less likely to suffer a costly lapse in concentration or make a potentially lethal mistake (Taylor, 2011). PPE should be suited to the environment, properly selected for the individual and task, readily available, clean and functional, correctly used when required and maintained by appropriately trained staff in accordance with personal protective equipment maintenance and servicing program.

3.6 Some Effects of Discomforts Associated with the use of Safety Helmets and Goggles

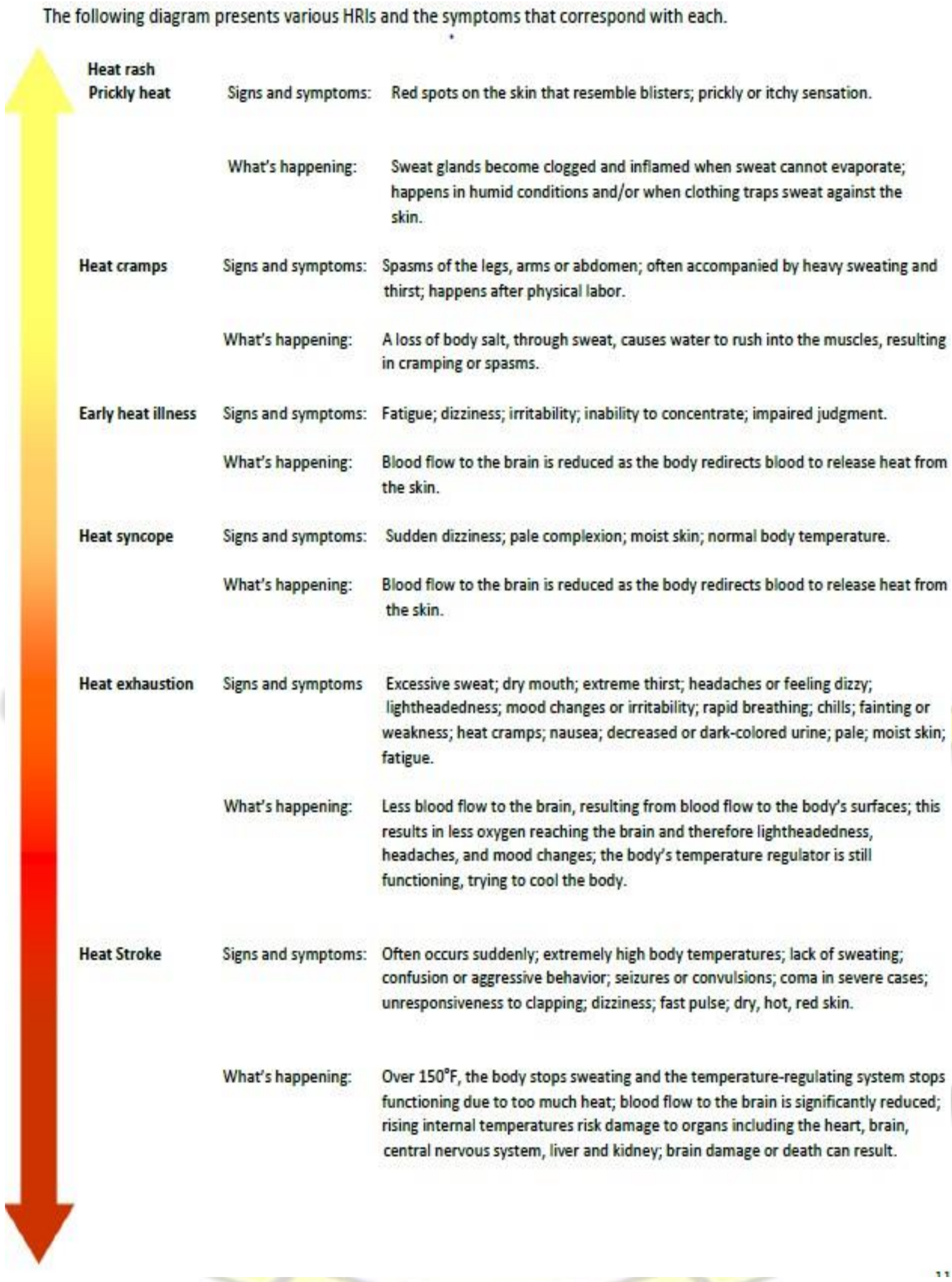
Heat Stress

According to OSHA, (2010) human beings must maintain a constant internal body temperature of roughly 98.6ºF or 37ºC, as this is the ideal temperature at which a person's internal chemical reactions and processes function to their fullest potential. The body's internal temperature is however influenced by a host of both internal and external factors, thus it is constantly engaged in a balancing act of heat generation and heat release in order to maintain this ideal body temperature. Examples of internal factors that generate body heat are metabolic activities such as by-products of chemical reactions and from the heat generated by the work of the body's muscles. External factors also include surrounding air, direct light, equipment that gives off large amounts of heat and also from clothing worn (OSHA, 2010).

To maintain an optimum temperature, the body moves excess heat form its core through blood vessels to the surface of the skin via mechanisms such as evaporation (heat is released when liquid sweat is converted to gas and lifted off the body), conduction (heat is transferred to an item that is cooler and is in direct contact with the body), convection (cooler air lifts heat off the body's surface) and radiation (heat leaves the body even in the absence of cold wind) which occur unconsciously and are controlled by the brain (OSHA, 2010).

3.6.1 Heat Stress

Heat stress occurs when the body is unable to maintain its ideal body temperature under the effect of heat exerted through both its metabolic activities and external environment resulting in strain on the body. Heat stress increases the likelihood of suffering heat-induced disorders or illnesses such as stroke, heat cramps etc. OSHA outlines heat related illnesses according to their severity in Figure 3.3 below.



The following diagram presents various HRIs and the symptoms that correspond with each.

Heat rash Prickly heat	Signs and symptoms:	Red spots on the skin that resemble blisters; prickly or itchy sensation.
	What's happening:	Sweat glands become clogged and inflamed when sweat cannot evaporate; happens in humid conditions and/or when clothing traps sweat against the skin.
Heat cramps	Signs and symptoms:	Spasms of the legs, arms or abdomen; often accompanied by heavy sweating and thirst; happens after physical labor.
	What's happening:	A loss of body salt, through sweat, causes water to rush into the muscles, resulting in cramping or spasms.
Early heat illness	Signs and symptoms:	Fatigue; dizziness; irritability; inability to concentrate; impaired judgment.
	What's happening:	Blood flow to the brain is reduced as the body redirects blood to release heat from the skin.
Heat syncope	Signs and symptoms:	Sudden dizziness; pale complexion; moist skin; normal body temperature.
	What's happening:	Blood flow to the brain is reduced as the body redirects blood to release heat from the skin.
Heat exhaustion	Signs and symptoms	Excessive sweat; dry mouth; extreme thirst; headaches or feeling dizzy; lightheadedness; mood changes or irritability; rapid breathing; chills; fainting or weakness; heat cramps; nausea; decreased or dark-colored urine; pale; moist skin; fatigue.
	What's happening:	Less blood flow to the brain, resulting from blood flow to the body's surfaces; this results in less oxygen reaching the brain and therefore lightheadedness, headaches, and mood changes; the body's temperature regulator is still functioning, trying to cool the body.
Heat Stroke	Signs and symptoms:	Often occurs suddenly; extremely high body temperatures; lack of sweating; confusion or aggressive behavior; seizures or convulsions; coma in severe cases; unresponsiveness to clapping; dizziness; fast pulse; dry, hot, red skin.
	What's happening:	Over 150°F, the body stops sweating and the temperature-regulating system stops functioning due to too much heat; blood flow to the brain is significantly reduced; rising internal temperatures risk damage to organs including the heart, brain, central nervous system, liver and kidney; brain damage or death can result.

Figure 3.3: Heat Related Disorders (OSHA, 2010)

According to Abeysekera and Shahnavaz (1998), hotness, weight, fitting problems etc., are the primary reasons why industrial safety helmets are unpopular in tropical environments in developing countries. Also, Ueno and Sawada (2019) purport that wearing safety helmets under hot-working conditions may result in workers discomfort and could increase the risk of heat disorders, as the head is one of the most susceptible regions to heat stress. According to Ueno and Sawada (2019), construction workers are at a high risk of heat related discomforts due to the safety attires usually worn and suggest that it is imperative that the head maintains an adequate temperature in order to prevent damage to the brain as a result of heat.

A study conducted by Abeysekera and Shahnavaz (1988) identified that white helmets are more comfortable, as they retain less heat, compared to the other colours, e.g. red, green etc., when worn in the presence of radiant heat in the laboratory. Similarly, a study conducted by the Missoula Technology and Development Center (US) to investigate the effect of colour on temperatures within hard hats, discovered measurable differences in the temperatures within the different helmets, with lighter coloured hard hats being dramatically cooler than darker coloured ones. The study also identified that white industrial safety helmets absorbed the least amount of heat amongst all the colours, supporting the principle that lighter colours absorb less solar radiation, generating less heat inside a hardhat than darker colours. Researchers recommend the selection of white coloured helmets that are adequately ventilated, especially for use with workers susceptible to heat stress (Abeysekera and Shahnavaz, 1988; Smith and Throop, 2006).

3.6.2 Physiological Responses to Heat Stress

A high level of protection is required by personal protective clothing and this results in a drastic impedance to heat exchange by sweat evaporation. This creates an enabling environment for workers to experience physiological strain leading to early onset of fatigue while using protective clothing in hot environments (Holmer, 2006).

Physiological strain refers to how the body responds to heat stress exerted on it. The most common physiological strain indicators are increased body temperature and heart rate (Garzón-Villalba et al, 2017).

3.6.3 Cognitive Responses to Heat Stress

There are varying reports on cognitive performance in response to heat stress. For instance, while several studies have reported a decrease in mental performance with increased heat, others have indicated no effects of heat stress on mental performance (Hancock and

Vastimidzt, 2003). Researchers have blamed these contradictions on a lack of a systematic approach in investigating the effect of heat stress on cognitive performance and the fact that, most of the experiments to demonstrate the relationship have been conducted in laboratory settings.Hancock and Vastimidzt (2003) suggest that these conflicting findings can be explai ned by a number of factors such as job difficulty, individual skill level and length of heat str ess exposure. Other factors described are the acclimatization level of the participants which may cause them to endure heat stress better, gender (women purportedly perform better in under heat stress) and high incentives that may keep people working, nevertheless.

Several models and theories have been developed to explain the effect of stress on psychological performance, popular amongst which is the arousal theory which has been criticized severely for its low predictive power (Hancock and Vastimidzt, 2003).

A more recent model is the Maximal Adaptability Model, which assumes that heat exerts its detrimental effects on performance by competing for and eventually draining attentional resources. The model illustrates the effects of increased intensity and duration of exposure to stress and its resultant effect on cognitive and physiological performance. The model shows a continuum of stress from very low (hypo stress) to very high (hyper stress). The middle of the continuum is the normative region where performance is optimal requiring no adjustments. The comfort region surrounds the normative region. Tasks are easily achievable at this stage and performance within this zone is near-optimal level. Beyond the comfort region, attentional resources are progressively drained resulting in decreasing performance levels. Further increases in stress intensity move the body outside the zone of homeostasis (physiological zone of maximal adaptability) into life-threatening circumstances (heat stroke for example) Hancock and Vastimidzt (2003).

With respect to heat stress, the maximal adaptability model establishes a relationship between the physiological and psychological aspects of work in the heat. As it assumes attentional resource depletion to be the mechanism for the debilitating effects of heat stress, it also establishes a relationship between the magnitude of such depletion (expressed in terms of dynamic body core temperature increase) and the onset of performance decrement.

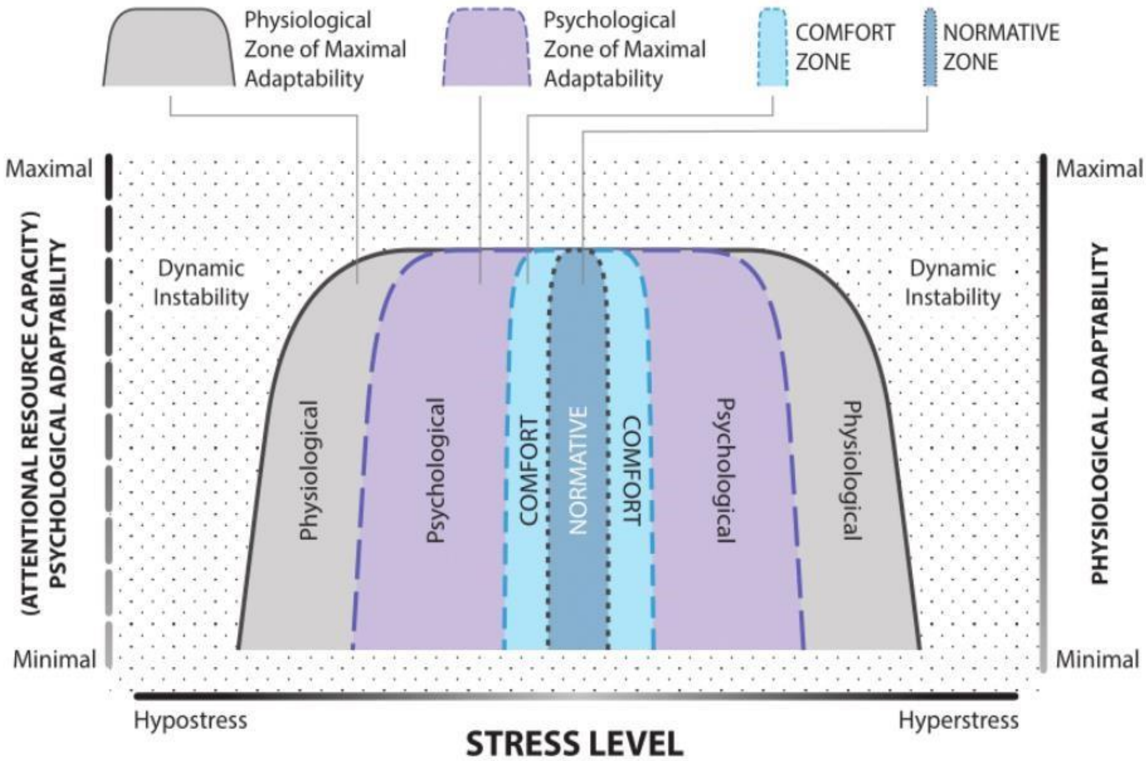


Figure 3.4: The Maximal Adaptability Model (Hancock, 1989)

Heat stress results in reduced work capacity and effectively reduces productivity as workers have to engage in work-rest cycles in order to minimize heat strain and increased risk of accidents. (Gotshall et al, 2001; Kjellstrom et al, 2009).

Previous research suggests that discomforts with safety helmets described by construction workers are usually experienced by users in hot climatic areas or hot temperatures. In Ghana, construction workers execute their duties in a physical environment characterized by two main climatic regions; warm-humid climate which is characterized by hot, sweaty and sticky conditions as well as continual presence of dampness, and hot-dry climates, typically characterized by dry hot, dry air and dry ground (Oppong and Badu, 2012). Temperatures normally range between 26 and 46ºC (Agyekum et al, 2013). In some instances however the country records mean annual temperatures of between 18 – 40ºC (Asante and AmuakwaMensah, 2015). Humidity readings are usually between moderate to low (Koenigsberger et al., 1974 in Oppong and Badu 2012).

Construction workers in hot climates are vulnerable to heat stress as they perform many physically demanding tasks in hot environments.

3.6.4 Poor Fit

The issue of poor fit is another challenge faced by PPE users. Fit issues with PPE relate to how apparel sizing and body geometry allow for the attire to be completely compatible with its user (McPherson, 2008). PPE are mostly produced in industrially developed countries and imported by users in industrially developing countries and significant differences exist between the physical environment and anthropometry of people living in these two areas. (Abeysekera, 1988)

In their study on ergonomics aspects of PPE and its use in industrially developing countries, Abeysekera and Shahnavaz (1988), conducted their study on the premise that apparent variability in the physical, cultural and sociological environments as well as technological and anthropometric differences between indigenes of industrially developed countries and those in industrially developing countries would result in a failure of using transplanted PPE technology. For example, a Europe designed adjustable helmet did not fit properly on 40% of heads in a study (Adeysekera,1988) in Sri Lanka (an industrially developing country), and for people living in a hot and humid environment in the tropics, it extremely uncomfortable and unsuitable to use safety clothing designed with insulation properties for cold climates (Abeysekera and Shahnavaz, 1988).

According to Abeysekera and Shahnavaz (1988), PPE designers in industrially developed countries would ideally select design parameters suitable for a known population and a given known environment. As a result, designed PPE from these places may need to be adapted, modified, or redesigned to meet the needs of users in industrially developing countries. The authors again point out that designers of PPE in industrially developed countries are guided by local standards regarding these goods and these standards predominantly emphasize hazard protection performance for the wearers and not ergonomic factors such as comfort, fit, etc. This implies that manufacturers will not be mandated to make ergonomic considerations and tend to deliberately overlook same for both local and foreign users.

3.6.5 The body's Responses to Poor fit

- External Compression Headaches

Although few people experience external compression headaches, it is prevalent amongst users of helmets (including industrial helmets), and safety goggles. In the construction industry, external compression headaches are associated with headwear that places pressure on the head including tight hats, helmets, headbands and goggles. The headaches are believed to result from pressure on pain receptors or pain fibres that transmit sensation from the face to the brain or on nerves in the back of the head.

Although external compression headaches are still quite under-studied, existing literature suggests that the only remedy for this kind of headache is to remove the equipment lying on the affected nerve. While this compromises the safety of the worker, construction workers are forced to remove a poor fitting helmet or goggle at regular intervals due to the discomforts they feel. Protective headwear like helmets and goggles should fit properly and be positioned correctly.

To address this predicament, workers should try various styles and sizes of safety headwear to find the most comfortable options. McPherson (2008) purports that it is more likely for PPE to be used when they are procured in consultation with users and suggests that the in selection of PPE's fit/compatibility/wearability and style factors should be considered as well, as this makes it more automatic comply, giving the workers some level of control over their appearance, without compromising safety, and allow them to show their individuality. According to the author, people are less likely to make modifications to their PPE attires when they are content with how they look.

3.7 Clothing Comfort

Slater (1986) purports that comfort is the most important subject in the world and as such human beings consciously or unconsciously, continually strive to maintain or improve upon it throughout their lives. It is not simple to objectively define comfort, therefore a subjective definition is offered by Slater (1985) as "a state of physiological, psychological, and physical harmony between a human being and the environment. Slater (1986) describes the three dimensions of comfort in his discussion on comfort assessment, i.e. physiological comfort refers to the body's ability to maintain life, psychological comfort is the ability of the mind to keep functioning correctly without assistance and physical comfort as the effect of the external environment on the body.

Previously, Sontag (1985) had also established that the concept of comfort consists of three dimensions: physical, psychological and social. He defines physical comfort *a*s a mental state of physical well-being expressive of satisfaction with physical attributes of a garment such as air, moisture, heat transfer properties, and mechanical properties such as elasticity, flexibility, bulk, weight, texture, and construction (Sontag, 1985). Psychological comfort is a mental state of psychological well-being expressive of satisfaction with desired affective states such as femininity, sophistication, or having fun (Sontag, 1985).

Textile researchers indicate that one of the key attributes that affects the desirability of consumers for apparels, as identified by major marketers in the textile and fibre industry is comfort. (Li, 2001).

Clothing as a near environment of the human body plays a vital role in achieving human comfort and over the past few decades, extensive and systematic investigations of clothing comfort, function, and ergonomics have been conducted, specifically with protective clothing. The mechanisms and underlying principles associated with human physiological needs, comfort attributes of clothing, and their interaction with a variety of environments have been formalized and established. Methods for the study and evaluation of human comfort and clothing function have also been developed, and findings and discoveries from these studies have led to the development of high performance fibres, novel structures for yarns and fabrics, and new concepts for clothing systems such as the development of hollow and profiled fibres, which manage heat and moisture transport in factory wears and cold weather clothing (Song, 2011).

In addition, numerous mathematical models involving the human body, clothing, and environment provide useful tools for identifying key parameters in material design and for predicting clothing performance under extreme environmental conditions (Song, 2011). However, there is still much work left to do, particularly for protective clothing. The additional requirements of these garments to provide protection against hazards while simultaneously maintaining an acceptable level of human comfort poses a tremendous challenge (Slater, 1996; Song, 2011). As a result, the performance provided by the individual pieces of protective clothing or the clothing system ensemble has been significantly compromised (Song, 2011).

Researchers seem to agree that comfort is complex and subjective and is influenced psychologically and physiologically by clothing and surrounding environmental conditions (Slater, 1985; Song, 2011). According to Slater (1986) physical discomforts, which are the easiest dimension of comfort is the effect of the external environment on the body has a direct relationship with both physiological and psychological such that physical discomforts have an adverse on the other two.

Songtag (1985), however suggests that a key physiological variable affecting an individual's comfort status is the level of physical activity. According to Abeysekera (1988), discomforts associated with PPE result from anthropometric features and environmental differences. In addition, Holmer (2006), asserts due to the nature of their manufacturing materials, using personal protective equipment in hot environments results in physiological strain and early fatigue.

Considering the discomforts associated with safety apparel, the selection and procurement process for these PPE should be done carefully and must consider especially the physical comfort of the user and his environmental characteristics (Slater, 1986). An appropriate selection and procurement procedure will ensure that users remain within the normative or comfort state of the Maximal Adaptability model to ensure their physiological and psychological satisfaction through the selection of PPE with appropriate physical characteristics.

3.8 Ensuring PPE Meets Adequate Comfort Requirements

Ensuring Physical and Physiological Comfort

3.8.1 Proper Procurement Methods

To ensure PPE meets comfort requirements of users, it is important to consider how PPE gets onto the construction site. The buying of goods and services required by an organization is often referred to as purchasing. This term is however often used interchangeably with procurement. According to Abouzheid (2018), procurement is wider than purchasing as it encompasses some activities prior to and beyond the purchase and summarizes the two terms as follows; The purchasing Process

1. Purchase requisition received from the user department
2. Quotations obtained from suppliers and evaluated.
3. The purchase order is placed
4. Products are received
5. Payment is effected

The Procurement Process

1. Supply market monitoring.
2. Identifying potential suppliers.
3. Preparing approved supplier list.

4. Identifying the right needs of internal user departments.
5. Converting needs into clear specifications that can be understood by suppliers.
6. Obtaining and evaluating quotations.
7. Selecting the right suppliers.
8. Efficient negotiations.
9. Contract development.
10. Contract management.
11. Payment.
12. Supplier relationship management.

In comparison the purchasing process seems quite simple and involves the getting the requested goods in the right quantity at the right time and for the right price.

The procurement process seems slower but more likely to obtain goods that match the peculiar need of users while maintaining a relationship with the supplier as well.

Bildsten (2016), disagrees with the assertion that the construction industry is price-driven with respect to suppliers as portrayed by some researchers. The author debunks this assertion with his research that reveals that the choice of suppliers is based to a large extent on long-term relationships, where the trustworthiness of suppliers plays an important part. Through long-term relationships, the project team can rely on the experiences acquired from previous purchases to overcome problems of coordination, communication and integration.

One big challenge faced by manufacturers of protective clothing, is the achievement of comfort by the wearer, due to the nature of materials required to ensure its protective abilities (Slater, 1996; Song 2011). Perhaps even more worrying is how susceptible users in hot weather conditions are to physiological strain (Holmer, 2006).

That notwithstanding, considering that a lot of effort has been made to improve comfort in protective clothing, a good place to start in ensuring PPE comfort is to procure them with sufficient consideration for the physical comfort of the wearer and the environmental conditions within which they will be used.

The researcher is enthusiastic that construction workers will be successful in procuring userfriendly PPE when procurement methods are followed through with the necessary considerations.

3.8.2 Anthropometric Characteristics

Anthropometric characteristics are traits that describe parts of the human body. The principles of anthropometry are scientific in nature and when used are able to provide a better fit for clothing users (Gupta, 2014), thus improved physical comfort.

According to Gupta (2014) it is necessary to obtain a thorough understanding of body shapes and sizes that exist in a particular population in order to design clothing that truly fits the target bodies it is intended for. This process requires the systematic measurement of anthropometric characteristics of a representative sample of the population. An analysis of the shapes and sizes of the human bodies can then be used to design clothing items that adequately fit the requirement of the users.

Gupta (2014) further intimates that with respect to clothing, "user requirements must be fulfilled with respect to appearance and comfort, while at the same time allowing them to perform their tasks without any impedance or restriction". Similar to Abeysekera and Shahnavaz (1988)'s assertions, Gupta (2014) purports that human beings vary significantly not only in the shapes and dimensions of their body parts but also their perceptions of what constitutes 'a good fit' or 'what looks good'. This makes it impossible to institute a 'one size fits all' approach in finding a good fit for all users. According to Pheasant and Haslegrave (2006), reported in Gupta (2014), the ability to produce an Ergonomic design requires an understanding of this variability in human bodies as well as human preferences, and its incorporation into the design process. In the researcher's opinion, the conventional approach of using the head circumference alone as an indicator of the size required of safety helmets should be reconsidered in favour of other measurements such as those required in the manufacture of wig caps to improve fit issues. Fit issues with safety goggles would also be improved if the frame lengths of the provided goggles are compatible with users on the site.

3.9 Standardization

Standards may also be designed by individual countries to specify the requirements expected of goods and services produced or exported into those places. Some popular examples of PPE standards are; The American National Standards Institute (ANSI),

Canadian Standards Association (CSA) and European Standards (EN)

The International Organization for Standardization (ISO) creates documents that provides the requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. The organization has published 22,432 standards for public purchase and use (ISO, 2018).

3.9.1 The Ghana Standards Authority

The Ghana Standards Authority is a government agency which creates, publishes and promotes standards in the country. The organisation has the mandate to contribute to industry growth, consumer security and trade facilitation through standardization and conformity assessment (Gsa.gov.gh, 2018).

Six (6) technical divisions within the agency work together towards the achievement of the agency's mission, namely, Testing, Metrology, Certification, Standards, Inspectorate and the Planning, Monitory and Evaluation divisions (Gsa.gov.gh, 2018).

The Inspectorate Division is responsible for ensuring consumer protection from the manufac turing and service industries through the Products, Fish and Import Inspectorate (Technical) departments using the under the under listed objectives.

- To give assurance of safety and quality of locally manufactured, imported and exported products.
- To improve the level of compliance with both national and international standards
- To improve the level of compliance with regulations on imported and exported products
- To support the certification of locally manufactured products through inspection
- To enhance the skills of staff for effective and efficient performance
- To gain and maintain accreditation to ISO 17020:2012 (Conformity assessment Requirements for the operation of various types of bodies performing inspection)

The three technical departments achieve the above objectives through the following key activities.

- Import inspection of high-risk goods (i.e. on imported goods)
- Inspection of local factories for Certification purposes
- Inspection of fish and fishery products for local consumption and Export
- Consignment inspection of manufactured goods and issuance of export certificates

- Issuance of health certificates
- Market surveillance
- Staff training and participation in national and international workshops

3.9.2 High Risk Goods

The Ghana Standards Authority has a system in place to ascertain the quality and safety of imported products, through conformity assessment at their points of entry. However, inspection of imported goods is limited to those classified as ‘High Risk’. High risk goods are defined by the agency as “goods that have serious health, safety and environmental implications on the consuming public”. Broad groupings of these goods as stated by the agency are:

1. Food products
2. Pharmaceuticals, cosmetics, medical devises
3. Alcoholic and non-alcoholic products
4. Chemicals and allied products
5. Petroleum products
6. Electrical appliances
7. Electrical products: e.g. bulbs, switches, sockets, Cables, etc.
8. Electrical cables
9. Electronic products
10. Building materials
11. African textile Prints
12. Used Goods: e.g. second-hand clothing
13. Pyrotechnic products
14. Motor vehicle batteries
15. Vehicle spare parts

16. Industrial machinery

17. Arms and ammunitions

18. Machetes and cutlass

19. LPG cylinders and accessories

20. Toys

(Gsa.gov.gh, 2018)

It is observable from the list provided that imported PPE is not classified as a High Risk good. This presupposes that imported PPE is not inspected to ensure conformity with international standards. Considering the efforts made through standardization to ensure PPE is effective, it is advisable to that PPE conforming to International Standards is procured as this may be enough in ensuring users attain physiological comfort.

