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Title of the Dissertation

Attitude and behaviour change in adopting advanced wearable sensing devices by construction workers to improve personal health and safety.

Student's name

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Submitted for the degree of MSc Project Management for Construction

University of Portsmouth

School of Civil Engineering & Surveying (SCES)

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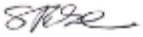
Signed:  Date: 06th September 2023

ABSTRACT

The rapid expansion of technology has underlined the need for greater understanding of requirements to promote an attitude and behaviour change in adopting advanced wearable sensing devices (AWSDs) by construction workers to improve personal health and safety. Previous research has primarily relied on acceptance models such as, TAM, TAM 2, UTAUT, and UTAUH 2, which identify key barriers and obstacles toward adoption. One of the main barriers identified is a lack of knowledge regarding the devices and the associated technology, therefore a research programme has been undertaken to investigate the gaps in current construction education courses and training schemes. Qualitative online interview with fourteen carefully selected construction management professionals were undertaken as the data collection method, the questions constructed were designed to encourage discussion around the used of AWSDs and the training processes that are presently in place; the information obtained was thematically analysed. The findings suggest a lack of content in current construction training courses and associated schemes relating to technology use to improve personal health and safety. Furthermore, it was found that there is a lack of legislation to support, education, standardisation, and IT solutions to substantiate the adoption of AWSDs.

ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to Dr. Quan Phung, my supervisor, for his valuable guidance and suggestions concerning the content and structure of my dissertation. Additionally, I extend my appreciation to all my course lecturers and my fellow cohort for their unwavering support and assistance throughout. I would like to give special recognition to our Wednesday evening study group, comprising of Kris Zakrzewaki, Joe Williamson, and Josh Armet, whose discussions, analysis, and brainstorming sessions proved to be of immense value in comprehending the course material and generating new ideas.

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CHAPTER 1: INTRODUCTION

1.1. RESEARCH TOPIC

This research topic is an important issue as it relates to measures required to change attitudes and behaviours of construction workers to enable improved personal health and safety standards to be realised; it highlights the benefits related to the technology advancements that are now available. Alaloul et al., (2020) indicates, "*The trend of digitalisation, automation and the increased use of Information and communications Technology (ITC) as the main concepts of the Industrial Revolution (IR) 4.0."* IR 4.0, (IR 4.0 Explained, n.d.), presents many opportunities to improve current construction health and safety practices by adopting Advance Wearable Sensing Devises (AWSD's) and utilising the Internet of Things (IoT), (Häikiö et al., 2020).

The construction industry has been shown as limited in its approach to the adoption of IR 4.0 (Khurshid et al., 2023). This is partly attributed to levels of education and an aging workforce (Pereira et al., 2019) and directly relates to this research topic; Nnaji & Awolusi, (2021-a) provides support by identify an inherent lack of education, training, and communication strategies across the construction industry regarding the use of AWSD's, resulting in resistance from construction workers towards there adoption.

1.2. RATIONALE

The purpose of this study is to evaluate the status of knowledge on this subject. It is intended that an understanding will be gained allowing advanced knowledge sharing through the development of concepts and ideas (Purpose of Research, n.d.).

The ambition is to enhance construction workers personal health and safety through improved attitudes and behaviours towards the adoption of AWSDs. It is thought this can be achieved by ensuring relevant technology related education content is included in all construction related training schemes, which will then assist with the removal of barriers and obstacles towards their adoption (Yap et al., 2021). The barriers to implementation formed by construction workers are shown, in part, to be a lack of awareness, (Yap et al., 2022-a), which can be attributed to gaps in content in construction education courses and training schemes. Presently the availability of the required content in relevant courses is limited; Lim & Lee, (2021) identifies, "*There is little literature available into the application of wearable technology within construction education courses."* It is believed relevant content should be added to all construction education courses and training schemes to enable a construction wide knowledge sharing initiative to be undertaken to ensure all construction workers are aware of AWSDs and the benefits they offer (Ahn et al., 2019).

Common concerns of construction workers relate to data use and storage, reluctance to change, ease of use, and usefulness (Chowdhury et al., 2019). It is believed by educating and demonstrating the benefits of adopting AWSDs, information, communication, and incentivisation's will be provided to enable a change in negative attitudes and behaviours.

Amendments to current legislation that ensures technology content is included in education courses and training schemes, as well as providing clarification regarding how data is collected, managed, and stored would greatly assist with promoting an attitude and behaviour change towards the adoption of AWSDs. It is thought updates could be considered regarding the General Data Protection Regulations (GDPR) (GDPR - IT Governance, n.d.-a) and the Data Protection Act 2018 (Data Protection Act 2018, n.d.-a), to ensure these keep pace with the rapid advancements being made with technology. It is also believed that the construction (Design and Management) Regulations 2015 (CDM 2015, n.d.-a) could be updated to ensure AWSDs are considered as a compulsory hierarchy of control measure.

In summary, the inclusion of educational content in construction related training programs will raise awareness and transform attitudes and behaviours regarding the adoption of AWSDs, leading to a tangible enhancement in the personal health and safety of construction workers. Achieving this goal will require a careful evaluation of potential legislative enhancements.

Figures 1 to 4 below show examples of AWSD's discussed in the research interviews.

Figure 1. Wearable Sensing Hi-Viz.
Image sourced from: www.elitacwearables.com
(Smart-Shoulder.Jpg 1,713×1,281 Pixels, n.d.)

Figure 2. Smart Watch
Image sourced from: www.mikscholars.com
(15 Best Smartwatches for Construction Workers, n.d.)

Figure 3. Wearable Sensing Glasses.
(Thiruchelvam et al., 2022)

Figure 4. Smart Hard Hat.
Image sourced from: www.jepower.net
(4G Smart Hard Hat for Construction, n.d.)

1.3. IMPACT OF RESEARCH

The construction industry is deemed to be a dangerous working environment, (Nghitanwa & Zungu, 2017), therefore identifying ways to improve the attitudes and behaviours of construction workers in the adoption of AWSD's will enable improvements in personal health and safety standards to be realised. Ibrahim et al.,

(2023-a) highlights that AWSD's will allow improvements in construction workers health and safety by monitoring individual biometrics. The adoption and implementation of AWSDs across all sectors of construction will then assist with improved safety statistics and the zero harm aspirations of the construction industry (Achilles, n.d.).

1.4. RESEARCH AIMS & OBJECTIVES

1.4.1. Aims

The overall aim of undertaking this research study is to enhance construction workers personal health and safety through improved attitudes and behaviours towards the adoption of AWSDs. Ultimately, the research outputs will enable the identification of relevant technology course content recommendations to be presented, these improvement measures will then be implemented across all construction training schemes to enable attitudes and behaviours to change towards the adoption of AWSDs. Yap et al., (2022-b) supports the need for these improvement measures by highlighting low technology adoption and an inherent reluctancy to innovate in the construction industry. Johari & Jha, (2020) further supports this by identifying regular training is required to change workers attitudes and behaviours.

1.4.2. Objectives

This study is intended to identify gaps in previous research and construction practices regarding education content that is delivered through construction related training schemes. The objectives that were required to be achieved centred around understanding the obstacles and barriers towards the adoption of AWSDs (Okpala et al., 2022), promoting the benefits of adoption (Abuwarda et al., 2022-a), and solutions to attitude and behaviour changes (Langford et al., 2000-a). Limitations in current data collection, use, and storage solutions, alongside any legislative gaps were identified under sub-aim 1. Understanding barriers and obstacles, as further objectives to be achieved to enable solutions to be identified.

Figure 5 details the research aims and objectives framework approach that has been undertaken to enable solutions to be presented from the conclusions and outputs produced.

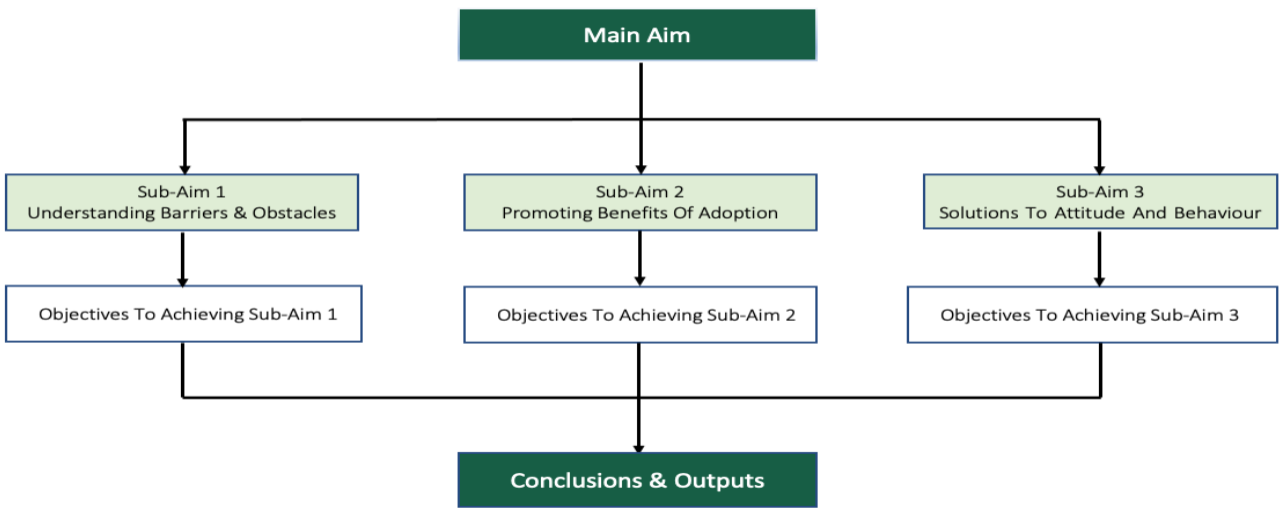


Figure 5. Aims & Objectives Research Framework (Constructed by the author)

CHAPTER 2: LITERATURE REVIEW

2.1. LITERATURE REVIEW UNDERTAKEN

The literature studied comprised of books, peer-reviewed journals, academic papers, websites, and current legislation, all of which are related to the proposed area of study. The literature reviewed enabled a better understanding to be gained of research already undertaken. By identifying gaps in the existing literature, improvement measures could be identified and recommended to address solutions to the question posed by this dissertation topic. The following areas of research study have been identified as particularly relevant.

2.1.1. Attitude and behaviour changes, models of acceptance

Langford et al., (2000-b) suggest that the foundation of *"all safety and health initiatives must rest upon human involvement, implying that worker attitudes and behaviours play a pivotal role in formulating, embracing, and sustaining strategies."* The authors identify critical factors influencing attitudes towards safety management, pinpointing various elements intricately linked to cultivating favourable attitudes through acceptance models.

Similarly, Choi et al. (2017) investigate the inclination of workers to adopt wearable technology for occupational health and safety. Their study brings the Technology Acceptance Model (TAM) to the forefront, a framework employed to examine the rationale behind construction workers' potential reluctance to embrace and employ AWSDs. However, Shachak et al. (2019), highlights TAM as oversimplified, this underdeveloped model is subsequently refined and enhanced, evolving into the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT model endeavours to encompass more comprehensive and pertinent factors, aiming to address the comprehensive aspects of technology acceptance. Further theoretical extensions have been produced, resulting in models TAM2 and TAM3, and concluding in UTAUT2. This final iteration extends its view to incorporate influences from the social sphere (SI), data security considerations, and other related dimensions (Nnaji et al., 2023). Fugate & Alzraiee, (2023-a) suggests that the UTAUT model (Venkatesh et al., 2003) stands as the most successful. An illustrative depiction of the UTAUT model can be observed in Figure 6.

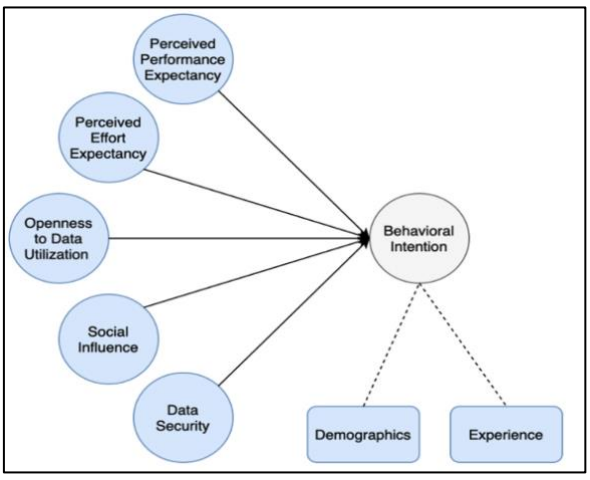


Figure 6. Example UTAUT Model, (Fugate & Alzraiee, 2023-b)

All the papers researched are significantly connected to pivotal aspects within this dissertation, they accentuate crucial factors essential for comprehending and facilitating shifts in attitudes and behaviours regarding the adoption of AWSDs. However, it has been noted that a common theme of limitation exists, this relates to a lack of guidance on how to manage the identified attitudes and behaviours, specifically, there is no reference to training enhancements within construction education initiatives.

2.1.2. Personal health and safety advantages

Awolusi et al., (2019-a) indicates, that wearable sensing devices (WSDs) in conjunction with the internet of things (IoT) have been recognised as emerging technologies that hold substantial potential to bring about a transformation across various dimensions of safety monitoring for construction workers. This transformation encompasses diverse aspects, including the real-time tracking and transmission of safety-related information for workers. The authors have identified fundamental elements relating to, physiological monitoring, environmental monitoring, location tracking, and proximity detection, as shown in figure 7.

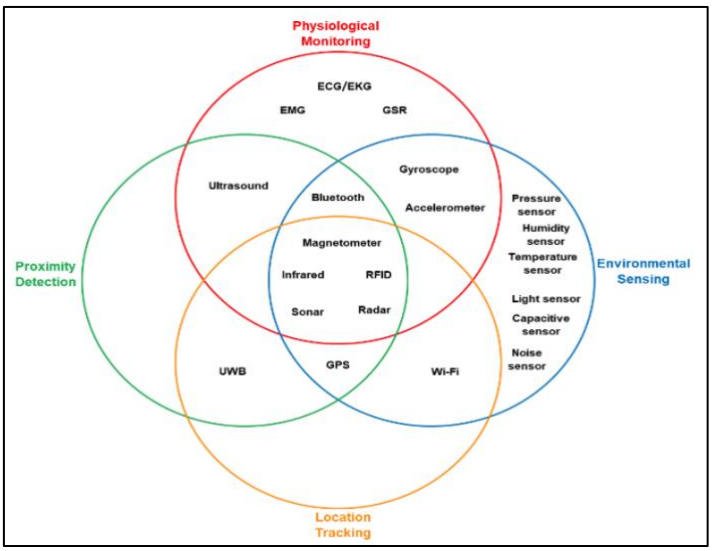


Figure 7. Sensors and Systems for AWSD's (Awolusi et al., 2019-b)

Abuwarda et al., (2022-b) highlights that the utilisation of AWSDs presents a prospect for enhancing both safety and productivity, the advantages stem from the deployment of AWSDs that are designed for monitoring personal health and safety. These devices integrate embedded biosensors aimed at overseeing physiological parameters like heart rate, skin temperature, blood pressure, fatigue, work intensity, and stress. The realisation is that consistent monitoring through these devices contributes to the enhancement of the health and safety of construction workers.

Yan et al., (2017-a) identifies, "*development of Inertial Measurement Units (IMUs) enables a precise measurement of posture and body movements for safety management in the construction industry.*" Consequently, potential concerns relating to musculoskeletal disorders can be identified. The authors also identify details regarding how AWSDs can be used to issue warning notices, how mobile phone technology is utilised, and how data management is controlled by a back-end server linked to the site WiFi, as shown in figure 8.

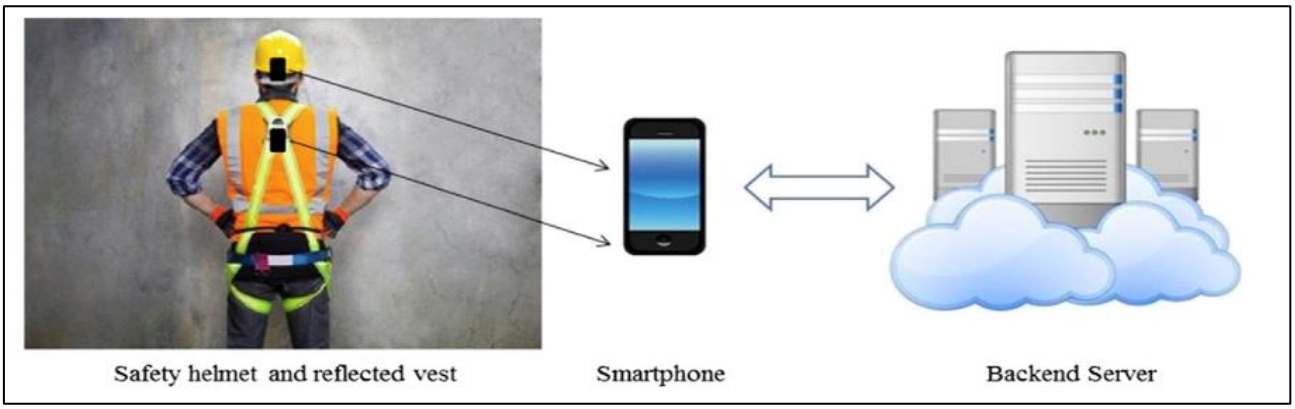


Figure 8. Real time motion warning system, (Yan et al., 2017-b)

The collected readings have unveiled crucial insights closely aligned with the main theme of this dissertation. They illustrate aspects concerning the collection, storage, and use of data, alongside the methods employed in the analysis of the acquired information. Of significant value is the comprehensive assortment of biometric monitoring options now available, along with the innovative technology developed for monitoring body posture. However, shortcomings have been identified that pertain to the apparent oversight in detailing strategies aimed at encouraging the acceptance and endorsement of the technology; the readings lacked the provision of measures that could facilitate a shift in attitudes and behaviours for individuals resistant to change. A noticeable void emerged in the dialogue, where no consideration was given to potential legislative adjustments that might be a requisite to the scope of personal data amassed through these advancements.

2.1.3. Data collection and storage

A central concern expressed by construction workers relates to the handling of personal data, including storage duration and how long the data is retained (Calvetti et al., 2020; Yap et al., 2022-c). Yang et al., (2020-a) notes, *"The continued growth of data storage pressure drives the rapid development of the entire storage market on account of the massive data generated."* In response to this challenge, Vijayan et al., (2021) suggests *"cloud-based data storage solutions tailored to wearable technology, where construction workers data is disassembled and processed into meaningful results, promoting comprehensible interpretation and presentation to the user."* However, a critical perspective is presented by Jiang & Shi (2021-a), who highlights weaknesses within cloud storage solutions applied to information extracted from AWSDs. Their assessment acknowledges the susceptibility of these solutions to potential cyberattacks and data breaches. This vulnerability can trigger an intricate chain reaction leading to diminished control over data flows within wearable technology systems, thereby escalating the likelihood of data and privacy breaches (Jiang & Shi, 2021-b). Anticipating the impending surge in data volumes necessitating storage within cloud-based systems, service providers struggle with an ongoing apprehension. Jit et al., (2010-a) indicates that cloud storage providers are acutely aware of the requirement to design systems capable of managing and governing the inevitable escalation in data storage and privacy concerns. Figure 9 provides an overview of cloud storage solutions for AWSDs.

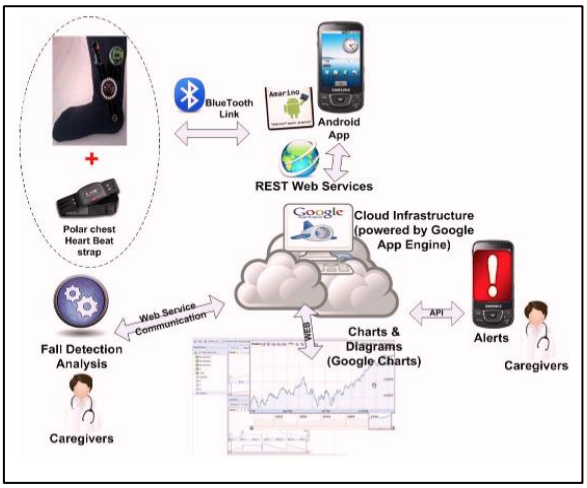


Figure 9. AWSD's, Cloud Storage, (Doukas & Maglogiannis, 2011)

The comprehensive analysis of relevant literature has proven highly relevant to the scope of this dissertation, particularly in light of the requirement to comprehend the intricate process of collection, storage, and use of construction workers personal data. Yap et al., (2022-d) highlights, *"Privacy of workers personal data is not guaranteed,"* which exposes limitations in the literature reviewed. There was a notable void concerning the absence of dialogue around viable remedies essential for managing the ever-increasing amount of personal data generated by construction workers. The study also emphasised the absence of considerations pertaining to potential legislative adjustments imperative to alignment with the evolving data solutions. Notably, there is also a conspicuous absence in addressing the strategies necessary for educating construction workers about the process governing their data, further highlighting the limitations of the reviewed literature.