Enhancing Psychological Comfort

3.10 Improving Safety Behaviour through Behaviour Based Safety (BBS)

Research has identified unsafe acts as the leading cause of workplace accidents (Choudhry, 2014). Some researchers advise that the reduction of accidents and improvement of safety performance can be effectively achieved by systematically focusing upon those unsafe behaviours on construction sites (Choudhry and Fang, 2008; Choudhry, 2012). This implies an urgent need to eradicate unsafe behaviours and stimulate the exhibition of safe behaviour to reduce construction accidents.

Behaviour can be defined as the observable physical actions of an individual (Choudhry, 2014; IOSH, 2015). Available literature indicates a direct link between behaviour change and motivation. According to Gordan and Amuthan (2014), motivation can be described as that which works intrinsically or extrinsically on an organism to initiate and direct behaviour. Several theories of motivation exist; however, the Behavioural Conditioning Theory is one of the oldest that describes human behaviour.

3.11 Behavioural Conditioning Theory

The conditioning theory is based on the premise that behaviour is learned, and that learning involves the establishment of a relationship between a stimulus and a response.

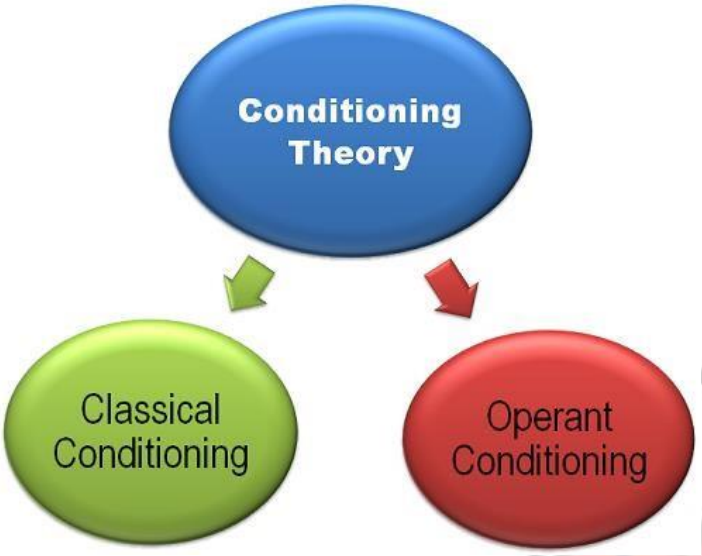


Figure 3.5: The Conditioning Theory (McLeod, 2018)

The classical and operant conditioning are the two main theories of conditioning. As indicated in Figure 3.5. The Classical conditioning theory proposed by Russian Physiologist Ivan Pavlov proposed that behaviour is learnt by a repetitive association between the response and the stimulus, i.e., two stimuli are linked together to produce a new learned response in a person or animal (McLeod, 2018). Classical conditioning has the strength of being scientific, however, it emphasizes the importance of learning from the environment, and supports nurture over nature. Psychologists however opine that "it is limiting to describe behaviour solely in terms of either nature or nurture and attempts to do this underestimate the complexity of human behaviour. It is more likely that behaviour is due to an interaction between nature (biology) and nurture (environment)" (McLeod, 2018).

3.12 Operant Conditioning

Operant conditioning is a method of learning that occurs through rewards and punishments for behaviour. Through operant conditioning, an individual makes an association between a behaviour and a consequence. Thus McLeod (2007) defines it as the changing of behaviour because of reinforcement obtained after the desired response. The Operant conditioning theory was developed by B.F. Skinner in 1938 to address the inherent weakness of classical conditioning. According to Skinner, the best way to understand behaviour is to look at the causes of an action and its consequences instead of the proposal that behaviour is learnt by a repetitive association between the response and the stimulus (McLeod, 2018).

Skinner's work on operant conditioning was based on Thorndike's Law of effect which states that behaviour that is followed by pleasant consequences is likely to be repeated, and behaviour followed by unpleasant consequences is less likely to be repeated (McLeod, 2018). He introduced the concept of Reinforcement into the Law of effect. According to Skinner, behaviour which is reinforced tends to be repeated (i.e., strengthened) whilst behaviour which is not reinforced tends to die out-or be extinguished (i.e., weakened).

Three types of responses, or operant, that can follow behaviour were identified by Skinner; Neutral operants, which have no effect on the probability of the behaviour being repeated; Reinforcers (either positive or negative), that increase the probability of repeated behaviour and Punishers that decrease the probability of repeated behaviour and actually weakens behaviour (McLeod, 2018).

The operant conditioning learning theory is classified under behavioural psychology, which focuses on the scientific or objective study of observable interactions between organisms. Behavioural psychology recognises the presence of cognition and emotion in interactions but prefers not to study these because they are observable but immeasurable (McLeod, 2017).

The Operant Conditioning learning theory has been criticized for not considering the agentic capabilities of humans but focusing on only observable phenomena (Bandura, 1999). Bandura (1999), argues that despite the wrenching paradigm shifts that psychology has undergone, the theories developed therein grant humans little or no agentic capabilities. According to Bandura (1999), the position of operant analysts is an extreme methodological position and it makes them more restrictive than natural scientists.

3.12.1 The Social Learning Theory (SLT)

Bandura believes that reinforcement alone cannot be responsible for all kinds of learning as indicated by operant analysts. Hence, he introduced a social element to the theory on the basis that people learn new behaviours by watching other people (Nabavi, 2012).

Bandura's Social Learning Theory is set on the basis that learning occurs through interactions with others in a social context. Thus people develop similar behaviours by observing that of others, assimilating and then imitating the behaviour when they observe it to be positively reinforced (Nabavi, 2012).

The SLT therefore purports that learning occurs through:

- Observation;
- Imitation; and
- Modelling

Even though behaviourists indicate that learning is characterized by a permanent change in behaviour, in contrast, social learning theorists (E.g. Bandura, 1965) purport that learning can occur through observation alone, and may not be shown in their performance (Nabavi, 2012). Bandura, (2006) purports that learning may not automatically result in a behaviour change. The Social Cognitive theory was expanded from the Social Learning Theory by Bandura, and provides a framework that enables the understanding, predicting and altering of human behaviour. (Green & Peil, 2009).

3.12.2 The Social Cognitive Theory (SCT)

The SCT addresses the methodological flaws of the Operant Conditioning Theory by emphasizing the cognitive processes that occur between the stimulus and the response (McLeod, 2016). The SCT posits that the process of learning occurs through a triadic reciprocal interaction between the person, the environment and behaviour (World Bank, 2010.).

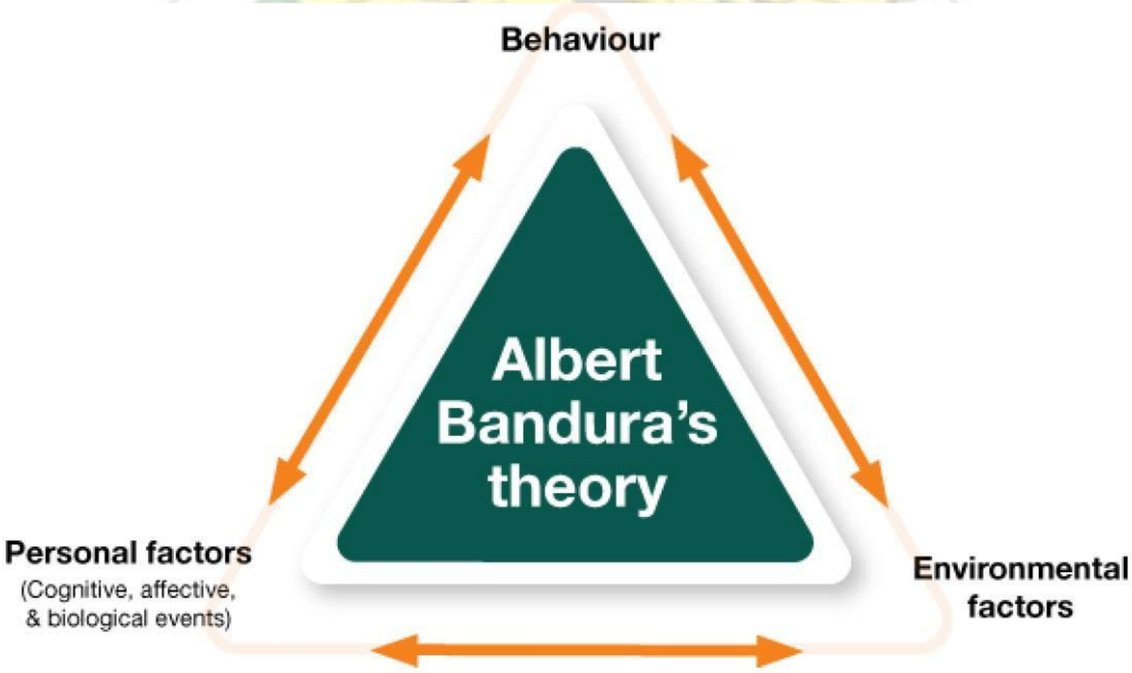


Figure 3.6 The Social Cognitive Model (Source; Nabavi, 2012)

In this model of reciprocal causation, behaviour, cognition and different personal factors, as well as environmental function as interacting determinants that influence each other in a bidirectional manner. (Figure 3.6). The different factors operate with varying levels of strength and may not occur simultaneously. A causal factor takes time to exert influence and activate the reciprocal influences.

Environmental factors reflect situational influences and the environment in which action is preformed, while individual factors include impulses, drives, characteristics and other motivating forces (World Bank, 2010). In addition, the following variables may also play critical roles in the process of behaviour change;

- Self-efficacy, which is an assessment of one's capacity to perform the actions.
- Outcome Expectations, i.e., an assessment of the likely consequences that will result from a conduct.
- Self-Control, which is the individual’s ability to control their behaviour.
- Reinforcements, i.e. that which increases or decreases the likelihood of a behaviour being repeated.

Emotional Coping, i.e., an individual's capacity to tolerate emotional stimuli.

- Observational Learning, which refers to learning through studying the behaviour of others and the consequences of such behaviour.

While it may be necessary to provide resources and support to boost individual trust to increase self-efficacy rates, other researchers propose that improvement in behaviour should be viewed as a series of small measures to increase self – efficacy (World Bank, 2010).

- Even when people have a strong sense of effectiveness, they may not be performing the action if they are not motivated. This seems to indicate that it may be necessary to provide opportunities and rewards for behaviours if we are interested in getting others to act.
- Environmental shaping will promote changes in behaviour. This could include provi ding opportunities for behavioral change, promoting such changes and providing soc ial support.
- Recognizing environmental factors that may prevent changes in behaviour is of great importance. (World bank, 2010)

3.13 Behaviour Based Safety (BBS) Interventions

Behaviour Based Safety Interventions have shown considerable promise in being successful when employed in different industries and cultures (Choudhry, 2014).

A Behaviour-Based Safety (BBS) methodology aims at improving safety through the integration of behavioural science, quality and organizational development principles with safety management in order to reduce industrial injuries. This approach becomes especially important in tackling safety issues since it focuses on the psychology of the human at work and focuses on employee behaviour as a critical element in achieving better safety standards (Salem et al, 2007). The concept of BBS can be traced to Skinner's Operant Conditioning Theory (Tuncel et al, 2006), as such, "The overarching theme in behaviour analysis and BBS is that behaviour is maintained by what occurs after it", i.e. the consequences. (HSA, 2013).

Two main features promote the BBS approach over others, namely:

- It focuses on employee behaviour which is claimed to be the main source of injuries and illness
- It encourages employee involvement in safety issues as safety is not seen solely as the management's responsibility (Salem et al, 2007)

In a case study involving construction sites, safety performance at one project improved from 86% (at the end of 3rd week) to 92.9% in the 9th week when a behaviour based intervention programme was applied to construction workers. Significant performance improvements were observed with personal protective equipment use, housekeeping, access to heights, plant and equipment, and scaffolding (Choudhry, 2014). The intervention used in this case study utilized initial safety behaviour measurements, goal setting, performance measurements of safety and feedback to the parties involved. Supervisors were encouraged to commend workers when they excelled at improving behaviour (Choudhry, 2014).

The emphasis of a BBS approach to safety is, as the name suggests, on behaviour. According to the HSE, in about 80% of work-related accidents, employee behaviour in the form of acts or omissions (at-risk behaviour) is a critical contributing factor. The consistent occurrence of such 'at-risk' behaviour can garner into several negative events (IOSH, 2015).

According to IOSH, employees engage in 'at-risk' behaviour for several reasons including:

- Cutting corners to save time: when workers do not follow due process such as the refusal to use appropriate PPE because of the assumption that the task at hand can be completed in a short period.
- Ergonomic factors: sometimes the construction sites lack appropriate arrangements leading to potentially dangerous access routes.
- Misunderstanding of at-risk behaviour: employees who lack training or information may not perform at-risk behaviour in their ignorance. Sometimes these behaviours may also be reinforced through the actions of supervisors.
- Some workers instinctively engage in risk-taking behaviour.

The behaviour-based approach to safety is a systematic process that focuses exclusively on the observable, measurable behaviours critical to safety in a particular setting. It identifies and targets specific unsafe acts or 'at-risk' behaviours that need to be extinguished to reduce negative occurrences. Figure 3.7 describes the process of a BBS process in an establishment.

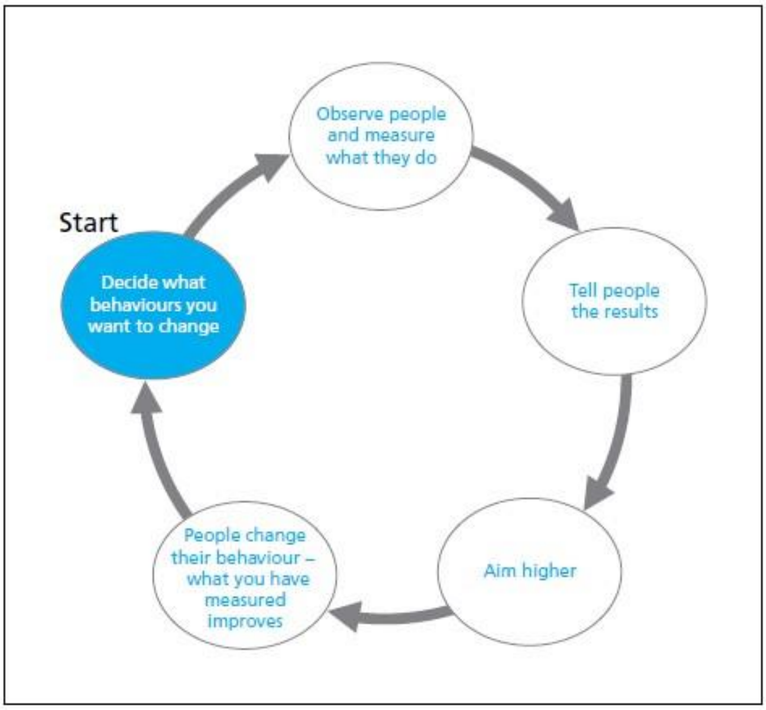


Figure 3.7: The BBS Process (IOSH, 2015).

Several researchers and the Institution of Occupational Safety and Health (IOSH), advocate the use of a Behavioural Safety process to improve safety performance, by identifying and reinforcing safe behaviour, and reducing unsafe behaviour. The construction industry stands to benefit immensely if BBS interventions are employed to improve health and safety performance particularly with respect to improving PPE use

3.14 Chapter Summary

Safety helmets and goggles have been identified as an effective means of protecting the head and face regions of construction workers on the site. However available literature indicates many discomforts with the use of both PPE such as poor fit, poor visibility and hotness within. Users of uncomfortable safety helmets and goggles may experience conditions such as heat stress, external compression headaches and the consistent interruption of work. These conditions arising out of the discomforts may subsequently impair workers' cognitive abilities while on site, thereby creating unsafe working conditions. In other instances, workers may remove the safety helmet or goggle (which is an unsafe act) when the discomfort gets unbearable, creating other unsafe conditions.

The unsafe acts and conditions described can be placed in the context of the Multiple Causation Model (Peterson, 1971), with the sub-causes being the numerous discomforts experienced with safety helmets and goggles. Again, looking at the scenarios created in the context of the Accident Root Causes Tracing Model, unsafe acts and conditions arising out of discomforts experienced may be described as causal factors while the causes of the discomforts may be described as the root causes of accidents that may arise. In order to improve the use of safety helmets and goggles, it important to deal with the root causes which lead to the unsafe conditions created and acts performed, by eliminating or minimizing the discomforts felt by users of safety helmets and goggles. The study recognizes a need to improve the attitude of construction workers towards the use of safety helmets and goggles, through the clear identification of the discomforts experienced with their use in order to propose suitable remedies, however, the following gaps were identified after the literature review;

- Although several studies have been conducted on discomforts associated with safety helmets and goggles and recommendations made for improvements, no study was identified that has investigated the presence of physiological strain amongst construction workers with the continual use of uncomfortable PPE in real life settings.
- In addition, considering that vast differences exist between people living in different geographical locations, it is unclear whether anthropometric characteristics of users

outside the manufacture location are considered in the production of safety helmets and goggles, or even in their importation by dealers and construction firms within the user location.

- Many studies on improving PPE use often focus on physical and physiological comfort more than psychological comfort
- It is not known if a behaviour based safety intervention will be successful in improving the safety behaviour of construction workers with regards to the use of safety helmets and goggles.

The gaps identified in the literature review, set the stage for the design of research questions and objectives to improve the attitude of construction workers towards the use of safety helmets and goggles.

CHAPTER FOUR

RESEARCH DESIGN AND METHODS

4.1 Introduction

The previous chapter indicated the need to identify the underlying causes of discomforts with the use of safety helmets and goggles, to guide the process of improving its use among construction workers. This chapter details methods used to inquire about discomforts felt by users of safety helmets and goggles, the underlying causes of the discomforts and considerations made in the selection and procurement of PPE, by construction firms. In the ensuing discussion, the principles, procedures and tools that were employed in achieving the objectives of the study are elaborated. In addition, the philosophical worldview and considerations that shaped the research strategy and the data collection procedures are described.

4.2 Research Design

Literature abounds with several strategies for conducting research. According to Yin (1994), a research design is what connects the data to be collected and conclusions to be drawn to the initial questions of a study, as such it provides a conceptual framework and an action plan that moves a researcher from a set of questions to a set of conclusions.

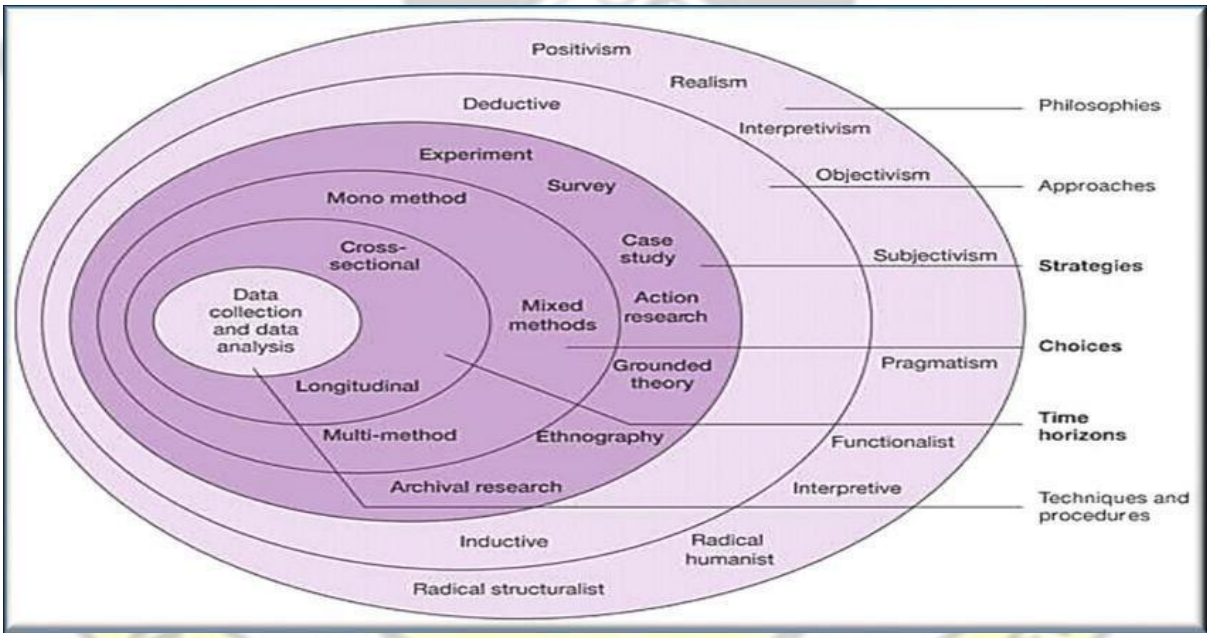


Figure 4.1: The Research Onion (Saunders et al., 2009)

The 'Research Onion Model' proposed by Saunders et al., (2009) and indicated in Figure 4.1 is the preferred approach for the research design because it provides a systematic procedure for researchers to provide the necessary answers and conclusions to their research questions. In addition, Bryman (2012) purports that the research onion is adaptable for almost any type of research methodology and can be used in a variety of contexts.

4.3 Philosophical Considerations

The philosophical position is found in the outermost part of the “Research Onion”. Creswell (2009) presents this overarching term as “a basic set of beliefs that guide action”. According to him, philosophical ideas influence the practice of research and need to be identified. Perhaps a simpler definition is given by Crotty (1998), who describes it as the philosophical stance that informs the methodology and provides a context for the research process that grounds its logic and criteria. Similarly, Saunders et al, (2009) simplify this term as a relation between the development of knowledge and the nature of this knowledge indicating that the research philosophy adopted contains pertinent assumptions of how the researcher views the world. These assumptions subsequently underpin the research strategy and the methods used. Guba (1990), summarises this as:

(i) Ontology – What is reality?

(ii) Epistemology – How do you know something?

(iii) Methodology – How do you go about finding it out?

4.3.1 Ontological Considerations

Ontological considerations refer to the nature of reality. Objectivism is one school of thought that perceives reality as independent of social actors whilst subjectivists purport that social phenomena exists as a result of the perceptions and actions of the social actors involved (Saunders et al, 2009). Unlike objectivists, proponents of subjectivism prefer to study the underlying reasons accounting for the observed social phenomena and believe that social phenomena undergo changes because of the continual actions of the actors involved.

4.3.2 Epistemological considerations

Epistemological considerations are concerned with what is considered acceptable knowledge in a field of study (Saunders et al., 2009). Researchers either embrace a positivist or an interpretivist position. Positivist research works with observable and preferably measurable entities from which law-like generalizations can be made. Interpretivism emphasizes that humans play a huge role as social actors in the scheme of things and there is the need to understand the differences between these actors (Saunders et al., 2009).

4.3.3 Philosophical Position of this Research

The best choice of philosophical positioning depends on the research question i.e. which position best answers the question involved. This study sought to investigate discomforts associated with the use of safety helmets and goggles in the construction industry and proceeded to identify factors that would ensure that safety helmets and goggles procured would be user-friendly and accepted by construction workers. The under listed research questions were developed as a means of achieving the research aim;

1. What discomforts do construction workers feel in the use of safety helmets and goggles?
2. What accounts for the discomforts felt by construction workers in the use of safety helmets and goggles?
3. What considerations are made in the selection and procurement of Construction safety helmets and goggles?
4. How can the user-experience of construction workers regarding safety helmets and goggles use be enhanced?

In the opinion of the researcher, the research questions for which answers are sought does not explicitly lean towards a positivist nor an interpretivist philosophy. The researcher believes that values play an important role in the interpretation of results, and prefers to view the nature of reality in multiple ways, considering both observable phenomena and subjective meanings and thus allowing for the best method to be chosen in providing acceptable knowledge in answering the research question. Thus, the research adopts the philosophical position of the Pragmatist, a position that argues that it is perfectly possible to adopt variations in the philosophical considerations (Saunders et al., 2009).

4.3.4 Research Approach

The next layer of the Research Onion enquires whether a deductive or inductive approach is employed in the research. The deductive approach lends itself to the development of an explicit theory and a research designed to rigorously test the hypothesis emanating from the theory. The inductive approach requires the researcher to collect data and develop a theory from the analysis of this data (Saunders et al., 2009). A summary of the main differences between both approaches is outlined in table 4.1.

Table 4.1: Differences between deductive and inductive approaches to research

DEDUCTIVE APPROACH	**INDUCTIVE APPROACH**
Emphasizes Scientific principles	Prefers to gain an understanding of the meanings humans attach to events
Moves from theory to data	Encourages a close understanding of the research context
Emphasizes the need to explain causal relationships between variables	The collection of qualitative data
Usually collects quantitative data	Has a more flexible structure to permit variations in the research emphasis as the research progresses
Ensures the application of controls to ensure the validity of data	Realises that the researcher is part of the research process
The operationalization of concepts to ensure clarity of definition	Is less concerned with the need to generalize
Involves a highly structured approach The researcher independence of what is being researched	
The necessity to select samples of enough size in order to generalize conclusions	

Source: (Saunders et al, 2009)

Although Creswell (2002) suggests several practical criteria, Saunders et al., (2009) purport that the emphasis of the research and the nature of the research topic are the most important criteria to consider in selecting a research approach. The pragmatic approach adopted by this study required the use of a diverse approach to achieve the set objectives.

4.4 Research Strategy

The study initially employed a preliminary investigation to ascertain the main reason behind construction workers' refusal to use PPE.

The preliminary study involved the administration of a structured questionnaire to one hundred and twenty-three (123) construction operatives drawn from purposively selected construction sites. Subsequently, a survey and a case study were employed to critically interrogate the issues arising from the preliminary study.

According to Saunders et al., (2009), surveys enable the collection of a large amount of data from a sizeable population in a highly economical way. The study required information from construction firms operating in Ghana, regarding considerations made in the selection and procurement of PPE for use on site. A questionnaire survey provided the best option for obtaining data from the construction firms.

A multiple case study was concurrently employed to get a deeper understanding of the discomforts felt by workers with the use of safety helmets and goggles and to identify the causes of these discomforts. Specific methods used within the case study were; semistructured interviews, observational field experiment and anthropometric measurement of construction workers. A case study was preferred because the phenomena (discomforts amongst workers with use of PPE) could be studied within its natural environment /context (i.e. construction site).

Saunders et al., (2009), define research choices as the combination of quantitative and qualitative methods for achieving set objectives. Quantitative research is synonymous with data collection and data analysis techniques that use and generate numerical data (Saunders et al., 2009). It is objective in nature, tests theories and hypotheses and is usually associated with the deductive approach (Baiden, 2006). In contrast, qualitative research employs nonnumeric data in its data collection and data analysis techniques. Qualitative research may use data other than words such as pictures and video clips (Saunders et al., 2009).

Saunders et al., (2009) propose the Mono and Multiple Method as options for research choices as shown in Figure 4.3.

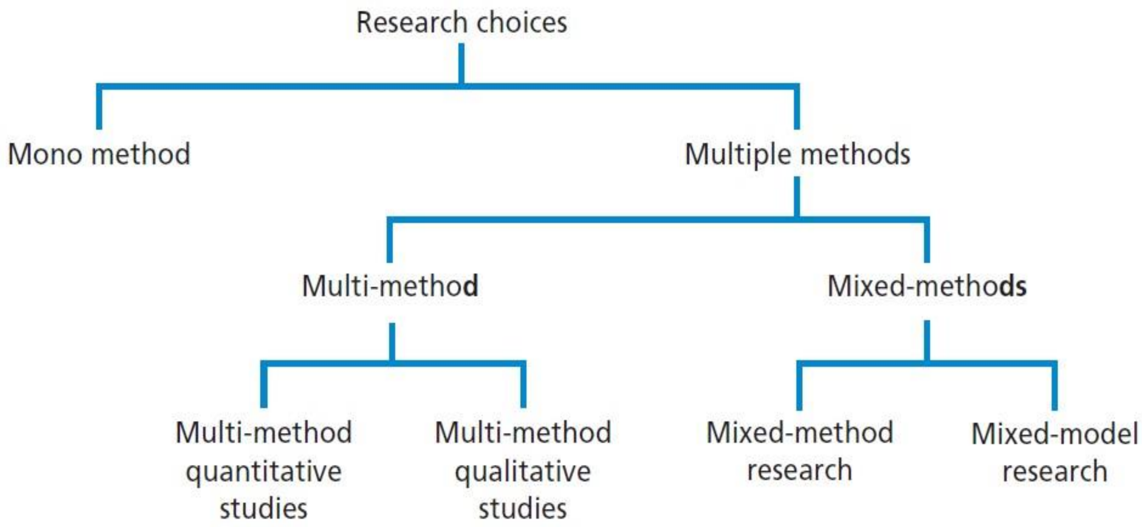


Figure 4.2: Research Choices (Saunders et al., 2009)

The mono method involves the use of a single data collection technique and its corresponding analysis while the multiple method uses more than one data collection and analysis method to answer the research question. According to Saunders et al., (2009), the multiple method consists of the multi-method and the mixed method of inquiry. The researcher may choose to either use a few quantitative (multi-method Quantitative studies) or qualitative (multi-method qualitative) methods and their corresponding analysis.

In using multi methods, the researcher cannot combine both quantitative and qualitative methods in one study. However, under mixed methods of inquiry, the options available to researchers is a combination of qualitative and quantitative data collection techniques and analysis procedures. For example, quantitative data can be converted into a narrative and analysed qualitatively, while qualitative data can be converted to numerical codes that can be analysed statistically.

The multiple method is also described by some authors as research design (Saunders et al., 2009). According to Nauom, (2007) the Research design (multiple method) questions the research objectives and is dependent on the type of research and the information available.

4.4.1 Strategy Adopted in this Research

The Pragmatists viewpoint contends that values play a large role in interpreting results hence the pragmatist adopts both objective and subjective viewpoints in his research. Pragmatists require the use of a mixed method strategy of inquiry (Saunders et al., 2009). Opoku et al, (2016), purport that the selection of a research method should consider fitness for purpose, and is largely dependent on the research aim/s. The choice of a research method thus requires a compromise between factors such as validity, reliability and access to data and resources. This study employed the use of multiple methods, specifically, mixedmethod research in a cross-sectional study, to achieve the study objectives

A Mixed Method Strategy of inquiry was preferred because:

- The research objectives required information to be obtained from both management personnel of construction companies (Procurers of PPE) and site operatives (users of PPE)
- Management personnel are formally educated hence it was possible to obtain information through self-administered structured questionnaires hand-delivered and picked up upon completion.
- Site operatives predominantly have low levels of education hence subjective information required was better gathered through semi-structured face to face interviews and critical observation in a phenomenological study to objectively investigate the phenomena under study.

Several researchers suggest that 'mixed method' strategies of inquiry have the advantage of fostering deeper understanding of the research problem by offsetting the weaknesses inherent to using either quantitative or qualitative study. According to Day and Gunderson, (2018), research problems within the Built environment often require combined research tactics and strategies that span across multiple disciplines. The authors advise that a mixed research approach is the most appropriate tool for the built environment as it offers a platform to mix both qualitative and quantitative methods from different disciplines to solve the most complex research problems within the industry. Mixed methods improve the validity and reliability of the resulting data and strengthens causal inferences by providing the opportunity to observe data convergence or divergence in hypothesis testing (Abowitz and Toole, 2010).

4.5 Techniques and Procedures

4.5.1 Preliminary Investigation

In a preliminary study that set the stage for this work, 123 construction workers in Ghana were surveyed on their use of PPE. Structured questionnaires were personally administered to construction operatives on selected construction sites as a means of obtaining information for the study. Purposive sampling, which is a non-probability sampling technique, was used in the selection of the construction site with the following criteria; a site that promotes the use of PPE, a site with a high probability of identifying hazards identified from literature and a site which is active with at least 50 operatives.

Convenience sampling was used to select the respondents on the sites visited. Based on the trends of the response and the population of operatives on the sites, the number of respondents per site varied. Construction workers, who took part in the study, answered the questions on their own accord, and not in the presence of their supervisors. Data obtained from the questionnaire survey was described using descriptive statistics using the IBM SPSS v. 21 software tool.

The preliminary investigation identified feelings of discomfort as the main cause for refusal of construction worker to use given PPE, just like to sentiments raised by construction workers in other parts of the world. The findings from the preliminary investigation, which sets the stage for this study, indicate the need for a conscientious and pragmatic approach to provide PPE that is more user-friendly for construction workers to encourage its use.

The results of the preliminary investigation set the stage for this study with an aim to incorporate comfort considerations into the development of a framework for the procurement of construction helmets and safety goggles.

4.5.2 The Quantitative Inquiry

The study employed a quantitative survey to obtain information from construction companies in Ghana in a bid to achieve objective three (3). The survey strategy enables data to be collected from a good representative sample of a population in an economical manner (Saunders et al, 2009).

4.5.3 Population and Sample Size for the Survey

The target population needed to satisfy the requirements of objective three were D1/K1 and D2/K2 construction companies operating in Ghana. These construction firms are the highest and second highest category of building and civil engineering contractors in the country. Clients for these classes of contractors are usually government agencies and large private organizations. Because of the nature of their clients, these classes of contractors are usually required to and do provide personal protective equipment for their employees.

Attempts were made to obtain a comprehensive database of construction firms in Ghana from the Ministry of Water Resources, Works and Housing. But after several visits to the Ministry proved futile in this regard, the study resorted to a census survey of D1K1 and D2K2 members of the Association of Building and Civil Engineering Contractors of Ghana, a private and active association formed by construction firms in the country. One hundred and twenty-nine (129) D1/K1 and D2/K2 contractors were identified from the ABCECG database. These construction firms were largely based within the Greater Accra and Ashanti regions of Ghana but had projects in different locations across the country. However only a hundred (100) could be contacted on the telephone numbers provided. One hundred (100) self-administered questionnaires were hand delivered to the offices of these construction firms. Seventy-four (74) responses were received at the end of a three-month data collection period.

4.5.4 Data Collection and Data Analysis Process

A self-administered questionnaire (see appendix 1), was designed to elicit responses from officers responsible for procuring PPE in the various firms, about the considerations made in PPE selection and procurement. Questions were designed in simple and unambiguous English statements to facilitate easy understanding. Questions were mostly close ended with the inclusion of a few open-ended questions to avoid monotony and enhance interest (Babbie, 1990). Additionally, an even scale was employed to rank the intensity of respondent's opinions on factors obtained from literature as considerations for the selection and procurement of PPE, as well as their opinions on the discomforts felt by construction workers in the use of PPE. An even point scale was preferred over an odd point scale in order to compel respondents to "take a side". A mid-point was eliminated because the study desired that respondents make a definite choice instead of taking a neutral position on the questions asked. Several studies prefer to have a neutral point as they feel that forcing respondents to select an option does not reflect the true attitudinal position, however, several more studies (Eg. Alwin, 2007) have shown that maintaining a neutral position negatively impacts the quality of the measurement and affects reliability (DeCastellarnau, 2018).

Questionnaires were hand delivered to respondents with the help of the contact information provided by the association, and responses picked up at scheduled times. The questionnaires were intended to be answered by personnel responsible for the procurement of PPE within the construction firms.

Descriptive analysis consisting of frequency analysis, mean score and standard deviation were carried out on each variable.

4.5.5 The Qualitative Inquiry

The qualitative aspect of this study was conducted through a case study. Case study as an empirical inquiry can be used in studying a phenomenon within its real-life context (Yin, 1994). Objectives 1 and 2 sought to investigate discomforts associated with the use of safety helmets and goggles amongst workers on a typical construction site. A multiple, embedded case study was used to achieve this objective. Embedded units studied were construction workers who use both safety helmets and safety goggles.

4.5.6 Selection of Cases

A multiple case study design was selected in order to make for a robust argument and theoretical replication (Yin, 1994). The study selected three construction sites which were generally characterized by active operations, the strict enforcement of PPE protocols and the presence of diverse skilled workers. All three cases were in the Ashanti Region of Ghana, specifically the Kwame Nkrumah University of Science and Technology campus. The case study was carried out within a two – week period.

4.5.7 Orientation Process

Site management and workers were taken through an orientation process detailing the reasons for the study, the kind of data to be taken and the impact of the results for construction workers. Volunteers for the study were sought after the orientation process.

4.5.8 Selection of Units

The study required volunteers for the field experiment to have general characteristics of a healthy Body Mass Index (BMI), normal blood pressure (i.e. non-hypertensive/hypotensive) and no chronic medical condition. Volunteers underwent a pre-testing exercise where they had their blood pressure readings taken over a one-week period to ensure they were eligible for the study. Sixteen (16) volunteers were finally selected to take part in the study. Cases 1 and 2, both had five (5) volunteers each. Whilst Case 3 had six (6) volunteers. Volunteers in both Cases 1 and 2 were young with ages ranging between 20-39 years and with 5 to 10 years of working experience on construction sites. Case 3 volunteers consisted of middleaged volunteers with ages between 40 to 49 years and with construction work experience above 15 years. Selected candidates signed consent forms after they had indicated their complete understanding of the study requirements.

4.6 Methods Employed in the Case Study

The collection of data in a case study can be done through quantitative, qualitative or mixed methods (Yin, 1994). A sequential exploratory strategy (Creswell, 2009) was applied in this study. This strategy involves elaborating the findings of one method with another. For example, a quantitative inquiry may be used to elaborate the findings of a qualitative method (Tashakkori and Teddlie, 1998).

4.6.1 Semi-structured Interviews

In an attempt to achieve Objective 1, the study initially employed semi-structured interviews conducted on the volunteers for the study, to obtain information from construction workers about the discomforts they feel while using safety helmets and goggles, how they manage the discomforts felt and their opinions on measures that could improve their user experience. Semi-structured interviews allow the collection of in-depth data from interviewees in a flexible manner and hence enhances comprehensive participation by interviewees (Manu, 2012).

The interviews were mostly conducted in the Akan language as many construction workers cannot communicate effectively in the English language. The data obtained was subjected to a content analysis to identify the relevant issues arising out of the interviews.

4.6.2 Observation/Field Study

Observational research, sometimes referred to as field study involves a researcher taking critical notes of on-going behaviour, process or phenomena in its natural settings and it is a useful tool for studying feelings or experiences expressed by people (Shmuck, 1997; Kawulich, 2012). An observational study was subsequently conducted on the sixteen volunteers from the three case studies to investigate physiological strain associated with the use of safety helmets and goggles.

Physiological readings of heart rates and body temperatures were taken at set intervals within the day for five days. Air temperature and relative humidity readings were also taken concurrently. These readings were placed in the physiological strain equation; **Physiological Strain (PS) = 5(Tret - Tre0). (39.5 - Tre0)-1 + 5(HRt - HR0). (180 - HR0)-1** (Moran, 1998). Results obtained were interpreted on a universal scale of 0-10.

The heart rates and body temperatures of participants were measured with the use of well calibrated Sphygmomanometers (*OMRON HEM 907XL*), and non-contact infra-red thermometers (*RoHS AT-B886)* respectively. Air temperature and relative humidity were measured with a HOBO Analogue temperature/relative humidity Data Logger.

4.6.3 Anthropometric Measurements

Issues of fit with regards to the use of helmets and safety goggles were frequently mentioned in the interview. According to Abeysekera, (1998), PPE produced in developed countries and exported to developing countries do not take anthropometric details into consideration resulting in issues of poor fit. The study took head and face measurements as identified in Figures 3.3 and 3.4 of one hundred and twenty-seven (127) construction workers within the three case studies with the help of an inelastic tape measure and a scale rule, to compare typical anthropometric readings to the helmets and safety goggles imported into the country.

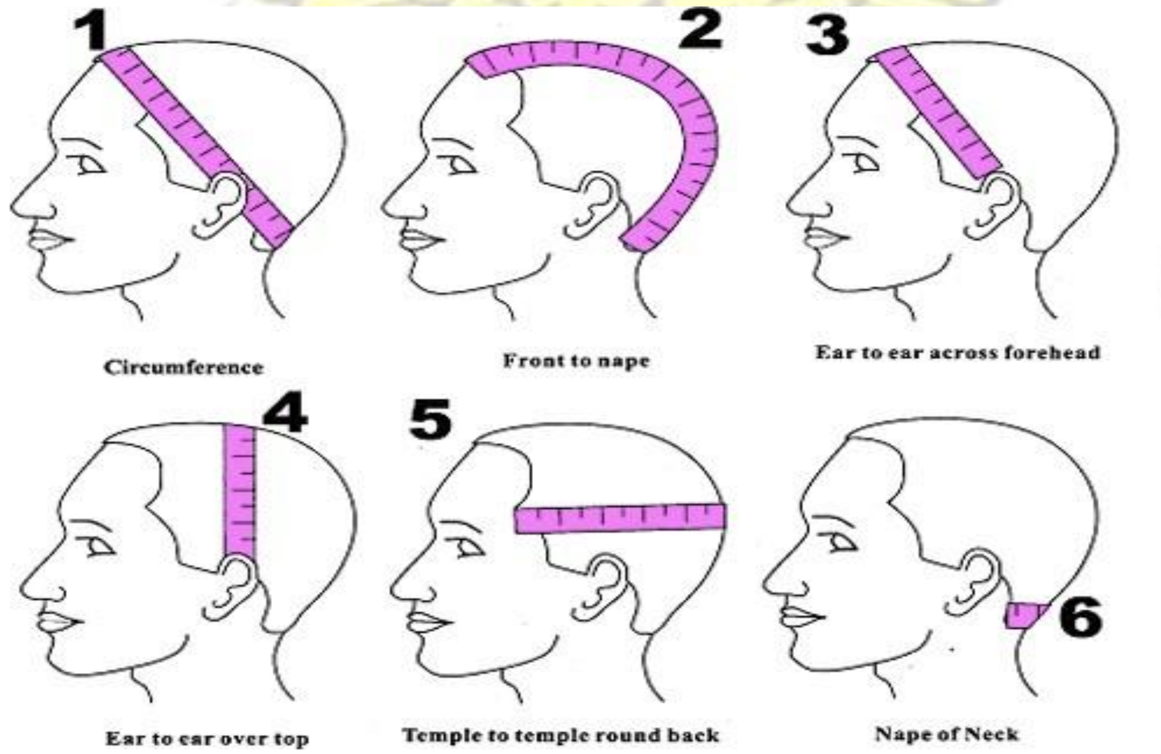


Figure 4.3: Typical Head measurements used in the manufacture of wig caps

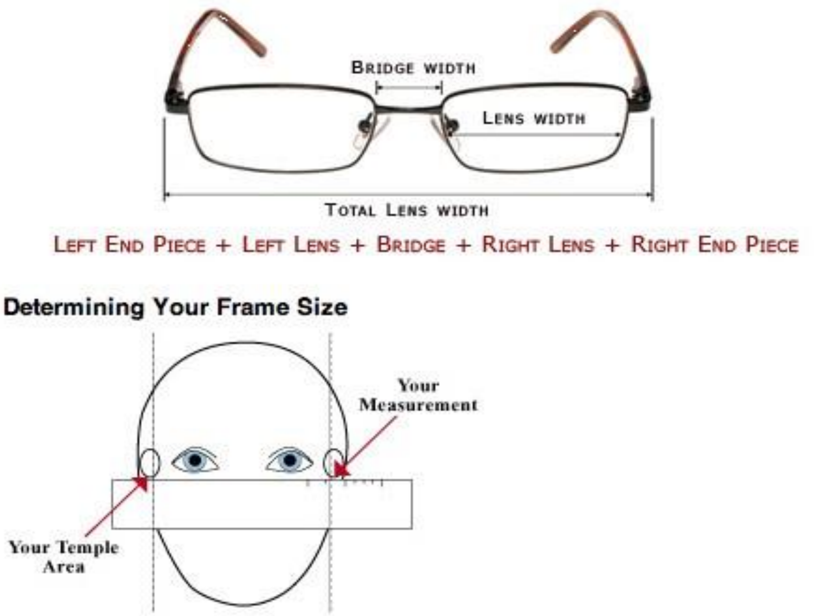


Figure 4.4: Typical Measurements required for a spectacle to fit well (Frame width)

4.7 Validity and Reliability

4.7.1 The Survey

Pretesting was necessary to ensure that questions were fully conveying their intended meaning (Bowden et al, 2002). To ensure validity and reliability of the survey, questions were discussed several times with research supervisors to judge the appropriateness of the questions and review them as and when necessary to ensure their relevance to the study objective. The questionnaires were piloted among five (5) construction firms, to test their efficiency in interrogating the issues of interest.

Research assistants employed in the distribution and collection of questionnaires had a minimum educational level of a Bachelor of Science degree in building technology. Their educational level coupled with orientation processes given ensured they completely understood the intent of the data collection.

4.7.2 The Semi-Structured Interviews

To ensure linguistic validity of the interview process, the answers provided by interviewees were repeated to them for confirmation and written out in English on the answer sheets provided for this purpose. The primary language (mother tongue) of the interviewer being Akan coupled with the fact that all formal education undertaken by her (basic to post graduate level) were done in the English language ensured the context of the questionnaire was not lost and cultural validation of the interview process was achieved.

4.7.3 The Field Experiment and Anthropometric Study

Validity of the findings were ensured by employing the services of medical research students to take the measurements as well as the use of well calibrated equipment for the measurements. Readings were recorded appropriately.

4.8 **Ethical Considerations**

Ethics refers to the guiding principles or the values that govern the conduct of a person in every endeavour. In a research process, consideration of ethical standards prevents data obtained from the study from coming into disrepute. Heart rates and body temperature readings were taken from volunteers for the physiological strain experiment. These readings were taken in a non-invasive manner as the experiment was conducted on construction sites, as such the ethical considerations made in this study are based on the pointers proposed by Bryman and Bell, (2007).

1. The study ensured that the research participants were neither exposed to harm nor subjected to same in any way. Respondents to the survey filled their questionnaires in the privacy of their offices and submitted them when they were completed. All activities within the case study, i.e. the field experiment, anthropometric measurements and interviews were carried out on the site and in the full view of other participants.

2. Participants were treated with utmost respect and their dignity was not undermined in any way. Communication was done in very courteous language and they were not manhandled in any way.

3. Respondents to the surveys received introductory letters attached to the questionnaires indicating the reason for the research and assured them of the confidentiality of their responses. Similarly, permission was sought from the organisations in the case study through an introductory letter presented to their offices. The full consent of participants in the field experiment were obtained through a signed consent form prior to the study, after the researcher had carefully explained the aim of the study and all that was required of the participants to the entire workforce present on each site.

4. The privacy of both individual participants and organisations in every aspect of the study were totally protected and all data remain highly confidential. .

5. All communication with respect to the research were done with honesty and transparency and there was no exaggeration of the aim and objectives of the study.

6. The study tried at all costs to present a true representation of findings from the primary data without bias.

7. There was no avenue for a possible conflict of interest with any of the institutions from which the researcher was granted funding.

4.9 CHAPTER SUMMARY

The aim of this study was to develop a framework that enhances construction workers' experience with the use of safety helmets and goggles through a combination of behavioural learning theories and the consideration of anthropometric characteristics. The study adopted the Pragmatist's approach, which influenced the type of methods employed in the study. A summary of the methodological approach for this study is illustrated in figure 4.5.

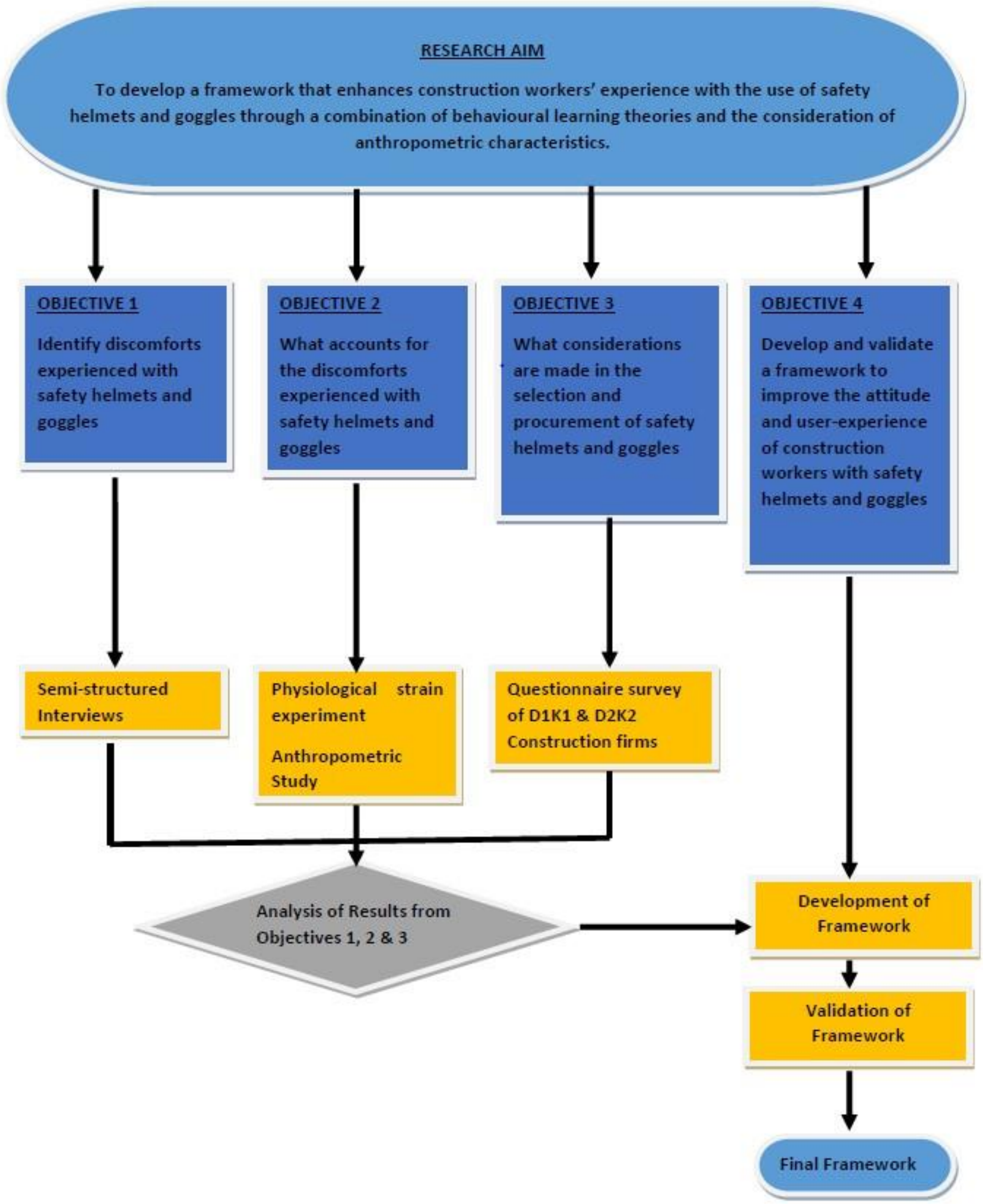


Figure 4.5: Methodological Framework for the study.

CHAPTER FIVE

PRESENTATION OF RESULTS

5.1 Introduction

This chapter focuses on the analyses and presentation of the results from the study. It is divided into three main sections representing the research tools employed in achieving the stated objectives. Each section presents details of results obtained and includes the background data on participants in the study.

5.2 The Preliminary Investigation

The preliminary study was conducted to investigate awareness of construction workers with regards to the job hazards that exist in their workplace and to identify why construction workers typically do not use the requisite personal protective equipment on site. Participants of the study and results obtained are described in the ensuing sections.

5.2.1 Background Information of Respondents in the Preliminary Investigation

Respondents consisted of one hundred and twenty-three (123) construction site operatives such as masons, carpenters, steel benders, electricians, plumbers, painters and labourers drawn from 15 construction sites. Sixty-seven percent (67%) of respondents were skilled workers while thirty-three percent (33%) of respondents were unskilled labourers.

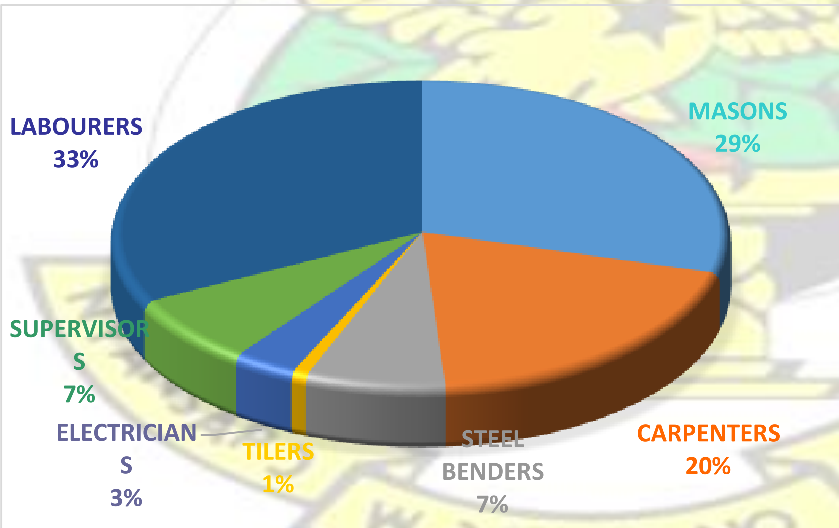


Figure 5.1: Expertise Profile of respondents in the survey

The researcher also sought to know the total work experience of the respondents and this is indicated in figure 5.2.

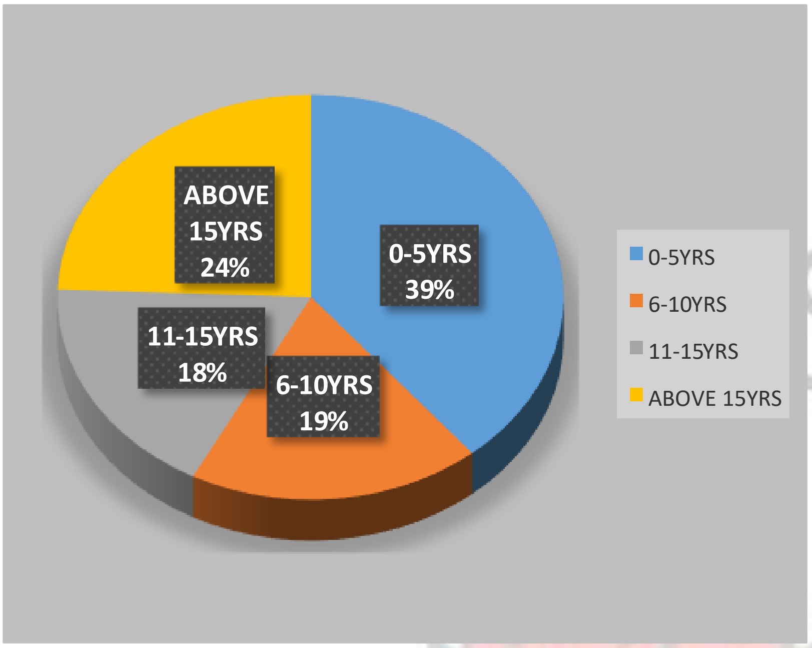


Figure 5.2: Work Experience of respondents in the survey

Respondents to the preliminary survey had construction industry work experiences ranging between one to over fifteen years. All 123 respondents were male. This was not planned as female construction workers were not encountered during the survey.

5.2.2 Results Obtained from Preliminary Investigation

Construction workers unanimously agreed that job hazards exist on their sites and they required PPE to protect themselves from the effects of these hazards. "Falls from a height" was unanimously agreed as the commonest hazard that occurred on sites. This is in line with the observation that "falls from height'' is the most common type of accident in the construction industry (Jeong, 1998; Haslam et al, 2005; BLS 2015). When asked if their companies provided PPE for their use on their sites and whether they used the provided PPE, respondents provided answers as shown in Table 5.1.