2.1.4. Barriers to Adoption

The most significant barriers to the adoption of AWSD's by construction workers is identified as *"productivity due to wearable sensors, the need for continuous monitoring, limitations on the hardware and software, and a lack of standardisation in effort,"* (Tabatabaee et al., 2022-a); a comprehensive account of supplementary obstacles is documented in Table 1. Addressing the pivotal role of proficient and well-trained workers, Nnaji & Karakhan, (2020-a) verifies, *"The successful assimilation and implementation of safety and health technology hinges on a skilled workforce."* In a bid to provide construction personnel with the relevant knowledge, the authors examine strategies for effective training implementation; this includes an outline of appropriate training subjects, encompassing the technology's efficiency, its safety benefits, and the organisational outcomes. The proposed training methodologies encompass hands-on training, written assessments, and appraisals. Lu & Deng, (2022-a) identify the benefits of the adoption of AWSDs as being obstructed by real world factors, these are seen as barriers and viewed with scepticism by the construction industry. The authors identified key elements with the technology acceptance model (TAM), see section 2.1.1, as tools to understanding the intended use of the technology by construction workers. Buenaflor & Kim, (2013) further heighten the significance of demographic characteristics, particularly age and gender, in

shaping attitudes and behaviours concerning AWSD adoption. Understanding these demographic viewpoints emerges as an imperative stride in managing a shift in attitudes and behaviours toward the adoption of AWSDs.

Barrier	Description
Lack of integration between technologies (B1)	Solutions that combine different technologies (e.g., BIM) with vision-based monitoring systems have not been sufficiently explored.
Limited scale of technology implementation (B2)	Most of these technologies tested their proposed algorithms on datasets that are proprietary to specific projects, which are bound by specific project constraints.
Lack of publicly available large datasets (B3)	Lack of publicly available large datasets for construction safety monitoring causes difficulties when comparing the performance of various algorithms.
Deficiencies in onsite data recording (B4)	Data, e.g., in the form of photos taken by workers on site, are mostly unorganized and stored locally.
The need for technical training (B5)	Proper technical training for workers and owner involvement are essential to prudently work with sensors functionalities (both workers and supervisors).
The need for high computational efficiency (B6)	For smooth functionality and effective data synchronization, high computational efficiency is critical.
The need for heavy batteries (B7)	Wi-Fi module is not an energy-saving solution for such technologies, thus requires high capacity and heavyweight batteries.
False alarms (B8)	Due to technological glitches and device registration issues, false alarms are quite common.
The need for off-line sensor network (B9)	For situations such as underground construction sites or isolated construction sites, neither the Wi-Fi nor general packet radio service (GPRS) are available, and the system would fail to upload data and receive orders. To address the communication coverage issue, an off-line sensor network is needed.
The need for proper light for smooth functionality (B10)	Systems might stop working or fail to detect wearing motions due to the constantly low illumination.
Data privacy issues (B11)	Workers are hesitant to adopt technology due to identity disclosure and related data privacy issues.
Challenges arising from physical interactions (B12)	Due to the wearable technological gadgets and involvement of high-tech solutions, physical interaction between workers is quite challenging.
The need for continuous monitoring (B13)	To achieve enhanced durability of the technological advancements, continuous monitoring and debugging of devices are essential.
Productivity reduction due to wearable sensors (B14)	Such technological methods require sensors to be attached to the workers' skin, which makes them feel uncomfortable and is inconvenient when performing a given task, eventually reducing productivity.
Safety hazards (B15)	Workers may exhibit high-risk behavior by ignoring prompts from the devices.
Limitations on hardware and software and lack of standardization in efforts (B16)	Since the field of study is emerging, there is still a lack of standardization efforts; therefore, there are limitations on both hardware and software.
Low reliance on the technology (B17)	Due to fear of the unknown and lack of concrete examples, users have low reliance on the technology and still believe in 'old school' solutions.
Poor governmental policies and incentives (B18)	Despite governments having invested significantly in research and development for technological advancements, the policies and related incentives have not been well defined, thereby resulting in low adoption.

Table 1. Barriers to adopting AWSD's, (Tabatabaee et al., 2022-b)

The authors of the examined literature collectively illustrated and engage with important factors integral to the barriers hindering technology acceptance among construction workers. These insights offer valuable perspectives that bear direct relevance to the research focus. The diversity in viewpoints regarding these barriers and obstacles, as well as the strategies necessary to enable a shift in attitudes and behaviours toward the acceptance and adoption of AWSDs, encouraged thought provoking considerations. A particularly insightful contribution emerges from Nnaji & Awolusi, (2021-b), where glimpses of feasible training and educational solutions surface. Additionally, the discussion around the technology acceptance model (TAM) by Lu & Deng, (2022-b) adds depth to the conversation. However, the literature assessed exposes certain omissions, notably, these include the absence of a robust framework for incorporating education content

within construction training programs, coupled with an oversight concerning the identification of potential legislative amendments necessary to support this transformative process.

2.1.5. Health and safety statistics

The HSE, (2022, n.d.-a) reports that in 2021/22 the United Kingdom construction industry recorded over a quarter of main industry fatal injuries, as shown in table 2; it also identifies that across all main sectors of industry nearly a quarter of fatal accidents were related to workers over the age of 60, as shown in table 3. These statistics indicate that construction workers and primarily the older work force are more likely to be involved in work related accidents. pbc today, (n.d.) highlights construction workers as those most likely to be exposed to high-risk environments.

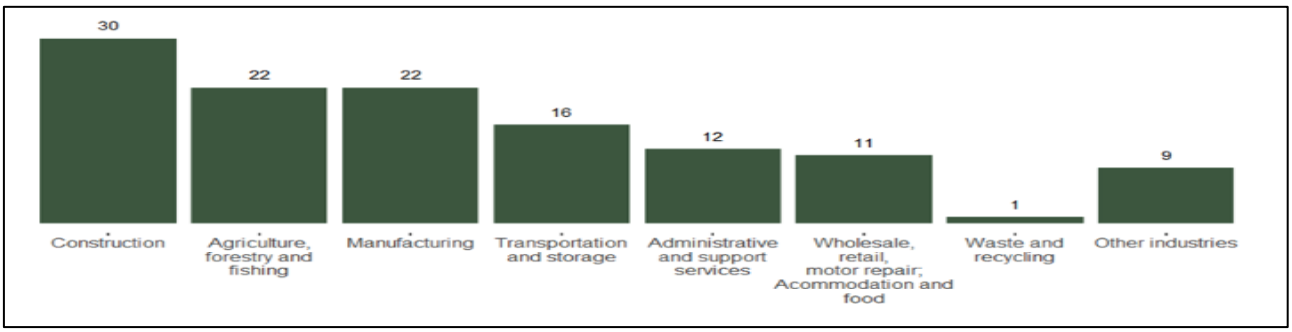


Table 2. UK 2021/22 Fatal Workplace Accidents, (The HSE, 2022, n.d.-b)

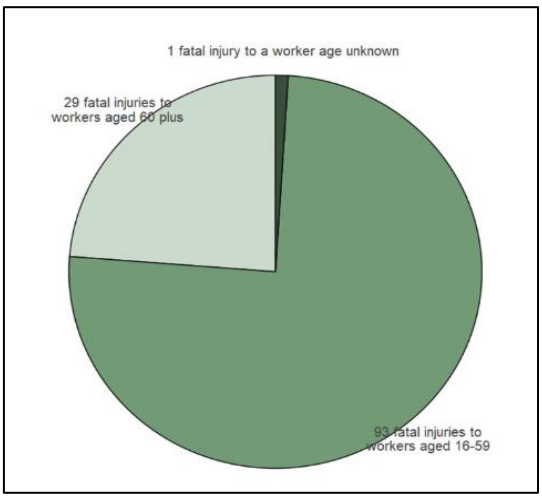


Table 3. UK 2021/22 Fatal Workplace Accidents for Workers over 60, (The HSE, 2022, n.d.-c)

The assessment of this literature review casts a spotlight on the alarming scope of fatal injuries sustained within the UK's construction industry during 2021/2022. The implications of these findings resonate within the context of this research, highlighting the need for enhanced strategies concerning the personal health and safety of construction workers. The studied literature underlines weakness and suggests the need for tailored improvement measures, particularly addressing the specific needs of the older demographic within the construction workforce. The scope of these reviews remains constrained, as they refrain from delving into potential avenues for implementing improvement measures. They also fall short of acknowledging technological advancements that could play a pivotal role in enhancing construction workers'

health and safety. A notable gap exists in terms of addressing legislative changes that might serve to bolster these unsettling statistics and foster improved outcomes within the construction industry.

2.1.6. Training schemes and legislation

It has been suggested that there is a need for targeted interventions to address construction workers' attitudes and behaviours towards the adoption of technology to improve their personal health and safety (van der Molen et al., 2018). Nnaji & Awolusi, (2021-c) suggests the need for training programs to educate workers on the benefits of using AWSD's, as well as addressing their concerns about privacy and ease of use. A review of current construction training schemes centred around the following was undertaken:

1. Apprenticeships Training Scheme (Apprenticeships, n.d.)
2. Construction Industry Training Board Courses (CITB, n.d.)
3. Site Manager Site Training Scheme (SMSTS and SMSTS-R, n.d.)
4. Site Supervisor Safety Management Scheme (SSSTS and SSSTS-R, n.d.)
5. NEBOSH Health and Safety Management for Construction (NEBOSH Construction Certificate, n.d.)

The literature reviewed was appropriate to the research topic as it identified the need for training programmes to include technology to change the attitudes and behaviours of construction workers, this is to ensure the acceptance of AWSDs and the associated technology. Failings were identified in current training schemes as no specific course content within the construction courses reviewed offered modules that incorporated technology training.

2.2. CONCLUSION, RESEARCH GAP

Previous research alongside the details contained in section 2.1.6 has identified gaps in current construction education courses and training schemes regarding technology training. This enabled a research topic to be formed that involves the implementation of specific construction related education enhancements, which it is believed will assist with changing attitudes and behaviours of construction workers towards the acceptance of AWSDs. A review of the following regulations was undertaken, the General Data Protection Regulations (GDPR - IT Govenance, n.d.-b), the Data Protection Act 2018 (Data Protection Act 2018, n.d.-b), The Health and Safety at Work etc Act 1974 (HSAWA 1974, n.d.-a) and The Construction (Design and Management) Regulations 2015 (CDM 2015, n.d.-b); based on the findings from the research it has been concluded that there is no legislative requirements for the inclusion of technology education modules in construction training schemes.

The gaps identified specifically highlight the need for improvements in technology content in construction related education, legislative changes required to support the changes, and guidance and standardisation regarding IT management.

CHAPTER 3: DESIGN AND METHODOLOGY

3.1. RESEARCH OVERVIEW

The research onion model depicted in Figure 10 has been modified to support the structure and approach of the research design and methodology undertaken. This adaptation serves to validate the chosen research direction and the methods employed for data collection, refer to Figure 11 for a visual representation of this process. The design and the collection methods will be discussed and supported by an analysis of strengths and weaknesses of each approach; further discussions will be undertaken regarding any limitations that are identified. Additionally, debate regarding the validity and reliability of the data obtained will be carried out alongside highlighting any ethical considerations identified.

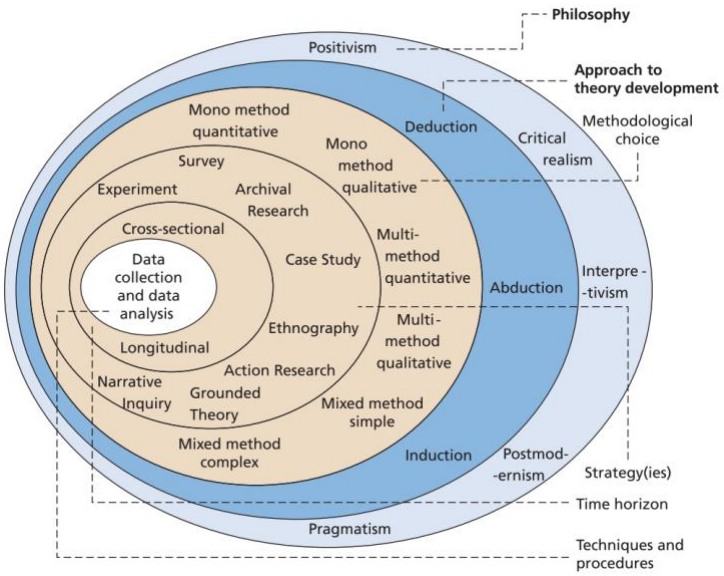


Figure 10. The Research Onion, (Saunders et al., n.d.-b)

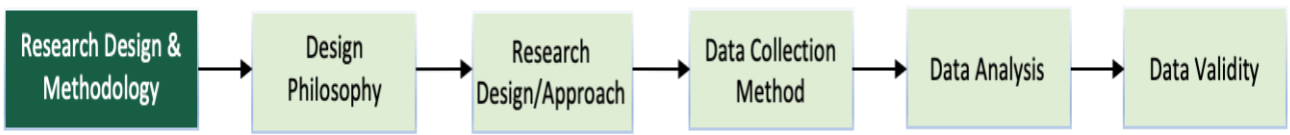


Figure 11. Adapted Research Model, (Constructed by the author)

3.2. RESEARCH PHILOSOPHY

A pragmatic and positive approach was taken in conducting this research study. Initially a diverse selection of literature was thoroughly examined, see section 2.1, facilitating the refinement of a broad topic into a precise research subject. Subsequently, the formulation of interview questions, see Appendix A, was purposefully undertaken, aiming to ensure the realisation of the study's objectives, as detailed in section 1.4. The outcomes of this process not only exposed gaps within existing practices but also paved the way for the identification of measures to effect improvements.

3.3 RESEARCH DESIGN

It was decided to approach experienced and qualified industry management professionals who are or have been associated with relevant construction organisations. This audience demographic was identified because it is believed that these individuals in their positions would be best placed to provide comments, their experiences, and related knowledge on the current use of AWSDs and any future plans to adopt the technology; it was also believed that they would have sufficient knowledge on barriers and obstacles expressed by construction workers towards the adoption of AWSDs. The data obtained from the selected interview participants will enable improvement measures to be identified that will assist with achieving the sub-aims of:

1. Understanding barriers and obstacles toward adoption
2. Promoting the benefits of adoption
3. Identifying solutions to attitude and behaviour change

Ultimately, this leads to the main aim of enhancing construction workers personal health and safety through improved attitudes and behaviours towards the adoption of AWSDs. The interviewees were identified through known work associates, relationships within the industry and requests sent to suitable candidates identified through internet searches.

The process of collecting the required information was obtained through abduction, this was in the form of a qualitative approach that was undertaken by conducting video conferencing interviews with fourteen pre-selected industry professionals. There was also an element of deduction used from the responses issued by the participants. The information obtained enable the research objectives to be met. The decision to use online interviews allowed a wider geographical audience to be considered when selecting suitable interviewees (Irani, 2019-a), which enabled a selection of relevant interview participants to be assembled. Online interviews can be a practical and cost-effective approach, particularly for researchers who have limited resource. Braun & Clarke, (2021) refers to the practical benefits to online interview stating: "*Data collection is typically non-demanding of time and resource, and there is little or no need for out of hours working, leaving researchers more time to complete their analysis, this is particularly useful in limited time projects."* The interviews were conducted with pre-consent gained from each of the participants, the method of data storage was clearly identified and the right to withdraw distinctly communicated. An approval from the university was required for the risk assessment constructed in relation to conducting the interviews as well as further approval regarding the details produced to support the universities ethics policy, see Appendix E and Appendix F.

3.3.1. Strength of qualitative research approach

It was decided that qualitative interviews should be completed due to the strength of the research if conducted correctly, Anderson, (2010) identifies this suggesting, "*qualitative research when carried out properly is unbiased, in depth, valid, reliable and credible."* Additional support is provided by Choy, (2014)

who indicates that different perspectives from interviewing diverse groups enables a greater nuance then that obtained from surveys. A greater cultural assessment can be obtained by exploring underlying principals, opinions, and expectations, as well as the interview discussion, which by nature allows participants to raise any topical issues that have affected them directly.

Additional strengths of undertaking qualitative research are supported further by Johnson et al., (2020), who state, *"rigor in the research process and result are when each element of the study methodology is systematic and transparent through complete, methodical, and accurate reporting."* By conducting a strong research study, quality findings will be achieved; this will then enable the observations and recommendations from the study to be accurate and consistent. Moreover, Qualitative Research, (n.d.) identifies additional qualitative strengths as having fewer limitations, being more versatile, allowing for greater speculation, and the gaining of a targeted response.

3.3.2. Weakness of qualitative research approach

There are some potential weaknesses regarding the use of qualitative online interviews as a research approach, these are detailed in the following along with how the negative impacts have been managed.

Issue 1

Hawa et al., (n.d.) details general limitations relating to the standardisation of interview questions, which could potentially lead to the interview questions being answered in a certain way.

- Measures: This has been managed by identifying follow up questions to ensure a thorough, thought provoking personal response is given to each question.

Issue 2

Lack of privacy as the interviewer will know who is providing the relevant responses.

- Measures: The production of documentation that ensures the participants identity and their information is kept private and secure.

Issue 3

Lack of statistical data; qualitative research does not aim to provide statistical representation but instead focuses on capturing diverse perspectives and generating quality data. Responses obtained from this type of research cannot usually be measured, only comparisons are possible, which then tends to create data duplication over time (BrandonGaille.Com, n.d.).

- Measures: If statistical data is specifically required, quantitative research methods may be more appropriate.

Issue 4

Interviews are subject to response bias; participants may be hesitant to provide honest or complete answers. The questions themselves may be biased, leading participants to answer in ways that may not reflect their true attitudes or behaviours (Mehra, 2002). Social desirability bias is described by Bergen & Labonté, (2020)

as *"the tendency to present oneself and one's social content in a way that is perceived to be socially acceptable, but not wholly reflective of one's reality."* A lack of alignment between the perceived viewpoint and the reality will introduce weakness and limitations to the research study.

- Measures: A diverse data collection was utilised to ensure accurate and true responses were received.

Issue 5

The results of interviews may not be representative of the broader population of construction workers. Valentine et al., (2018) supports this by suggesting "*qualitative researchers tend to include samples as one of the limitations of their studies and admit that this can make generalisability questionable."*

- Measures: A diverse set of questions was produced to avoid generalising findings to a single group or demographic.

Issue 6

Data collection for qualitative research interviews is labour intensive as it involves a detailed analysis of each interview to enable trends to be identified. The Labour intensity of this type of research is highlighted by Pope, (2000) who suggests, *"Analysing qualitative data is not a simple task. Done properly, it is systematic and rigorous, and therefore labour-intensive and time-consuming."*

- Measures: To ensure good time management a dissertation programme was constructed and adhered too, see Appendix D.

3.4. DATA COLLECTION METHOD

The research methodology adopted involved obtaining qualitative data by conducting online interviews. This approach as highlighted by Irani, (2019-b),"*avoids the time and expense associated with travel and offers scheduling flexibility, providing participants with more options to fit the interviews in their busy work schedules and personal lives."* The online interviews enabled in-person discussions to take place, these involved real-time video images affording the interviewer the opportunity to gage body language, posture, and facial expressions (Video Interviews, n.d.). Interviews are versatile research tools that can be customised to align with research questions and context, offering researchers the flexibility to adjust their questions and techniques to better suit the participants requirements and research goals (Rosenthal, 2016). The software system used for the interviews was Microsoft Teams (MS Teams, n.d.) the benefits relate to convenience, recording facilities, transcript production, screen sharing and interactivity (Archibald et al., 2019).

3.5. DATA ANALYSIS METHOD

The interview transcripts were installed into the qualitative data processing software NVivo (About NVivo, n.d.), this then enabled technical driven data coding techniques to be utilised to produce relevant and accurate data. The outputs from the program were in the form of clear concise tables, schedules, and diagrams which allowed the data produced to be easily analysed resulting in conclusions being formed and recommendations being presented, an example of a data set produced from an interview can be found in

Appendix C; to support this data analysis approach a results schedule, see Appendix B, has been produced from which a thematic analysis has been completed, this analysis is described by Braun & Clarke, (2006) as *"a qualitative analysis method that searches for themes and patterns, offering an accessible and flexible approach to analysing qualitative data."* Each of the transcripts were reviewed and key elements detailed in the results schedule, this then allowed the researcher to engage in a process of familiarising themselves with the data, coding the data by assigning labels or themes to segments of text, and then organising these themes into codes, details of the research codes can be seen in Figure 12.