Table 5.1: The use of PPE on construction site

Type of PPE	The Company Provides the stated PPE		I usually use the stated PPE	
	YES (%)	NO (%)	YES (%)	NO (%)

Safety Helmet	83.20	16.80	78.60	21.40
Safety Goggles	58.80	40.30	55.90	43.20
Nose Mask	54.60	44.50	48.30	50.00
Ear Plugs	41.20	58.00	33.90	65.30
Reflective Jacket	77.30	22.70	67.50	31.60
Hand Gloves	68.10	31.90	65.00	34.20
Safety Harness	47.10	52.90	40.70	58.50
Safety Boots	68.10	31.90	72.40	27.60
Average	62.30	37.38	57.79	41.48

An average response of 62.3% indicated that construction firms provided PPE on the site. Helmets, reflective jackets, safety boots, nose masks, ear plugs and safety harnesses were identified as the commonly procured PPE on the sites; however, workers usually received helmets, reflective jackets and safety boots, while the other PPE were given when it was considered necessary. A surprising average response of 41.5% of these respondents however admitted to not usually using the requisite PPE while they worked.

Construction workers were subsequently interviewed on their reasons for not using the requisite PPE. Responses to the interview are indicated in Table 5.2.

Table 5.2: Reasons for Non-Use of PPE on construction sites

TYPE OF PPE	Percentage Response (%)					
	I feel Uncomfortable	I don't know how to use it	It gets in the way of work	It is not relevant to my work	I was not given	No Reason
Helmet	49.00	2.00	11.80	0.00	37.30	0.00
Safety Goggles	32.80	1.60	11.50	0.00	54.10	0.00
Nose Mask	25.90	5.20	5.20	5.20	58.60	0.00
Ear Plugs	19.70	4.90	4.90	11.50	59.00	0.00
Reflective Jacket	40.00	2.20	4.40	0.00	51.10	2.20
Hand Gloves	29.60	3.70	7.40	7.40	51.90	0.00
Safety Harness	23.10	10.80	7.70	6.20	52.30	0.00
Safety Boots	36.40	2.30	9.10	0.00	52.30	0.00
Average	32.06	4.09	7.75	3.79	52.08	2.20

Several reasons were given by the workers for the non-use of PPE as indicated in Table 5.2. Notably, 52.8% of respondents reported that although PPE were on site, it was not given to them to use. In the personal interviews with the workers, some lamented that they were sometimes refused PPE because they were not permanent staff of the construction companies. In other cases, PPE that had worn out were never replaced by the supervisors hence their refusal to use them. The supervisors on the other hand indicated that most workers handled PPE in a manner that easily destroyed them. For instance they had on some occasions seen workers eating out of safety helmets and as such, there was no point in replacing PPE that were spoilt.

Various complaints of discomfort were also indicated by workers with the use of PPE. Typical among the complaints were headaches and hotness with the use of helmets and reflective vests, safety boots being too heavy, poor visibility with safety goggles and impaired hearing with ear plugs. Others complained that the nose masks made breathing quite difficult. Similar complaints were made by Nigerian construction workers (Tanko and Anigbobu, 2012). On the average, 7.75% of respondents indicated that PPE got in the way of work, while 4.08% admitted they did not even know how to use the requisite PPE. A further 3.8% declared that some PPE were usually not relevant to their work on site while 2.2% had absolutely no reason for not using the PPE.

5.2.3 Conclusions Derived from Preliminary Study

The responses obtained from this preliminary survey expounded the reality that the paramount reason for lack of PPE use by construction workers could be ascribed, to the various discomforts experienced during use and this was similar to complaints raised by Nigerian construction workers expressed in Tanko and Anigbobu (2012).

5.3 The Case Study

The case study employed the use of a semi-structured interview, a field experiment and an anthropometric study to inquire into objectives 1 and 2, which sought to identify;

- What discomforts construction workers experience in the use of safety helmets and goggles? and
- What accounts for the discomforts experienced by construction workers in the use of safety helmets and goggles?

There were two sets of respondents within the case study. The first group consisted of 16 construction workers who took part in both semi-structured interviews and a field experiment. The second set comprised 127 construction workers who took part in an anthropometric study. Both sets of respondents were found within the three cases, and details of results obtained from them are presented below.

5.3.1 Respondents to the semi-structured interviews and field experiment.

Sixteen (16) construction workers drawn from all three construction sites voluntarily participated in semi-structured interviews and an observational study (field experiment).The background information of these respondents is summarized in Table 5.3 and includes information on the gender, age group, marital status, level of education, nature of work and number of years of working in the construction industry.

Table 5.3: Background Information on Respondents to the Semi-structured Interviews and Field Experiment.

Description	Frequency (N)	Percentage (%)
Gender		

Male	16	100.00
Female	0	0.00
Marital Status		
Married	9	56.25
Unmarried	7	43.75
Educational Level		
None	2	12.50
Basic school	2	12.50
JHS	2	12.50
SHS/Vocational school	9	56.25
Tertiary	1	6.25
Years of Experience in the construction industry		
0-5yrs	3	18.75
6-10yrs	6	37.50
11-15yrs	4	25.00
Above 15yrs	3	18.75
Job Description		
Carpentry	6	37.50
Electricals	1	6.25
Masonry	2	12.50
Machine operators	2	12.50
Unskilled labourers	3	18.75
Steel benders	2	12.50

The researcher encountered only adult males as volunteers for the study. This was not surprising because construction work in most developing countries is labour-intensive and is usually dominated by men because they have the requisite strengths for most of the tasks undertaken. Volunteers consisted of carpenters (6), masons (2), steel benders (2), electricians (1), machine operators (2) and unskilled labourers (3). Nine (9) out of the sixteen (16) volunteers were married. Majority of the volunteers (9) had been educated up to the Senior High School level while one (1) had a Higher National Diploma (HND). Two (2) volunteers had completed basic school while two (2) others had completed Junior high school. Two others had no formal education whatsoever.

Three (3) volunteers had working experience in the construction industry of up to 5years, six (6) had between 6-10years of work experience, four (4), 11-15years whilst the remaining three (3) had above 15years of work experience.

5.4 Results Obtained from the Semi-structured Interviews

PPE users in the construction industry have indicated that the discomforts they feel while using given PPE is the reason they fail to use them as required (Tanko and Anigbobu, 2012; Adade-Boateng et al, 2016). Objective one of the study; "To identify the discomforts felt by construction workers with the use of safety helmets and goggles'' was interrogated by means of a semi-structured interview administered to the 16 volunteers from the three cases in a bid to know in detail the nature of the discomforts felt by users of safety helmets and goggles. Responses to the interview are indicated below;

5.4.1 Discomforts felt while using safety Helmet

Construction workers were asked to describe the discomforts they felt while using the safety helmets. The interviewees complained of regular intense heat build-up within the helmets especially during very hot weather conditions. According to them, in comparison with white helmets, the coloured helmets were usually hotter within. Interviewees also complained about how plastic harnesses got uncomfortable to use especially in hot weather. One respondent lamented, *"Some helmets have no ventilation holes…"* (Construction Worker, Case 1). Another also remarked, "*I sweat more when I use it…* "(Construction Worker, Case 1). Almost all the interviewees agreed that ventilation holes on the helmets are too few to enable sufficient aeration of the micro-environment within the helmet.

Another complaint by workers was that of poor fit with the helmets. In addition to, workers seemed to experience discomforts such as itching, and experiencing marks on their skin upon contact with the harness (especially plastic ones). According to one worker, "*my head is very small and so even though I adjust it, it keeps dropping down my face*" ... (Construction worker, Case 2). Another lamented that "*my scalp itches when in contact with the harness*" ... (Construction worker, Case 1). The researcher observed that almost all the construction workers were clean shaven as is typical amongst Ghanaian men. This results in direct contact of the harness with the scalp. One worker (Case 2) commented that helmets that had fabric harnesses felt more comfortable to use than those with the plastic ones. Discomforts relating to a poor physical interaction or resulting from the physical characteristics of the helmet can result in physical strain on the PPE user.

The interviewees also indicated that the helmets are usually heavy. According to one worker, it feels like a punishment to keep the weight of the helmet on his head as he goes about his duties. Workers also complained that often the helmets get smelly. It is possible that this occurs because of constant exposure to sweat without a proper maintenance routine. Workers complained that using helmets with all these discomforts often resulted in early onset of fatigue and headaches before the end of each day. Again, workers can undergo psychological strain as they continually battle with discomforts such as described above. Table 5.4, outlines the discomforts described by the interviewees, and categorizes them according to the nature of their impact on users of the safety helmets, i.e., physical, physiological and psychological impact. Prevalent amongst the discomforts are; helmet are hot within (33%), poor fit (22%), helmets are heavy (11%), helmets get smelly (11%) and users get headaches sometimes (11%).

Table 5.4: Discomforts with safety helmet use

Description of discomfort	Percentage (%)	Discomfort Type
Helmet is hot inside	33.00	Physiological
Helmets do not fit properly	22.00	Physical
Helmets are heavy	11.00	Physical
Helmets get smelly	11.00	Psychological
Headaches	11.00	Physiological

Early onset of fatigue	6.00	Physiological
Obstructs Vision	3.00	Physical
Too Old and so not preferred	3.00	Psychological
Total	100.00	

Source: Fieldwork, 2017

5.4.2 Discomforts felt while using Safety Goggles

Workers interviewed described safety goggles as quite difficult to use because they had to manage several discomforts at the same time while working. According to respondents, the lens in the goggles were sometimes not clear even though they were not prescription lenses (plain lenses). Items looked blurred when viewed through the safety goggles. One worker mentioned that he "*actually prefers to work without the goggles because he feels unsafe when he has to see through goggles that are not clear enough*" ... (Worker in Case 3). "*The lenses easily get scratched when you try to clean it and then you have to manage it like that*" (Case 1 worker).

Workers also complained of having to deal with the sun's glare because all goggles received are plain lenses.

Like helmets, users of safety goggles complained that they did not fit well. Workers lamented that goggles usually pinched the bridge of their noses and behind their ears. For others, the goggles were bigger and slid off their noses while they worked. Goggles usually had little or no ventilation holes as such the lenses easily got foggy due to sweat from the user. Some workers complained that the goggles felt heavy on their face. One worker out of frustration remarked "*why can't they just make them like sunglasses? We don't have any problem using those, after all we're constantly working in the sun*" (Case 1 Worker). Some workers complained that having to deal with all these discomforts associated with safety goggles also resulted in headaches for them. From Table 5.5, the top three discomforts associated with using safety goggles were poor visibility (30%), goggles not fitting properly (20%), and heat build-up (15%) between the goggles and the skin surface.

Table 5.5: Summary of discomforts with safety goggle use

Description of Discomfort	Percentage (%)	Discomfort Type
Blurred/Compromised vision	30.00	Physical

Poor fit	20.00	Physical
It feels heavy	10.00	Physical
Heat build-up inside goggles	15.00	Physiological
Early onset of fatigue	10.00	Physiological
Headaches	10.00	Physiological
Dislike the colour	5.00	Psychological
Total	100.00	

Source: Fieldwork, 2017

From the interviewee's responses on safety goggles discomforts, it was observed that 60% of the discomforts due to safety goggle use were physical in nature, 35%, physiological with the remaining 5% being psychological.

5.5 Management of Discomfort with the Use of Safety Helmets and Goggles.

The study further probed the interviewees to find out how they managed their discomforts with both the safety helmets and the goggles and requested for their recommendations for a more comfortable user experience.

5.5.1 Management of Discomforts with Helmets

The interviewees indicated that helmet discomforts often got unbearable. This results in workers often removing the helmets at regular intervals, especially on the blind side of their supervisors. Interestingly one machine operator said, "*I take it off, immerse it in water to cool it and put it back on*". (Construction Worker, Case 2). Another worker said, "*I tie my head with a head scarf before wearing the helmet, so it doesn't scratch me and leave marks on my skin*" (Construction Worker, Case 1). So basically, most workers remove the safety helmet at one point or another when the discomfort gets unbearable.

The interviewees indicated a preference for fabric harnesses and white helmets because coloured ones got hotter on sunny days. They also suggested the procurement of helmets with many ventilation holes to reduce the heat within them.

5.5.2 Management of Discomfort with Goggles

Users of safety goggles indicated they simply took them off when it felt too uncomfortable to use. Workers said that they would be more comfortable if goggles were lighter, had some ventilation holes, fit better and came with darker lenses instead of plain ones.

5.6 Observation/Field Experiment to Investigate Physiological Strain Associated with Discomforts

Objective two of the study sought to identify the sources of discomforts felt by workers with the use of safety helmets and goggles. The discomforts described by the respondents were similar in nature to symptoms of physiological strain which include increased heart rate and body temperature.

The next stage of the research involved a quantitative inquiry to investigate physiological strain on users of helmets and safety goggles as suggested by the responses from the interviews. To investigate physiological strain, vital signs of the volunteers such as heart rate and body temperature which are indicators of physiological strain were monitored over a five-day period while they worked. During this period air temperature and the relative humidity of the external environment of the study area were also measured and are indicated in Table 5.6.

Table 5.6: Summary Statistics of Temperature and Humidity Readings

Description	Air Temperature (°C)	Relative Humidity (%)
Mean	28.81	72.18
Std. Deviation	2.14	7.91
Minimum	22.63	44.00
Maximum	39.35	94.55

Heart rate (HR) and body temperature (BT) readings for the 16 volunteers in the three cases over a five-day period are outlined in Tables 5.7, 5.8 and 5.9. The readings were taken intermittently during the day, precisely at 6.30am, 8.30am, 11.30am and finally at 5.30pm. The time spells used for the measurement were selected based on the reasoning that work on the construction sites began at 7am each day. The study sought to know the nature of respondents' heart rates and body temperatures at 6.30 am, when workers had just reported for work and were not involved in strenuous activity. By 8.30 am, workers would have worked for about an hour and half. Readings at 11.30 am, were sought because respondents would have worked steadily for about four hours while the sun would have risen to almost its peak. 5.30 pm marked the close of day and hence workers were a bit more relaxed.

Table 5.7: Heart Rate and Body Temperature Readings from Case 1

Description	6.30am		8.30am		11.30am		5.30pm	
	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)
Mean	78.08	35.39	75.16	35.34	74.32	35.75	75.36	35.41
Median	78.20	35.26	75.20	35.44	73.00	35.64	76.60	35.38
Std. Deviation	6.17	1.19	8.10	0.76	6.86	0.76	7.79	0.92
Minimum	70.20	34.10	65.00	34.54	66.40	35.02	65.00	34.40
Maximum	86.20	36.84	85.20	36.24	82.60	36.84	84.00	36.54

Table 5.8: Heart Rate and Core Body Temperature Readings from Case 2

Description	6.30am		8.30am		11.30am		5.30pm	
	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)
Mean	67.72	37.98	67.84	36.12	69.88	36.25	71.48	36.13
Median	65.00	36.42	65.60	36.14	66.40	36.30	67.40	36.24
Std. Deviation	10.50	3.73	11.18	0.48	10.83	0.38	12.20	0.52
Minimum	58.40	35.92	57.60	35.52	59.00	35.78	60.80	35.26
Maximum	82.80	44.48	86.00	36.72	84.40	36.76	90.00	36.58

Table 5.9: Heart Rate and Core Body Temperature Readings from Case 3

Description	6.30am		8.30am		11.30am		5.30pm	
	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)	HR (beats/min)	CBT (^{0}C)
Mean	71.20	37.09	70.43	36.09	71.83	37.02	71.93	35.93
Median	70.60	36.32	71.70	36.09	72.10	36.11	72.00	36.07
Std. Deviation	9.09	2.46	10.26	0.34	8.09	2.38	9.98	0.54
Minimum	59.20	35.66	57.20	35.62	60.20	35.80	59.20	35.00
Maximum	83.60	41.80	83.00	36.54	81.80	41.80	85.00	36.54

According to the American Heart Association (AHA), the maximum heart rate during exercise should not exceed 220bpm minus the age of the person (McGill, 2017). Even though heart rate readings altered in the course of the day, it was observed that the heart rate readings in all three cases remained within the prescribed resting heart rate range of 60 – 100bpm (McGill, 2017). Body temperature readings did not alter significantly in-between readings either. The median values of heart rate and core body temperature variables were placed in the physiological strain equation (Moran et al, 1998). The values obtained were subsequently interpreted on the universal scale to find out whether construction workers using uncomfortable helmets in hot weather experienced physiological strain.

Physiological Strain (PS) = 5(Tret - Tre0). (39.5 - Tre0)$^{-1}$ + 5(HRt - HR0). (180 - HR0)$^{-1}$

(Moran, 1998), where Tre = Core Body Temperature and HR = Heart Rate

Table 5.10 shows the mean physiological strain values obtained from workers within the different time spells.

Table 5.10: Physiological Strain Values Observed within the Three Cases in Different Time Spells

TIME SPELL/DURATION	Case 1	Case 2	Case 3
8.30AM - 11.30AM	0.14	0.27	0.05
11.30AM - 5.00PM	-0.17	-0.05	-0.05
8.30AM - 5.00PM	-0.01	0.23	-0.02

Readings of physiological strain can be interpreted from the universal scale as shown in Table 5.11.

Table 5.11: Physiological Strain Key

No/Little			Low		Moderate		High		Very High	
0	1	2	3	4	5	6	7	8	9	10

According to the results obtained, volunteers in all three cases experience little or no physiological strain (Table 5.11). According to Slater (1985), physiological comfort is related to the human body's ability to maintain life. Based on this assertion, it can be implied that construction workers do not necessarily experience a challenge in their ability to maintain life while they work in hot weather using their safety helmets.

5.7 Background Information of Respondents to the Anthropometric Study

The second sample of respondents within the case study consisted of a total of one hundred and twenty-seven (127) random construction workers from the three cases under study, who volunteered to have head and face anthropometric readings taken. This activity was targeted for a comparative analysis between the head and face anthropometric measurements and the internal dimensions of safety helmets found at the three sites. Measurements were taken with the help of an inelastic tape measure, a scale rule and a notebook dedicated for this purpose.

5.7.1 Anthropometric Measurements to investigate fit issues with Safety helmets and goggles

Complaints about poor fit of the selected PPE led the researcher to take anthropometric head and face measurements of 127 construction workers, to make a comparison between that and the dimensions of helmets and goggles available in the country. Women were not encountered in this exercise. The native origins of the participants could be traced to all the ten regions of Ghana. Anthropometric measurements taken were as illustrated in Figures 4.4 and 4.5 in the preceding chapter.

This activity was aimed at identifying whether safety helmets and goggles available in the country offer a good fit for indigenous construction workers because according to Li (2001), thermal and mechanical body-clothing interactions as well as the external environment are critical in determining the state of comfort of the wearer.

Head measurements were taken with an inelastic tape measure, held taut close to the scalp and readings recorded in a spreadsheet designed for the study. Frame lengths were measured with the help of a scale rule. Table 5.12 shows the summary statistics of safety helmet and head dimensions measured from 127 volunteer construction workers. Table 5.13 indicates the face measurements and safety goggle measurements. A two sampled t-test was conducted to determine the significance of the variations between the means of the head measurements and the internal dimensions of the helmets and goggles encountered on the cases at a 95% confidence interval indicated in Table 5.14.

Table 5.12: Summary Statistics of Safety Helmet Measurements from the Open Market Compared with Head Measurements from Respondents

	SAFETY HELMET MEASUREMENTS (CM)					**HEAD MEASUREMENTS (CM)**				
	Mean	Median	Std. Dev.	Min	Max	Mean	Median	Std. Dev.	Min	Max
HM1	61.47	65.00	1.33	49.00	66.00	55.60	56.00	3.72	38.00	65.30
HM2	32.53	32.00	2.21	27.00	38.00	33.40	34.00	3.14	21.00	38.00
HM3	28.97	28.50	1.55	27.50	32.50	27.20	30.00	7.04	10.00	35.00
HM4	28.91	27.50	1.52	22.00	31.00	28.90	32.00	7.94	9.00	37.00
HM5	29.91	27.50	3.70	25.00	37.00	32.40	35.00	8.27	12.00	46.00
HM6	8.65	9.50	2.76	4.00	20.00	11.50	12.00	3.45	3.00	19.00

Table 5.13: Summary Statistics of Safety Goggles Measurements from the Open Market Compared with Face Measurements from Respondents

	SAFETY GOGGLES (CM)					**FACE MEASUREMENTS (CM)**				
	Mean	Median	Std. Dev.	Min	Max	Mean	Median	Std. Dev.	Min	Max
FL	16.54	15.00	2.89	14.00	22.50	13.50	15.00	1.71	10.00	18.00

Table 5.14: Results of Two Sample T-Test between Anthropometric Measurements and Dimensions of Safety Helmets and Goggles.

Description	N	Mean	Stud Dev.	P-Value
Head Measurement 1	24	-6.61	0.79	0.00
Head Measurement 2	24	1.59	0.67	0.20
Head Measurement 3	24	-1.65	1.45	0.26
Head Measurement 4	24	0.71	1.64	0.67
Head Measurement 5	24	3.04	1.73	0.08
Head Measurement 6	24	1.96	0.81	0.02
Face Measurements	13	-3.01	0.54	0.00

The results obtained from a two sampled T-Test at a 95% confidence interval (see Table 5.14) indicated a non-significant difference between head measurements (HM) 2, 3 and 4 and the interior dimensions of the helmets found on the site (Table 5.14). However, significant variations were obtained between the helmet dimensions and HM1 (Circumference; M=-6.61, SD=0.79), HM5 (Temple to temple round back; M=3.04, SD= 0.08) and HM6 (Nape of neck; M= 1.96, SD=0.02). The results also indicate a significant difference between face measurements of volunteers and safety goggle dimensions.

Additional information taken on the helmets found on the three cases are listed below;

- Helmets possessed an elliptical shell configuration
- The vertical clearances between the harness and the inside of the shell were averagely 35mm
- The horizontal clearances between the headbands and the insides of the shell were averagely 12mm
- Helmets had ventilation gaps with an average area of 480mm^2
- The nape strap could be adjusted in increments of 5mm

The physical characteristics of the helmets found at the three sites compare favorably with the international requirements suggested by the Hong Kong head program described in section 3.2.

5.8 THE SURVEY

Objective three of the study sought to investigate the considerations made by construction firms in the procurement of PPE for construction workers. This section presents the results from the analysis of a survey of personnel of construction firms responsible for the procurement of PPE. The objective here is to assess how informed procurement officers are about construction worker discomforts and whether the knowledge subsequently impacts selection considerations made in procuring safety helmets and goggles in Ghana.

5.8.1 Background Information of Survey Respondents

The third group of respondents were personnel responsible for the procurement of construction PPE for the firms they work with as illustrated in table 5.15.

Table 5.15: Background Information of Survey Respondents

Description	Frequency (N)	Percentage (%)
Contractor Class		
D1/K1	50	67.57
D2/K2	24	32.43
Educational Level		
Tertiary	74	100.00
Experience in Procuring PPE		
Less than 5years	33	44.59
6-10years	18	24.32
11-15years	3	4.05
Above 15years	20	27.03

The survey was targeted at D1/K1 and D2/K2 construction firms in Ghana which are the top two largest category of construction firms in the country. These firms were preferred because they have similar clientele and are usually expected to comply with strict PPE protocols on their sites. Firms were selected through a census survey of members of the Association of Building and Civil Engineering Contractors in Ghana (ABCECG), which is a recognised body of active construction firms operating in the country. Of the one hundred (100) questionnaires hand delivered to the offices of the construction firms, seventy-four (74) responses were obtained. Sixty-eight percent (68%) of respondents belonged to the D1/K1 category while thirty-two percent (32%) were in the D2/K2 category. All respondents to the survey held tertiary level educational qualifications. Forty-five percent (45%) of the survey respondents had less than 5years experience in procuring PPE. Twenty-four (24%) of respondents had 6-10years PPE procurement experience, four percent (4%) had 11-15years and the remaining twenty-seven percent (27%) had accumulated above 15years of procurement experience. The survey sought responses from personnel involved in the procurement of personal protective equipment. The survey results indicated that respondents had a vast array of professional qualifications as shown in Table 5.16. In classifying the respondents into managerial levels, 23% of respondents fell within the Top category of management level, 54% fell within the middle category and 23% were in the low category.

Table 5.16: Professional Details of Personnel Involved in the Procurement of PPE

MANAGEMENT

LEVEL	PROFESSION	FREQUENCY	PERCENTAGE
TOP	Finance Administrator/Manager	2	2.70
	Managing Director	3	4.05
	General Manager	2	2.70
	Assistant Manager	2	2.70
	CEO	2	2.70
	Commercial Manager	2	2.70
	Contracts Manager	2	2.70
	Director	2	2.70
MIDDLE	Engineering Manager	1	1.35
	Project Coordinator	2	2.70
	Project Manager	4	5.41
	Technical Director	2	2.70
	Project Engineer	6	8.11
	Quantity Surveyor	16	21.62
	House Officer	2	2.70
	Maintenance Coordinator	2	2.70
	Safety Officer	2	2.70
	Site Engineer	3	4.05
LOW	Procurement Officer	3	4.05
	Site Supervisor	3	4.05
	Technical Assistant	2	2.70
	Site Manager	5	6.76
	Technical Supervisor	2	2.70
	Technical Officer	2	2.70
TOTAL		74	100.00

5.9 Understanding the Basis of the PPE Procurement Decision

Contractors indicated that the firm's Health and Safety policy dictates the decision to procure PPE (30.3%). Others indicated that requirements of the contract (27.7%) document and requests by the project management's team (26.5%) also play a role in the decision to procure PPE. The country's policy requirement (15.5%) was however a not a strong reason for the procurement of PPE.

5.9.1 PPE Usually Procured on Construction Sites

Respondents were presented with a list of PPE from which to select the usual equipment procured. Procurement officers in the construction companies indicated the usual PPE bought and given to workers were safety helmets, reflective jackets, protective/safety boots and goggles, earplugs, safety harnesses and nose masks as shown in Table 5.17. Respondents indicated that in addition to the list provided, they also procure overalls and fire blankets for construction workers.

Table 5.17: Type of PPE Procured

Description	**Frequency**	**Percentage**
Helmets	10	13.20
Reflective Jackets	10	13.20
Safety Boots	10	13.20
Safety Goggles	9	12.70
Ear Plugs	7	10.20
Nose Masks	9	12.70
Safety Harness	8	11.00
Hand Gloves	10	13.20
Total		100.00

5.9.2 Sources of PPE Procurement and Countries of PPE Importation

Respondents indicated that PPE are usually procured from the open market (67.6%). Others (18.4%) indicated that they are supplied directly by PPE suppliers. The remaining 14.3% indicated that they imported their PPE from overseas sources, as it is a more economical option and they had a wide variety to choose from. Imported PPE were obtained predominantly from China (Tables 5.18 and 5.19).

Table 5.18: Countries of PPE Importation

Description	Frequency	Percentage
Supplied by a dealer	14	18.91
Open Market Sources	50	67.57
Direct Importation from overseas	10	13.52
TOTAL	74	100.00

Table 5.19: Countries of PPE Importation

Description	Frequency	Percentage
U.S.A, Britain	2	7.10
Lebanon, Dubai	3	14.30
Italy, German	2	7.10
Europe	3	14.30
China, Italy	2	7.10
China	6	28.60
Canada	5	21.40
TOTAL		100.00

5.9.3 Considerations Made in the Selecting and Procuring PPE for Construction Workers.

The study sought to identify key considerations made by construction firms in the selection and procurement of PPE and how these considerations are impacted by the companies' perception of discomforts associated with PPE use. Respondents were presented with a list of factors identified from literature and from interactions with construction personnel that are usually considered in the procurement of safety equipment. The consideration factors are grouped under five different themes, namely; nature of the project, characteristics of PPE users, comfort and fit considerations, socio-cultural considerations and compliance considerations.

Respondents were subsequently presented with a list of discomforts associated with PPE use, obtained from interactions with construction workers. These discomforts were classified under physiological, physical and psychological discomforts based on the effect they had on the user.

The study reasoned that PPE selection considerations were based on construction companies' knowledge or perceptions of discomforts associated with using PPE. As a result, the study examined the effect of the independent variables (discomforts associated with helmet and goggle use) on the dependent variables (PPE selection considerations). Respondents were made to rank the level of importance they attach to both the dependent and independent variables on an attitude scale of Strongly Agree, Agree, Disagree and Strongly Disagree. A mid-point was not offered to respondents because the researcher considers considerations for procuring items as either important or unimportant hence a mid-point is irrelevant. The variables are subsequently classified as either important or unimportant, indicating the degree of importance as indicated in Table 5.20 and Table 5.21.