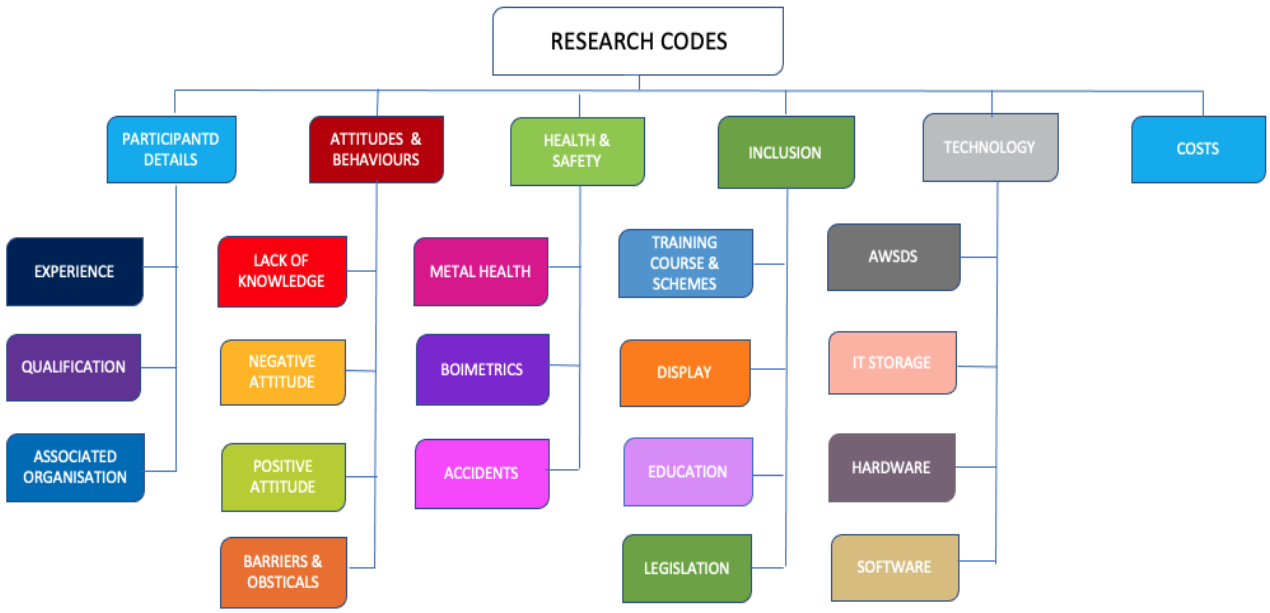


Figure 12. Research Codes, (Constructed by the author).

A measured, and methodical approach was taken to all aspects of this research study, this is shown in the research methodology framework diagram detailed in figure 13.

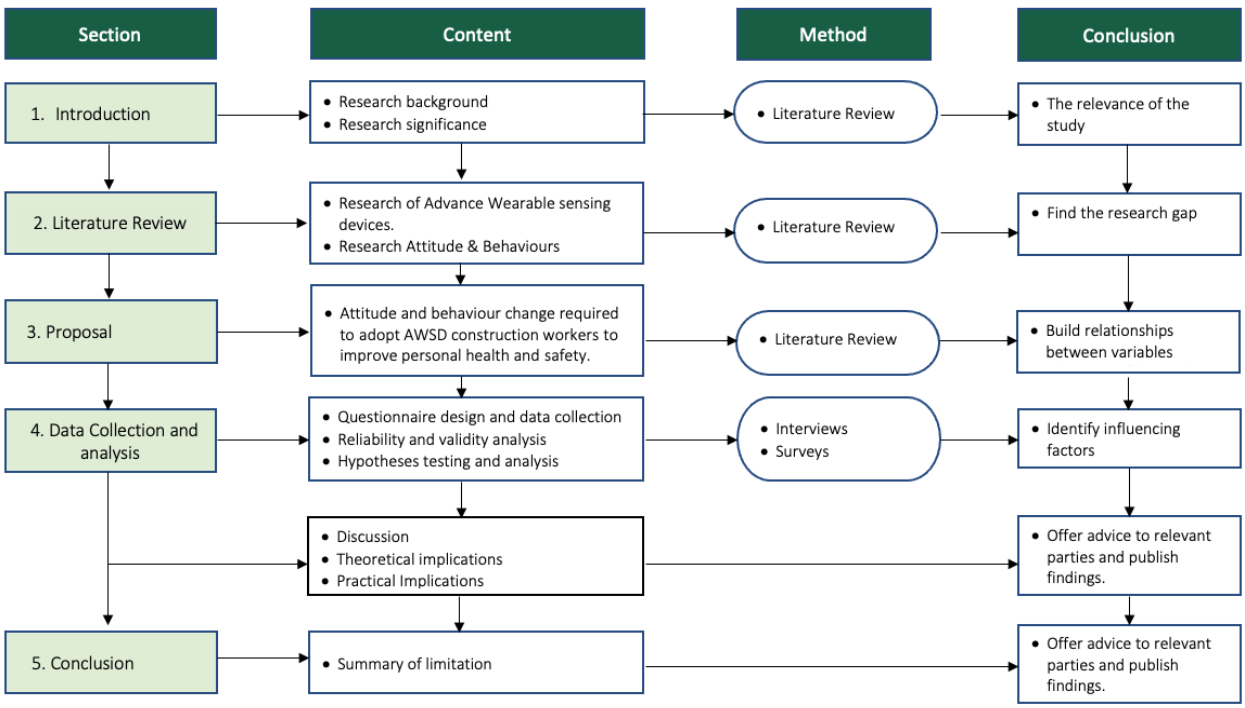


Figure 13. Research framework (Constructed by the author)

3.6. CONSIDERATION OF DATA VALIDITY AND RELIABLITY

Table 4 details the demographic information obtained via the online qualitative interviews completed with each of the participants. The details confirm the validity of the interview participants in terms of their associated organisations, the amount of industry experience and knowledge they have, their highest level of construction related education, as well as their core business.

Interview Participants Demographic

Participants	Age	Highest Qualification	Position	Gender	Organisation	Experience	Core Busines	Interview Time
1	46-55	Undergraduate Degree	Managing Director	Male	Tier 2	25 + Years	Main Contractor	38 Mins
2	56-65	Trade Qualification	Project Manager	Male	Tier 1	25 + Years	Principal Contractor	43 Mins
3	56-65	College	Site Manager	Male	Tier 1	25 + Years	Principal Contractor	48 Mins
4	36-45	Professional Qualification	Project Manager	Male	Tier 1	20 - 25 Years	Principal Contractor	38 Mins
5	46-55	Professional Qualification	Project Director	Male	Teit 1	25 + Years	Principal Contractor	37 Mins
6	56-65	Postgraduate Degree	UK & Ireland Project Director	Male	Tier 1	25 + Years	Principal Contractor	44 Mins
7	46-55	Undergraduate Degree	UK & IR Project Director	Male	Tier 1	25 + Years	Principal Contractor	63 Mins
8	56-65	Professional Qualification	Project Manager	Male	SME	25 + Years	Main Contractor	41 Mins
9	36-45	Trade Qualification	Site Manager	Male	Micro-Entity	15-20 Years	Trade Services	44 Mins
10	56.-65	Profssional Qualification	Health & Safety Manager	Female	Teir 1	25 + Years	Professional Services	41 Mins
11	36-45	Undergraduate Degree	Project Director	Male	Tier 1	20-25 Years	Principal Contractor	45 Mins
12	46-55	Undergraduate Degree	Global Projects Director	Male	Tier 1	25 + Years	Principal Contractor	43 Mins
13	56.-65	Trade Qualification	Project Director	Male	Tier 1	25 + Years	Principal Contractor	48 Mins
14	36-45	Postgraduate Degree	Managing Director	Male	Tier 2	25 + Years	Main Contractor	51 Mins

Table 4. Demographic Schedule, (Constructed by the author via NVivo)

The interview times varied in duration from thirty-seven minutes to sixty-three minutes, the average time to complete an interview was forty-eight minutes, as shown in table 5. Fourteen interviews were conducted in total, the interviews were scheduled around the participants diaries and had to consider their work and personal commitments. The duration of the interviews varied due to the expansion of each individual discussion and the responsiveness of the participant.

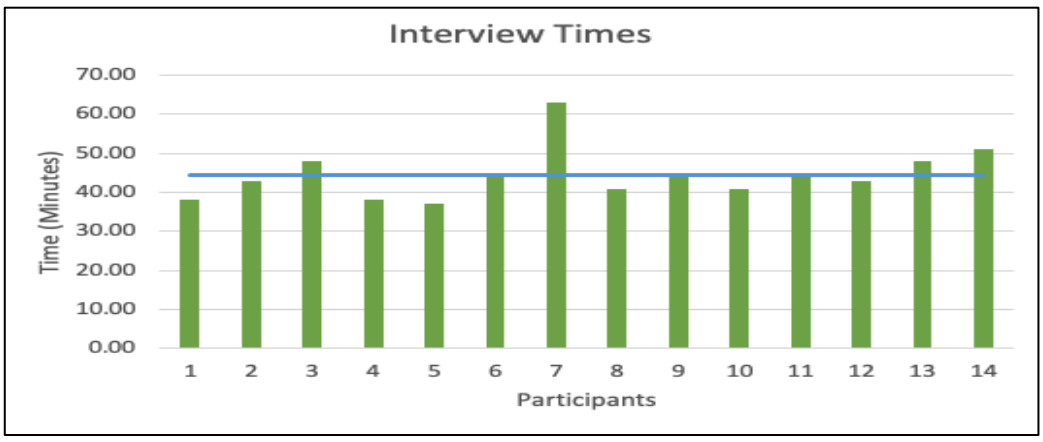


Table 5. Interview times, (Constructed by the author)

Further validity was gained by asking the interview participants to review the transcripts produced, this is to ensure their accuracy and to confirm an agreement is in place regarding the details to be used. Confirmation of acceptance of this approach is provided by McGrath et al., (2019) who affirms, "*As part of*

ensuring trustworthiness in qualitative data driven explorations, members checking, also known as respondent validation or participant validation, can be used. Members checking is a method of returning an interview transcript or debriefing the analytical result with participants for agreement." Additionally, Validity Research, (n.d.) suggests additional validity can be achieved by asking question such as *"Does it make sense?"* and "*Can I trust it?"* This is an approach that was undertaken whilst conducting the research interviews, it was also one that was considered when analysing the results produced. This form of validity relates to the researcher using experience and knowledge to identify any anomalies.

In accordance with the details provided in section 3.5, a comprehensive thematic analysis was conducted (Thematic Analysis, n.d.-a). This analysis encompassed a dual approach involving the examination of the manual outputs, see Appendix B, against the findings produced by the computer software NVivo. Alongside the electronic generated datasets NVivo also created a word cloud, (DePaolo & Wilkinson, 2014), as depicted in Figure 14, which effectively presents the prominent keywords and their relationships derived from all of the fourteen conducted interviews; additionally, NVivo enable the generation of various word trees, (Hearst et al., 2020), an example is identified in Figure 15, these identify interconnected branches associated with the detected keywords. The identified methodologies were analysed collectively to enhance the credibility and robustness of the derived findings.

Figure 14. Word Cloud, (Constructed by the author via NVivo)

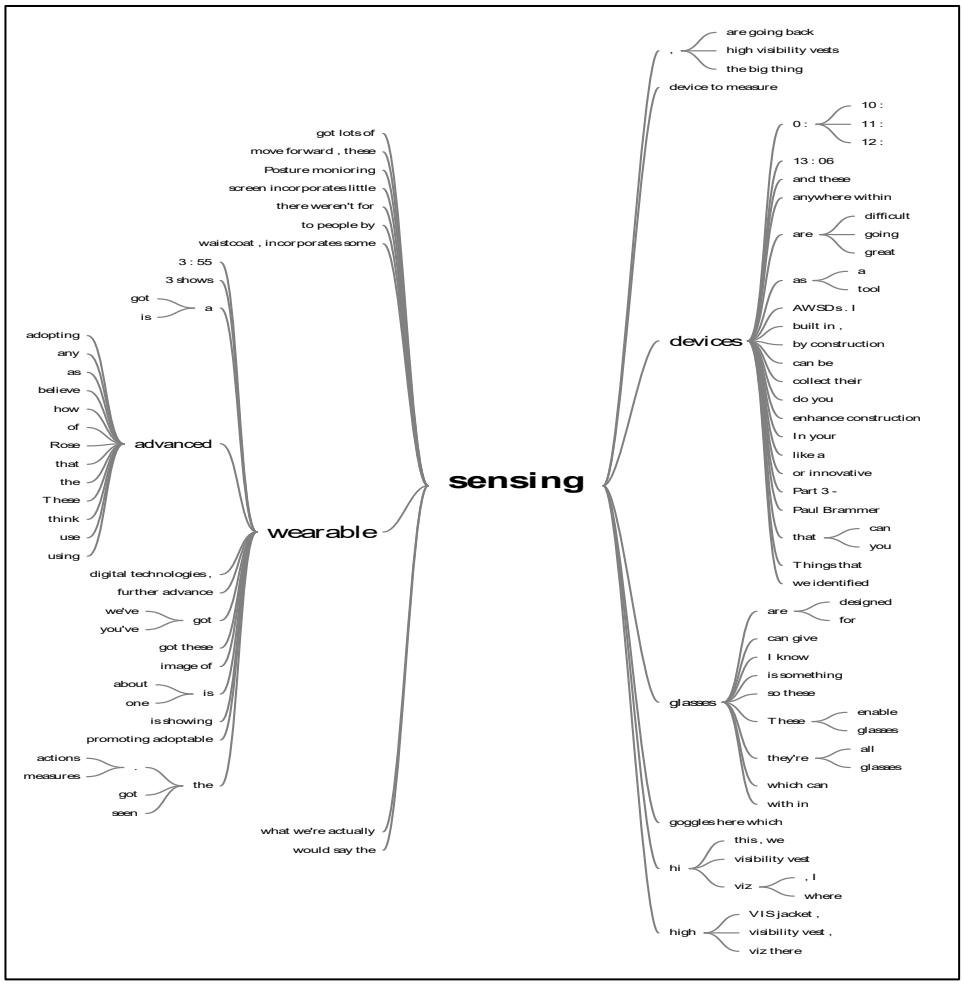


Figure 15, Word Tree, (Constructed by the author via NVivo)

3.7. ETHICAL CONSIDERATIONS

Undertaking qualitative research involves the collection of data from human interactions which lead to situations and relationships which are complex and unpredictable (Reid et al., 2018). The personal accounts and experiences obtained from the interview participants explored thoughts and opinions which result in ethical issues such as confidentiality, alongside the responsibility of the researcher to collect, manage, store, and use relevant data (Ethical Issues, n.d.). An information pack was issued to each of the interview participants to provide them with all the details regarding the interview and ensure an ethical data collection approach was undertaken, this contained the following.

- Invitation Letter
- Participant Information Sheet
- Dissertation Questions
- Risk Assessment
- Certificate of Ethical Review
- Dissertation Participation Sheet
- Research Study Consent Form

Ethical considerations were required to be identified and documented, and approval from the university was a prerequisite to any research being undertaken. For this research program minimum ethical issues were identified, see document in Appendix E. Further ethical considerations that were considered are highlighted in figure 16.

Principle	Content
Honesty	• A researcher must be honest in the proposing, planning, performing, and reporting of research • A researcher must honestly describe the research contribution and disclose any potential conflicts of interest • Fabrication, falsification, and misrepresentation are not allowed in scientific communication
Objectivity	• The researcher needs to be free from external influences such as personal interest, value commitments, or community bias • A researcher should strive for objectivity in research design, data analysis and interpretation and publication • Science will never be completely free from political, social, cultural, or economic influences
Carefulness	• Research should be conducted in a precise manner to avoid mistakes and errors • Researchers should critically examine their own work as well as the research of peers • Researchers must avoid self-deception, bias, and conflicts of interest • All research activities, such as consent forms, data collection, and data analysis should be well documented.
Fair credit	• Researchers must ensure the fair allocation of research credit, for example, authorship credit in publications, patents and other materials
Openness	• Openness promotes the advancement of science and scientific knowledge • Data, resources, and ideas should be shared among researchers • Researchers should be urged to review and criticise each other's work
Confidentiality	• Researchers must protect parts of the research project that should remain private (e.g., research plan, papers, personal records, and proprietary information) • Researchers must protect study participants' personal information
Respect for collegians	• Researchers must treat their peers, research staff, and students fairly and avoid causing them harm • A researcher cannot discriminate against colleagues and students based on their sex, race, ethnicity, religion, or other characteristics, such as qualifications • Researchers should help, educate, train, mentor, and advise their co-workers and students
Respect for intellectual property	• Every researcher must respect intellectual property, for example, copyrights • *Researchers must respect the work of others*, i.e., they cannot use unpublished data or results without permission and must make sure to give credit to whom it belongs • Researchers must avoid *plagiarism*
Freedom	• No organisation or institution should hinder a researcher's right to independently conduct research • Nobody should interfere with a researcher's freedom of thought and inquiry

Continued

Principle	Content
Protection of human research subjects	• Researchers are responsible for protecting the rights, dignity, and welfare of human subjects • Researchers must protect research participants' autonomy and obtain valid informed consent • Any researcher who is involved with study participants must protect study subject privacy and ensure the confidentiality of their personal data • Researchers should strive to minimise research harms and risks and maximise benefits • Researchers should pay special protection to subjects from vulnerable populations • Researchers must fairly distribute the benefits and burdens of research
Stewardship	• Researchers should make good and fair use of human, financial, and technological resources • Every researcher is responsible for taking care of the research site as well as the research materials and tools
Respect for the law	• Researchers must conduct research according to relevant law and institutional policies
Professional responsibility	• Researchers should proactively improve their professional competence and expertise throughout their careers • Researchers should promote scientific competence through mentoring, education, and leadership • Researchers are responsible for reporting misconduct as well as any illegal or unethical activities that threaten the integrity of research
Social responsibility	• Researchers are responsible not only for the people participating in the research, but also for anyone who may be affected by their research results • Researchers should avoid causing harm and strive to conduct research that will benefit society • Researchers should share research results in an ethical way, inform the public about the research results, and provide policymakers information that supports decision-making

Figure 16. Ethical Considerations, (Pietilä et al., 2020)

CHAPTER 4: RESEARCH FINDINGS

4.1 OVERVIEW

This chapter will present the findings obtained from the research study conducted in this dissertation. These outputs originate from five primary subject domains, encompassing the tools employed for research analysis and the inquiries posed throughout the conducted interviews. The main topics covered are:

- Findings 1: Interview properties
- Findings 2: Background and experience of participants
- Findings 3: Understanding the barriers and obstacles in adoption of AWSDs
- Findings 4: Promoting the benefits of adoption of AWSDs
- Findings 5: Solutions required to enable attitude and behavioural change

All sections within this chapter will be subject to an analysis of the findings produced and each will be subject to relevant discussion to ensure an in-depth understanding of the key factors are in place.

4.2. FINDINGS 1 – INTERVIEW PROPERTIES

4.2.1. Coding references

The completion of data processing from the interviews involved creating a hierarchy code plan. This plan entailed designing and structuring parent and child codes in a coherent order, aligning with the distinct responses gathered during the interviews. Narratives tied to corresponding themes were linked with their respective parent or child codes. Occasionally, these narratives were associated with both. It's worth noting that certain themes were associated with multiple codes, allowing them to appear in several contexts. For a visual representation of the codes and the colours used to identify themes, refer to Figure 12.

Table 6 presents the findings derived from the coding process conducted with the NVivo computer program. This table showcases the aggregate count of thematic items attributed to each specific detailed code. Furthermore, it highlights the cumulative count of participants who underwent coding, along with the ratio representing the distribution of themes among individual interview participants. The generated dataset is both expansive and intricate, revealing a substantial allocation of themes within the hierarchical code framework. Notably, a majority of themes frequently align with various codes. The data highlights the primary focal points of conversation, revolving around three pivotal subjects:

1. Attitudes and Behaviours
2. Technology
3. Implementation of AWSDs

Additionally, it becomes evident that enhancements to the interview questions could potentially stimulate more extensive deliberations regarding categories encompassing a total of themed codes involving

fewer than 30 participants, instances where participants have been associated with 10 or fewer themes, and all outcomes featuring a ratio of 3 or less.