Table 5.20: Importance placed on Considerations Made in the Procurement of PPE

Description	**Not Important (%)**	**Somewhat Important (%)**	**Important (%)**
Nature of the project Job hazard analysis	30.60	0.00	69.40
Experience from previous work	6.10	36.70	57.20
Foremen's requests	28.60	32.70	38.70
Worker feedback	24.40	24.50	51.10
PPE price	32.70	36.70	30.60
Characteristics of PPE Users			
Gender	40.80	44.90	14.30
Body geometry	18.30	46.90	34.80
Age of workers	44.90	36.70	18.40
Medical condition	28.50	30.60	40.90
Comfort and fit considerations			
PPE weight	24.50	63.30	12.20
PPE style	40.80	46.90	12.30
PPE breathability	14.20	28.60	57.20
Least restriction to movement	14.30	36.70	49.00
Least obstruction of work	16.30	32.70	51.00
Wearability of PPE	12.20	28.60	59.20
Colour preference	65.30	30.60	4.10
Wearer comfort	65.30	30.60	4.10

Socio-cultural considerations			
Indigenous cultural practices	81.70	12.20	6.10
Religious practices	81.60	14.30	4.10
Environmental factors	12.20	34.70	53.10
Compliance considerations			
International standards	20.40	28.60	51.00
National standards	26.50	20.40	53.10
User Involvement	28.60	42.80	28.60

5.9.4 Means and Standard Deviation Analysis of PPE Selection Considerations

Table 5.21: Means and Standard Deviation Analysis

Selection Considerations in the Procurement of PPE	N	Minimum	Maximum	Mean	Std. Deviation
NATURE OF THE JOB					
Job Hazard Analysis	74	0	2	1.65	0.559
Experience from previous works done	74	0	2	1.51	0.614
Foremen’s request	74	0	2	1.10	0.820
Worker feedback	74	0	2	1.27	0.833
CHARACTERISTICS OF PPE USERS					
Gender	74	0	2	0.74	0.698
Age of worker	74	0	2	0.74	0.755
Body Sizes of workers	74	0	2	1.16	0.714
Medical Condition	74	0	2	1.12	0.830
COMFORT AND FIT CONSIDERATIONS					
PPE Weight	74	0	2	0.88	0.598
PPE Style	74	0	2	0.71	0.675
PPE Breathability	74	0	2	1.43	0.733
Least Restriction to Movement	74	0	2	1.35	0.721
PPE Wearability	74	0	2	1.47	0.708
Least Obstruction of vision	74	0	2	1.35	0.749

Colour preference	74	0	2	0.39	0.569
General wearer comfort	74	0	2	1.04	0.703
SOCIO CULTURAL CONSIDERATIONS					
Indigenous cultural practices	74	0	2	1.20	0.863
Religious practices	74	0	2	0.22	0.558
Environmental factors	74	0	2	1.40	0.702
COMPLIANCE CONSIDERATIONS					
Compliance with international standards	74	0	2	1.31	0.793
Compliance with national standards	74	0	2	1.27	0.858
User –involvement	74	0	2	1.00	0.761

5.10 Nature of Job Considerations

All the listed indicators of 'Nature of Job' as a selection consideration came out as significant as their means were above the theoretical mean. 'Job hazard analysis' recorded the highest mean and was rated as 'of Great importance' by 69.4% of respondents. 'Experience from previous works' was alluded as important by 93.9% of respondents but had a mean score of 1.51. This was followed by a mean score of 1.27 for 'Worker feedback' considered by 75.6% as important.

For 71.4% of respondents, "Foremen's request" for PPE was an important consideration with a mean score of 1.10. 67.3% of workers found 'PPE price' to important as a selection consideration.

5.11 Characteristics of PPE Users

Under this category of considerations, only 'body sizes' of workers and 'medical conditions' of PPE users had significant mean scores of 1.16 and 1.12 respectively. 81.7% of respondents indicated 'body geometry' is of importance whilst 71.5% also consider 'medical conditions' of employees an important consideration. The remaining variables under this consideration, i.e., 'Gender' and 'Age of workers had mean scores below the group mean.

5.11.1 Comfort and Fit Considerations

Respondents indicated strongly that considerations such as 'PPE wearability' (87.8% with a mean score of 1.47), 'PPE breathability' (85.8%, 1.43), 'least restriction to movement' (85.7%, 1.35) and ‘least obstruction of work’ (83.7% 1.35) as important considerations. Even though only 34.5% of respondents considered ‘general wearer comfort’ as important, it had a mean score of 1.04. The remaining variables in this category such as ‘PPE weight’, ‘PPE style’ and ‘colour preference’ did not have significant mean scores as considerations for selecting PPE.

5.11.2 Socio Cultural Considerations

For Socio-Cultural factors, ‘Environmental conditions’ such as air temperature and atmospheric humidity is considered important (87.8%, 1.4) in the selection and procurement of PPE.

‘Indigenous cultural beliefs’ had a mean score of 1.2 even though 81.7% of respondents considered it unimportant. ‘Religious beliefs’ however were considered by 81.6% as not important considerations in PPE procurement.

5.11.3 Compliance Considerations

All variables under compliance considerations had significant mean scores and were considered by respondents as of importance in the selection and procurement of PPE. Respondents indicated the importance of the variables as follows; ‘compliance with international standards’ (79.6%, 1.31) and ‘national standards’ (73.5%, 1.27) are important considerations in the procurement of PPE. 71.4% of respondents also indicated it is important to involve users of PPE in the procurement process with a mean score of 1.00

5.12 PPE Use on Construction Sites

Procurement Managers were queried on their knowledge of employee discomforts with PPE supplied for work. According to Slater (1985) comfort is a pleasant state of physiological, psychological, and physical harmony between a human being and the environment. In a bid to show how important the environment is to a person’s comfort, Slater further elaborates the three types; “Physiological comfort is related to the human body's ability to maintain life, psychological comfort to the mind's ability to keep itself functioning satisfactorily with external help, and physical comfort to the effect of the external environment on the body (Li, 2001). Comfort is defined for this study as freedom from physiological, psychological and physical strain.

This section of the quantitative inquiry attempted to investigate the perceptions or levels of importance placed on these employee complaints with the use of helmets and goggles, as an indicator of whether these discomforts were considered in the procurement of safety helmets and goggles. Discomfort complaints were classified into physical, physiological and psychological themes in accordance with the definition of comfort employed in this study and are shown in Tables 5.21, 5.22, 5.23 and 5.24.

5.13. Association between Physical discomfort and Helmet use

Table 5.22: Physical Discomforts Associated with Helmets

VARIABLES	RESPONSES							
	Unimportant		Highly Unimportant		Important		Highly Important	
	Freq	%	Freq	%	Freq	%	Freq	%
It gets hot inside	2	2.00	21	28.60	27	36.70	24	32.70
It is heavy	-	-	29	38.80	24	32.70	22	28.60
It does not fit very well	-	-	28	38.70	23	30.60	24	30.60
It obstructs vision	-	-	23	30.60	32	42.90	20	26.50
It impedes the work	-	-	27	36.70	30	40.80	18	22.50
It is too tight	-	-	42	57.10	15	20.40	18	22.50
It is too loose	2	2.00	44	59.20	12	16.30	17	22.40

Source, fieldwork, 2017

Procurement Managers consider employee discomforts such as helmets being loose (61.2%), being too tight (57%) and causing neck pain (51%) as not important. On the other hand, discomforts such as heat build-up within the helmet (69.4%) heaviness (61.3%) and helmets not fitting very well (61.2%) are considered important. Other discomforts such as obstruction of vision (69.4%) and helmets impeding work (68.3%) are also considered important.

5.14 Association between Physiological Discomforts and Helmet use Table
5.23: Physiological Discomforts with the Use of Helmets

	RESPONSES (%)							
	Unimportan		Highly Unimportant		Important		Highly Important	
Variables		%		%	Freq	%	Fr	%
It obstructs vision	-	-	22	29.72	32	43.24	20	27.03
Early onset of fatigue	1	1.35	50	67.57	17	22.97	6	8.10
I get Headaches	3	4.05	23	31.08	30	40.54	18	24.32
It makes me feel dizzy	3	4.05	29	39.19	24	32.43	18	24.32
It makes me have convulsions	5	6.75	30	40.54	18	24.32	21	28.38
I feel like fainting	6	8.10	32	43.24	20	27.02	16	21.62
I constantly feel tired	5	6.75	35	47.30	21	28.38	13	17.57
Giddiness (dizzy and silly)	8	10.81	32	43.24	14	18.92	20	27.03
It gives me heat rashes	8	10.20	27	36.70	27	36.70	13	16.30
I feel pain in the neck	2	2.00	36	49.00	21	28.60	16	20.40
It makes me sweat excessively	2	2.00	32	42.90	26	34.70	15	20.40
I feel dehydrated	8	10.81	41	55.41	17	22.97	8	10.81

Procurement managers indicated that employee complaints such as obstruction of vision (70.27%), headaches (64.86%), dizziness (57.3%) and tendency for convulsion (52.7%) were important compared to complaints such as early onset of fatigue (68.92%) constant tiredness (53%), dehydration (66.22%), giddiness (54.05%) and excessive sweating (51.9%). Respondents were almost evenly divided on the importance of tendency to faint as a complaint.

5.15 Association between Psychological discomforts and Helmet use Table 5.24: Psychological Discomforts with the Use of Helmets

VARIABLES	RESPONSES (%)							
	Unimportant		Highly Unimportant		Important		Highly Important	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
It makes me feel uncomfortable	-	-	30	40.54	30	40.54	14	18.92
It is not fashionable	5	6.76	65	87.84	4	5.41	-	
It is too old/worn out	1	1.35	30	40.54	38	51.35	5	6.76
I do not like the colour	5	6.76	50	67.57	14	18.92	5	6.76
It is not relevant to my job	3	4.05	40	54.05	14	18.92	17	22.97
It is smelly	3	4.10	44	59.20	11	14.30	17	22.40

Worker complaints that helmets are uncomfortable (59.5%) and worn out (58.11%) are considered important by procurement managers while complaints like helmets are unfashionable (94.6%), 'I do not like the colour' (74.33%) 'Helmets are irrelevant to my job' (59.2%), are smelly (63%) are not important.

5.16 Association between Physical discomfort and Goggle use

User complaints associated with safety goggles such as ‘not fitting very well’ (67.3%), ‘goggles impeding work’ (65.4%), goggles being too tight (61.2%) and goggles being too loose (53.1%) were considered important by respondents as indicated in Tables 5.25, 5.26 and 5.27.

Table 5.25: Physical Discomforts Associated with Goggles

	RESPONSES (%)							
	Unimportant		**Highly Unimportant**		**Important**		**Highly Important**	
VARIABLES	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
It is heavy	1	1.35	45	60.81	17	22.97	11	14.86
It does not fit very well	0	0.00	24	32.43	35	47.30	15	20.27
It impedes the work	0	0.00	26	35.14	24	32.43	24	32.43
It is too tight	0	0.00	29	39.19	29	39.19	16	21.62
It is too loose	0	0.00	35	47.29	21	28.38	18	24.32

5.17 Association between Physiological discomforts and Goggles use

Respondents indicated again that they consider physiological complaints on safety goggles such as obstruction of vision (79.6%), dizziness (53%) and giddiness (55.1%) as important complaints from users as indicated in Table 5.25.

Table 5.26: Physiological discomforts with the use of goggles

	RESPONSES (%)							
	Unimportant		Highly Unimportant		Important		Highly Important	
VARIABLES	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
It gets hot inside	3	4.10	35	46.90	26	34.70	10	14.30
It obstructs vision	0	0.00	15	20.40	35	46.90	24	32.70
I get tired very quickly	0	0.00	54	73.50	14	18.40	6	8.20
I get Headaches	3	4.10	56	75.50	12	16.30	3	4.10
It makes me feel dizzy	6	8.20	29	38.80	23	30.60	16	22.40
It makes me have convulsions	16	8.20	30	40.80	24	32.70	4	8.20
I feel like fainting	6	8.20	38	51.00	17	22.40	14	18.40
I constantly feel tired	4	6.10	47	63.30	14	18.40	9	12.30
Giddiness (dizzy and silly)	6	8.20	27	36.70	24	32.70	17	22.40
I get muscle cramps	11	14.30	36	49.00	15	20.40	12	16.30
I feel nauseous	8	10.20	38	51.00	17	24.50	11	14.30
I feel dehydrated	6	8.20	48	65.30	11	14.30	9	12.20
It gives me heat rashes	9	12.16	32	43.24	20	27.03	13	17.57
I feel pain in the neck	9	12.16	45	60.81	11	14.86	9	12.16
It makes me sweat excessively	3	4.05	51	68.91	14	18.91	6	8.11

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5.18 Association between Psychological discomforts and Goggle use

Table 5.27 Psychological discomforts with the use of goggles

VARIABLES	RESPONSES (%)							
	Unimportant		Highly Unimportant		Important		Highly Important	
	Freq	%	Freq	%	Freq	%	Freq	%
It makes me feel uncomfortable	2	2.00	25	34.70	38	51.00	9	12.20
It is not fashionable	-	0.00	60	81.60	11	14.30	3	4.10
It is too old/worn out	2	2.00	25	34.70	35	46.90	12	16.30
I do not like the colour	8	10.20	35	46.90	21	28.60	10	14.30
It is not relevant to my job	3	4.10	38	51.00	16	22.40	17	22.40
It is smelly	6	8.10	50	67.57	9	12.16	9	12.16

For psychological discomforts, ‘feeling uncomfortable’ (63.2%) and worn out goggles (63.2%) were considered important complaints by workers, while complaints such as goggles are unfashionable (81.60%), smelly (75.67%) and dislike for the colour (57.3%) were considered unimportant considerations.

5.19 How Construction Workers Manage Discomfort associated with Helmet Use

The study additionally sought to inquire the construction firms' knowledge of how employees manage PPE discomforts at the construction sites. Table 5.28 presents results on management's knowledge of management techniques used by construction workers for uncomfortable helmets.

Table 5.28: Discomfort Management Techniques for Helmets and Goggles

Description	Safety Helmets		Safety Goggles	
	Freq(N)	Percentage (%)	Freq(N)	Percentage (%)
They do not use it	4	5.41	2	2.70
They take it off periodically	47	63.51	41	55.41
They modify its use	15	20.27	14	18.92
They keep using it	8	10.81	17	22.97
TOTAL	**74**	**100.00**	**74**	**100.00**

Respondents indicated that for 63.51% of the time, construction workers dealt with discomforts by periodically taking off their helmets for short periods. Workers sometimes 'modify its use' (20.27%) e.g. by wearing it over a head scarf, immersing in water etc. while working while others 'keep using them' (10.81%). For 5.4% of the time, workers totally refuse to use the helmets due to discomforts (Table 5.28).

For management of safety goggle discomforts, respondents indicated their awareness that workers 'periodically take it off' (55.41%) and others 'modify its use' (18.92%). Respondents again indicated that some workers just keep using the safety goggle (22.97%) while others did not use it at all (2.7%).

Table 5.29: How Construction firms manage Employee discomforts with safety helmets and goggles

Management Technique	Frequency (N)	Percentage (%)

We force them to comply with PPE protocols	29	39.19
We conduct safety inductions to enhance their knowledge	44	59.46
We allow them to use them as they please	1	2.70
TOTAL	**74**	**100.00**

Construction firms indicated that in dealing with safety helmet and goggle discomforts, 59.46% would usually conduct safety inductions to enhance workers' knowledge of the benefits of using PPE. 39.19% of respondents however indicated that they forced workers to comply with PPE protocols. The remaining 2.7% of respondents indicated they did not impose anything on the workers (Table 5.28).

5.2 CHAPTER SUMMARY

The chapter presented results obtained from the methods employed to achieve all four listed objectives. Semi –structured interviews were conducted to identify discomforts experienced with safety helmets and goggles (Objective one). The findings from the interviews listed several discomforts with both safety helmets and goggles. Physiological and physical discomforts were prevalent among the experiences described. Hotness within the helmets and poor fit were the top two discomforts associated with safety helmets, whilst blurred vision and poor fit were the two main discomforts associated with safety goggles. Workers indicated they removed the PPE or modified its use when the discomforts got unbearable.

Objective two was interrogated by means of a physiological strain experiment and an anthropometric study. Whilst findings from the physiological strain experiment conducted on the three cases, suggested that workers experience little or physiological strain with the uncomfortable helmets, the comparison of head and face anthropometric measurements with safety helmets and goggles imported into the country, indicated some statistically significant differences between their means.

Results from the survey conducted to achieve objective three indicated construction firms do make several considerations in an attempt to ensure some comfort with the procured PPE.

CHAPTER SIX
DISCUSSION OF FINDINGS

6.1 Introduction

This chapter presents a discussion of the findings made in answering the research questions posed in the introduction to the research. Data for this study was obtained through semistructured interviews and a field experiment from three case studies with sixteen (16) participants, a survey of seventy-four (74) construction companies operating in Ghana and an anthropometric measurement of one hundred and twenty-seven (127) construction workers.

6.2 Discomforts Associated with Using Safety Helmets and Goggles

Objective one of this study sought to identify discomforts that construction workers felt in using PPE. To achieve this objective, a semi-structured interview was conducted on sixteen volunteers from the three selected cases to ascertain the discomforts they experience while using safety helmets and safety goggles. Additionally, construction procurement officers were presented with a list of discomfort complaints. From this list, procurement managers indicated the degree of importance they attached to the listed discomforts.

According to the responses received from both groups of respondents, hotness inside the helmet was a predominant discomfort complaint. The next highest discomfort complaint from workers was that the helmets did not fit properly. Both workers and officers also agreed that helmets were heavy and obstructed vision. Workers further complained again that helmets got old and got smelly with continuous use and resulted in headaches by users. This however, was not concurred by procurement officers. The officers however indicated that discomforts such as helmets impeding work, and causing excessive sweating were important.

Interviewees in the study listed poor fit, heavy goggles and blurred vision (as a result of foggy lenses and scratched lenses) as discomforts associated with safety goggle use. On the other hand, procurement officers considered poor fit, obstruction of vision and impedance to work as significant discomfort complaints. Subsequently, construction workers listed heat build-up within the goggles, early onset of fatigue and headaches as discomforts whilst procurement officers considered dizziness and giddiness as significant discomforts with safety goggle use. The responses obtained from both construction workers and procurement officers showed close similarities under physical and physiological discomforts complaints. However, while construction workers attached great significance to colour preference under psychological discomforts, the procuring officers only consider general discomfort and worn out PPE as significant complaints.

The discomfort complaints mentioned by the two groups of respondents were indeed similar to findings in literature on the subject. According to Lombardi et al, (2009), a lack of comfort/fit, and fogging and scratching of the eyewear are the most important barriers to safety goggles usage.

Research on the improvement of helmet use indicate that hotness, weight and fitting problems are major issues that require attention to encourage continuous use by employees. Abeysekera et al, (1996) identified that hotness is a significant problem with helmet users in tropical climates. Subsequent research carried out in different industries has reiterated that hotness within safety helmets results in workers' refusal to use them as required to avoid thermal stress (Davis et al, 2001; Vigneswaran and Arulmuruga, 2014). In their study to investigate the effects of ventilation openings in commercial industrial safety helmets on evaporative heat dissipation, Ueno and Sawada (2019) identified that the ventilation openings provided on most industrial safety helmets are not sufficient to facilitate effective heat dissipation from within the helmets and suggested improvements on helmet ventilation systems. Ueno and Sawada (2019) conducted their study with thermal head manikins under simulated outdoor temperature conditions of 34.0 Degree Celsius and relative humidity of 50% like outdoor conditions in the study area. Ueno and Sawada's (2019) findings may be the reason why construction workers in this study continue to experience hotness within their helmets in spite of their ventilation holes.

Responses on discomforts felt with the use of safety helmets and goggles by employees suggests that what was procured for their use at the construction site were not user-friendly. Even though a comparably small percentage of psychological discomforts are reported, it is worth noting that the cognitive abilities of such complainants may be affected while they work, putting them at risk of accidents. According to Beeh & Franz (1987), physical and psychological stress results in physical and psychological strain and impacts job performance. Again, Construction workers with high levels of psychological strain are at higher risks of near misses while those with high levels of physical/physiological strain are at higher risks of injuries. This knowledge obtained on the nature of discomforts experienced by construction workers is essential in mapping out the direction to go to resolve the problem of discomforts with the use of safety helmets and goggles.

6.3 What Accounts for Discomforts with Safety Helmets and Goggles

6.3.1 Anthropometric Differences

The purpose of objective two, was to determine what accounted for the discomforts experienced by construction workers with the use of helmets.

In the responses obtained from the interviews, respondents indicated that safety helmets and goggles sometimes did not fit well. While some said they were too loose, others indicated they were too tight resulting in headaches. Some workers even complained that their scalps got scratched by the plastic harness within the helmets.

The observed statistically significant variations between helmet sizes and head sizes in the study was an indication that the complaints of poor fit by construction workers in the interviews are indeed justified. The issue of poor fit was accountable for complaints of obstruction of vision while using safety goggles. In other words, a construction worker using a helmet or goggle that is too loose would have his hands busy keeping the PPE stable on his face as it would keep sliding off and blocking his sight. A worker in this situation was most likely at risk of an accident as his concentration is divided between managing the PPE and his work.

According to Abeysekera and Shahnavaz (1988), physical, cultural, sociological and anthropological differences between people living in different geographical locations accounts for issues of poor fit in clothing items manufactured in one geographical location for people living in another. For example, an adjustable helmet designed in Europe did not properly fit 40% of heads in a Sri Lanka (an Industrially Developing Country) study (Abeysekera, 1989).

Given that safety helmets and goggles found on construction sites in Ghana are all imported from different locations abroad, it is possible that poor fitting helmets might be responsible for the intermittent headaches reported by workers. Even though they are usually unreported and undocumented, the symptoms described, and the fact that removing the helmet provides relief are comparable to the characteristics of external compression headaches. The headaches are believed to result from pressure on pain receptors or pain fibres that transmit sensation from the face to the brain (trigeminal nerve) or on nerves in the back of the head (occipital nerves).

Doctors believe that people who experience prolonged pressure as a result of the tight equipment are more likely to experience a migraine. The remedy for external compression headaches is to eliminate the causal factor, in this case the tight helmet or goggle. Apart from experiencing external compression headaches with tight goggles, goggles that are too lose will keep sliding off and the user will focus their attentional resources on keeping it on, making them susceptible to an accident due to the divided attention.

Helmets and safety goggles are very essential to a construction worker as the head and face region are the most vulnerable places in the event of an accident (Jeong, 1998). If not properly attended to, the regular removal of helmets by workers in their attempt to mitigate the effects of the discomforts felt will increase their risk of injury or even a fatality on the construction site. On other hand, workers with symptomatic expressions of ECH may suffer other complications from the continuous use of tight safety helmets.

With the high statistics of head and face injuries emanating from the construction industry globally, it is essential that safety helmet and goggles use are not compromised, and workers are adequately protected from the risks they encounter on a daily basis. Abeysekera and Shahnavaz (1994) suggest that articles transferred from an industrially developed country (or country of importation) might need to be adapted, modified, or redesigned to meet the acquirers' or users' needs. The suggestion that workers should try various styles and sizes of safety headwear to find the most comfortable options (McPherson, 2008; Krymchantowski, 2010; Nill, 2019) should be considered as of high importance to avoid discomfort issues of poor fit

In this regard, it is essential that construction helmets and safety goggles procured for the Ghanaian market be adapted to the country's characteristic anthropometric data (i.e. using a database of head and face measurements such as within the range of observed measurements taken in this study) and environmental considerations, (the appropriate colours and adequate ventilation should be considered to minimize heat absorption within existing hot environmental conditions) to satisfy the comfort requirements of users in order to improve the PPE user experience.

6.3.2 Conformity to Standards

Several international standards exist to ensure that PPE are comfortable enough to be used. For example, these standards identify certain key features that construction helmets should have in order to satisfy international standards such as the shell profile, the respective clearances between the shell and the harness at various locations, down to minor details such as the range of adjustable increments of headband and nape strap. Additionally, the materials used in manufacture of safety helmets should be of durable quality with consideration for durability and the environmental elements that these helmets will be subjected to such as sunlight, humidity, temperature and vibration. For example, Nill (2019), proposes that helmet shells made of polycarbonate or polyester and woven suspension systems are better suited for high temperature applications. International standards such ANSI Z87.1 set by OSHA sets forth the requisite criteria for general requirements, testing, permanent markings, selection, care and use of protectors, including safety glasses, to minimize the occurrence and severity or prevention of injuries (Motchan, 2019). Safety goggles procured in conformity to standards will eliminate the discomfort of blurred or compromised vision for users as their lenses will be made of the right materials.

According to interactions with the Ghana Standards Authority, although it is a known fact that most PPE in use on construction sites are uncomfortable to use especially in hot weather, the country is yet to outline specific standards to be met by imported PPE. PPE importers are however expected to procure PPE that conforms to international standards. Despite this expectation, no checks or inspections are carried out on imported PPE to ensure their conformance to these standards because they are not considered as ‘high risk’ goods. Procurement officers in this study indicated that in spite of the considerations made, the final price of PPE determined their sources of procurement. Considering that several helmets encountered in the market survey were not branded and showed no evidence of conforming to international standards, it is evident that importers are able to import any kind of PPE into the country regardless of their ergonomic characteristics. Sadly, these PPE are also procured by many construction firms due to their low prices.

Since there is no control as to the nature of PPE that is procured for use in the country, it is possible that discomforts associated with safety helmets and goggles are as a result of the procurement of inferior or low-quality non-standardized PPE for use on construction sites resulting in complaints of poor ventilation/heat dissipation, poor fit and PPE being heavy with attendant physiological effects like headaches and dizziness.

Research has shown that poor heat dissipation within helmets and safety goggles is a common complaint amongst construction workers. Heat stress might be experienced by construction workers in hot and humid environments as a result of poor ventilation. Heat stress could be described as the total load exerted on an individual as a result of his metabolic activities, environmental conditions and clothing worn. Heat stress results in increased risk of frequency of accidents and therefore threatens the safety of workers. Additionally, heat stress increases the potential for heat-induced disorders such as heat cramps, heat exhaustion, and heat stroke and effectively reduces worker productivity as work-rest cycles need to be employed to reduce heat strain (Gotshall et al, 2001).

Construction workers in hot climates are vulnerable to heat stress as they undertake several physically exerting tasks in hot and humid environments resulting in physiological strain (the body's compensatory thermoregulatory response to this stress) that may result in increased heart rates and core body temperatures. Kirk and Sullman (2001) purport that heart rate indices is effective in determining physiological strain of in field experiments. The values of physiological strain recorded in this study (little or no strain) despite the hot ambient temperatures may be explained by acclimatization of the individuals involved in the study as explained by Gibson et al (2015). Gibson et al., (2015), opine that, heat acclimation (HA) attenuates physiological strain in hot conditions via phenotypic and cellular adaptation.

Effective heat dissipation within the microenvironment of the helmets and safety goggles is very necessary especially for users in hot and humid climates such as the study location. However too many ventilation holes would result in a reduction in the surface area of the helmet or goggles that should be available to absorb the impact. For this reason, it is necessary to have a good balance between effective ventilation and adequate protection to protect users from heat related stresses hence the need to ensure that imported PPE complies with international standards. If construction companies are mandated to procure and import PPE that conform to the requisite international standards, it is possible that the required balance between adequate ventilation holes and sufficient protective ability of the helmet and goggle will be achieved with the accompanied reduction in the discomfort of 'heat build-up' within inadequately ventilated PPE.

6.3.3 Poor Maintenance Practices of PPE

The proper care and maintenance of PPE on construction sites is often overlooked. However, maintenance of PPE is essential to ensure they are in good shape and their quality is not compromised to effectively protect the user from harm. It also ensures that PPE lasts through its intended life span. Most construction sites do not have specific arrangements that ensure that proper maintenance practices are used to ensure that PPE is safe to use. Workers would usually store given PPE haphazardly with their used clothing in the change room. Construction workers interviewed indicated that, when PPE is distributed at the start of the project, management fails to monitor their proper use at site. Thus, workers are solely responsible for the upkeep of their PPE till the end of their working contract. Worn out PPE is often not replaced, and workers must endure using these till the end of their contract terms.