THEMED CODES COMPARED TO PARTICIPANTD CODED

CODES	TOTAL NUMBER OF THEMES CODED	TOTAL NUMBER OF PARTICIPANTS CODED	RATIOs
Codes\\1. Participant Details	117	14	1:8.36
Codes\\1. Participant Details\a. Associated Organisation	30	12	1:2.5
Codes\\1. Participant Details\b. Experience	39	14	1:2.79
Codes\\1. Participant Details\c. Qualifications	44	14	1:3.14
Codes\\2. Technology	307	14	1:21.93
Codes\\2. Technology\a. AWSDs	114	14	1:8.14
Codes\\2. Technology\b. Hardware	16	9	1:1.77
Codes\\2. Technology\c. IT Storage	37	13	1:2.85
Codes\\2. Technology\d. Software	19	9	1:2.11
Codes\\3. Health & Safety	176	14	1:12.57
Codes\\3. Health & Safety\a. Accidents	15	7	1:2.14
Codes\\3. Health & Safety\b. Biometrics	17	10	1:1.7
Codes\\3. Health & Safety\c. Metal Health	16	4	1:4
Codes\\4. Implementation of AWSDs	274	14	1:19.57
Codes\\4. Implementation of AWSDs\a. Demonstrations	15	10	1:1.5
Codes\\4. Implementation of AWSDs\b. Education	54	14	1:3.86
Codes\\4. Implementation of AWSDs\c. Legislation	85	14	1:6.07
Codes\\4. Implementation of AWSDs\d. Training Courses and Scheme	40	13	1:3.08
Codes\\5. Attitudes & Behaviours	736	14	1:52.57
Codes\\5. Attitudes & Behaviours\a. Barriers & Obstacles	109	14	1:7.79
Codes\\5. Attitudes & Behaviours\b. Lack of knowledge	105	14	1:7.5
Codes\\5. Attitudes & Behaviours\c. Negative	142	14	1:10.14
Codes\\5. Attitudes & Behaviours\d. Positive	197	14	1:14.07
Codes\\6. Cost	37	12	1:3.08

Table 6. Code Referencing Schedule, (Constructed by the author via NVivo)

From the resultant research outputs a manual coding system was implemented. This system entailed the identification of significant statements extracted from the interviews facilitating the recognition of patterns and themes; these findings underwent cross-referencing with the outcomes generated through NVivo to ensure the accuracy and dependability of the amassed data. The outcomes are also visually represented in a hierarchical diagram, as depicted in Figure 17. This visualisation proved highly effective, enabling an instant understanding of the weighting associated with the data produced. It corroborates the principal themes discovered in the dataset:

1. Attitudes and Behaviours
2. Technology
3. Implementation of AWSDs

HIERARCHY OF ASSIGNED THEMES

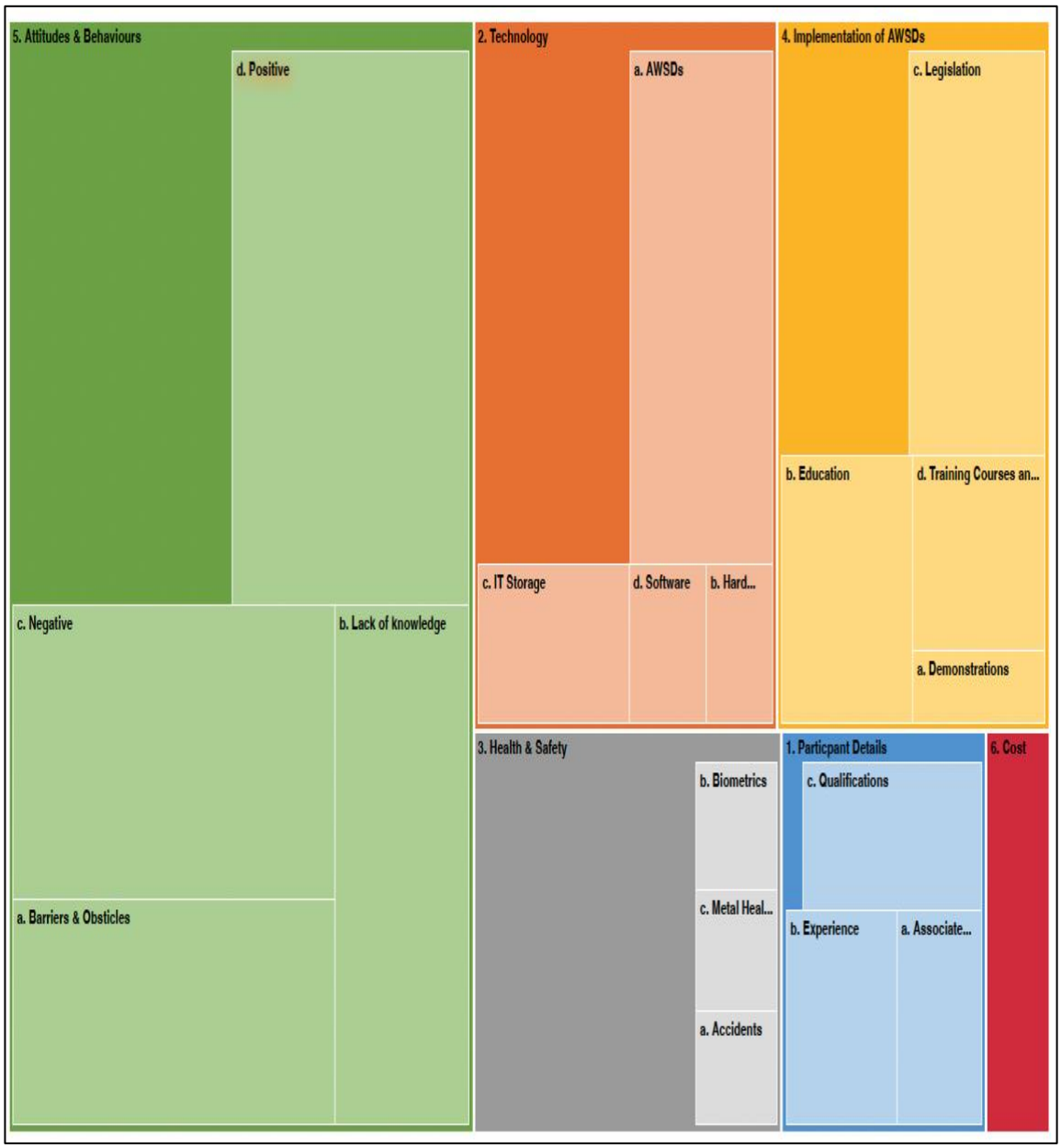


Figure 17. Hierarchy of Assigned Themes, (Constructed by the author via NVivo)

4.3 FINDINGS 2 - INTERVIEW PARTICIPANTS BACKGROUND AND EXPERIENCE

4.3.1. Supporting documents

The comprehensive demographic schedule presented in Table 4 offers relevant insights into the background and experiences of the interview participants. This contextual data is further substantiated by the demographic statistics schedule featured in Table 7. The contents of these documents bear direct relevance to the preceding narratives.

WHAT IS THE HIGHEST LEVEL OF EDUCTION THAT BEST DESCRIBES YOU	COUNT	%
Secondary or less	0	0
College	1	7%
Trade Qualification	3	21%
Profession Qualification	4	29%
Undergraduate Degree	4	29%
Postgraduate Degree	2	14%
Other	0	0%
TOTALS	**14**	**100%**
WHAT JOB TITLE BEST DESCRIBES YOU	**COUNT**	**%**
Managing Director	2	14%
Project Director	6	43%
Project Managers	3	21%
Site Managers	2	14%
Construction Professional	0	0%
Health & Safety Managers	1	7%
Other	0	0%
TOTALS	**14**	**100%**
WHAT AGE GROUPS BEST DESCRIBES YOU	**COUNT**	**%**
18 – 25 Years Old	0	0%
26 – 35 Years Old	0	0%
36 – 45 Years Old	4	29%
46 – 55 Years Old	4	29%
56 – 65 Years Old	6	43%
Other	0	0%
TOTALS	**14**	**100%**
WHAT GENDER BEST DESCRIBES YOU	**COUNT**	**%**
Male	13	93%
Female	1	7%
Other	0	0%
TOTALS	**14**	**100%**
HOW MANY YEARS IN THE CONSTRUCTION IN DUSTRY DO YOU HAVE	**COUNT**	**%**
0 – 5 Years	0	0%
5 – 10 Years	0	0%
10 – 15 Years	0	0%
15 – 20 Years	1	7%
20 – 25 Years	3	21%
25 + Years	10	72%
TOTALS	**15**	**100%**
WHAT SIZE IS YOUR ORGANISATION	**COUNT**	**%**
Tier 1	10	72%
Tier 2	2	14%
Tier 3	0	0%
SME	1	7%
Micro-Entity	1	7%
TOTALS	**14**	**100%**
WHAT IS YOUR COMPANY'S CORE BUSINESS	**COUNT**	**%**
Professional Services	1	7%
Principal Contractor	9	65%
Main Contractor	3	21%
Trade Services	1	7%
Other	0	0%
TOTALS	**14**	**100%**

Table 7, Demographic Statistics Schedule, (Constructed by the author)

4.3.2. Interview particicpants experience

The conducted interviews brought to the forefront a noteworthy trend of substantial employment history within relevant construction entities, particularly tier 1 contractors (Tier - Designing Buildings, n.d.). This observation was verified by Participant 5, who confirmed, *"I was involved with managing very large projects that had more than 100 people on site, projects with values in the region of £200 million, whilst working for*

a tier 1 contractor." Participant 12 further emphasised this trend, stating, *"I was responsible for delivering Data Centres new builds and infrastructure upgrades, values of 10 to 30 million UK pounds, and now as Project Director I manage a global account where I'm responsible for delivering $350 million worth of projects."*

The research findings also evidenced the presence of smaller construction companies in the study, as indicated by participant 1, who shared, *"We're now at a stage where we turnover up to £11 million per year."* Whilst tier 1 contractors emerged as the dominant organisations related to the participants, the information gathered offered a glimpse into the involvement of other construction entities, such as small and medium-sized enterprises and micro-entities (SME, n.d.; Micro-Entity, n.d.). However, it is important to note that the findings lacked representation from tier 3 organisations.

The outcomes strongly indicate that the majority of interview participants hold positions as either Project Directors or Project Managers. This assertion is represented by Participant No. 6, who recounts, *"I started off as a graduate quantity surveyor, moved into an operational role in my early 30s, I now lead our construction operations business in North, Central and South America."* This sentiment is further reinforced by Participant 7, who elaborates, *"I started off as a head of projects for a sector role and then ended up as Project Director for the UK and Ireland."* Additionally, Participant 4 confirms, *"I'm a Project Manager, currently I'm working on various projects within an oil refinery owned by a global organisation."* Within this context, a minority of participants assumes the role of Managing Director, this is substantiated by Participant 1, who shares, *"I worked for the family business as the Operations Director and in 2004 I took over the company and became the Managing Director."*

The findings presented in Table 4 and Table 7 provide further comprehension of the background and experience of the interview respondence, as they directly correlate with factors such as the participants' age, gender, and their respective companies' core business.

4.3.3. Interview participants education and training

The outcomes resulting from the conducted interviews, which are detailed in both Table 4 and Table 7, strongly indicate that the interview participants possess the highest level of construction-related education in the form of postgraduate degrees. This observation is reaffirmed by Participant 14, who states, *"I've spent my whole life studying, I have completed all my nationals and basically worked my way up to a level 7 qualification."* Participant 6 echoes this sentiment by stating, *"I hold an MBA in Business Administration."* The dominant trend in terms of qualification leans towards undergraduate degrees, as validated by Participant 12 who indicates, *"I have obtained a building services first-class honours degree."* Similarly, professional certifications also hold considerable popularity, as attested by Participant 5 who remarks, *"I've been in the construction industry for 30 years, I started by taking ONC & HNC qualifications."* From the findings, it is abundantly clear that all interview participants boast appropriate and relevant qualifications. Supplementary data was gathered to ensure a comprehensive understanding of the full spectrum of construction related education courses attended by the participants, as detailed in Figure 18.

ID	POSITION	RESPONSE	KEY
1	MD	Management Courses, CITB Black CSCS Card, Safety Management	
2	PM	NEBOSH, IOSH, SMSTS, CSCS card, City and Guilds	
3	SM	MOD Standard Management training AP, Chemical AP, Confined Space AP, Medical Gas, Safe Opening Diploma, CDM, IOSH, NEBOSH I, L8, Asbestos, 18th Edition IEE Wiring Regulations..	
4	PM	NEBOSH, IOSH, SMSTS, CSCS Card, City and Guilds, Professional Qualification	
5	HOP	Professional Qualification, ONC, HNC, NEBOSH, IOSH, SMSTS, CSCS Card, City and Guilds	
6	PD	Postgraduate Degree, NEBOSH, SMSTS, CSCS	
7	PD	Undergraduate Degree, Fire Safety, NEBOSH, IOSH, SMSTS, CSCS card	
8	PM	Professional Qualification, NEBOSH, IOSH, SMSTS, CSCS Card, City and Guilds	
9	SM	City and Guilds, 16th Edition IEE Wiring Regulations, NEBOSH, IOSH, SMSTS, CSCS Card,	
10	HSM	Professional Qualification, NEBOSH, CDM, Basic Explosives, Incident Investigation,	
11	HOP	Undergraduate Degree, National Diploma, Higher National Certificate, Fire Safety, Regulatory Compliance, Asbestos, NEBOSH, CDM,	
12	PD	Postgraduate Degree, ILM 5, NEBOSH Construction, CDM, City & Guides	
13	PD	Trade Qualification, HND	
14	MD	Postgraduate Degree, NEBOSH, SMSTS, CSCS, City and Guilds	

Figure 18. Further Education Courses Attended, (Constructed by the author)

After establishing a comprehensive understanding of the participants' educational backgrounds, they were asked about their perspectives on the adequacy of educational content within current construction training programs and schemes. Specifically, the focus was on content that emphasises the personal health and safety advantages of embracing innovative digital technologies. All participants uniformly indicated that no existing education or training courses deliver content tailored to this aspect. Participant No. 12 substantiates this consensus by stating, *"No, I don't think they do touch on it as much as they possibly could. The evaluation of the construction industry in terms of production and the Industrial Revolution 4.0 is accelerating at a rapid pace, but I feel that construction health and safety around AWSDs and the related benefits are lagging a little in terms of training and awareness of the products."*

4.3.4. Interview participants knowledge of AWSDs

The majority of the participants demonstrated awareness of monitoring devices used in high-risk environments such as confined spaces or underground works. Two of the participants had prior experience with using glasses such as HoloLens, as depicted in figure 3, but not in relation to personal health and safety. These findings indicate a level of familiarity with certain technologies related to environmental safety and monitoring but a lack of awareness concerning AWSDs for construction workers personal health and safety. This view is supported by Participant No. 1 who suggests, *"No, we don't use AWSDs. We've not had the need to use these or been advice that we should be using them, this maybe something that we might consider in the future."* This is confirmed by Participant 6 who indicates, *"No, I'm not aware of anything now, If I'm not aware where that's happening and how that's working, then it certainly isn't happening in my sphere of influence."*

4.4 FINDINGS 3 – UNDERSTANDING BARRIERS AND OBSTACLES IN ADOPTING AWSDs

4.4.1. Barriers and obstacles in adopting AWSDs

The data presented in Table 8 & 9 pertains to this specific field of investigation.

Code/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Attitudes & Behaviours	-	-	-	1	1	1	1	1	1	-	1	1	1	1	10
Lack of Knowledge	-	1	-	1	-	-	-	1	1	1	1	1	-	-	7
Negative	1	1	1	1	1	1	1	1	1	-	-	-	-	-	9
Health and Safety	1	-	-	-	-	-	-	-	-	1	1	-	1	-	4
Education	-	-	-	-	-	-	-	-	-	1	-	-	-	1	2
Techology	-	1	-	-	-	-	-	-	-	-	-	1	-	-	2
AWSDs		-	-	-	-	-	-	-	1	-	-	-	-	-	1
Cost	1	1	1	-	-	-	-	-	-	-	-	1	1	1	6

Table 8. Data Collection, Identified Barriers & Obstacles, (Constructed by the author)

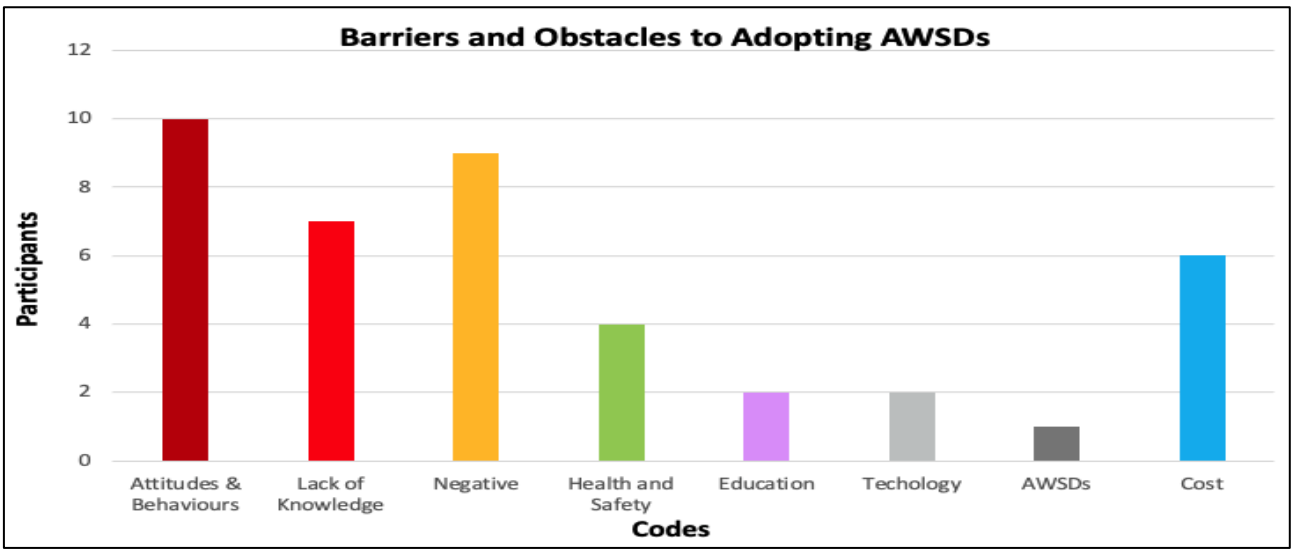


Table 9. Data Representation, Identified Barriers & Obstacles, (Constructed by the author)

The primary barrier identified by the interview participants revolves around attitudes and behaviours, a sentiment strongly echoed by Participant 4, who conceives, "*People's mindset, they could see this technology as another way to keep tabs on them, like a Big Brother aspect, where people are being monitored continuously to see how they are preforming.*" Participant 5 similarly emphasises the resistance to change, theorising that, "O*ne of the biggest barriers is always people and change, especially workers that have been in construction for a long time. It could be that those people see this as an invasion of privacy."* Another pivotal obstacle is the lack of knowledge, an aspect explained by Participant 6 who suggests, *"I think certainly from myself at the moment it's awareness, I don't really see people in the industry coming forward necessarily to say that this technology is now available."* Reinforcing this standpoint, Participant 14 highlights the necessity to educate individuals about the advantages and limitations of these devices, noting, "*One of the main obstacles would be the individuals themselves understanding the benefits of these devices, educating people with the benefits of it and the restrictions of it, I think that's something else that could be tackled.*" Financial considerations also emerge as a noteworthy constraint, as articulated by Participant 12 who suggests, *"Costs are always passed on to the end user and I find sometimes with customers when we talk about health and safety and the cost you get a lot of kickbacks, cost is a barrier."* This viewpoint finds further resonance in the observations of Participant 3, who asserts, *"Cost, companies have got to have this within their budget, this would be a major barrier."*

Additional barriers and obstacles were highlighted concerning the imperative need for educational initiatives aimed at changing attitudes and behaviours and rectifying gaps in knowledge. These concerns are linked to the incorporation of supplementary health and safety protocols in conjunction with the integration of AWSD technology and the devices themselves. It is noted that a predominant portion of the collected responses exhibits a negative undertone, illustrating the complex nature of the raised issues that demand concerted efforts to pursue viable resolutions.

4.4.2. Personal data collection, use, and storage

The data presented in Tables 10 & 11 relates solely to this research area.

Codes/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Attitudes & Behaviours	1	-	-	-	-	1	1	-	1	1	1	1	1	1	9
Lack of Knowledge	-	-	-	-	-	1	1	-	1	1	1	-	1	-	6
Negative	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Positive	1	1	1	-	-	-	-	1	-	-	-	-	-	-	4
Barrier & Obstacles	-	-	-	-	-	1	1	-	1	-	-	1	1	1	6
Health and Safety	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Implementation of AWSDs	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
Education	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Legislation	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
AWSDs	1	-	-	-	-	-	-	-	1	-	-	-	-	-	2
IT Storage	-	1	1	1	1	1	-	1	-	1	1	1	-	-	9
Hardware	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Software	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Cost	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1

Table 10. Data Collection, Concerns Regarding Personal Data Collection, (constructed by the author)

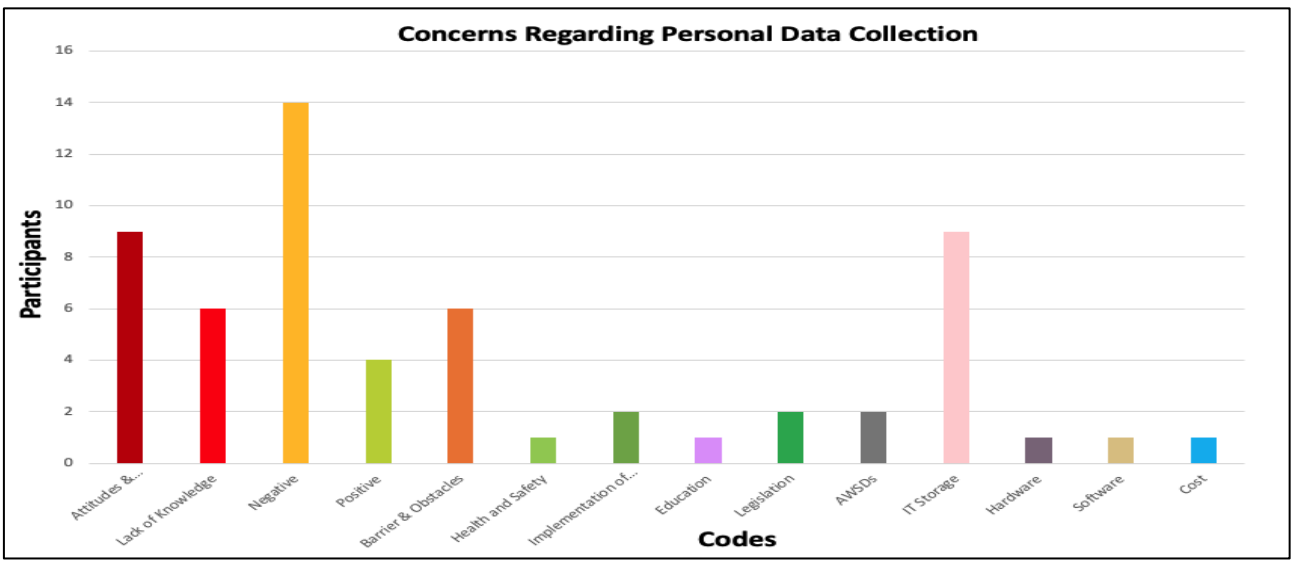


Table 11. Data Representation, Concerns Regarding Personal Data Collection, (Constructed by the author)

A core concern identified is attributed to attitudes and behaviours, a sentiment conveyed by Participant 1, who states, *"I think if you're collecting people's personal data, whether its heart rates, locations etc. people are always concerned as to being tracked or being monitored."* This sentiment gains additional validation through the perspective shared by Participant 11, who suggests, *"Some people will see this as an overreach, they will rebel and push back if there's something that's monitoring their performance on a minute scale like that."* Equally noteworthy is the concerns surrounding data storage and utilisation, an element expanded by Participant 12, who contends, "*Data collection and storage regarding having all that*

information on individuals, is another minefield. I can see that collecting personal health and safety data could be a challenge legally." This viewpoint is enhanced by Participant 5, who states, *"I believe some people would definitely be asking questions about how the data is used, what type of data is actually collected and why is it being collected."* Furthermore, reservations emerge concerning the lack of knowledge regarding the methodologies underpinning data collection, storage, and use. Participant 6 heightens this perspective, stating, "*I think the challenge here is you're collecting data and information which people see as personal and you're not really demonstrating what you're doing with that data."* Participant 7 echoes this sentiment, expressing, *"They would need to know that the AWSD's were not Big Brother monitoring progress, that actually the systems are being employed because we were really truly worried about their well-being and want to help them maintain it."* The aspect of legislative constraints surfaces as an additional barrier, suggesting a potential need for legislative reform to accommodate requisite IT solutions. Participant 14 intermates, "*There may be legislative considerations, I think if you were introducing this scheme what would follow would be an updated legislation built around it. Because the data is not useless data, it'll have all the information on individuals, you would definitely have to have something in place legally in regard to the storage of that data."*

Additional apprehensions identified centre around the complicated sphere of implementation, encompassing costs, hardware and software solutions, the deployment of AWSDs, and the essential need for educational initiatives aimed at reshaping attitudes and behaviours while amending knowledge gaps. These concerns interconnect with the need to incorporate supplementary health and safety protocols alongside the integration of AWSD technology and the corresponding devices themselves. It is noteworthy that a general sense of negativity infuses the entirety of the collected responses, highlighting the difficultly of the issues raised and emphasising the need for a collaborative approach in seeking viable resolutions. However, it is worth highlighting, certain responses do display a positive acknowledgement that the collection, utilisation, and safeguarding of personal data as a potentially constructive quality.

4.4.3. Standardisation of software and hardware solutions relating to implementing AWSDs

The information showcased in Tables 12 & 13 are associated with this specific area of investigation.

Code/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Attitudes & Behaviours	-	-	-	-	-	-	1	-	-	-	1	-	-	-	2
Lack of Knowledge	-	-	1	-	-	1	1	-	-	1	1	1	1	1	8
Negative	-	-	1	-	-	1	-	-	-	-	-	-	-	1	3
Positive	1	1	-	1	1	1	1	1	1	1	1	1	1	1	13
Barrier & Obstacles	-	-	-	-	-	1	1	-	1		-	1	1	1	6
Health and Safety	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Implementation of AWSDs	-	-	-	-	-	-	1	-	-	-	1	1	-	-	3
Legislation	-	1	-	1	1	-	-	1	-	-	1	1	1	1	8
AWSDs	1	-	-	-	-	-	-	-	1	-	-	-	-	-	2
IT Storage	1	1	-	1	-	1	-	1	-	-	1	1	1	1	9
Hardware	1	1	-	1	1	-	1	1	-	1	1	-	1	1	10
Software	1	1	-	1	-	-	-	1	-	-	-	-	-	-	4
Cost	-	1	-	-	-	-	-	-	-	1	-	-	-	-	2

Table 12. Data Collection, Concerns Regarding IT Standardisation, (Constructed by the author)

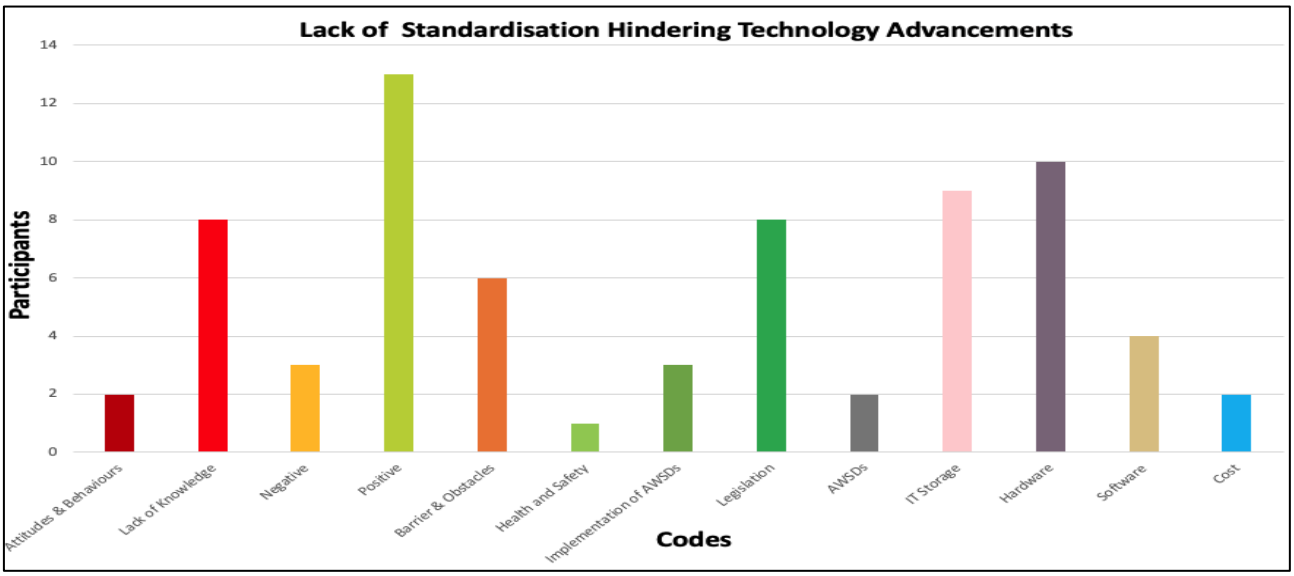


Table 13. Data Representation, Concerns Regarding IT Standardisation, (Constructed by the author)

Central to this exploration is a concern pertaining to the standardisation of IT storage, facilitated through the integration of hardware solutions. Participant 2 highlights this concern by expressing, "*There seem to be many software solutions available but what I think is missing is a standardisation around a hardware common data environment for each site setup."* This sentiment is further reinforced by the perspective shared by Participant 8, who suggests, *"It's got to be a common access protocol, I would agree there is no evidence to support there is a standard*." Recognising the crucial role of legislative frameworks in the establishment of an agreed standardised methodology, Participant 5 states, *"There's got to be some kind of standardisation put in place and some legislation introduced to support its use*." Participant 6 enhances this standpoint by asserting, *"I'm sure the technology is in place, it just requires legislation to be amended for standardisation to be achieved."* Verifying an absence of awareness on this matter, Participant 11 confesses, "*I don't know if these systems are standardised or not, if I'm honest, because I haven't seen any."* This perspective is echoed by Participant 12, who articulates, "*I don't know enough about IT site setups and adopting all of the required solutions."*

Further concerns relate to an intricate field of implementation, encompassing financial considerations, software integrations, the practical utilisation of AWSDs, and the integration of associated devices. These apprehensions link with the essential introduction of supplementary health and safety practices. It is noted that an extensive sense of positivity exists from all respondence, as the pursuit of standardisation is universally viewed as a progressive requirement. Some concerns are distinctly highlighted, particularly concerning attitudes and behaviours of the individuals who would interact with this technology. Coupled with a noticeable lack of knowledge, these factors contribute to a perspective held by some that identifies potential barriers to successful implementation.

4.5 FINDINGS 4 – PROMOTING THE BENEFITS OF ADOPTING AWSDs

4.5.1. How can AWSDs be used to improve construction workers personal health and safety

Tables 14 & 15 captures the findings for this area of study.

Code/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Attitudes & Behaviours	-	-	1	-	-	1	1	-	1	-	1	1	-	-	6
Lack of Knowledge	-	1	-	-	-	1	1	-	-	1	-	1	1	1	7
Negative	-	-	-	-	-	-	-	-	-	-	-	1	1	1	3
Positive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Barrier & Obstacles	-	-	-	-	-	-	-	-	-	-	-	1	1	1	3
Health and Safety	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Mental Health	1	-	-	-	-	-	-	-	1	-	-	-	-	-	2
Biometrics	1	-	-	-	-	1	1	1	1	1	1	1	1	1	10
Implementation of AWSDs	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
Technology	1	1	1	1	-	1	1	-	1	-	1	1	1	-	10
AWSDs	1	-	-	1	1	1	1	1	1	1	1	1	1	1	12
Hardware	-	-	-	-	1	-	1	1	-	1	1	-	1	1	7
Software	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Cost	-	1	-	-	-	-	-	-	-	-	-	1	1	1	4

Table 14. Data Collection, How can AWSDs improve workers personal health and safety, (Constructed by the author)

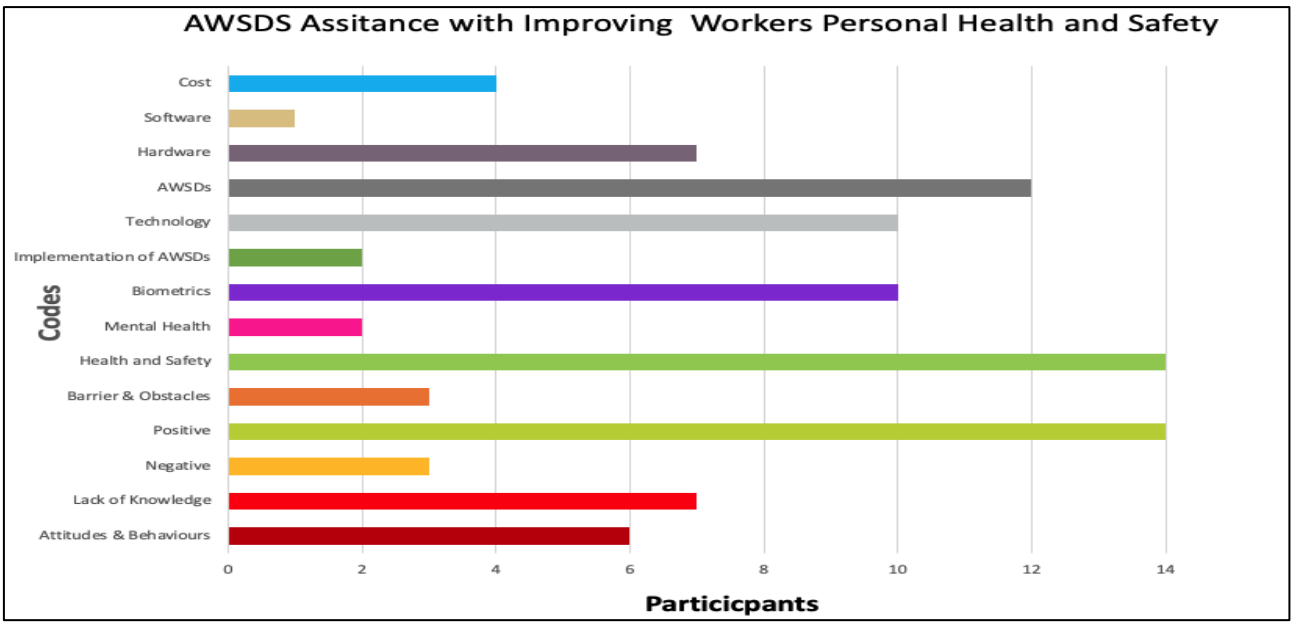


Table 15. Data Representation, How can AWSDs improve workers personal health and safety, (Constructed by the author)

A unanimous and positive consensus was produced acknowledging that AWSDs hold substantial promise in enhancing the well-being of construction workers. Participant 6 captures this sentiment by stating, *"Using AWSDs will improve behaviours of people because they are being monitored, changing methods of construction rather than changing individuals will have the biggest impact on construction workers personal health and safety."* Further validation is provided by Participant 7, who expands, *"I believe AWSDs could be used to improve construction workers personal health and safety by monitoring things like lung capacity and fatigue, issuing warnings when required."* Technology, specifically AWSDs, hardware solutions, and biometrics, surface as key components in realising these improvements. Participant 8 highlights this by affirming, *"I believe AWSDs could be used to improve construction workers personal health and safety by monitoring personal biometrics and warning them about personal health issues that they may not have been*

aware of." Participant 12 supports this, concluding, "*By monitoring all aspects of construction workers personal health and safety utilising biometrics as wearable technology and being able to provide early warnings, potentially saving lives."* A knowledge gap was noted, as indicated by Participant 7, who emphasises, "*Construction workers just need to be aware of AWSDs and trained on the benefits of use."* This knowledge gap is reiterated in recommendations rather than precise usage descriptions, illustrated by Participant 3, who states, *"AWSDs could be used to monitor and record peoples risk activities by identifying patterns of bad behaviour so they can be targeted and managed accordingly."*

Additional concerns are tied to the implementation process, spanning financial evaluations, software integration, and considerations surrounding mental health. The establishment of health and safety measures is directly linked with the apprehensions that surface. Within this context, certain concerns have the potential to evolve into barriers towards the adoption of AWSDs. Notably, financial commitments and the prevailing attitudes of construction workers toward the adoption of technological advancements emerged as focal points of concern.

4.5.2. How can AWSDs be used to ensure compliance with legal acts and regulations

Tables 16 & 17 serves to outline the outcomes within the scope of this research area.

Codes/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Negative	-	-	-	-	-	1		-	-	-	1	-	-	-	2
Positive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Health and Safety	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Mental Health	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Biometrics	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Implementation of AWSDs	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Training Course and Schemes	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Demonstrations	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Techology	-	-	1	1	-	-	1	-	-	-	1	1	-	1	6
Legislation	1	1	1	1	-	1	1	-	1	1	-	1	-	1	10
AWSDs	1	1	1	1	-		1	-	1	1	-	-	1	-	8
IT Storage	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Hardware	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Table 16. Data Collection, How can AWSDs assist with legislative requirements, (Constructed by the author)

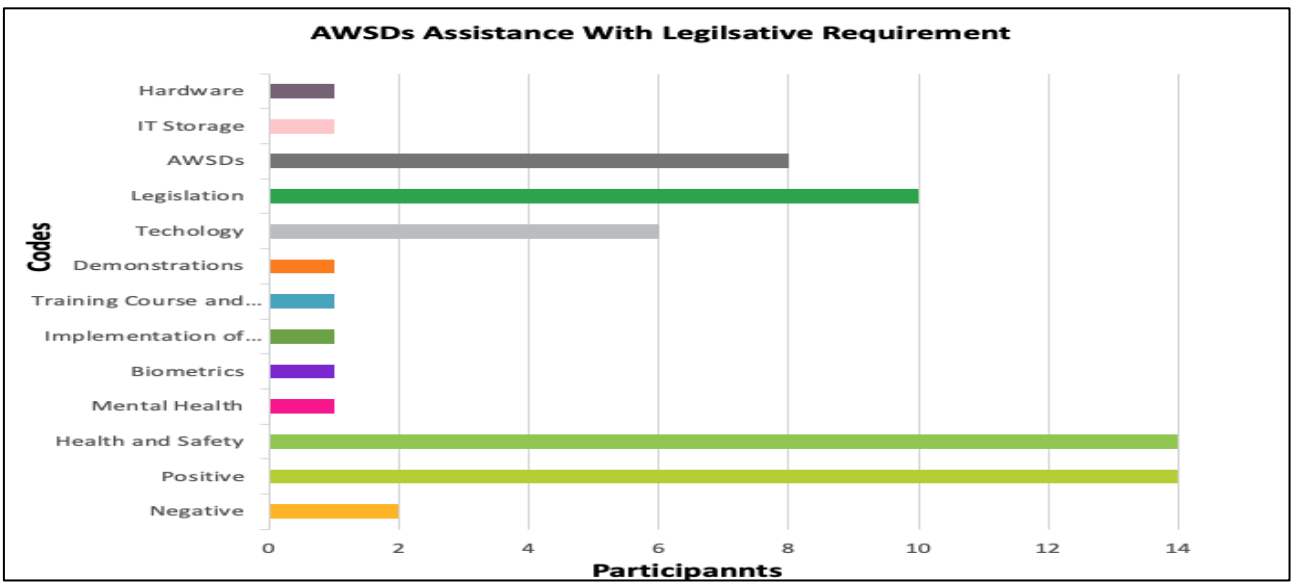


Table 17. Data Representation, How can AWSDs assist with legislative requirements, (Constructed by the author)

An undisputed positive consensus emerges, confirming the potential of AWSDs in aiding compliance with legislative frameworks. The implementation of AWSD technology will assist with improving safety standards throughout the construction industry. This perspective is identified by Participant 14, who proposes, *"AWSDs can assist the regulations because they're designed to ensure personal health and safety is improved."* Participant 9 lends further support, noting, *"The working time regulations, definitely. Some of the other acts I could see it being useful to gather data to ensure compliance."* Participant 2 adds to this consensus, stating, *"AWSDs could be considered as part of any risk assessment that are undertaken to ensure compliance with CDM 2015. Improved safety for construction workers by using this technology will enable the requirements of the health and safety at work act to be met."* A contrasting viewpoint was expressed, suggesting that continuous monitoring could potentially result in a deterioration of workers' mental well-being; this perspective was presented by Participant 4, who conveyed, *"AWSDs could influence workers mental well-being as be monitored could lead to time constrains being attached to work activities, workers would then feel under pressure constantly to deliver outputs within the times identified."*

In order to harness the compliance enabling potential of AWSDs, notable areas of improvement have been highlighted. These areas encompass advancements in technology integration, device functionality, IT solutions, comprehensive implementation guidelines, tailored training programs, demonstration sessions, and legislative refinement. It's worth noting that while these avenues of enhancement generated undivided positivity towards the benefit of using AWSDs, a minority of interview participants also expressed slight reservations regarding implementation.

4.6. FINDINGS 5: SOLUTIONS REQUIRED TO ENABLE ATTITUDE AND BEHAVIOURAL CHANGE

4.6.1. Responsibilities of construction companies, technology developers and education bodies

Tables 18 & 19 outlines the findings that fall within this research area.