Care and maintenance of safety equipment include storage, cleaning, inspection and replacement. This implies that each PPE should be stored in an appropriate manner that does not affect its protective abilities, e.g. Helmets need to be stored on a shelf away from direct sunlight, and goggles need to be protected from scratches to the lenses. PPE need to be regularly cleaned of dirt and or sweat residue after each use before storage. Again, it is essential for regular inspections to be carried out by supervisors to ensure workers' PPE are in good shape to afford the needed protection and where necessary replaced to ensure full protection. Failure to effectively maintain PPE results in discomfort complaints such as PPE getting old, worn out and smelly, thus discouraging workers from using them.

6.3.4 A Lack of Involvement of Workers/Users in the Selection and Procurement Process

Researchers of clothing comfort have indicated that a lack of adequate wearability (good fit, adequate ventilation and aesthetics) will reduce their acceptance (Li, 2001; McPherson, 2008). McPherson (2008), indicates that personal protective equipment that is procured in consultation with users is more likely to be used. McPherson (2008), suggests that apart from functionality, considerations for the procurement of PPE should ensure a good fit. She purports that PPE should also appeal to the style sense of users as this would allow an expression of their individuality, have some control over their looks, and finally enable automatic compliance with PPE.

Li (2001), also purports that consumers in recent times demand a lot in terms of the comfort experience in clothing. It is interesting to note that even though procurement officers purportedly assign importance to selection considerations that should improve the PPE user-experience, construction workers do not experience the needed comfort to maintain the continual effective use of PPE. Perhaps an important reason lies with the significance alluded to user-involvement as a selection consideration. Procurement officers (42.8%) indicated that the involvement of PPE users was somewhat important as a selection consideration, 28.6% classified it as not important, while only 28.6% attached great importance to it.

Guided by this, we may infer that significant importance is not attached to the active involvement of construction workers during the selection and procurement of PPE. To improve the user experience, the end users of PPE should be involved in the selection and procurement process by allowing them to fit the PPE, satisfy their aesthetic requirements etc. Giving workers (or even a section of them) the chance to try on PPE before procurement will contribute to eliminating issues of poor fit, often resulting in obstruction of vision, impeding of work and other physical/physiological discomforts. Psychological discomforts such as colour preference can also be dealt with in like manner.

According to McPherson (2008), construction workers are more apt to use given PPE when they are involved in the selection and procurement. Perhaps workers' refusal to use given PPE may be as a result of them feeling that anything could be dumped onto them and they must use it irrespective of how it felt using them. McPherson (2008) advises that PPE should satisfy comfort, fit and style requirements of users and this can be achieved by involving workers, at least sectional heads to assist in the selection of PPE proposed for procurement.

6.4 Considerations that are made in the Selection and Procurement of Construction PPE

Objective three of the study sought to examine selection considerations that were made in the selection and procurement of construction PPEs. Selection considerations were presented to respondents under five main groups, namely; 'Nature of the job', 'Characteristics of PPE users', 'Comfort and Fit considerations', 'Socio-cultural and compliance" considerations'.

Under 'Nature of job' considerations, job hazard analysis, experience from previous works, worker feedback and foremen's requests were rated as of significant importance by respondents.

Job hazard analysis coupled with experience from previous works helps to determine the type of PPE to be procured and where to procure it. Foremen's request gives an indication of the quantity of PPE to be procured while worker feedback might give an indication of the userexperience with the PPE.

Under "Characteristics of PPE users' category, body sizes and medical conditions of workers had significant mean scores. Body sizes are helpful in determining the variety of sizes of PPE to be procured as workers come in different body sizes. Medical conditions of workers also help with the procurement of PPE to suit specific medical conditions. For example, workers who use visual aids and need to use safety goggles can be provided with prescription safety goggles, or safety goggles that are designed to enable use with prescriptive lenses. If the considerations of body sizes and medical conditions are implemented, discomforts that are medical and ergonomic in nature would be greatly minimized.

Respondents also indicated that 'PPE wearability', 'breathability', 'least restriction to movement' and 'least obstruction of work' had significant means under 'Comfort and fit considerations'. These considerations would mean that procured PPE should be easy to put on and take off, enable sufficient aeration to prevent heat build-up between the PPE and the body surface leading to the prevention of heat related stresses and excessive sweating. These considerations would also prevent the PPE from getting in the way of the worker's work thus reducing discomfort considerably.

'Environmental factors' were considered significant under Socio-cultural considerations. It is essential to consider the environment in the purchase of clothing items as it has a significant bearing on the body clothing interaction. For example, PPE procured for hot environments should be light and made from material that is user-friendly because of the already existing harsh weather conditions.

Finally, 'compliance with both national and international standards' as well as 'userinvolvement' in the selection of PPE were rated as significant considerations by respondents under compliance considerations. This means that construction firms should pay attention to the requirements set by the country and international standards in the procurement of PPE.

Despite the considerations purported to be taken by procurement officers in the purchase of PPE, construction workers continue to experience discomforts with their use. Procurement officers in the survey indicated that they were aware that most workers usually took off PPE periodically due to the discomforts associated with them. These challenges were dealt with by conducting safety inductions for workers and forcing them to comply with PPE protocols. A few respondents indicated workers were allowed to use PPE is they pleased, perhaps because they felt helpless to resolve their discomfort complaints.

In Ghana, there are no strict regulations regarding the nature of PPE procured into the country.

Even though the country's regulations mandate employers to provide the requisite PPE for workers, it is silent on specific required characteristics of PPE to be provided. PPE that are imported into the country are not inspected to ensure compliance with international standards because they are not classified as high-risk goods (GSA, 2018). Procurement officers indicated in the survey that the decision to procure PPE is largely dependent on the price. Based on this, we may infer that despite all the considerations taken, it is possible that these considerations are sacrificed for price. The case for procuring standard and ergonomic PPE are made worse considering the fact that imported PPE are not screened to ensure they conform to standards.

6.5 Measures to Make Construction Workers Utilize Procured Safety Helmets and Goggles.

Objective four of the study sought to establish measures that would make construction workers use procured safety helmets and goggles. Information obtained from the study so far suggests that even though construction firms were dedicated to protecting employee safety by providing the requisite PPE, employees failed to use them as required due to their claims of discomforts associated with their use.

The results from the study compared against findings in literature also show that the discomforts complaints by the workers were indeed justified. It is imperative to ensure that safety helmets and goggles are used properly, because they are a worker's first and personal guard against the impact of hazards such as traumatic brain injuries that workers experience at their workplaces.

In as much as it is necessary to ensure that helmets and goggles are used, it is imperative to remove obstacles that impede their function such as discomforts associated with their use to prevent them from becoming additional stressors. People who regularly undertake physically demanding work such as construction workers can experience physical fatigue which may subsequently lead to decreased productivity and motivation, inattentiveness, poor judgment, poor quality work, job satisfaction, accident and injuries (Abdelhamid and Everett, 2002).

Also, Mathiassen (1993) purported that prolonged exposure to excessive levels of physical strain results in increased risk of developing musculoskeletal or cardiovascular disorders in the future.

The Maximal Adaptation Model demonstrates how a person subjected to continual increased stress, moves into maximal psychological and physiological adaptation and subsequently dynamic instability leading to potentially fatal accidents. It is essential that the discomfort complaints associated with PPE use be given enough attention to prevent workers from attaining a state of hyper stress leading to several accidents or possible fatalities.

The findings of this study indicate a dire need for a practical and efficient effort to eliminate the unsafe behaviour of not using needed safety helmets and goggles and the unsafe conditions created by uncomfortable helmets and goggles to ensure the proper use of PPE amongst workers.

Recent research has targeted the enhancement of employee safety behaviours to improve safety performance. This recommendation is based on statistics indicating that human behaviour is often associated with injuries and accidents at workplaces. The link between accidents and behaviour was first established by Henreich's (1931) Domino Theory of Accident Causation which purports that human unsafe acts account for 88% of industrial accidents. In subsequent studies, human behaviour has been undeniably linked to injuries and illnesses arising out of occupational accidents, particularly in the construction industry. (McSween, 2003; Gharibi et al., 2016).

Considering the information obtained in this study, both construction workers and employers require a change in behaviour to improve the PPE user- experience. It is therefore recommended that a Behaviour Based Safety Intervention be adopted to remedy the situation.

For a BBS intervention to be successful, it requires a conscientious commitment from top management and significant workforce participation. Employees work hand in hand with management to ensure an effective process. Research suggests that consumers are more likely to use an apparel if it satisfies their comfort requirements. Likewise construction workers are more likely to use given safety helmets and goggles if they are comfortable enough. To improve the user experience of construction PPE, the study recommends a total overhaul in the PPE procurement practices of the Ghanaian construction industry through a Behaviour Based Safety Intervention Framework described in the next chapter.

6.6 Chapter Summary

The findings obtained in the previous chapter are discussed at length in this chapter. According to the findings, construction workers are faced with discomforts similar to experiences of safety helmet and goggle users across the globe. Little or no physiological strain is experienced but there exists significant differences between the human measurements and dimensions of the PPE in the country resulting in considerable physical discomfort. These physical discomforts might be causing the other discomforts as indicated by Slater (1986). The findings describe a need to improve the comfort experience of the users. However, beyond improving their comfort, it is necessary that construction workers maintain the right attitude to PPE use to avoid the latent effect of safety interventions as decribed by Hasazandeh et al., (2019). The next chapter details how comfort and behavioural factors are put together to ensure a good safety helmet and goggle use experience.

CHAPTER 7

FRAMEWORK DEVELOPMENT, VALIDATION AND DISCUSSION

7.1 Introduction

This study seeks to improve the user experience of construction workers with respect to safety helmets and goggles in order to enhance conformity to PPE protocols on construction sites.

Chapter five presented several identified discomforts associated with the use of both helmets and goggles. The discomforts were found to be dominantly physical and psychological in nature. Chapter six concluded that both physical and psychological interventions are key to improving the user-experience of safety helmets and goggles on the construction sites.

This chapter presents the development of a framework to improve the user-experience of construction safety helmets and goggles and discusses the components of the framework. Validation of the framework and the implications of its application in the construction industry are also discussed in this chapter.

7.2 The Need for the Framework

The framework was developed in two stages. The first stage of developing the framework, illustrated the relationship between the discomforts experienced from using safety helmets and goggles as indicated by construction workers, and incidents on construction sites within the Accident Root Cause Tracing Model (ARCTM) indicated in Figure 7.1.

The ARCTM basically identifies and classifies causes of accidents into causal factors and root causes. Causal factors are the group of factors that contribute to an accident. Root causes are however the underlying factors that give rise to the causal factors, thereby resulting in accidents. It is possible to reduce the severity or frequency of accidents when causal factors are identified and dealt with. However, dealing with the root causes results in total elimination of the accident (Abdelhamid and Everett, 2000).

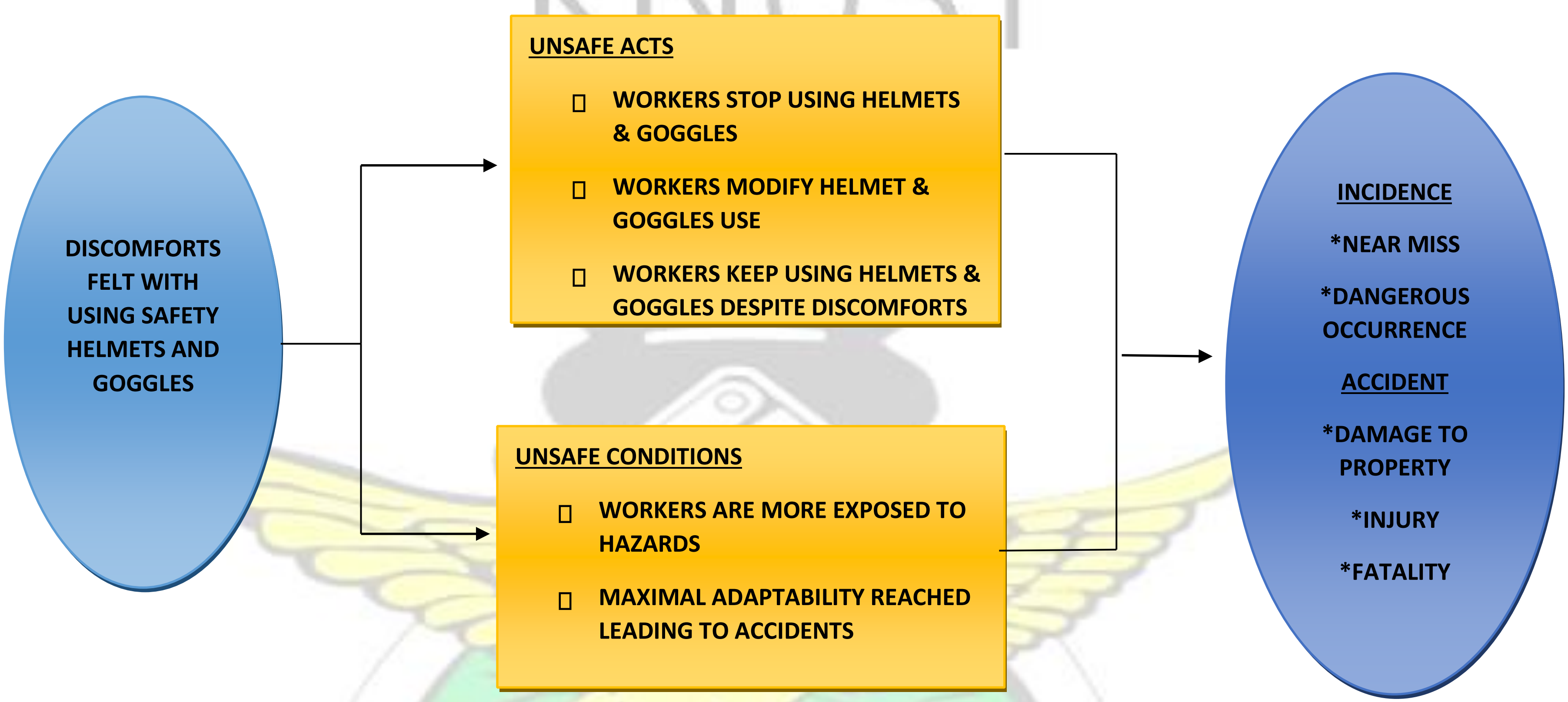

Figure 7.1: Discomforts Associated with Safety Helmets and Goggles in the context of the Multiple Causation Theory and Accident Root Cause Tracing Model

(Source: Author's Construct)

Discomforts associated with safety helmet and goggle use on construction sites are a potential root cause of accidents on construction sites. Construction workers engage in unsafe acts when they do not use safety helmets and goggles or modify its use on the construction site. An unsafe condition is subsequently created with these unsafe acts because workers are now more highly exposed to the risk of direct contact with hazards that exist and could result in avoidable accidents resulting from impact to the head and eyes.

Workers who maintain the use of uncomfortable helmets and goggles are not exempt from danger. According to the Maximal Adaptability Model, a person subjected to continual increasing stress goes through the phases of psychological and physiological adaptation to keep the body comfortable despite the stress. However, beyond the stage of maximal adaptability, this person will suffer psychological and physiological instability which may also result in an accident (Hancock, 1989). It is important that any attempt to improve helmet and goggle use on construction sites focus on improving both the physical and psychological user experience to achieve good results.

7.3 An Overview of the Proposed Behaviour Based Safety (BBS) Intervention Framework

The next stage of the framework development addressed the discomforts expressed by construction workers within a two-tier intervention process, aimed at removing the physical discomforts and enhancing the psychological acceptance of safety helmets and goggles by construction workers as shown in Figure 7.2.

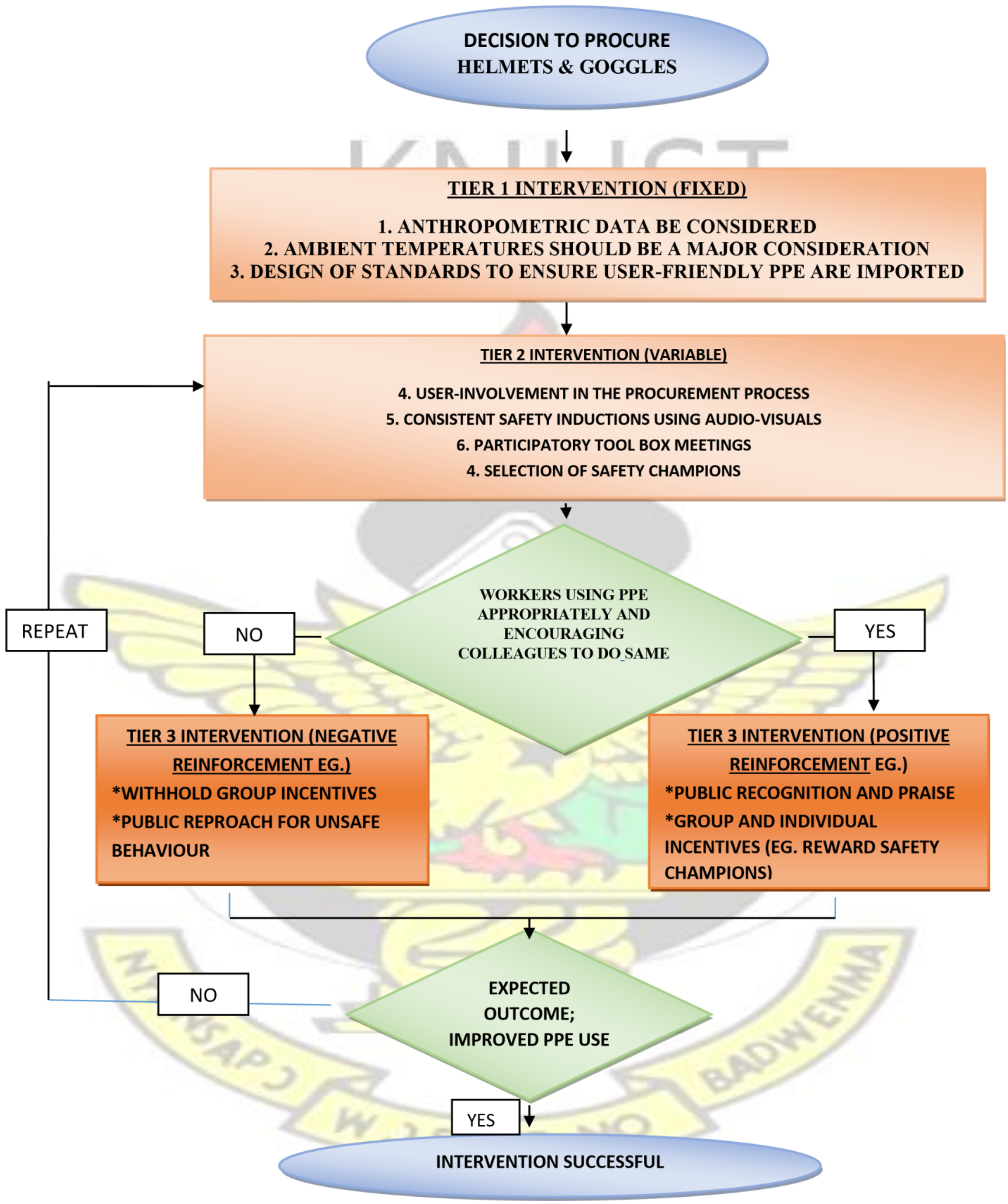

Figure 7.2: Proposed Behaviour Based Safety (BBS) Intervention to Improve the Use of Safety Helmets and Goggles (Source: Author's Construct)

7.4 How The Social Cognitive Theory Improves Safety Helmet and Goggle use

The SCT emphasizes a dynamic interaction between a person, his environment and his behaviour. According to the SCT, new behaviour is learned through observation. When a person observes reinforced or accepted behaviour around him, it affects his way of thinking such that he starts to exhibit or model this behaviour too. The extent to which this new behaviour can be sustained depends on the reinforcements (intrinsic or extrinsic) that follows the behaviour. As new individuals continue to model this behaviour (i.e. using safety helmets and goggles appropriately), the behaviour is then spread in a diffusion chain process and becomes a way of life.

7.5 The Intervention Stage

Tier One – Fixed Interventions

1. The study discovered a significant variance between workers' head measurements taken across the three construction sites and the safety helmets as well as between the safety goggle dimensions and the face measurements. It is recommended that the importation and or procurement of safety helmets into the country should be done considering anthropometric (physical) measurements of users to remedy discomfort complaints of poor fit.
2. From the research, several safety helmet and goggle users complained of heat build-up within the PPE while they used them. The study recommends that safety helmets and goggles imported into the country should be properly examined to ensure they have adequate ventilation holes and are made of material suitable for the ambient temperatures that exist in the country.
3. The study proposes the development of a set of standards (by the Ghana Standards Authority) for safety helmets and goggles that would be used in the country, taking into consideration anthropometric features of users and existing environmental conditions to ensure that they are specifically suited to the existing environmental conditions.

Tier 2 - Adjustable Interventions

4. Previous research suggests that workers are more likely to use the requisite PPE when they play an active role in the acquisition process. To encourage improve compliance with safety helmets and goggles use, construction firms should involve the construction employees

(supervisors, trades headmen), in their selection and procurement process (by seeking their opinions on the characteristics of helmets and goggles that are bought for them). Workers should be allowed the chance for fitting and trial uses before bulk procurement.

5. Safety helmet and goggles use can be improved when construction workers undergo regular periodic safety inductions using audio visuals. Audio visuals showing effects of non-helmet and goggle use and near misses are preferred as it will enable workers to see real human beings who have been impacted by site incidences as result of the non-use or improper use of PPE.
6. Daily toolbox meetings (short morning meetings that discuss work packages planned for the day) are carried out in a manner that is participatory and allows the workers to contribute personal and observed experiences. This meeting should also aim to discuss the risks and hazards that are likely to be encountered in every work area for the day.
7. The selection of safety champions from amongst the workers to champion safety initiatives in their work areas by leading health and safety meetings and ensuring that colleague workers adhere to PPE protocols, as well as being duly rewarded for safe behaviour.

7.6 The Observation Stage

It is expected that the interventions proposed, when executed diligently, will result in a gradual change /modification of behaviour, amongst some employees, setting the stage for the next stage of improving the behaviour of a wider group of employees. Within the context of the SCT, it is expected that a few employees will initially embrace change and start exhibiting safe behaviour, thus serving as models for the rest of the team. The remaining employees by observing the good behaviour and reward (motivation) of the models and finding it to be a good thing (cognitive processes) may then try to alter their own behaviours by observing the proper use of the PPE. It is also expected that some workers after this stage may still refuse to comply with the required safety behaviour of using PPE the right way.

7.7 Tier 3 - The Reinforcement Stage

This stage is very important to the process because reinforced behaviour tends to be repeated. Thus, when an employee observes consistent reinforcement of a model's good behaviour by the superiors, he/she will be encouraged to exhibit same. Even though positive reinforcement is preferred, negative reinforcement and punishment for consistent unacceptable behaviour is necessary to eliminate such behaviour.

Positive reinforcement processes prescribed to improve the use of construction helmets and safety goggles include:

- Public recognition and praise for safe behaviour. Workers who consistently adhere to helmet and goggles protocols should be identified and commended for good behaviour in the presence of others, e.g., at toolbox meetings. The site could also put up names or pictures of fully compliant personnel on notice boards to motivate others to aspire to be recognized in such manner also.
- Company or site management could develop an incentive scheme that would be utilized periodically to award consistent compliance with safety helmets and goggle protocols by individuals. A group incentive scheme (in the form of a quarterly, half yearly or annual bonus) to reward the whole team for good safety performance will also encourage the effective use of PPE.
- The team should consistently be persuaded and encouraged to engage in safe behaviour by prioritizing safety over work schedules because it is the right thing to do.

Negative reinforcement can be executed through;

- Warning notices at the initial stages.
- Public acknowledgment and reproach of unsafe behaviour.
- Withholding of group incentives from offending personnel.

7.8 The Outcome Stage

According to the Operant Theory, behaviour that is reinforced is likely to be repeated. Subsequently, the Social Cognitive theory asserts that as people observe models being rewarded for 'good' behaviour, they will likely engage in same. It is expected that as safe behaviours with respect to helmets and goggles are reinforced, this behaviour will be diffused amongst the workers resulting in improved group safety culture. At this stage it is important to document and present feedback on safety performance to workers to further boost their morale and increase safety helmet and goggle use. If feedback is negative or not encouraging enough, modifications should be made to the variable interventions to improve subsequent results. A recalcitrant worker that refuses to comply with the safety helmet and goggle protocols after being repeatedly taken through the intervention process should be punished by dismissal.

When feedback obtained, is acceptable, then it implies the intervention has been successful.

7.9 Validation of the Framework

The following section expounds the objectives and process used in validating the proposed framework. The respondents and results from the validation are also presented in this section.

7.9.1 The Objectives of the Validation

The objectives of the validation process were to;

1. Obtain the opinions of users of safety helmets and goggles on whether the listed interventions can affect their user-experience.
2. Find out from procurement officers how well the listed interventions can affect the attitude towards the use of safety helmets and goggles.
3. Draw additional comments from purchasers and users of safety helmets and goggles, which can aid in improving the attitude of construction workers towards their use.

7.9.2 The Validation Process

7.9.3 Respondents

The validation process was undertaken by three groups of respondents made up of construction operatives (consisting of various tradesmen, some of whom took part in the field experiment described in chapter four), construction managers and academics. Construction operatives were required for the validation process as they are primary users of safety helmets and goggles and as such would be at the receiving end of the proposed intervention. Some of the operatives were also participants in the data collection stage of the study. The interventions proposed, requires commitment from construction managers to make it successful hence their practical perspective and input were needed in the validation process. Academics in the built environment contributed to the process by providing an objective analysis of the framework with respect to both theory and practice. Table 7.1 outlines the three groups of respondents in the validation process.

Table 7.1: Respondents to the Validation Questionnaire

Item	Description of Respondent Group	Frequency	Percentage	Relevance to the validation process
A	Construction Operatives	9	45	Primary users of PPE and beneficiaries of the intervention
B	Construction Managers	5	25	Implementers of the intervention
C	Built Environment Academics/Researchers	6	30	To provide a practical cum theoretical assessment of the intervention
	TOTAL	**20**	**100**	

7.9.4 The Process

The validation process was completed in two stages. It began with an introduction of the various teams present. A short Power Point presentation was made to participants outlining the problem statement, data collection process and results from the research that culminated in the design of the proposed framework.

In stage two of the process, the framework was presented to the participants to analyse the various components within it. Participants of the validation process were subsequently presented with a two-page questionnaire that would aid in assessing the components of the framework. The questionnaire required respondents to rate the listed components of the framework, on a scale of 1-5, on their effectiveness at contributing to an improved user-experience of construction helmets and goggles.

The ratings provided in the questionnaire were explicitly defined as;

5 = Strongly agree - respondent had no doubt on the certainly of question being asked.

4 = Agree - respondent generally agreed with the issue or principle underlying the issue being questioned.

3 = Uncertain - respondent was not sure but cannot confirm or deny the importance of issue under discussion or being questioned.

2 = Disagree - respondent did not agree with the issue or the principle underlining the issue being discussed or questioned.

1 = Strongly disagree - respondent was completely aware that the issue under consideration was not possible from his/her perspective.

Each question was read out to the hearing of all participants and translated verbatim into the Akan language to enable easy understanding for the operatives. Respondents indicated complete understanding of the questions before providing answers. The researcher expressed gratitude to the teams for their contribution to the research process.

7.10 Results of the Validation

Table 7.2 presents the results of the validation of the proposed BBS framework to improve the attitude of construction workers towards safety helmets and goggles.