Codes/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Attitudes & Behaviours	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Lack of Knowledge	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Negative	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Positive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Barrier & Obstacles	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Health and Safety	-	-	-	-	-	-	1	-	-	1	1	-	-	1	4
Implementation of AWSDs	-	-	-	-	-	1	-	-	-	1	-	1	-		3
Training Course and Schemes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Demonstrations	1	1	-	-	1	-	-	1	-	1	-	-	-	-	5
Education	1	1	1	1	1	1	1	1	-	1	1	1		1	12
Techology	1	1		1	1	1	1	-	1	-	1	1	1	1	11
Legislation	-	1	1		1	-	-	-	1	-	-	-	1	-	5
AWSDs	-	-	-	-	-	-	1	1	1	-	-	1	-	-	4
IT Storage	-	1	-	-	-	-	1	-	-	-	-	1	-	1	4
Cost	-	-	-	-	-	-	-	-	1	-	1	-	1	-	3

Table 18. Data Collection, Solutions required to enable attitude and behaviour change, (Constructed by the author)

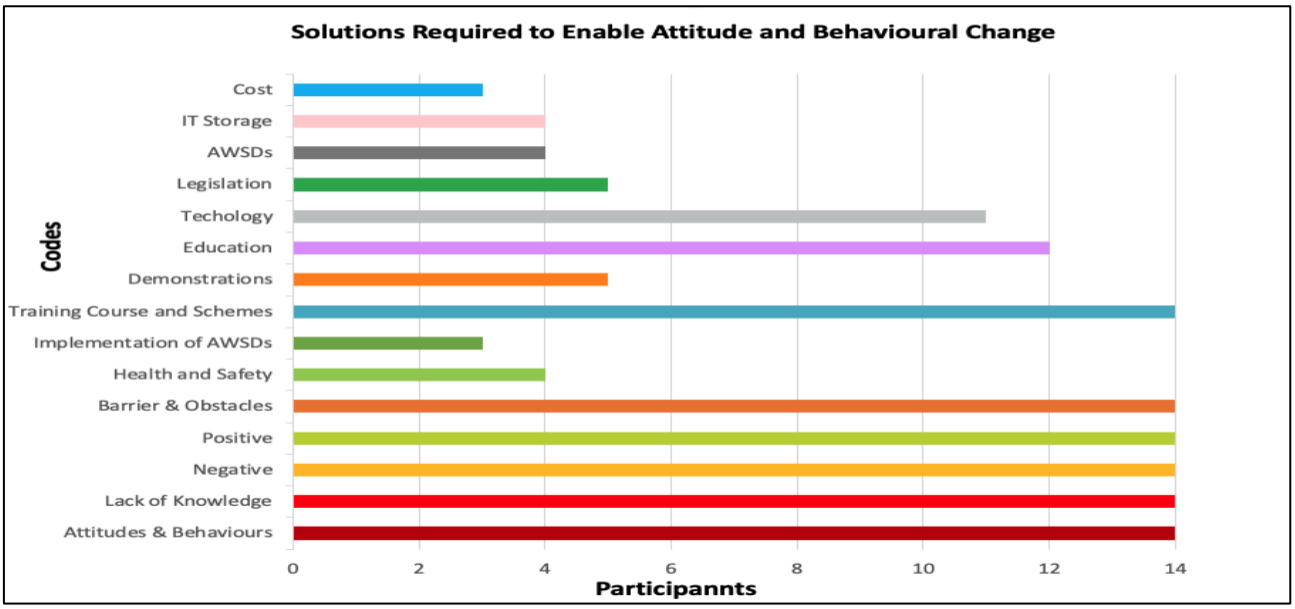


Table 19. Data Representation, Solutions required to enable attitude and behaviour change, (Constructed by the author)

An undivided positive opinion is presented, highlighting the obligation of construction-related organisations to promote awareness among construction workers regarding AWSDs and their associated advantages. This perspective is emphasised by Participant 1, who proposes, *"Companies need to provide awareness of this via internal training mechanisms such as e-learning, the technology developers should partner up with the construction companies and provide demonstrations to promote the benefits of using AWSDs. The education bodies and training schemes need to include relevant content within their courses."* This sentiment finds reinforcement through Participant 3, who asserts, *"All construction organisations should have a responsibility to make construction workers aware of AWSDs through various different types of medium, training courses, in-person demonstrations, literature, promotions etc."* The responses take a negative tone as participants uniformly express reservations regarding barriers to implementation, primarily attributed to organisational lack of knowledge and attitudes and behaviours. This sentiment is captured by Participant 12, who remarks, *"Let's talk about this technology, nobody's talking about it, as such there is a distinct lack of awareness about these devices and the benefits they offer."* Participant 6 aligns with this apprehension, stating, "*Companies believe they will benefit from AWSDs, but they don't really know, they can't granularized what that benefit is yet. It's the same as any PPE that you bring in, the logic of it works well but the practice of it is yet to be established*." Furthermore, cost surfaces as an additional hurdle, accompanied by a negative undercurrent. Participant 9 highlights this observing, *"Companies will look at the cost perspective, they'll look at this thinking, that's going to potentially cost a lot more money in relation to the traditional PPE that's available."*

To establish clear definitions of responsibilities concerning the training and promotion of AWSDs, several additional fields warranting enhancement were identified. These encompass IT storage solutions, the devices' functional attributes, legislative adaptations, and execution strategies. These enhancements are inherently tied to the essential integration of supplementary health and safety processes, these were regarded as obstacles that fostered a sense of negativity.

4.6.2. Changes in current legislation

Tables 20 & 21 provides an overview of the outcomes produced by this research domain.

Codes/Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Totals
Lack of Knowledge	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Negative	1	1	1	1	1	1	-	-	1	1	-	1	-	-	9
Positive	1	1	1	1	1	-	1	1	1	1	1	1	1	1	13
Barrier & Obstacles	1	1	1	1	1	-	-	-	-	-	-	-	-	-	5
Health and Safety	1	1	-	1	-	1	-	-	-	1	-	-	1	-	6
Implementation of AWSDs	1	1	-	-	-	-	1	-	-		-	-	-	-	3
Training Course and Schemes	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Education	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Techology	1	1	1	1	1	1	-	1		1	-	-	-	1	9
Legislation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
AWSDs	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
IT Storage	1	-	1	-	-	-	-	1	-	-	1	-	1	-	5

Table 20. Data collection, Change in current legislation, (Constructed by the author)

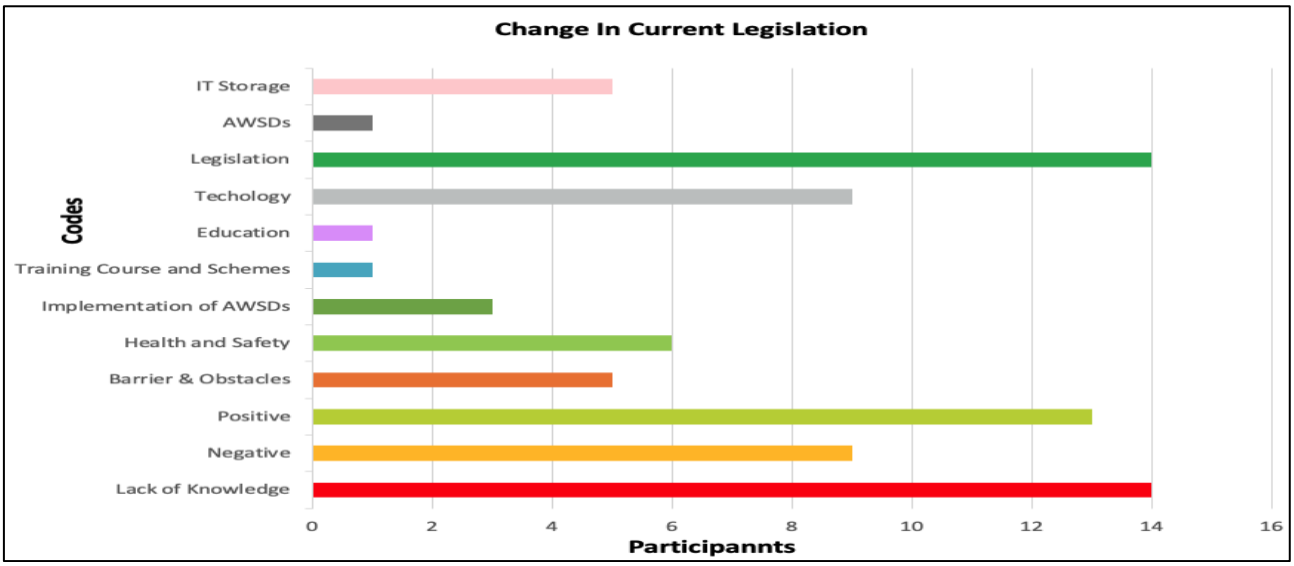


Table 21. Data Representation, Change in current legislation, (Constructed by the author)

The consensus among interviewees was that a shift in legislation is necessary to bolster the incorporation of AWSDs to enhance the personal health and safety of construction workers. The prevalent response indicates a preference for a phased implementation strategy, a stance illustrated by Participant 4, who suggests, *"I believe a phased approach, maybe for the top guys, the tier ones should be asked to implement this initially. This can then be monitored and if beneficial implemented further in differing areas of construction."* This perspective finds alignment with the comments of Participant 11, who intermates, *"I believe tier 1 contractors should undertake the implementation of AWSDs and the legislation initially, once this then becomes more accepted it can be introduced into other areas of construction via a gradual implementation approach, one sector at a time."* However, Participant 6 offers a differing viewpoint, advocating for an industry led response in over a legislative one, stating, *"I think there are other ways of doing it, maybe not as good. I'd much rather see an industry response to this rather than a legislative response."* Participant 12 provides a tone of negativity when illustrating a crucial aspect relating to lack of knowledge about the technology highlighting proposed legislative amendments, particularly regarding data

storage solutions, indicating, "*I think you need to understand who's going to store that information, who can access the information and what control measures are in place to limit data breaches before discussing legislation change."* Additionally, a further tone of negativity was expressed when the implementation of the devices themselves were highlighted as demanding careful consideration to ensure alignment with the proposed legislative advancements. Participant 8 stresses this need, noting, *"There'll be certain areas that will struggle to use standard AWSDs, for example, an intrinsically safe environment, a small spark from a battery powered AWSD could cause an issue."*

In order to facilitate the proposed legislative changes, areas necessitating improvement were identified. These areas revolve around the incorporation of AWSD related content into construction education programs and training schemes, the devices and their functional capabilities, the adjustment of current legislation, and the optimisation of execution strategies. These improvements are strategically linked to the integration of supplementary health and safety procedures, it's important to highlight that these areas were recognised as challenges that produced a sense of negativity.

CHAPTER 5: RESEARCH DISCUSSIONS

5.1. GENERAL THOUGHTS AND OBSERVATIONS

The combined manual and digital thematic approach enabled detailed and accurate findings to be produced. The author adeptly presented the findings through charts, tables, and schedules, these findings were supported by the production of word clouds (Ramlo, n.d.), word trees (Wattenberg & Viégas, n.d.), and hierarchical depictions. This information supports the successful implementation of a robust, comprehensive, and meticulous research investigation. The collective considerations of all the information obtained alongside convincing supporting narratives from the interview participants, in the opinion of the author, produced strong adequate research findings.

This vigorous research study supported by robust validation checks effectively fulfilled the identified research objectives which in turn enabled the sub-aims to be met. These findings then enabled improvement measures to be identified that, once enacted, will assist greatly with meeting the main aim of enhancing construction workers personal health and safety through improved attitudes and behaviours towards the adoption of AWSDs.

5.2. DISCUSSION 1 – UNDERSTANDING BARRIERS AND OBSTACLES TO THE ADOPTION OF AWSDs

5.2.1. Barriers and obstacles in adopting AWSDs

The identified barriers and obstacles to adopting AWSDs aligned with the associated literature review, see section 2.1.4. Particularly pertinent to this alignment were aspects concerning attitudes and behaviours, lack of knowledge, costs, and education, all of which were identified by the interview responses. Notably, the predominant concerns regarding attitudes and behaviours shed light on the mindset of workers. A prominent consensus emerged among the interview participants emphasising their apprehension towards personal data collection. This hesitation stemmed from the potential implication such data might have on their ongoing employability in light of health-related issues, compromised productivity assessments, and the tracking of work hours. Furthermore, a conspicuous lack of knowledge was highlighted as a significant hurdle, with approximately half of the interviewees directly identified this as an issue, implying that the absence of training and education initiatives to facilitate the integration of these technologies has hindered their awareness and understanding. The burden of the cost factor was unmistakably apparent, the collective opinion acknowledged that the introduction of this technology would inevitably entail supplementary expenditure. Central to this concern was the necessity for a planned incorporation of these costs into the tendering process, signifying a call for impartial and transparent financial adjustments.

Support of the findings produced is demonstrated by Nnaji & Karakhan, (2020-b) who identify key barriers to technology that directly relate to the analysed research outputs, specifically, concerns associated with the technology, lack of information, and costs. Nnaji et al., (2019) suggests that the observed barriers associated with the responses, when connected with attitudes and behaviours, relate partially to

demographic differences where older, experienced workers might exhibit resistance towards adopting technology, while younger individuals who are more technologically aware are likely to be more receptive. They also indicate that the lack of knowledge in part pertains to training that is required to get acquainted with the technology. Schall et al., (2018-a) states, *"The single biggest concern regarding wearable technology in the workplace is cost,"* this aligns with numerous interview participants who identify this as a barrier.

The research conducted suggests that the field of barriers and obstacles warrants a more comprehensive investigation, as highlighted in Table 1. Although the findings do shed light on pivotal barriers and obstacles, it is evident that this insight predominantly emanates from the management perspective. Additionally, a broader acknowledgment exists that these insights are limited due to an inadequate perception of the full scale of existing challenges. Supplementary limitations arise from the notable omission of input from the intended users of AWSDs.

It is the opinion of the author that the main issues highlighted would be consistent across the construction industry. However, it is recognised that a more refined understanding could be attained through a subsequent study that incorporates the perspectives of construction workers themselves. Such an inclusion would invariably contribute to a deeper and more enhanced comprehension of the subject matter.

5.2.2. Personal data collection, use, and storage

The individuals interviewed unanimously believe that construction workers will have concerns about the manner in which their personal data is collected, utilised, and stored. These concerns primarily revolve around the attitudes and behaviours of construction workers, as the outputs suggest they are reluctance to subject their personal health information for monitoring or to have their location and productivity closely recorded. A marked lack of awareness exists regarding the devices, the related technology, their potential advantages, and the procedures for data storage. The findings indicate that these identified concerns are considered significant barriers and obstacles in the adoption of AWSDs. There were additional mild concerns raised, spanning the technology's specifics, required implementation procedures, necessary legislation, the requisite educational support for the technology, and the attendant implementation costs. To ensure the acceptance of the necessary data solutions, all the identified concerns should be addressed. Although the findings identified negative outputs, some of the interview participants express positive benefits if the technology could be managed and controlled effectively.

The main areas of improvement relate to IT storage solutions, the attitudes and behaviours of construction workers, and the lack of knowledge on AWSDs and the related technology. The associated literature review, see section 2.1.3, highlights areas of improvement required to address the issues identified which correlate to the findings as identified by, Yang et al., (2020-b) who acknowledges the need for growth, this relates to the issues identified with current IT storage solutions, Jiang & Shi, (2021-c) highlights the need to address failings and vulnerabilities of cloud-based storage solutions as well as the lack of data flow and privacy leaks, this relates to a lack of knowledge, and Jit et al., (2010-b) illustrates the requirement for future

expansion requisites of cloud-based storage solutions, this relates to attitudes and behaviours and a lack of knowledge.

The findings highlight strong concerns regarding construction workers' personal data collection, storage, and use, leading to limitations that primarily stem from the absence of dedicated IT solutions exclusively tailored to meet the requirements of construction workers. This void illustrates a notable lack of confidence in the existing IT solutions currently in use. The outcomes suggest a necessity for the implementation or enhancement of legislation to establish definitive and authoritative guidelines for the collection, storage, and use of personal data related to construction workers.

The author recognises the rapid progress of technology, and as such believes there will arise a requirement to establish a robust infrastructure to cater for the demands of data collection, storage, and use that's associated with personal health and safety technology. This expansion is likely to persist without significant deceleration, underlining the importance of taking proactive steps to accommodate forthcoming innovations. Given the rapid pace of technological evolution, it becomes imperative that legislative reviews pertinent to the associated regulations are regularly undertaken and amended to ensure adherence and alignment.

5.2.3. Standardisation of software and hardware solutions relating to implementing AWSDs

The interview outputs demonstrate a unanimous consensus among all participants that there is a lack of standardisation in the software and hardware solutions related to the implementation of AWSDs. The main factor identified is related to lack of knowledge (van Lier et al., 2020). This lack of knowledge is reflected in the need for legislation improvements, which once in place will provide guidance in regard to IT solutions, hardware, and software requirements. The outputs, from the interviews conducted, suggests a need for an initial standardised approach to hardware solutions, it is believed these should be followed by software guidance to ensure AWSDs are compactable with the agreed hardware solutions. The common opinion that relates to construction site setups involve a hardwired internet connection, that supports a whole site WIFI infrastructure. The results obtained suggest that the standardisation required will be in relation to legislation, programming, IT collection, cloud-based storage solutions and use of the data collected.

Gaining an understanding of the requirements of implementing standardisation protocols relating to both hardware and software technology aligns with the objectives outlined in this research study. The recognition of the importance of AWSD standardisation is widely acknowledged as an essential requirement, ensuring the technology is harnessed to its full potential. Upon the establishment of agreed standards, it is believed tangible enhancements in construction workers' personal health and safety will be realised, the resultant improvements will play a pivotal role in advancing the research aim. This progress will be driven by the development of more positive attitudes and behaviours towards the incorporation of AWSD technology, ultimately contributing significantly to the desired outcome.

The execution of legislative measures to establish standardisation is inherently a time-consuming process, and this aspect constitutes a notable constraint. Once agreed it will then need to be decided how and when the technology should be introduced, alongside the selection of a responsible organisation to oversee its implementation. An additional limitation surfaces concerning the financial implications associated with introducing the technology; these expenses are fundamentally linked to the standardisation of both hardware and software components, necessitating approval from both clients and construction companies. As well as covering the technological aspects, these costs must encompass all related elements, including education and training initiatives, as well as the monitoring and documentation of outcomes resulting from the technology's implementation.

The author supports the view that the standardisation of hardware and software solutions is essential to the introduction of AWSDs into construction processes. Once in place, it is believed the technology will greatly assist with improving the personal health and safety of construction workers.

5.3. DISCUSSION 4 – PROMOTING THE BENEFITS OF ADOPTING AWSDs

5.3.1. How can AWSDs be used to improve construction workers personal health and safety

The findings concerning the potential enhancement of construction workers' personal health and safety through the integration of AWSDs align with the insights highlighted in the literature review, as detailed in section 2.1.2. This Illustrates that AWSDs present the prospect of enhancing construction workers' safety, which aligns with all the interviewed participants. The planned improvements are anticipated to stem from advancements in technology encompassing both hardware and software solutions, alongside the adoption of AWSDs. Further alignment is noted pertaining to the incorporation of biometric sensing devices and utilising hardware solutions for efficient data management. Several participants suggested that AWSD implementation could yield positive outcomes for workers' mental well-being. However, the findings also illustrate the identification of barriers that harbour certain reservations, these reservations predominantly centre around workers' attitudes and behaviours, a knowledge gap, the intricacies of AWSD implementation, and the associated financial implications.

Improvements in construction workers personal health and safety can be achieved by biometric monitoring (brahim et al., 2023-b). The implementation of health monitoring can produce notable advantages in terms of timely detection of health concerns, facilitating the prompt application of treatments or preventative measures aimed at mitigating risks and enhancing overall well-being.

Limitations were highlighted suggesting the promotion of the benefits of adoption is hampered by, the associated costs, (Ibrahim et al., 2023-b), the lack of knowledge regarding technology deployment (Aghimien et al., 2022), and the attitudes and behaviours of construction workers (Schall et al., 2018-b).

The outcomes highlight a notable hesitancy towards embracing AWSDs among construction workers, originating from concerns of being subjected to a surveillance reminiscent of a Big Brother scenario, where their ongoing location and productivity are subjected to constant monitoring. From the author's perspective,

it becomes imperative for construction companies to navigate this situation carefully in order to encourage a favourable reception of the technology. Assurance needs to be extended that the data related to their location and productivity won't be utilised in a penalising manner. It should be highlighted that the fundamental intention behind the implementation of AWSDs is to primarily monitor and enhance their personal health and safety standards.

5.3.2. How can AWSDs be used to ensure compliance with legal acts and regulations.

There was a unanimous response indicating agreeance that AWSDs can be used to improve compliance with legal Acts and Regulations, references were made to specific legislations where it is believed AWSDs could assist. The Acts and Regulations highlighted relate to the Health and Safety at Work etc. Act 1974 (HSAWA, 1974, n.d.-b), the Construction (Design and Management) Regulations 2015 (CDM 2015, n.d.-c) and the Working Time Regulations 1998 (The Working Time Regulations 1998, n.d.). It is believed the utilisation of AWSDs will assist compliance by enhancing the personal health and safety of construction workers, leading to a direct improvement in health and safety compliance statistics, benefiting both the Health and Safety at Work etc. Act 1974 and the Construction (Design and Management) Regulations 2015. Monitoring operatives working hours and ensuring adequate rest breaks are taken will ensure compliance with the Working Time Regulations of 1998.

The individuals interviewed raised apprehensions linked to costs associated with the necessary training, the devices themselves, hardware solutions, and the overall implementation process. They also voiced concerns about the reluctance displayed by construction workers toward accepting AWSDs. The consensus among the participants was that these apprehensions represent obstacles that must be overcome to facilitate the technology's acceptance.

The findings suggest an area of improvement related to enhancements of the Construction (Design and Management) Regulation 2015, which implies that wearable technology should be a compulsory consideration in the hierarchy of controls when detailing construction risk reducing measures.

The author is of the opinion that integrating AWSD technology will contribute to enhancing adherence to existing legislative mandates. To fully realise these advantages, it will be essential to observe enhancements in the health and safety culture within the construction industry. Construction health and safety culture can be improved by understanding the technology, this can be experienced through the introduction of education and knowledge sharing initiatives, as well as any necessary legal measures to promote the adoption and utilisation of AWSDs and the associated technology.

5.5. DISCUSSIONS 5: SOLUTIONS REQUIRED TO ENABLE ATTITUDE AND BEHAVIOURAL CHANGE

5.5.1. Responsibilities of construction companies, technology developers and education bodies

The findings suggest a unanimous belief among all interviewed respondents that construction companies, technology developers, and educational institutions, collectively representing the construction industry, bear the responsibility of offering training programs and initiatives. These initiatives are meant to foster awareness and education among construction workers regarding available technology for enhancing their personal health and safety; it was widely agreed that this responsibility should be compulsory. Currently there is an absence of construction related training that provides guidance on technology aimed at improving the personal health and safety of construction workers, as highlighted in section 2.1.6. This shortcoming results in a lack of knowledge and the development of unfavourable attitudes and behaviours toward technology adoption. From the conducted interviews, a prominent factor identified is the lack of awareness. It was suggested that conducting demonstrations in conjunction with relevant training would facilitate better understanding. There is a general consensus that the training should encompass not only AWSDs and the associated technology but also IT management aspects, including data collection, storage, and utilisation alongside any related legislative requirements.

Identified enhancement measures are deemed necessary for facilitating the required knowledge-sharing initiatives. It is believed that enhancements are needed in IT storage solutions for effective management of construction workers' personal data, the standardisation of AWSDs with guiding principles to ensure compatibility and compliance, the implementation of legislative improvements, and an understanding of the planned technology integration. Once these components are established the associated information can be circulated through construction related education programs and training schemes.

The author agrees that the construction industry as a whole bear an obligation to educate construction workers about technologies capable of improving their personal health and safety; it is believed that if deemed reasonably practical, these devices should be made available to construction workers at the earliest opportunity. The author's perspective is that the integration of the identified enhancements will require a period of time to implement, as such, it is believed that interim measures should be considered to allow for the realisation of personal health and safety benefits from the technology. This approach could be taken whilst agreement, standardisation and implementation of the technology is being processed.

5.5.2. Changes in current legislation

The findings relating to changes in current mandates generated outputs that indicate legislation should be amended to allow for the integration of AWSDs and the associated technology, this was identified in the literature review, see section 2.2. It was agreed by the majority of the interview respondence that further research is required to ensure a complete comprehension of the key factors is in place before implementing

any legislative changes. The discussion around how to implement any legislation into the current Acts and Regulations produced a general consensus that these should be introduced via a phased approach. It was suggested that the implementation for a compulsory legislative backed strategy should be initially introduced to tier 1 contractors on mega or large construction projects, alongside any construction environments that are deemed high-risk, such as underground works akin to mining or works undertaken in refineries or on oil rigs. Some concerns were expressed regarding AWSDs and the suitability of these devices in certain construction environments, such as dangerous substance and explosive atmospheres, as well as environments where the transmitted signals produced by AWSDs may interfere with operational practices. Additional concerns were raised regarding costs, specifically when the technology is introduced to other areas of construction, and it then starts to affect small companies with limited budgets.

It is believed that various constraints with implementing the legislative requirements will lead to a prolong integration. These challenges pertain to the identification and validation of the necessary legislation, the designation of appropriate organisations to execute new policies or update existing ones. There will also be a requirement for oversight and reporting regarding the outcomes of legislation implementation and its associated technology, an appointment will need to be made in this regard. Additionally, there will be time restraints associated with the integration of the technology along with the correlated legislation; this will demand a well-structured approach for its introduction, involving identifying construction projects and contractors that should be initially mandated to incorporate AWSD technology as a compulsory component within their construction projects.

It is the opinion of the author that a phased approach to implementing the AWSDs and any associated legislation is appropriate and sufficient. This approach will enable supportive data to be produced and presented to promote the gradual integration of the technology into other areas of construction.

5.6. KEY TOPICS 3, 4, & 5 OVERVIEW

The findings suggest common themes across all 3 main interview topics discussed and analysed, see section 4.1, these relate to the following.

1. A noticeable deficiency in understanding exists concerning AWSD products and the associated technology, as well as the advantages these devices offer for the personal health and safety of construction workers.
2. Attitude and behaviours of construction workers toward the adoption of AWSDs.
3. Legislation improvements required.
    a. To implement software and hardware standardisation requirements.
    b. Improvements to education content and training schemes.
    c. Health and safety legislation related to health and safety technology.
    d. IT storage solutions regarding the collection, storage and use of construction workers' personal health and safety data.

Key topic 3 - Understanding the barriers and obstacles to the adoption of AWSDs. The findings identify the lack of knowledge, standardisation, and legislation improvements as key factors that need to be improved to enable barriers and obstacles to be removed. This will then support a change in attitudes and behaviours towards AWSDs acceptance by workers across the construction industry.

Key topic 4 - Promoting the benefits of adoption of AWSD's. This would enable construction workers to become more aware of the advantages to their own personal health and safety, in turn this would assist with breaking down negative attitudes and behaviours of those resistant to change. It is evident that the concept of AWSDs is seen positively. It is believed that if implemented the use of AWSDs could assist with various legislative compliance requirements.

Key topic 5 - Solutions required to enable attitude and behavioural change, suggests that the responsibility of providing relevant training to promote awareness, in regard to AWSDs and the associated technology, needs to be made compulsory to ensure an understanding of the benefits of use are in place. A good level of discussion, relevant to this research study, was undertaken regarding the implementation of AWSDs and any required legislation improvements. Addressing these factors is crucial for facilitating a shift in the attitudes and behaviours of construction workers, which ultimately will enable the successful integration of AWSDs into the construction industry.

The author is of the opinion that the general lack of knowledge that is identified can be addressed by implementing educational content into construction related training courses and schemes; legislative improvements can assist with implementing relevant education content, standardisation, and data management which will then enable improvements in attitudes and behaviours towards AWSDs adoption to be experienced. It is believed that if solutions can be implemented to address the issues identified, this will then lead to the research objectives being met, which will then enable improvement measures to be identified that will assist with achieving the main research aim.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1. REFLECTIONS AND REVIEW OF AIMS AND OBJECTIVES

The findings acknowledge extensive technology growth, this has seen the evolution of advanced wearable sensing devices (AWSDs) that are now available and that have been specifically designed to improve construction workers personal health and safety. These devices monitor workers' biometrics by placing microchip technology into wearable personal protective equipment (PPE), construction clothing, and wearable devices, allowing early warnings to be issued regarding any identified personal adverse health conditions. This technology has been used in other areas of industry, such as production; it was noted that the construction industry is deemed to be lagging in terms of adoption.

To address the issue of adoption, a main aim of enhancing construction workers personal health and safety through improved attitudes and behaviours towards the adoption of AWSD technology was identified. To enable this to be achieved sub-aims were recognised, they relate to:

1. Understanding barriers and obstacles toward adoption
2. Promoting the benefits of adoption
3. Identifying solutions to attitude and behaviour change.

These sub-aims were then assigned objectives to enable the main aim to be achieved, with an overall objective of presenting solutions and improvement measures relevant to addressing attitude and behaviour change towards the adoption of AWSDs.

The benefits to construction workers' personal health and safety through the utilisation of AWSDs in construction site environments is evident. Some workers are receptive to change and will embrace the adoption of AWSDs and some are set in their ways and need to be convinced the recommended changes are in their best interests. The gathering of personal information, its use, and its storage is a main topic of concern alongside having workers locations and their productivity monitored. To enable construction workers acceptance of AWSDs and the associated technology there may need to be a relaxed attitude from employers.

6.2. WHO WILL MY RESEARCH BE ADOPTED BY

It is believed that the research, if adopted, could be of benefit to organisations that are related to AWSD technology and its implementation and use within the construction industry, whether indirectly or directly. The following have been identified:

- Technology manufacturers could use the research to identify potential future enhancements that are required to ensure products are aligned with suggested standardisation and legislative improvements.

- Construction companies could develop insight into potential obligations associated with the introduction of AWSDs. Being informed in advance could facilitate a robust preparation for a state of readiness prior to actual implementation
- Colleges and training organisations could obtain understanding of the potential content that may need to be added to their training programmes, this would enable awareness of potential changes that could be required of them.
- Relevant government departments could identify areas where they believed legislation changes may be required.
- Construction organisations such as the Chartered Institute of Building (CIOB) and the Association of Project Managers (APM) could track the implementation process and keep their members updated.
- The Health and Safety Executive could look at any improvements to their regulations, processes, and procedures that may be required to accommodate the implementation of AWSDs.

6.3. FUTURE RESEARCH

It is believed the research conducted and the findings recorded represent a good foundation for future research studies. It's recommended that any future research considers looking at completing a full study that obtains the thoughts, opinions, and experiences of construction workers. The findings could then be considered alongside the outputs from this management study to assist with further understanding. Additionally, research could be undertaken in relation to the data management solutions required to support the rapid expansion of data produced regarding AWSDs, specifically looking at the validity of current legislative requirements regarding data collection, storage, and use; further expansion of this study could investigate IT security, data leaks, and future data storage requirements.

6.4. KEY FINDINGS AND RECOMMENDATIONS

The outputs resulting from the findings suggests negative attitudes and behaviours toward the adoption of AWSDs by construction workers is directly linked to a lack of knowledge regarding the technology and the personal health and safety benefits of its use. It was identified that there is no technology content included within current construction related education courses and training schemes, it was further identified that generally employers, technology developers and education bodies do not currently provide training or knowledge sharing initiatives regarding AWSDs. It is recommended all construction related education courses and scheme should incorporate technology content to promote understanding on how to use these devices, the benefits of use, and how the related data is managed. Additionally, it is believed that companies should have a statutory requirement to promote AWSDs and their associated technologies through internal training schemes such as e-Learning or demonstrations delivered by the technology manufacturers.

It was highlighted that there is a distinct lack of standardisation regarding the hardware and software solutions required to support the use and integration of AWSDs on all construction sites. It is recommended that guidance is offered to ensure a common data environment is in place for each site, supported by a stable internet connection which will allow construction workers to couple their software devices enabling the monitoring of personal health and safety to be undertaken and relevant warnings to be issued. This approach will require input from relevant governing organisations, construction bodies, and technology developers to ensure suitable solutions are presented and agreed.

The following improvements to current legislation are recommended due to the personal health and safety benefits construction workers could experience if AWSD technology is implemented throughout the construction industry.

- The inclusion of relevant content in all construction training courses and schemes pertaining to health and safety technology.
- Ensure AWSD technology is considered as a compulsory element to the hierarchy of controls under the Construction (Design and Management) Regulations 2015.
- Ensure guidance is offered regarding the standardisation of software and hardware solutions for construction sites regarding the use of AWSDs.
- Update current legislation or the construction of a new policy that specifically offers guidance on construction workers personal data management, this should cover the collection, storage, and use of personal information, it also needs to address security issues, data leaks and future expansion.

It is recommended that the implementation of any legislation relating to the employment of AWSDs should be introduced via a phased approach. The initial rollout could focus on tier 1 companies engaged in substantial construction projects or those handling projects with high-risk profiles. Information supporting the benefits of AWSDs can then be produced to promote acceptance before being integrated into other areas of construction.

6.5. IMPACT OF IMPLEMENTATION

Education and training enhancements will lead to relevant knowledge being extended to all regions of the construction industry, resulting in heightened attitudes and behaviours towards the adoption of AWSD's, improved industry wide health and safety culture, and an enhance construction industry safety reputation (Okpala et al., 2021). Reducing or eliminating the perception that construction is a dangerous working environment will allow the construction industry to become a more appealing career choice to a wider and more diverse demographic (Randstad, n.d.). A good health and safety record will also assist with improving workers productivity and staff retention, (Staff Retention, n.d.). Additionally, a reduction in construction site accidents and fatalities will result in reduced costs for construction companies due to less claims being processed (EcoOnline, n.d.).

To support this implementation process there will be a requirement to assess current legislation to ensure guidance is in place to assist with the employment of AWSDs, this will impact the individuals and the organisations responsible for managing and updating the relevant Acts and Regulations. There will also be an unknown period of time associated with obtaining the approvals for relevant legislations, this will impact when the benefits of adoption are experienced by construction workers. Once guidance is in place, to ensure compliance, further ramifications will be experienced by technology developers who will have to adapt their equipment and data storage solutions, as well as education bodies who will need to update their course content. If the updated legislation is aligned with a phased approach to the implementation of the technology, the initial schemes selection for implementation will identify contractors that will be required to comply, they will be impacted as they will need to ensure investment is in place to support the required changes, as well as ensuring relevant training is undertaken by managers and site operatives. There will also be a requirement to monitor and record the benefits of using AWSDs, this will impact the construction companies and the bodies enforcing the legislation change.

6.6. LIMITATIONS

The study is limited as only fourteen management professionals were interviewed, they represent the UK construction industry primarily, there was no interviews conducted with construction workers. Additionally, a thematic analysis was conducted of the data produce, Thematic Analysis, (n.d.-b) suggests limitations of a thematic research relate to the identification of relevant text and associated themes. It is believed that this is largely due to personal interpretation and the information selected for analysis may not correspond with others undertaking the same research.

APPENDICES

APPENDIX A - DISSERTATION INTERVIEW QUESTIONS

Dissertation Title

Attitude and behaviour change in adopting advanced wearable sensing devices by construction workers to improve personal health and safety.

Part 1 – Introduction background and experience

Initial engagement: Seek verbal confirmation of participant acceptance to video and audio record the interview, also ensure they understand transcripts will be produced and how their data will be managed. Once confirmation has been obtained ask them if they have any concerns about the interview, if yes make sure these are address before moving forward. Finally, ensure an understanding is in place regarding their right to withdraw consent at any stage before the data analysis is undertaken.

Start the video and audio recording. Thank the participant for attending, confirm their name and they that have completed the consent form and the dissertation participant schedule.

Q 1. Could you please tell me how long you have worked in construction and the various construction related jobs you have held throughout your career? *Develop the conversation to ensure a full understanding of the participants construction background is understood. (1-2 minutes)*

Q 2. What construction related education courses and training schemes have you attended? *Let them answer before probing deeper into schemes such as apprenticeships, SSSTS, SMSTS, CSCS etc. (1-2 minutes)*

Q 3. Do you believe there is sufficient educational content within current construction training processes and training schemes to promote the personal health and safety benefits of adopting innovative digital technologies? *If yes ask:* What content has been included in training courses you have attended? *If no ask:* Can you explain why? *Let them answer before probing deeper to gain a better understanding of their prospective. (2-3 minutes)*

Before moving to the next question show them images of AWSDs and discuss these.

Q 4. Does your company/employer currently use AWSD's as a tool to improve your operative's personal health and safety? *If yes ask:* What type of devices do you use? *If no ask*: What is preventing you from using AWSD's? *Let them answer before probing deeper to understand their perspective. (3-5 minutes)*

Part 2 – Understanding barriers and obstacles in adopting AWSD's

Q 5. In your opinion what are the main barriers and obstacles hindering the adoption of AWSD's? Deep dive into the response given *by asking* 1. Why they consider this to be a barrier. 2. Do they consider this a major

and or minor barrier. 3. Can they relate their response to a project they have been involved in. *Consider their response to Q 4.* Understand the differences in response between someone who has already adopted AWSD's and those who haven't. *Let them answer before probing deeper to gain a better understanding of their prospective. (3-4 minutes)*

Depending on the answers given move on to question 6-9 below.

Q 6. In your opinion do construction workers believe AWSD's are difficult to use and may hinder or impact their daily work activities? *If yes ask*: Can you explain why? *If no ask*: Can you explain why? *Let them answer before probing deeper to gain a better understanding of their prospective. (2-3 minutes)*

Q 7. Do you think construction workers harbour concerns regarding how AWSD's collect their personal data and how that data is then stored? *If yes ask*: What do you think these concerns are, and do you have any justification for those concerns? *If no ask*: Why do you think they are not concerned? *Let them answer before probing deeper to gain a better understanding of their prospective. (2-3 minutes)*

Q 8. Do you believe construction workers having their site location monitored continuously will bother them? *If yes ask:* Can you explain why? *If no ask*: Can you expand on your response? *Let them answer before probing deeper to gain a better understanding of their prospective by looking at the associated monitoring of activities including the number and the duration of any breaks that are taken. (2-3 minutes)*

Q 9. Do you believe the software and hardware solutions relating to the adoption of AWSD's is lacking standardisation resulting in limitations of the technology? *If yes ask*: Can you explain your thinking? *If no ask*: Can you justify your response? *Let them answer before probing deeper to gain a better understanding of their prospective. (2-3 minutes)*

Note the response give in this section and revisit these in part 4

Part 3 - Promoting the benefits of adoption of AWSD's

Q 10. In your opinion how do you think AWSD's can be used to improve construction workers personal health and safety? *Then ask:* In your opinion what are the positive and negative factors of adopting AWSD's? *Let them answer before probing deeper into the personal Health and safety benefits that have not been discussed such as biometric data, heart rate and respiration, to detect signs of fatigue, heat stress, or other health issues to gain a better understanding of their prospective. (2-3 minutes)*

Q 11. Can you explain how AWSD's enhance construction workers environmental health and safety? *Discuss their response by talking about how AWSD's can monitor environmental conditions, such as temperature, humidity, and air quality, in real-time. This information can help workers avoid exposure to hazardous conditions and take necessary precautions to protect themselves. Discuss how warning messages can be sent*

to construction workers via AWSD's informing them of hazardous conditions they may be near and advising on risk reducing measures that should be taken. (3-4minutes)

Q 12. How do you believe AWSD's can be used to ensure compliance with legal Acts and Regulations such as The Working Time Regulations (1998) and the Health and Safety at Work etc Act 1974? *Let them answer before probing deeper to gain a better understanding of their prospective, discuss how the technology could be used to conform with the Construction (Design and Management) Regulations 2015. (3-4 minutes).*

Part 4 – Solutions required to enable attitude and behavioural changes

Q 13. You previously stated that the main barriers to adopting AWSD's by construction workers are, Barriers 1,2,3,4 etc. *Ask:* In your opinion what can construction companies, technology developers, educational bodies and training schemes do to solve these outstanding problems? *Let them answer before probing deeper to gain a better understanding of their prospective. (4-5 minutes)*

Q 14. Do you think AWSD's, and innovative digital technologies should be a compulsory training element for construction workers? *If yes ask*. How do you think this could be achieved. *If no ask:* Why do you think this. *Let them answer before probing deeper to gain a better understanding of their prospective. The conversation should be led to ensure discussion on the involvement of organisations such as apprenticeship schemes, Construction Skills Certification Scheme (CSCS), Site Supervision Safety Training Scheme (SSSTS) and the Site Management Safety Training Scheme (SMSTS). (3-4 minutes).*

Q 15. Due to the rapid expansion of technology and its inevitable increased use to maximise construction workers personal health and safety, do you think there should be improvements made to current legislation to manage this. *If yes ask:* What legislation amendments do you believe should be implemented? *If no ask:* How do you believe technology advancements should be managed? *Let them answer before probing deeper to gain a better understanding of their prospective. Expand the discussion to include legal Acts and associated Regulations such as GDPR (which is related to EU's data protection), The data protection Act 2018 (applicable to the UK since Brexit), The Health and Safety at Work etc Act 1974 and The Construction (Design and Management) Regulations 2015. Should these be updated to include the use of technology to enhance the personal health and safety of construction workers. (3-4 minutes).*

Q16. *If yes to Q15 ask:* How do you think this should be undertaken. *Let them answer before probing deeper to gain a better understanding of their prospective. Expand the discussion to include full implementation and Partial implementation, discuss projects such as High Speed 2, rail project (HS2), mining etc*

APPENDIX B – INTERVIEW FINDINGS

OVERVIEW OF RESPONSES TO THE DISSERTATION QUESTIONS

THEMES (KEY)

- Participant Details
  - Experience
  - Qualifications
  - Associated Organisati
- Attitudes & Behaviours
  - Lack of Knowledge
  - Negative
  - Positive
  - Barrier & Obstacles
- Health and Safety
  - Mental Health
  - Biometrics
  - Accidents
- Implementation Of AWSDs
  - Training Course and Schemes
  - Demonstrations
  - Education
  - Legislation
- Technology
  - AWSDs
  - IT Storage
  - Hardware
  - Software
- Cost

Question 1: Could you please tell me how long you have worked in construction and the various construction related jobs you have held throughout your career?

ID	POSITION	RESPONSE			
		EXPERIENCE	ORGANISATION	HIGHEST QUALIFICATION	KEY
1	MD	25 + years on Small and large construction sites	Tier 2	Undergraduate Degree	
2	PM	25 + years on Small and large construction sites	Tier 1	Trader Qualification	
3	SM	25 + years on Small and large construction sites	Tier 1	College	
4	SP	20 - 25 Years Small and Large construction sites	Tier 1	Professional Qualification	
5	HOP	25 + years on Small and large construction sites	Tier 1	Professional Qualification	
6	PD	25 + years on Small and large construction sites	Tier 1	Postgraduate Degree	
7	PD	25 + years on Small and large construction sites	Tier 1	Undergraduate Degree	
8	PM	25 + years on Small and large construction sites	SME	Professional Qualification	
9	SM	15 - 20 Years on Small and medium construction sites	Micro-Entity	Trade Qualification	
10	HSM	20 - 25 + years on Small and large construction sites	Tier 1	Professional Qualification	
11	HOP	25 + years on Small and large construction sites	Tier 1	Undergraduate Degree	
12	PD	25 + years on Small and large construction sites	Tier 1	Undergraduate Degree	
13	PD	25 + years on Small and large construction sites	Tier 1	Trade Qualification	
14	MD	25 + years on Small and large construction sites	Tier 2	Postgraduate Degree	

Question 2: What construction related education courses and training schemes have you attended?