Table 7.2: Summary of Validation Results on the Proposed BBS Intervention

	DESCRIPTION OF INTERVENTION	AVERAGE	
		SCORE	%
	THE INTERVENTION STAGE	**4.51**	**90.21**
1	Consideration of anthropometric characteristics before procuring PPE	4.16	83.16
2	Consideration of ambient temperature	4.89	97.89

3	Consistent persuasion and encouragement to exhibit safe behaviour	4.53	90.53
4	Direct involvement of workers in the selection and procurement of PPE	3.95	78.95
5	Regular periodic safety inductions using audio-visuals to increase awareness of PPE need	4.58	91.58
6	Participatory toolbox meetings	4.58	91.58
7	Periodic selection of safety champions to motivate colleagues towards safe behaviour	4.89	97.78
	THE REINFORCEMENT STAGE	**4.65**	**93.02**
8	Public recognition and praise for safe behaviour	4.89	97.89
9	Group and individual incentive scheme to reward safe behaviour	4.47	89.47
10	Reward scheme for safety champions for leading peers to observe safe practices	4.68	93.68
11	Consistent encouragement to exhibit safe behaviour	4.83	96.67
12	Denying workers of liberties for engaging in unsafe behaviours	4.37	87.37
	THE FEEDBACK STAGE	**4.63**	**92.63**
13	Exhibiting safety performance improvement statistics on notice boards	4.79	95.79
14	Verbal communication of safety performance improvements	4.63	92.63
15	Making modifications to the listed interventions	4.47	89.47

Table 7.3: Raw Scores of Validation Questionnaire

	QUESTIONS	**AVERAGE SCORES**				
		O	**M**	**A**	**TOTAL**	**%**
	THE INTERVENTION STAGE	**4.52**	**4.68**	**4.38**	**4.51**	**90.21**
1	Consideration of anthropometric characteristics before procuring PPE	3.67	4.50	4.67	4.16	83.16
2	Consideration of ambient temperature	5.00	5.00	4.67	4.89	97.89

3 Consistent persuasion and 4.56 4.75 4.33 4.53 90.53 encouragement to exhibit safe behaviour

4 Direct involvement of workers in the 3.67 4.75 3.83 3.95 78.95 selection and procurement of PPE

5 Regular periodic safety inductions using 5.00 4.00 4.33 4.58 91.58 audio-visuals to increase awareness of PPE need **6** Participatory toolbox meetings 4.78 4.75 4.17 4.58 91.58

7 Periodic selection of safety champions to 5.00 5.00 4.67 4.89 97.78 motivate colleagues towards safe behaviour

THE REINFORCEMENT STAGE 4.73 4.58 4.57 4.65 93.02

8 Public recognition and praise for safe 5.00 4.75 4.83 4.89 97.89 behaviour

9 Group and individual incentive scheme to 4.44 4.50 4.50 4.47 89.47 reward safe behaviour

10 Reward scheme for safety champions for 4.89 4.75 4.33 4.68 93.68 leading peers to observe safe practices

11 Consistent encouragement to exhibit safe 5.00 4.67 4.67 4.83 96.67 behaviour

12 Denying workers of liberties for 4.33 4.25 4.50 4.37 87.37 engaging in unsafe behaviours

THE FEEDBACK STAGE 4.89 4.50 4.33 4.63 92.63

13 Exhibiting safety performance 5.00 4.50 4.67 4.79 95.79 improvement statistics on notice boards

14 Verbal communication of safety 5.00 4.25 4.33 4.63 92.63 performance improvements

15 Making modifications to the listed 4.67 4.75 4.00 4.47 89.47 interventions

Key: O – Operatives of construction companies, M – Management members of construction companies, A - Academics

7.11 Comments and Recommendations to Improve the Framework

The results presented in Table 7.2 indicates that all three categories of respondents are confident that the listed interventions would be successful in improving the attitude of construction workers towards the use of safety helmets and goggles.

A few comments were however made by respondents purported at improving the framework.

With regards to the intervention stage, respondents in the 'construction managers' category indicated that the use of safety helmets and goggles should be regulated by law on all construction projects irrespective of size, to compel its appropriate use. Respondents in the 'academics' category advised the inclusion of a medium that would detect errors in Tier 1 of the intervention stage.

Comments on the reinforcement stage, suggested that although group and individual incentives were acceptable, expulsion or dismissal of a recalcitrant employee is too harsh. In their opinion, the payment of a fine or temporary suspension from the works premises instead would be a suitable alternative. Respondents proposed that clear notifications should be placed at vantage points to remind workers that safety helmets and goggles need to be kept worn while on site. Respondents again indicated that safety officers should be hired and be dedicated to ensuring full compliance with PPE.

Under the feedback section, respondents indicated that safety improvement statistics be presented at morning meetings instead of being displayed on notice boards and should be trade specific. Finally, respondents commented that the framework be shared with worker union groups to sensitize construction workers all over the country on its benefits.

Some of the comments obtained from the validation process were incorporated to modify the framework. Extinction was maintained because maintaining an employee who refuses to exhibit acceptable behaviour in spite of all the effort made, may seem as a reinforcement of his behaviour and may result in other employees imitating the unwanted behaviour. The modified framework is presented in Figure 7.3.

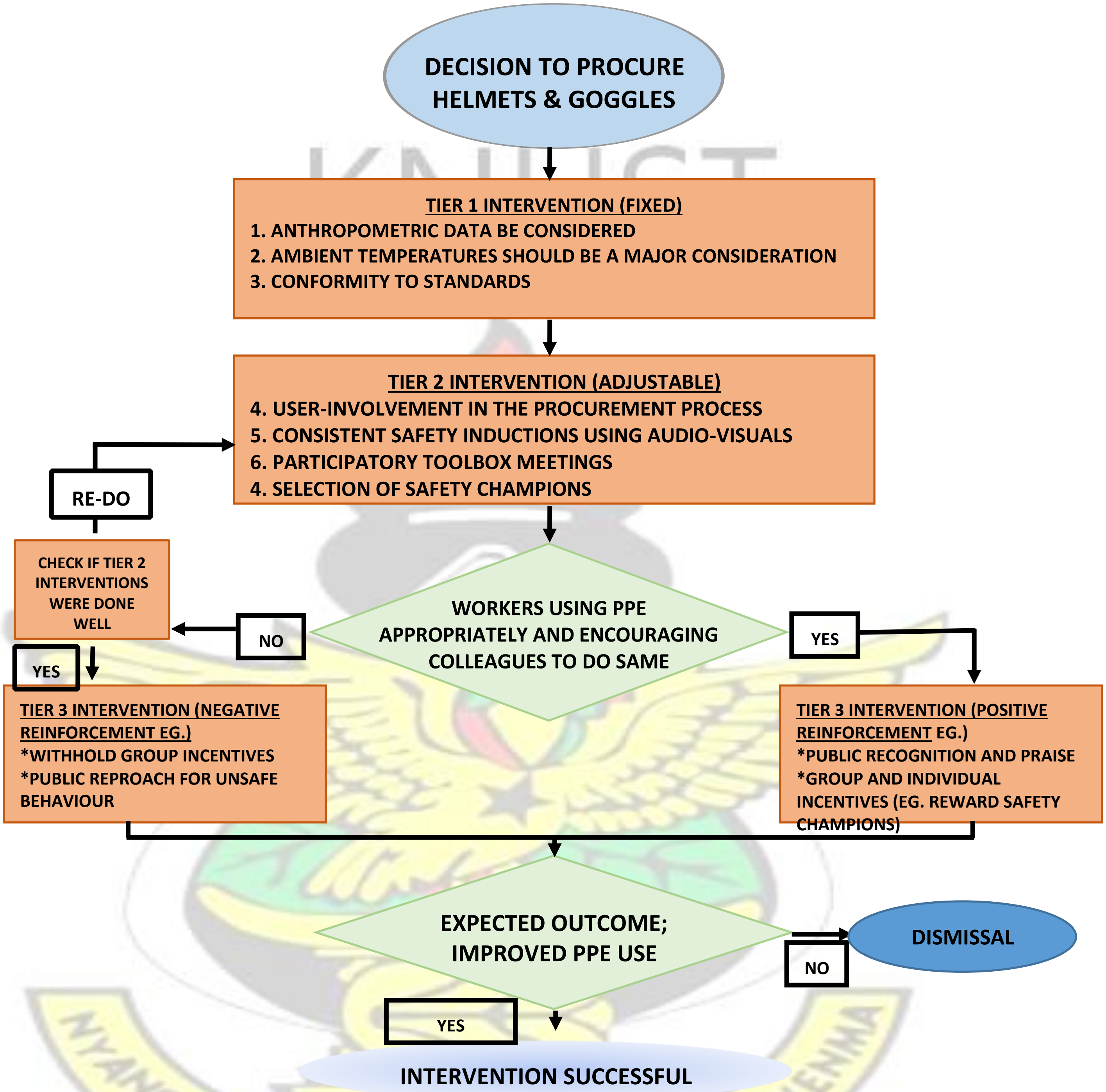
DECISION TO PROCURE HELMETS & GOGGLES
TIER 1 INTERVENTION (FIXED)
1. ANTHROPOMETRIC DATA BE CONSIDERED
2. AMBIENT TEMPERATURES SHOULD BE A MAJOR CONSIDERATION
3. CONFORMITY TO STANDARDS
TIER 2 INTERVENTION (ADJUSTABLE)
4. USER-INVOLVEMENT IN THE PROCUREMENT PROCESS
5. CONSISTENT SAFETY INDUCTIONS USING AUDIO-VISUALS
6. PARTICIPATORY TOOLBOX MEETINGS
4. SELECTION OF SAFETY CHAMPIONS
RE-DO
CHECK IF TIER 2 INTERVENTIONS WERE DONE WELL
NO
WORKERS USING PPE APPROPRIATELY AND ENCOURAGING COLLEAGUES TO DO SAME
YES
YES
TIER 3 INTERVENTION (NEGATIVE REINFORCEMENT EG.)
*WITHHOLD GROUP INCENTIVES
*PUBLIC REPROACH FOR UNSAFE BEHAVIOUR
TIER 3 INTERVENTION (POSITIVE REINFORCEMENT EG.)
*PUBLIC RECOGNITION AND PRAISE
*GROUP AND INDIVIDUAL INCENTIVES (EG. REWARD SAFETY CHAMPIONS)
EXPECTED OUTCOME; IMPROVED PPE USE
NO
DISMISSAL
YES
INTERVENTION SUCCESSFUL

Figure 7.3: Framework to Improve the Attitude of Construction Workers Towards Safety Helmets and Goggles

7.12 Limitations of the Validation Process

A focus group discussion was preferred for testing the framework because it enabled the researcher to provide a clear explanation of the background to the study, results obtained and the need for the validation process, especially to construction operatives who are mostly semi- literate.

Even though many construction industry stakeholders were invited, the validation process, was limited to the opinions of twenty (20) respondents who willingly attended the programme.

7.13 Implications of the Framework

Although the use of the BBS Intervention framework would not automatically propel construction workers into full compliance with PPE protocols, it provides a roadmap which will enable workers to gradually appreciate the importance of safety helmets and goggles, the efforts undertaken to ensure their user-friendliness, eventually leading to a permanent change in their behaviour towards safety helmets and goggles use.

The order of the framework is set out in a very simplified format for easy adoption and implementation on any construction site. Additionally, the processes in the framework are more suggestive than declarative making it easily adaptable.

7.14 Summary

This chapter presented a proposed framework to improve the attitude of construction workers towards the use of safety helmets and goggles. The framework combines factors that improve the comfort experience of the safety helmet (tier one) with behavioural modification factors (tier 2) to improve worker attitudes towards these PPE. Improved safety behaviour, i.e. proper and consistent use of the safety helmets and goggles are maintained through the reinforcement practices in tier 3. By ensuring that helmets and safety goggles are carefully selected with adaptive considerations and improving the attitude of construction workers towards their use, the framework thus addresses the physical, physiological and psychological discomforts associated with safety helmet and goggle use.

The chapter discussed how the framework was constructed, the validation process to test its workability in the construction industry, and the implications of its use in the construction industry.

Stakeholders in the construction industry such as operatives, management staff and academics within the industry accepted the framework with few recommendations for its effectiveness.

CHAPTER 8

RESEARCH CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

This chapter presents the conclusions of the study. It discusses the achievement of the research objectives and highlights the contributions of the research to knowledge and practice. The main limitations of the research are also presented here in. The chapter concludes with recommendations for the construction industry and further research (into improving the userexperience of construction PPE) that can be conducted based on the conclusions and limitations of the study.

8.2 Achievement of Objectives

The aim of the research is to develop a framework for enhancing construction workers' experience with the use of safety helmets and goggles through an inclusive selection process that considers their anthropometric characteristics and physical environment. The research objectives were developed to achieve this aim.

Objective 1: To identify discomforts that construction workers experience in using safety helmets and goggles.

This objective was achieved using semi-structured interviews on construction operatives within a multiple case study to obtain detailed information on the discomforts experienced with the use of safety helmets and goggles. The construction sites were selected as case studies for the research. Respondents to the interviews consisted of construction operatives like masons, carpenters, steel benders and machine operators. Through the interviews, construction workers elaborated on the discomforts they felt while using safety helmets and goggles, how they managed these comforts on site and their suggestions for improved comfort with the use of these PPE.

Objective 2: To identify the factors that account for the discomforts that construction workers experience in using safety helmets and goggles

Objective 2 sought to identify the causes of the discomforts identified in objective 1. Based on the responses obtained from the interviewees, a Physiological Strain field experiment was carried out to investigate physiological strain with construction workers while they worked using uncomfortable safety helmets and goggles. Anthropometric data of the head and face region were also taken from construction workers and compared with similar measurement taken of the helmets and safety goggles available in the case studies. Participants in both the Physiological Strain experiment and the anthropometric data collection voluntarily participated in the study after a brief explanation of the research aim and data collection methods.

Objective 3: To examine considerations that are made in the selection and procurement of construction PPE

To achieve objective three (3), a questionnaire survey was conducted on D1/K1 and D2/K2 construction firms in Ghana, to identify what considerations were taken before PPE were procured for use on construction sites. Respondents were also interrogated on their knowledge of discomforts associated with safety helmets and goggles use.

Objective 4: To develop and validate a framework for the procurement of safety helmets and goggles that enhance the user-experience of construction workers

Objective four (4) was achieved in two phases. An analysis of the results emanating from objectives 1, 2 and 3, culminated in the proposal of a framework to improve the attitude of construction workers to safety helmets and goggles.

The next phase involved the testing of the proposed framework by a group of construction industry stakeholders through a validation workshop. Participants in the workshop consisted of construction industry operatives, construction company owners and managers, and academics from the built environment. Table 8.1 summarises the methods of achievement of the research objectives.

Table 8.1: Summary of Research Objectives and Methods of Achievement

OBJECTIVE	DETAILS OF OBJECTIVE	METHOD OF ACHIEVEMENT
1	To identify discomforts that construction workers feel in using safety helmets and goggles.	Semi-structured interviews with construction operatives within a multiple case study.

2	To identify the factors that account for the discomforts that construction workers feel in using safety helmets and goggles.	Physiological Strain experiment in a Multiple Case Study. Comparison of Anthropometric features of construction workers with dimensions of safety helmets and goggles on the open market
3	To examine considerations that are made in the selection and procurement of construction PPE.	Questionnaire Survey of D1/K1 and D2/K2 construction firms in Ghana.
4	To develop and validate a framework for the procurement of safety helmets and goggles that is more user friendly.	Cross-case analysis of findings emerging from the case studies and survey. Testing of framework through a workshop comprising of construction firm management members, operatives and academics within the Built Environment

8.3 Contribution of the Research to Knowledge

There have been several studies on physiological strain in different work environments and working conditions. Physiological strain studies involving safety helmets are usually performed under laboratory conditions. This study recorded little or no physiological strain in a field experiment (i.e. within the respondents' natural working environment). The study contributes to the body of knowledge on construction safety that the use of uncomfortable helmets by construction workers in their natural environments does not result in physiological strain.

The study identified differences between anthropometric features of construction workers in the study location and safety helmets and goggle imported into the location. Considering that physical discomforts, particularly fitting problems, and heat within the PPE accounted for workers refusal to use given helmets and goggles, the study agrees with other literature that anthropometric features and weather conditions within a particular geographical location are key considerations in the selection and procurement of safety helmets and goggles for use on construction sites.

Additionally, behaviour-based interventions have gained a lot of attention as regards the improvement of health and safety statistics in various industries. The positive results obtained from the validation exercise, contributes to the body of knowledge that a behavioural based safety intervention can be an effective way of improving safety helmet and goggle use in the construction industry.

8.4 Implications of the Research to Industry and Practice

The results of the study identified that poor fit of the helmet and goggles as well as heat build-up within them contributed significantly to construction workers' refusal to use them on site. In terms of industry application, the research has shown that conformity to the use of safety helmets and safety goggles use by construction workers can be improved by an adaptive selection, that is, considering the physical characteristics of users to ensure a good fit and ensuring the procurement of adequately ventilated helmet and goggles with respect to the existing weather conditions in users' location. In addition, a behavioural conditioning process that makes workers understand the need for the helmet and goggle, reinforces their habits of using them with consequences for non-use will improve the attitude of construction workers to safety helmets and goggles use.

8.5 Scope and Limitations of the Research

There are many kinds of personal protective equipment used by construction workers. However, the research focused on improving the user-experience of only safety helmets and goggles by construction workers. These two PPE were selected due to the frequency and severity of injuries sustained by the head and face regions in occupational accidents.

Like any other research, this study had limitations in its conduct due to resource constraints. The limitations of this research are as follows:

1. The physiological strain experiment was conducted in the warm-humid climatic region of the country Ghana due to resource limitations. It is not known if alternative results would be obtained from the other climatic regions within the country or other geographical locations.
2. The physiological strain experiment was conducted over a period of five days due to the work schedules of the cases and time allowed the researcher on the site. It is not known if alternative results would be obtained within a longer duration or from a longitudinal study of the subject.

3. Female construction workers were not encountered during the study. Thus, the study results are limited to male construction workers. However, the framework is not gender specific and can be adapted to suit the varying needs of each firm.

4. It was not impractical to take invasive measurements of core body temperatures such as oesophageal or rectal temperatures on site.

8.6 Recommendations for Industry Practice

1. The Ghana Standards Authority can help improve the user-experience regarding the use of safety helmets and goggles in construction by ensuring that imported PPE conform to the requisite international standards. Contractors should be encouraged and guided to procure safety helmets and goggles with consideration for appropriate standards, anthropometric characteristics and climatic conditions.

2. The researcher recommends that comprehensive safety regulations be enacted by the government to provide clear guidelines on ensuring workplace safety. Subsequently, strict measures should be adopted to enforce such regulations to ensure their effectiveness in improving workplace safety performance.

3. The researcher recommends that contractors/employers consider implementing the validated BBS framework to help improve the use of safety helmets and goggles by construction workers.

8.7 Recommendations for Further Research

1. Physiological Strain experiments should be conducted on construction sites in different climatic/geographical locations, perhaps in a longitudinal study to determine if alternative results from those obtained in this study will be realised.

2. Construction workers often use a combination of PPE on site in practice. The physiological strain experiment was conducted only on helmet users in the study. The study recommends a physiological strain experiment on construction workers using the helmet in addition to other PPE such as ear plugs or safety glasses to see if results would vary.

3. Studies on the application of behaviour-based safety should be conducted in similar environments to determine their effectiveness in improving the use of other PPE such as safety harnesses and footwear, and health and safety performance in general.
4. Anthropometric data should be collected in other studies to serve as a database to guide the importation or standardisation of personal protective equipment for use in Ghana.

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APPENDICES

Appendix 1: Survey Questionnaire

IMPROVING THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES THROUGH ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING

(QUESTIONNAIRE FOR PROCUREMENT OFFICERS, SAFETY OFFICERS & SITE MANAGERS)

PART 1 (BACKGROUND INFORMATION)

1. What class of contractor is your institution

   D1/K1 ☐

   D2/K2 ☐

   D3/K3 ☐

   D4/K4 ☐

2. What is the highest level of formal education you have had

   Basic School ☐

   JHS ☐

   SHS ☐

   Tertiary ☐

3. What is your Position in this establishment?

   …………………………………………..

4. How long have you been procuring PPE for construction workers?

   >5yrs ☐ 5>10 yrs. ☐ 10>15 yrs. ☐ 15yrs and above ☐

PART 2 (KNOWLDEGE AND SELECTION OF PPE)

5. Which types of PPE is usually provided on site? (please tick as many as apply)

Helmet/hard hat ☐

Reflective jackets ☐

Safety boots ☐

Safety goggles ☐

Ear plugs ☐

Nose masks ☐

Safety harness ☐

Hand gloves ☐

Other (*please state)*……………………………………………………………..…..

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

6. From where does your company obtain PPE for your site?

Open market sources ☐

Supplied by a dealer ☐

Imported from overseas ☐

Other (*please state)*…………………………………………………………..………..

………………………………………………………………………………………

7. If imported, from which countries do you import PPE from? (*please state)*

…………………………………………………………

…………………………………………………………

8. Why do you buy from these countries? (*please state)*

………………………………………………………………………………………

……………………………………………………………………………………...

……………………………………………………………………………………….

9. What informs your firm's decision to procure PPE? (please tick as many as apply)

Requirements of the contract document ☐

Project management team's request ☐

The firm's Health and Safety Policy ☐

The country's policy requirements ☐

A. Other (*please state)*……………………………………………………………..…..

……………………………………………………………………………

10. Kindly rank the following criteria on a scale of 1, (Do not know) 2, (Of no importance), 3(Of some importance), 4, (Of great importance), as considerations made in the selection and procurement of PPE for construction workers.

SELECTION CONSIDERATIONS	1	2	3	4
Job hazard analysis				
Knowledge from previous work experiences				
Gender				
Age of workers				
Existing medical conditions, e.g. Hypertension, Refractive error, hence the need for prescription lenses, hearing aids etc				
Cultural considerations e.g. Traditional beliefs impeding workers from using some PPE				
Religious considerations e.g. Religious clothing/ beliefs preventing the use of some PPE				
Body sizes of workers				
Requests made by trades foremen				

Environmental conditions				
Colour preferences				
Weight of PPE				
Comfort of wearer				
Style of PPE				
Price				
Breathability of the PPE material				
Least restriction to movement				
Least obstruction of work				
Wearability of PPE				
Involvement of users				
Compliance with International standards				
Compliance with Ghana Standards Authority				
Feedback from workers' previous use of PPE				

11. What other considerations are made in the selection of PPE for construction workers?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

PART 3 (PPE USE ON CONSTRUCTION SITES)

12. Please rate the following factors from 1, (Do not know), 2 (Of no significance), 3(Of some significance), and 4, (Of great significance) in your opinion as causes for employee discomforts in using SAFETY HELMETS.

FACTOR	1	2	3	4
It is heavy				
It gets hot inside				
It does not fit very well				
It obstructs vision				
It impedes the work				
It is too tight				
It is too loose				
It makes me feel uncomfortable				
It is smelly				
It is not fashionable				
It is too old/worn out				
I get tired very quickly				
I do not like the colour				
I get Headaches				
It makes me feel dizzy				
It makes me have convulsions				
It gives me heat rashes				
I feel like fainting				
I feel pain in the neck				
It makes me sweat excessively				
I constantly feel tired				
Giddiness (dizzy and silly)				
I get muscle cramps				
I feel nauseous				
I feel dehydrated				

It is heavy				
It gets hot inside				
It is not relevant to my job				

13. Please rate the following factors from 1, (Do not know), 2 (Of no significance), 3(Of some significance), and 4, (Of great significance), in your opinion as causes for employee discomforts in using SAFETY GOGGLES.

FACTOR	1	2	3	4
It is heavy				
It gets hot inside				
It does not fit very well				
It obstructs vision				
It impedes the work				
It is too tight				
It is too loose				
It makes me feel uncomfortable				
It is smelly				
It is not fashionable				
It is too old/worn out				
I get tired very quickly				
I do not like the colour				
I get Headaches				
It makes me feel dizzy				
It makes me have convulsions				
It gives me heat rashes				
I feel like fainting				
I feel pain in the neck				
It makes me sweat excessively				
I constantly feel tired				
Giddiness (dizzy and silly)				

I get muscle cramps				
I feel nauseous				
I feel dehydrated				
It is heavy				
It gets hot inside				
It is not relevant to my job				

14. How do construction workers usually deal with the discomforts associated with the use of safety helmets?

They do not use the helmet ☐

They take it off periodically ☐

They modify its use ☐

They keep using it ☐

Other practices (please state)…………………………………………………

…………………………………………………………………………………..

……………………………………………………………………………………

15. How do construction workers usually deal with the discomforts associated with the use of safety goggles?

They do not use it at all ☐

They take it off periodically ☐

They modify its use ☐

They keep using it ☐

Other practice (please state)……………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

16. How does the company manage the issue of employees' refusal to accept/use given PPE?

We force them to comply with PPE protocols ☐

We conduct safety inductions to enhance their knowledge ☐

We allow them to use them as they please ☐

Other practice (please state)……………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… **Appendix 2: Semi-structured Interview Questionnaire**

IMPROVING THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES THROUGH ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING

SEMI-STRUCTURED INTERVIEW QUESTIONS FOR SITE OPERATIVES

PART 1: BACKGROUND INFORMATION

1. What is your gender?

   A. Male ☐

   B. Female ☐

2. How old are you?

   A. Less than 20 years ☐

   B. 20 < 30years ☐

   C. 30 < 40years ☐

   D. 40 < 50 years ☐ E. Above 50 years ☐

3. Are you married?

   A. Yes ☐ B. No ☐

4. Do you have children

   A. Yes ☐ B. No ☐

5. What is the highest level of formal education you have had?

   A. None ☐

   B. Basic School ☐

   C. B. JHS ☐

   D. C. SHS ☐

   E. D. Tertiary ☐

6. What is the nature of your work on this site? (Please tick)

   A. Masonry ☐ D. Tiling ☐ G. Welding ☐

   B. Carpentry ☐ E. Plumbing ☐ H. Supervisory ☐

   C. Steel Bending ☐ F. Electricals ☐ I. Other…………

7. How long have you been working on construction sites?

   A. 0-5yrs ☐ B. 5-10yrs ☐ C. 11-15yrs ☐ D. Above 15yrs ☐

PART 2: PPE USE ON SITE

8. What types of PPE are you usually given for use on this site?

A. Helmet/hard hat ☐
B. Reflective jackets ☐
C. Safety boots ☐
D. Safety goggles ☐
E. Ear plugs ☐
F. Nose masks ☐
G. Safety harness ☐
H. Hand gloves ☐
I. Other….. ☐

9. What kind of discomforts do you experience with using the safety helmet?

10. What kind of discomforts do you experience with using the safety goggles?

11. What do you think are the reasons for the discomforts you feel in using safety helmets?

12. What do you think are the reasons for the discomforts you feel in using safety goggles?

13. How do you manage the discomforts you feel while using safety helmets and safety helmets?

14. How do you manage the discomforts you feel while using safety helmets and safety goggles?

15. What would make safety helmets more comfortable and make you use it?

16. What would make safety goggles more comfortable and enhance your use of PPE?

Appendix 3 -Informed Consent Form

PROJECT TITLE:

IMPROVING THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES THROUGH ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING

RESEARCH UNDERTAKEN UNDER THE DEPARTMENT OF BUILDING TECHNOLOGY

SUPERVISORY TEAM:

REV. PROF. F.D.K. FUGAR

PROF. EMMANUEL ADINYIRA

1. I confirm that I understand the information required for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason. ☐
3. I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the data and if they agree to the terms I have specified in this form. ☐
4. I agree to take part in the above study. ☐
5. I agree to the interview / focus group / consultation being audio recorded ☐
6. I agree to the use of anonymised quotes in publications ☐

Participant:

________________________ ________________________ ________________

Name of Participant Signature Date

Researcher:

Name of Researcher Signature Date

Appendix 4- Experiment Data Collection Sheet

IMPROVING THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES THROUGH ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING

CASE NO.:

VOLUNTEER NO.:

BASELINE DATA

ITEM	**DESCRIPTION**	**INSTRUMENT**	**MODEL**	**DAY 1**	**DAY 2**	**DAY 3**
1	BLOOD PRESSURE	SPHYGMOMANOMETER				
2	HEART RATE	SPHYGMOMANOMETER				
3	BODY HEIGHT	STADIOMETER				
4	BODY WEIGHT	SCALE				

CURRENT MEDICATION (*PLEASE LIST)*:

1

2

3

4

5

SIGNED CONSENT FORM (YES/NO):

Appendix 4: Physiological Data Collection Sheet

IMPROVING THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES THROUGH ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING

EXPERIMENT DATA COLLECTION SHEET

PHYSIOLOGICAL AND ENVIRONMENTAL DATA

CASE NO.

:

VOLUNTEER NO. :

DAY	TIME	BP	HR	CBT	RH	ET
	6.30AM					
	8.30AM					
	11.30AM					
	5.30PM					
DAY	**TIME**	**BP**	**HR**	**CBT**	**RH**	**ET**
	6.30AM					
	8.30AM					
	11.30AM					
	5.30PM					

Appendix 5- Anthropometric Data Collection Sheet IMPROVING THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS THE USE OF SAFETY HELMETS AND GOGGLES THROUGH ADAPTIVE SELECTION AND BEHAVIOURAL CONDITIONING

VOL. NO.	HEAD MEASUREMENTS						FACE MEASUREMENTS	
	1	**2**	**3**	**4**	**5**	**6**	**TL**	**T - E**

Appendix 6: Questionnaire for Preliminary Investigation

AN INVESTIGATION INTO PERSONAL PROTECTIVE EQUIPMENT USE IN THE GHANAIAN CONSTRUCTION INDUSTRY

PROPOSED QUESTIONNAIRE FOR PRELIMINARY SURVEY PRECEDING PHD RESEARCH

PART 1: DEMOGRAPHIC INFORMATION

17. What is your gender?

A. Male { } B, Female { }

18. How old are you? { } A. Less than 20 yrs. { } B. 20-30yrs { }

C. 31-40yrs { } D. Above 40 yrs. { }

19. Are you married?

B. Yes { } { } B. No

20. Do you have children

B. Yes { } B. No { }

PART 2: BACKGROUND INFORMATION

21. What is the highest level of formal education you have had

F. Basic School { } B. JHS { } C. SHS { } D. Tertiary { }

E. None { }

22. What is the nature of your work on this site

A. Skilled { } B. Unskilled { }

23. What is your area of expertise on this site (Please tick)

D. Masonry { }
E. Carpenter { }
F. Steel Bender { }
D. Tiler { } G. Welder { }
E. Plumber { } H. Supervisor { }
F. Electrician { } I. Other………… { }

24. How long have you been working on a construction site

B. 0-5yrs { } B. 5-10yrs { } C. 11-15yrs { } D. Above 15yrs

PART 3: IDENTIFICATION OF HAZARDS

25. Please identify the accident types that occur on your site and rate their frequency of occurrence on a scale of 0-3, 0 = none, 1= lowest, 2 = intermediate and 3, highest.

ITEM	ACCIDENT TYPE	PROBABILITY OF OCCURRENCE		FREQUENCY OF OCCURRENCE			
		YES	NO	0	1	2	3
A	Struck by falling object						
B	Struck against an object						
C	Contact by equipment						
D	Contact with dangerous substance						
E	Caught on an equipment/object						
F	Caught in an opening/enclosure						
G	Caught between two objects						
H	Fall from a height						
I	Slipping/Tripping						
J	Overexertion						

K	Exposure to harmful condition over a period						

PART 4: PPE USE ON SITE

26. Please indicate the PPE given for use on site, whether you use them and reasons why you do not use them

ITEM	TYPE OF PPE GI (pls tick)	EN	DO YOU USE THEM		REASONS FOR NOT USING PPE (Pls Tick)			
			YES	NO	I FEEL UNCOMFORTABLE	I DO NOT KNOW HOW TO USE IT	IT GETS IN THE WAY OF WORK	OTHER
A	Helmet							
B	Safety goggles							
C	Nose mask							
D	Ears plugs							
E	Reflective jacket							
F	Hand gloves							
G	Safety harness							
H	Safety boots							

Appendix 8-Proposed Validation Study

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

PROPOSED STUDY TO VALIDATE FINDINGS OF A RESEARCH CONDUCTED TO IMPROVE THE ATTITUDE OF CONSTRUCTION WORKERS TOWARDS SAFETY HELMETS AND GOGGLES

NAME OF STUDENT: ANITA ODAME ADADE-BOATENG

SUPERVISORS: REV. PROF F.D.K.FUGAR

DR. EMMANUEL ADINYIRA

PART 1 – INTRODUCTION TO THE STUDY

RESEARCH BACKGROUND

Personal Protective Equipment (PPE) is a crucial element in the protection of employee health and safety on construction sites, as workers are exposed to a wide range of hazardous conditions such as working at height, the risk of falling objects, working with electricity, excavation, etc. In spite of its importance, there is an increasing trend of non-compliance with PPE use across the industry in many countries.

PROBLEM

Construction workers constantly try to outsmart their employers in the use of personal protective equipment (PPE) either by refusing to wear it or modifying its use because they claim PPE is usually uncomfortable. For workers in the construction industry, the head and face region is the most vulnerable part of their body in the event of an accident. For this reason, this study focuses on safety helmets and goggles.

Construction workers interviewed in a multiple case study in Ghana indicated several discomforts associated with safety helmets and goggles.

A summary of the usual discomforts experienced is outlined in Table 1 below:

Table 1: Discomforts Associated with the use of Safety Helmet and Goggles

Safety Helmets	Safety Goggles
They do not fit properly	Lens is sometimes not clear resulting in blurred vision
They are heavy and weigh users down	They do not fit properly
They get smelly and are uncomfortable to use	It feels heavy and weighs down on the face
They obstruct vision	Users experience early onset of fatigue
They give headaches with prolonged use	Users experience early onset of fatigue
Users experience early onset of fatigue	Heat builds up inside goggles resulting in foggy screens and compromised vision
Heat builds up inside the helmet making it very hot	Dislike for the colour of the lens because using the plain lens results in suffering from the sun’s glare often.
It is sometimes worn out, making it physically (e.g. the exposed harness scratch the scalp) and psychologically uncomfortable	

Figure 1, is based on the Accident Root Cause Tracing Model (ARCTM), and illustrates how discomforts associated with safety goggles and helmets use may lead to accidents on a construction site.

The ARCTM basically identifies and classifies causes of accidents into causal factors and root causes. Causal factors are the group of factors that contribute to an accident. Root causes are however the underlying factors that give rise to the causal factors, thereby resulting in accidents. It is possible to reduce the severity or frequency of accidents when causal factors are identified and dealt with. However, dealing with the root causes results in total elimination of the accident.

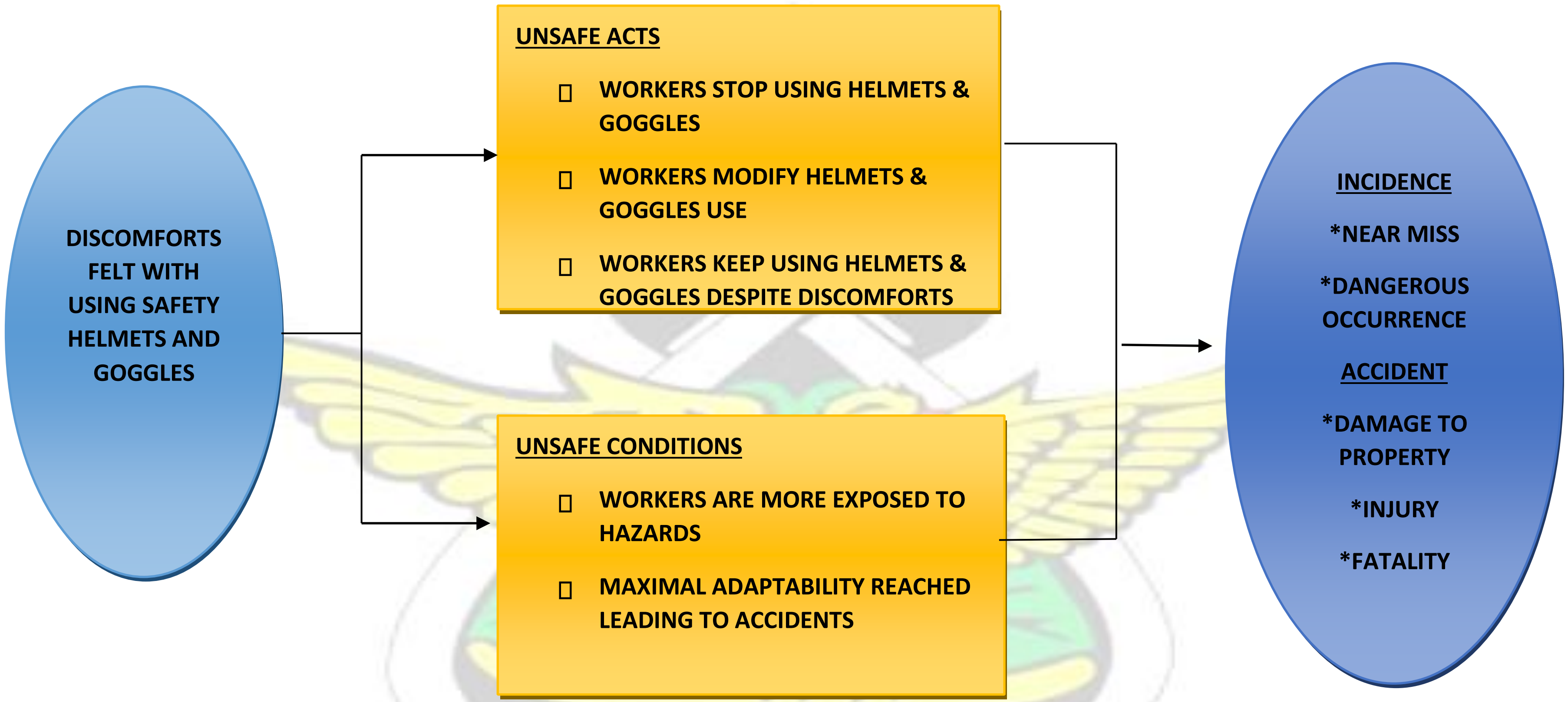


Figure 1: Flow Process of Incidents that may arise as a result of using uncomfortable Safety helmets and Goggles

(Source: Author's Construct)

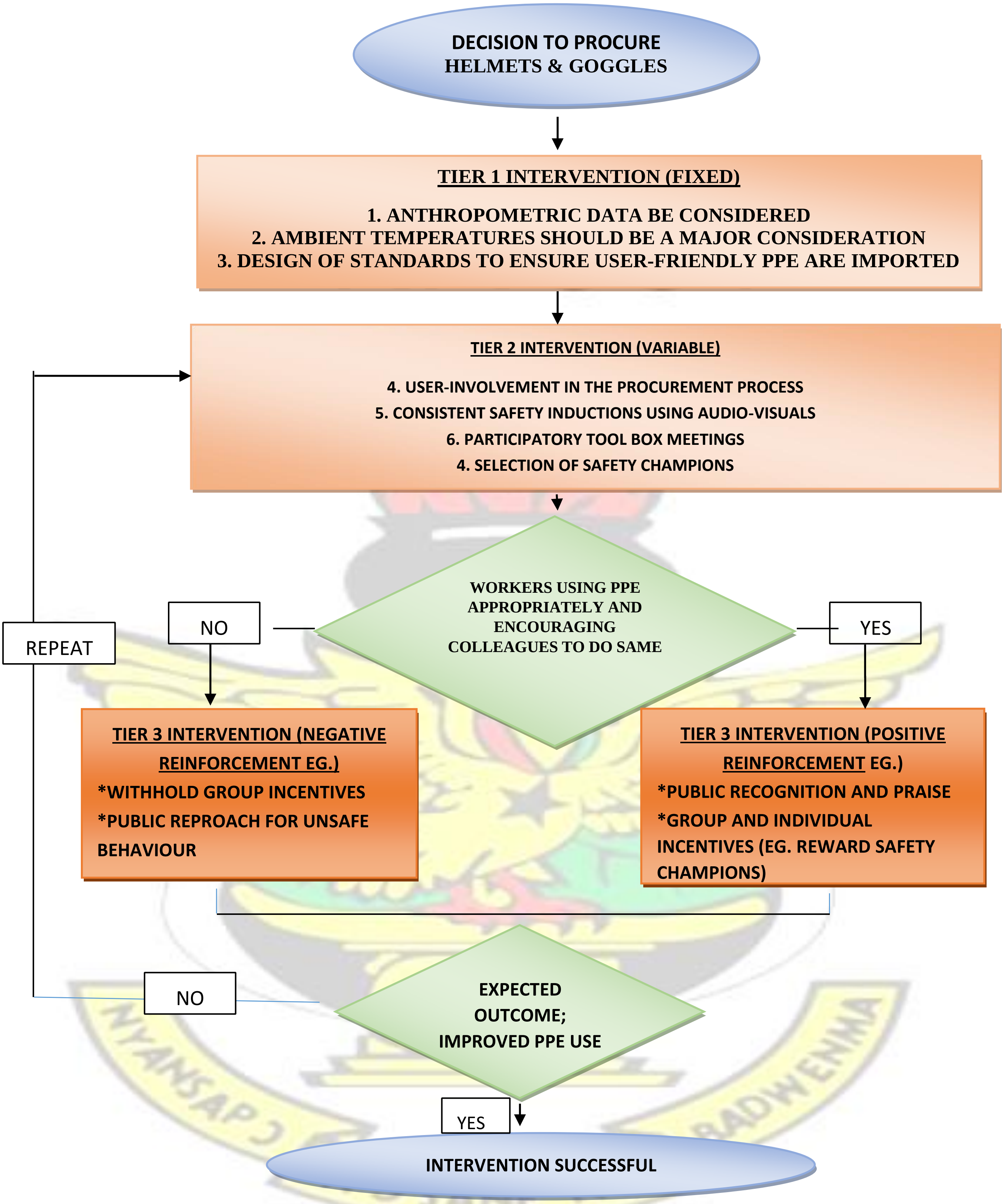
This study has identified discomforts associated with safety helmet and goggle use to be a potential root cause of accidents on construction sites. Construction workers engage in unsafe acts when they do not use safety helmets and goggles or modify its use on the construction site. An unsafe condition is subsequently created with these unsafe acts because workers are now more highly exposed to the risk of direct contact with hazards that exist and could result in avoidable accidents resulting from impact to the head and eyes.

Workers who maintain the use of uncomfortable helmets and goggles are not exempt from danger. According to the Maximal Adaptability Model, a person subjected to continual increasing stress goes through the phases of psychological and physiological adaptation to keep the body comfortable despite the stress. However, beyond the stage of maximal adaptability, this person will suffer psychological and physiological instability which may also result in an accident. It is important that any attempt to improve PPE use on construction sites focus on improving both the physical and psychological user experience to achieve good results.

A BEHAVIOUR BASED SAFETY (BBS) INTERVENTION

This study proposes a BBS intervention illustrated in figure 2 below as a remedy to the lack of proper use of construction safety helmets and goggles. The overall aim of the intervention is to improve worker behaviour pertaining to the use of safety helmets and goggles. It is hoped that through this intervention, construction workers will use these PPE because efforts have been undertaken to ensure they (PPE) are more comfortable and secondly because workers fully understand the need to use them.

The proposed BBS Intervention is designed based on both the Accident Root Cause Tracing Model (ARCTM) and the Social Cognitive Theory (SCT).



DECISION TO PROCURE
HELMETS & GOGGLES
TIER 1 INTERVENTION (FIXED)
1. ANTHROPOMETRIC DATA BE CONSIDERED
2. AMBIENT TEMPERATURES SHOULD BE A MAJOR CONSIDERATION
3. DESIGN OF STANDARDS TO ENSURE USER-FRIENDLY PPE ARE IMPORTED
TIER 2 INTERVENTION (VARIABLE)
4. USER-INVOLVEMENT IN THE PROCUREMENT PROCESS
5. CONSISTENT SAFETY INDUCTIONS USING AUDIO-VISUALS
6. PARTICIPATORY TOOL BOX MEETINGS
4. SELECTION OF SAFETY CHAMPIONS
REPEAT
NO
WORKERS USING PPE APPROPRIATELY AND ENCOURAGING COLLEAGUES TO DO SAME
YES
TIER 3 INTERVENTION (NEGATIVE REINFORCEMENT EG.)
*WITHHOLD GROUP INCENTIVES
*PUBLIC REPROACH FOR UNSAFE BEHAVIOUR
TIER 3 INTERVENTION (POSITIVE REINFORCEMENT EG.)
*PUBLIC RECOGNITION AND PRAISE
*GROUP AND INDIVIDUAL INCENTIVES (EG. REWARD SAFETY CHAMPIONS)
NO
EXPECTED OUTCOME; IMPROVED PPE USE
YES
INTERVENTION SUCCESSFUL

Figure 2: Behaviour Based Safety (BBS) Intervention to Improve the Use of Safety Helmets and Goggles (Source: Author's Construct)

The Social Cognitive Theory

Bandura's Social Cognitive Theory of learning is built upon The Operant Conditioning Theory and purports that behaviour is more likely to occur when it is reinforced. Reinforcement strengthens behaviour and may be either positive or negative. Positive reinforcement occurs when a person is rewarded for engaging in acceptable behaviour. Negative reinforcement occurs through the withholding of something valuable to the person when the right behaviour is not observed. Punishment is yet another way of weakening bad behaviour, by inflicting an action that would cause pain or discomfort e.g. Suspension or salary deduction. Although both reinforcement and punishment improve behaviour, several researchers have suggested that desired behaviour is more usually obtained through reinforcement than through punishment.

The SCT emphasizes a dynamic interaction between a person, his environment and his behaviour. According to the SCT, new behaviour is learned through observation. When a person observes reinforced or accepted behaviour around him, it affects his way of thinking such that he starts to exhibit or model this behaviour too. The extent to which this new behaviour can be sustained depends on the reinforcements (intrinsic or extrinsic) that follows the behaviour. As new individuals continue to model this behaviour, the behaviour is then spread in a diffusion chain process and becomes a way of life.

THE DECISION TO PROCURE PPE

This is informed by a Job Hazard Analysis or requests made by site supervisors. The types and quantities of PPE needed are established at this point. The next stage indicates the intervention designed to ensure that procured PPE is considered user-friendly by workers.

THE INTERVENTION STAGE

Section A – Fixed Interventions

8 The study discovered a significant variance between workers' head measurements taken across three construction sites and safety helmets that were in use on these sites. It is recommended that the importation and or procurement of safety helmets into the country

should be done considering anthropometric (physical) measurements of users in an attempt to remedy discomfort complaints of poor fit.

9 From the research, several safety helmet and goggle users complained of heat build-up within the PPE while they used them. The study recommends that safety helmets and goggles imported into the country should be tested to be certain they are suitable for the ambient temperatures that exist in the country.

10 The study proposes the development of a set of standards (By the Ghana Standards Authority) for safety helmets and goggles that would be used in the country, taking into consideration anthropometric features of users and existing environmental conditions.

Section B - Variable Interventions

11 Previous research suggests that workers are more likely to use the requisite PPE when they play an active role in the acquisition process. To encourage improve compliance with PPE use, construction firms should involve the construction employees (supervisors, trades headmen), in the PPE selection and procurement process (by seeking their opinions on the characteristics of PPE that should be bought for them). Workers should be allowed the chance for fitting and trial uses before bulk procurement.

12 Safety helmet and goggles use can be improved when construction workers undergo regular periodic safety inductions using audio visuals. Audio visuals showing effects of non PPE use and near misses are preferred as it will enable workers to see real human beings who have been impacted by site incidences as result of the non-use or improper use of PPE.

13 Daily toolbox meetings (short morning meetings that discuss work packages planned for the day) are carried out in a manner that is participatory and allows the workers to contribute personal and observed experiences. This meeting should also aim to discuss the risks and hazards that are likely to be encountered in every work area for the day.

14 The selection of Safety Champions from amongst the workers to champion safety initiatives in their work areas by leading health and safety meetings and ensuring that colleague workers adhere to PPE protocols and that workers are duly rewarded for safe behaviour.

THE OBSERVATION STAGE

It is expected that the 7 interventions proposed, when executed diligently, will result in a gradual change /modification of behaviour, amongst some employees, setting the stage for the next stage of improving the behaviour of a wider group of employees. Within the context of the SCT, it is expected that a few employees will initially embrace change and start exhibiting safe behaviour, thus serving as models for the rest of the team. The remaining employees by observing the models exhibit good behaviour and being rewarded (motivation) for same, and finding it to be a good thing (cognitive processes) may then try to alter their own behaviours by observing the proper use of PPE. It is also expected that some workers at this stage may still refuse to comply with the required safety behaviour of using PPE the right way.

THE REINFORCEMENT STAGE

This stage is very important to the process because reinforced behaviour tends to be repeated. Thus when an employee observes consistent reinforcement of a model's good behaviour by the superiors, he/she will be encouraged to exhibit same. Even though positive reinforcement is preferred, negative reinforcement and punishment for consistent unacceptable behaviour is necessary to eliminate such behaviour.

Positive reinforcement processes prescribed to improve the use of construction helmets and safety goggles include:

- Public recognition and praise for safe behaviour. Workers who consistently adhere to PPE protocols should be identified and commended for good behaviour in the presence of others, e.g., at tool box meetings. The site could also put up names or pictures of fully compliant personnel on notice boards to motivate others to aspire to be recognized in such manner also.
- Company or site management could develop an incentive scheme that would be utilized periodically to award consistent compliance with PPE protocols by individuals. A group incentive scheme (in the form of a quarterly, half yearly or annual bonus) to reward the whole team for good safety performance will also encourage the effective use of PPE.

- The team should consistently be persuaded and encouraged to engage in safe behaviour by prioritizing safety over work schedules because it is the right thing to do.

Negative reinforcement can be executed through;

- Warning notices at the initial stages
- Public acknowledgment and reproach of unsafe behaviour
- Withholding of group incentives from offending personnel

THE OUTCOME STAGE

According to the Operant Theory, behaviour that is reinforced is likely to be repeated. Subsequently, the Social Cognitive theory asserts that as people observe models being rewarded for 'good' behaviour, they will likely engage in same. It is expected that as safe PPE behaviours are reinforced, this behaviour will be diffused amongst the workers resulting in improved group safety culture. At this stage is important to document and present feedback on safety performance to workers to further boost their morale and increase PPE use. If feedback is negative or not encouraging enough, modifications should be made to the variable interventions to improve subsequent results. A recalcitrant worker that refuses to comply with the PPE protocols after being repeatedly taken through the intervention process should be punished by dismissal.

When feedback obtained, is acceptable, then it implies the intervention has been successful. Management thus has the duty of maintaining the acquired safe behaviour of personnel

PART 2 – VALIDATION QUESTIONNAIRE

Dear Participant,

The following pages contain questions that are intended to verify the findings of this research by determining whether the proposed framework shall be successful in improving the user experience of construction safety helmets and goggles.

The objectives of this stage are to;

4. Obtain the opinions of PPE users on whether the listed interventions can affect their user-experience.
5. Find out from procurement officers how well the listed interventions can affect the PPE user-experience.
6. Draw additional comments from PPE purchasers and users, which can aid in improving the user-experience.

Kindly indicate on a scale of 1 – 5, how the actions listed can contribute to an improved user-experience of construction helmets and goggles.

5 = Strongly agree - respondent had no doubt on the certainly of question being asked.

4 = Agree - respondent generally agreed with the issue or principle underlying the issue being questioned.

3 = Uncertain - respondent was not sure but cannot confirm or deny the importance of issue under discussion or being questioned.

2 = Disagree - respondent did not agree with the issue or the principle underlining the issue being discussed or questioned.

1 = Strongly disagree - respondent was completely aware that the issue under consideration was not possible from his/her perspective.

ITEM	DESCRIPTION	RATING				
		1	2	3	4	5
	The Intervention Stage					
A	The consideration of Anthropometric characteristics (E.g. workers' head and face measurements) in the procurement of safety helmets and goggles					
B	The consideration of the climate in Ghana in the procurement of safety helmets and goggles					
C	Consistent persuasion and encouragement to exhibit safe behaviour					
D	The direct involvement of workers in the selection and procurement of safety helmets and goggles for construction sites					
E	Regular periodic safety inductions using audio-visuals (short videos) to increase awareness of the need for PPE and encourage their use.					
F	Participatory tool box (regular morning meetings intended to discuss planned work and expected risks) meetings					
G	Periodic selection of safety champions to motivate colleagues towards safe behaviour					
	The Reinforcement Stage					
H	Public recognition and praise for safe behaviour					
I	Group and individual incentive scheme to reward safe behaviour					
J	Rewards scheme for safety champions for leading peers to observe safe practices					
K	Consistent encouragement to exhibit safe behaviour					
L	Denying workers of liberties (e.g.) for engaging in unsafe behaviours					

	The Feedback Stage					
M	Exhibiting safety performance improvement statistics on notice boards					
N	Verbal communication of safety performance improvements					
O	Making modifications to the listed interventions					

Please indicate other comments you may have regarding;

1. The Intervention Stage

……..

……..

……..

……..

……..

2. The Reinforcement Stage

……..

……..

……..
……..

……..

3. The Feedback Stage

……..

……..

……..

……..

……..

4. Please provide any other comment you may have

………

………

………

………

10th March, 2017

………………………………..

………………………………..

………………………………..

………………………………..

Dear Sir,

REQUEST TO USE YOUR CONSTRUCTION SITE AS A CASE STUDY

Anita Odame Adade-Boateng is a second year PhD Construction Management student, with the Department of Building Technology. She is currently working on the project "A Framework for the Procurement of User-friendly PPE for construction workers" with Rev Prof. F.D.K. Fugar and Dr Emmanuel Adinyira as her project supervisors. The aim of this research is to identify key processes that would aid the procurement of user-friendly/comfortable PPE suitable for construction workers in tropical climates

The Department would be grateful to have your permission for the use of your project site "…………………………………………………………………….……….." situated on KNUST campus as one of the case studies for conducting a field experiment in line with the study.

The researchers selected your project site because it was identified as having all the required characteristics of a good case study site, that is;

- The site is active
- The site has diverse skilled operatives
- There is strict enforcement of Personal Protective Equipment (PPE) Protocols

The activities to be undertaken on the site are basically:

1. Measurement of head sizes of construction workers to obtain some anthropometric data on Ghanaian construction workers.
2. Measurement of core body temperatures and heart rates of selected participants to investigate the presence and extent of physiological strain resulting from discomforts in the use of safety helmets and safety goggles.
3. Interviews with selected participants on discomforts associated with wearing safety helmets and safety goggles.

To maintain good ethical standards, an orientation session would be conducted for participants and their consent be sought before the programme commences. All measurements will be undertaken by a team of skilled and competent medical researchers and information obtained shall remain confidential and be used only for the purposes of academic work. However, findings from the study shall be made available if your company is interested.

The procedures will be carried out with minimal interference to the on-going work on site so as not to affect productivity. It is expected that the team will spend a maximum of two (2) weeks on the site.

Your consent to the use of your site for this study will go a long way to ensuring Ghanaian construction workers will be adequately protected in the line of duty, without compromising on good standards of comfort. The team is available to meet with management for further briefing if need be.

We look forward to your favourable response.

Thank you.

Yours faithfully,

Dr. Theophilus Adjei Kumi
(Head of Department)

10th January, 2017.

Kwame Nkrumah University of Science and Technology
Department of Building Technology,
Student Reference Number: 20398745

Dear Participant,

I invite you to participate in a pilot survey of a research study entitled Framework for the procurement of user-friendly PPE for construction workers. I am currently enrolled in the PhD Construction Management programme at the Kwame Nkrumah University of Science and Technology and in the process of writing my thesis.

The enclosed questionnaire has been designed to collect information on: Selection Considerations made by construction firms in the procurement of PPE.

Your participation in this research project is completely voluntary. You may decline altogether, or leave blank any questions you don't wish to answer. There are no known risks to participation beyond those encountered in everyday life. Your responses will remain confidential and anonymous. Data from this research will be kept under lock and key and reported only as a collective combined total. No one other than the researchers will know your individual answers to this questionnaire.

If you agree to participate in this project, please answer the questions on the questionnaire as best you can. If you have any questions about this project, feel free to contact the lead investigator on 020 8396860/ 024 9153163.

Thank you for your assistance in this important endeavour. Sincerely

yours,

Anita Odame Adade-Boateng