ID	POSITION	RESPONSE	KEY
1	MD	Management Courses, CITB Black CSCS Card, Safety Management	
2	PM	NEBOSH, IOSH, SMSTS, CSCS card, City and Guilds	
3	SM	MOD Standard Management training AP, Chemical AP, Confined Space AP, Medical Gas, Safe Opening Diploma, CDM, IOSH, NEBOSH l, L8, Asbestos, 18th Edition IEE Wiring Regulations..	

4	PM	NEBOSH, IOSH, SMSTS, CSCS Card, City and Guilds, Professional Qualification	
5	HOP	Professional Qualification, ONC, HNC, NEBOSH, IOSH, SMSTS, CSCS Card, City and Guilds	
6	PD	Postgraduate Degree, NEBOSH, SMSTS, CSCS	
7	PD	Undergraduate Degree, Fire Safety, NEBOSH, IOSH, SMSTS, CSCS card	
8	PM	Professional Qualification, NEBOSH, IOSH, SMSTS, CSCS Card, City and Guilds	
9	SM	City and Guilds, 16th Edition IEE Wiring Regulations, NEBOSH, IOSH, SMSTS, CSCS Card,	
10	HSM	Professional Qualification, NEBOSH, CDM, Basic Explosives, Incident Investigation,	
11	HOP	Undergraduate Degree, National Diploma, Higher National Certificate, Fire Safety, Regulatory Compliance, Asbestos, NEBOSH, CDM,	
12	PD	Postgraduate Degree, ILM 5, NEBOSH Construction, CDM, City & Guides	
13	PD	Trade Qualification, HND	
14	MD	Postgraduate Degree, NEBOSH, SMSTS, CSCS, City and Guilds	

Question 3: Do you believe there is sufficient educational content within current construction training processes and training schemes to promote the personal health and safety benefits of adopting innovative digital technologies? *If yes ask:* What content has been included in training courses you have attended? *If no ask:* Can you explain why?

ID	POSITION	RESPONSE	Key
1	MD	No not currently, but I think they differently should be for construction workers undertaking certain projects, like the mining industry and some of the larger construction projects, they're so vast.	
2	PM	No, to be quite honest with you. Unless someone introduces the content to the training modules than the trainer won't know a lot about it, how can he train somebody if he's not aware of it himself?	
3	SM	No, they train you how they want you to do it. You've got to cherry pick what's on these guidelines to fit the environment that you're in. They want to follow it to the law, but it's very selective. A smaller companies deliver it better than large institution.	
4	SPM	No, there wasn't. Not when I did my courses. I don't know if it's changed in the last five years, but there was no specific reference for using technology for personal health and safety at the time. My employer doesn't provide specific technology training in terms of personal health and safety, not really at all. They use digital technology to provide online training, but the training itself does not include specific content regarding the use of technology for my personal health and safety well-being.	
5	HOP	So, in terms of technologies not at all, courses normally get you to think about health and safety to get you to know the general rules about it. But when we talk about technology, I can't think of any course that I've been on that's actually brought technology into it.	
6	PD	No, I don't believe these educational courses have content in regarding the benefits of promoting adoptable wearable sensing devices or innovative digital technology.	
7	PD	No, I don't. I think I might have the premise for a design in my head around safety and occupancy and movement around construction sites, it's not too dissimilar to how you might analyse the players movements on a soccer pitch or a football pitch. I do see this as hugely important; you know, site safety is something that sits very, very dear to my heart. In my family my dad a was Site Safety Manager on a very, very big innovative construction job in rural Ireland where they were building a very high efficiency heat burning power station and regrettably, in the early stages of the steel construction, a steel worker overreach slipped and despite wearing a fall arrest system fell to his death in a flue tower, I saw what that did to my dad in terms of police involvement, HSE involvement, subsequent court case involvement, and whilst I knew my dad was diligent and would have crossed the T's and dotted the I's, it was not nice to see the impact of that review and investigation and subsequent court cases that it had on not only him, but people in the immediate family.	

8	PM	I've been involved in the personal monitoring equipment for harmful radiation basically, but in terms of all the types of personally worn technology outside of the clothing, no.	
9	SM	Not specifically in those courses, no. There were technologies that were worn, but that's more specific to other AP courses that I've done, that's mainly if working in confined spaces where you have a detector, which is a gas detector, giving you indication of danger within the area. But apart from that there's not many other courses that have been on that have indicated that there are new technologies available now for improving the health and safety and well-being of the individual. I mean the conversations we had within the courses was you identify your risks, you do your risk assessment and then you look towards technologies which can obviously reduce the risks even further or eliminate the need for doing certain things., with the newer technologies that are coming on the market these days, there's much more out there that's available to us today.	
10	HSM	No, because I think probably that's a more like something that's coming into use just now than in recent years. The training I've done was before those things were very commonplace. The only personal wearable monitoring I've been involved in is things like exposure monitoring checking on the exposure levels during the working day.	
11	HOP	To be honest with you, it's a new concept to me. So no, I think it's a simple answer to that one. As I'm not aware of this kind of thing, if I'm honest.	
12	PD	No, I don't think they do touch on it as much as they possibly could. The evaluation of the construction industry in terms of production and the Industrial Revolution 4.0 is accelerating a pace, but I feel that construction health and safety around AWSDs and the related benefits are lagging a little in terms of training and awareness of the products.	
13	PD	Specifically, around improving technology, I would suggest not. I think there is good, sound, health, and safety training through IOSH, NEBOSH, and through CDM, training courses, etcetera also through the project management and site manager courses in the construction industry. But focusing on technology, I'm not aware that there is good depth of course available in that regard.	
14	MD	No, and we work on a of a lot of construction sites in many different sectors. So other than people having watches I've not seen as anything like that technology before.	

Question 4: Does your company/employer currently use AWSD's as a tool to improve your operative's personal health and safety? *If yes ask:* What type of devices do you use? *If no ask*: What is preventing you from using AWSD's?

ID	POSITION	RESPONSE	KEY
1	MD	No, we don't. We've not had the need to use these or been advice that we should be using them, I have never really been aware of what the benefits are until you just discussed it with me. So, it's maybe something that we might consider in the future. I don't think there is any barriers to be honest, I think anything that can help the industry develop and be a safer environment to work in should never be a barrier	
2	PM	Not to my knowledge, I can't think of any situation where we have used this technology. They have been used for two reasons, no one has ever been made aware of these devices that were shown at the start of this interview and two, money.	
3	SM	I've not come across it in the companies that I work with or for, and I've worked with a few blue-chip companies. I guess it's the buy in from the individual that's wearing it, if you haven't got the buy in from the engineer, you can lead a horse to water, but you can't make it drink.	
4	SPM	I haven't really seen anything apart from lone working devices, but then that's just basic radios. I think it's knowledge, as the examples you just showed me is the first time that I've seen these or anything like these, I was not aware these were on the market. So, I just think it's a lack of knowledge, not knowing about these products.	
5	HOP	No, the only the technology that we got right now is apps basically. So, they've got one called stay safe, and that's mainly for loan working.	

6	PD	No, I'm not aware of anything now. I have very little doubt whether that this sort of thing is happening. We've got lots of high-risk things going on in different areas. If I'm not aware where that's happening and how that's working, then it certainly isn't happening in my sphere of influence if that that makes sense, but that that is, you know, 10% of a global organisation, construction management organisation.	
7	PD	In some of our deployment cross our business we do wear body cams for their personal protection but also to record incidents that they may come across, we have those quite a lot within our security business and a lot of our hospitals where you know you're dealing with members of the public. We have deployed technology to protect its employees. We've got a movement detection system as well around telephones and handsets to make sure that the person is not slumped in an isolated location. We're very much deploying them in security as a business offering. But we're particularly deploying them in construction site were where our officers and staff interact with members of the public and contractors. We know sometimes depending on different external stresses people can be unpredictable. So, it's good that they're there to protect your staff and to record known incidents and have evidence of this. These body cams I do see them being extended where a site manager or project manager could be recording their safety tours of safety audits. I think a body Cam deployed there would be beneficial. So, you're picking up live information or live behaviours as the individual is walking around that would be useful.	
8	PM	The only thing I would think of would be when you go into a confined space, those kinds of sensors, my company has that technology available but I'm not aware of any specially for lone working.	
9	SM	Not that I'm aware of, certainly not on this contract. They may well use them in other areas, but that information hasn't been filtered down to the wider team. The only devices we would have at the moment is a handheld radio and that relies on the individual calling in at certain prearranged time periods to make sure that they're OK.	
10	HSM	The glasses we're actually working on something like that at the moment, but not necessarily from a health and safety point of view, although you could interpret it like that because they're working on a system whereby engineers that are going out probably on their own some remote site and they need to service or repair a complex piece of equipment. The information is collected by a camera, and which includes audio so a remote person can guide and instruct the infield engineer in what to do next or how to solve the problem. It's technical support primarily for remote workers.	
11	HOP	No, not aware of them. My gut feeling is some of them will be seen as Big Brother and some contractors would deliberately, accidentally damaged them for that purpose. I'm very aware of my Health and Safety banner. I've looked at several different aspects of things like loan working as a particular one and I'm aware of certain devices that are available for lone workers and actually vehicles now have this device on. I believe the new iPhone has got a device that detects if you've fallen over, but what stopping us implementing these AWSDs is lack of knowledge of their availability and understanding of what they can do to keep our sites safer.	
12	PD	The HoloLens, yes, we use that within our business, you know we're on a global account, so we'll regularly ship a set of HoloLens, we've got two sets on this particular account around the globe in a strong box if it's something that's a benefit. The smartwatches, I think we sometimes use similar devices when we're working in confined spaces, I haven't seen the wearable sensing hi viz but I think it's an excellent idea, I've not seen the hard hat before either, they sound very similar to the sensor in the back of a high viz. Awareness is the only thing stopping us from adopting AWSDs, the awareness of what technologies there is out there that they could adopt within our construction sites; so each individual is taking an ownership and responsibility for sending everybody home safe and sound, then that can only ever be a good thing.	
13	PD	Yes, I have possibly. I mean, that's quite sophisticated when we're saying about a jacket with sensors that monitors people's well-being and heart rates etcetera and glasses that would then capture the safe activity for me. In my career an area of focus is more around lone working and because lone working is a risk for us in projects. What's preventing us implementing AWSDs is an awareness around the technology to potentially a cost benefit analysis. Moving forward we are a large business and a large organisation, and we would have to adopt the right system that fits.	

		Then any investments in technology across the board could be very significant so that will then sit with our specialist health and safety department and division to analyse that. It's absolutely our number one priority to keep people safe on our sites.	
14	MD	We do use some technology for lone working. Health and safety is a big thing for us, and we try and follow everything that's industry standard. It is difficult because if we're not principal contractor and we're set under another account, you're trying to adopt what they've done. So, sites we'll go to, and everything is fully compliant and then other sites we'll go to, and I've got my guys raising questions to me about the principal contractor. It's so varied out there regarding companies actually meeting the minimum requirements anyway. So, for something like this, I've not come across it, but the thing is now that you've kind of made it aware to me, maybe it is out there and I've kind of not seen it, but it's clearly not on any of our projects.	

Question 5: In your opinion what are the main barriers and obstacles hindering the adoption of AWSD's? Deep dive into the response given *by asking* 1. Why they consider this to be a barrier. 2. Do they consider this a major and or minor barrier. 3. Can they relate their response to a project they have been involved in. *Consider their response to Q 4.* Understand the differences in response between someone who has already adopted AWSD's and those who haven't

ID	POSITION	RESPONSE	Key
1	MD	I don't think there is any barriers to be honest, I think anything that can help the industry develop and be a safer environment to work in should never be a barrier. I'm not sure what the costs are for purchasing and implementing AWSDs, because I'm not aware of the products, but I think health and safety is paramount and costs should not be a factor.	
2	PM	You might not be able to wear those devices because of the high-risk environment I work in, a risk assessment would have to be put together based on what tasks were being undertaken, and then I'm sure something could be adapted or made to give you the same benefits as the ASWDs that you've just shown me. The main reasons for not adopting these devised is as you get older people don't like change, normally human nature takes us a little bit of time to adapt to the change, it will come back to the cost.	
3	SM	Cost, companies have got to have this within their budget, this would be a major barrier. Companies love doing the online PC training and it just isn't real life training.	
4	SPM	People's mindset. They could see it as another way to keep tabs on them, like a Big Brother aspect, where people are monitoring continuously to see how they are preforming. That's going to be a big hurdle. some site restrictions could be a hurdle depending on what sort of signals the equipment gives off. I obviously working in a refinery, it's very restricted with regards to mobile phones because of certain products they use, with the petrol and diesel refinery process you can only use certain equipment.	
5	HOP	One of the biggest barriers, which is always people and change. Especially the, the people, the ones that have been in construction for a long time, they don't really take to change because they believe that if it's, you know we're doing our job, we know how to do it. So let us get on with it kind of thing. It could be those people that it's an invasion of privacy. Like a Big Brother, that someone's keeping an eye on me? Where I am at all times and I think that's the biggest thing really, but the biggest barrier is going to be actual people wearing these things.	
6	PD	The main barriers I think there a lot of these. I just mentioned the bit around how we're structured as an industry, working with lots of small contractors. I think it would be much easier to adopt something like this in larger construction projects that are much more visible.	
7	PD	The crux of most of the challenges we have around deploying new technology is GDPR and people's reluctance to you know either log in or sign on to a system or a piece of kit that will track their whereabouts and show any type of personal information on them, because I think there's a fear factor that it may be used in a sort of way. There's resistance to deploy similar technology because of that sort of Big Brother is watching you concerns.	
8	PM	I would say the barrier is getting the user convinced it's to their advantage, I don't think we would have a company objection, my dealings with the health and safety people is, if it that can help, get it.	

9	SM	I think certainly from myself at the moment it's awareness, I don't really see people in the industry coming forward necessarily to say that this stuff is now available. There may be, I think as well, possibly not a stigma, but people are used to working in the ways they've worked for such a long time now, people aren't necessarily always happy to change and move on and do things in a different way, because they've done something the same way for so many years and that's the way they know. There're that not necessarily afraid, but not willing to change with the times.	
10	HSM	Educating people to the benefits of using the technology I would say. I think our staff would be quite open to something like that. For example, if they're going out onto a submarine to complete a fitout project, sometimes they're working on a submarine that's not fully complete, not fully working and not fully functional and it can be very hot. They might have to go to the Far East and work on kitting out of a ship, there doing a similar thing on a new Royal Navy supply vessel in a shipyard in Taiwan. It might be useful to be able to have that information so that people aren't put under that kind of heat stress and get over fatigue. I'm sure that our staff would be quite interested in that.	
11	HOP	I think you've got to be really clear with what these tools are being used for and identify the safety benefits that doesn't monitor and record usual construction activity, I think that's the key to it. The minute you say that's recording, how productive you are, that's when you'll get no buy in, and you'll get people walk away. That is my personal opinion.	
12	PD	One is cost. Costs are always passed on to the end user and I find sometimes with customers when we talk about health and safety and the cost you get a lot of kickbacks. As a client they are ultimately responsible to allow us and not stop us to deliver projects safely, to do it to the best of our ability. So therefore, cost is a barrier. Peoples attitude is another, if you came to me and we went into a site and you provided me with these devices as additional PPE items, we'd have an open grown-up discussion and conclude that it's the right thing to do, then I'm sure we'd set up and we'd have all that kit on when entering the site. But some of the youth that were bringing through the industry have their own ideas and it can be a challenge because the first thing they want to say is no.	
13	PD	Cultural barrier. In terms of the glasses in particular you know that's a fantastic concept there's somebody doing the work in a safe manner, are they doing it correctly? But to have the right mindset in the culture as an employee, perhaps older people are very set in their ways and have done things in a certain way for a long period of time. Then to drive those improvements, there's always a cultural barrier to overcome and certainly an education perspective, as a business technology health and safety go hand in hand as priorities, you'll see if you look into our strategy that there are five top strategic priorities, technology and health and safety are both within those. So, for us any barrier is around a personal or employee perspective, around culture and cultural change, any change needs people to embrace it.	
14	MD	The main barrier one is cost, everything in construction comes down to the bottom line, whether that be your memberships or implementing the health and safety as it is. It's cost, because that cost then gets put on a job that gets passed to the client, so then the client has to accept that additional cost. But the thing is, as you indicated earlier it's about educating people, that's the way forward. I think that's something that you tackle, the cost. The other obstacle would be the individual themselves understanding the benefits of these devices because you will get pushed back. People are very personal when they go to work, they don't want this type of data being pushed back to their employer, but done in the right way, educating people with the benefits of it and the restrictions of it, I think that's something else that could be tackled. I think they would probably be the two key obstacles regarding implementing this on construction sites.	

Question 6: In your opinion do construction workers believe AWSD's are difficult to use and may hinder or impact their daily work activities? *If yes ask*: Can you explain why? *If no ask*: Can you explain why?

ID	POSITION	RESPONSE	KEY
1	MD	If you're working in a mine you would want to wear it, wouldn't you? If you are going down all that way you would want to know that people know where you are. The use of this in a high-risk environment within high-risk industries would be an absolute benefit, a season professional I don't believe would object to wearing AWSDs in these environments. However, if he was working in an office building he's probably going to be	

		a little bit worried because you'll see how long it takes to go and get his cup of tea and how many cigarette breaks they are going to have, in this environment he maybe resistance to adopting the use of AWSDs.	
2	PM	From my experience, the hard hat is a good thing, and the technology do impact the primary function of the hat. I think the Hi-Viz is great because it is encapsulating your body and the watch is something that people ware all the time, this watch just has a different function. Technology's great if you can get a signal, but if you're working underground it may not work so well, it's got to be good across the board.	
3	SM	The devices shown to me don't look to dissimilar to current PPE, so I don't think that will be a problem.	
4	SPM	Yes, because they are not familiar with AWSDs, I believe it's down to the lack of knowledge. I speak to quite a few contractors, daily, weekly, all from different backgrounds, it could be an AC engineer to a bricklayer, and I've never heard anybody mention anything like this	
5	HOP	I can't see it hinder workers from the examples you've shown, if these things are pretty much how they are now, I can see that some people may feel that they are an invasion of privacy.	
6	PD	I don't think AWSDs would hinder daily working activities, but I can assure you they would. I've sat in an industry that 30 years ago people were just starting to wear hard hats and 20 years ago people said no, I never going to be able to work with glasses on and I'm never going to be able to do my task properly with gloves on. It's an oil tanker of an industry, but it does change.	
7	PD	Hi-Visibility vest, no, absolutely not. The helmet with the sort of heads-up display I would be concerned it could be a distraction and it would depend on the environment in which it is deployed. Many sites have uneven ground, people are trained and used to uneven ground around construction sites and they're generally weather dependent as well and the movement of equipment, introducing something in the in the eye line that distracts the person is not something I'd really be keen to consider, I think it could lead to more issues.	
8	PM	Personally, I think even if it was slight a hindrance it's an advantage because it makes them safer. It depends how big the item is, I'll just use the high vis jacket as an example, if you were being lowered down into a confined space if the technology is in a style that could snag it is not something you'd want on, that's the only reason, anything that stuck out would hinder people.	
9	SM	Not from what I've seen. The devices that you've shown on the screen look almost identical to what's available today, these just have more technology built into them. I was going to say potentially the glasses, they look quite big the ones that were shown there, so maybe it depends on the environment you're working in, they could be difficult to use in certain environments, if it's a tight area you're working in. The rest of them look fine, I couldn't really see any other issues using the other equipment.	
10	HSM	I don't think these items will cause any issues, it's more likely to be the perception of them that may cause some problems.	
11	HOP	I don't think so. They look like standard and operate like standard PPE, so I couldn't see them getting in the way at all.	
12	PD	No not all of them, but for me I think the watch, I see the watch and I see it as a piece of kit. It's just that physically on the construction site, you use your hands they are one of the most important tools that you've got on your whole body, you're continually moving and using them. I think that would probably be the one that stands out to me.	
13	PD	I don't think there's anything prohibitive to carrying out the tasks. I think that's been eliminated within the design element. So, I don't think they're a design issues or concerns that employees would have.	
14	MD	In terms of the physical attributes no, I think the only type of technology would have to be something that was worn permanently, because with high-risk environments these devices will get damaged or they might get accidentally swapped with someone else, so you can technically have someone else's data. Hard hats like you said, you can't always wear them, if they are taken off, they are then in danger of someone else picking them up and using them and you're could then be at risk of losing or corrupting the data.	

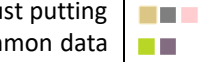
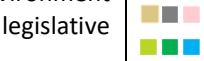
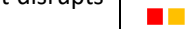
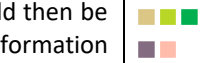
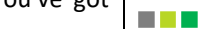
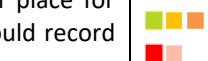
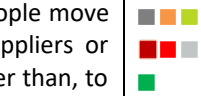
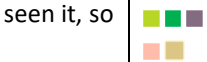
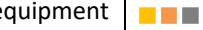
Question 7: Do you think construction workers harbour concerns regarding how AWSD's collect their personal data and how that data is then stored? *If yes ask*: What do you think these concerns are, and do you have any justification for those concerns? *If no ask*: Why do you think they are not concerned?			
ID	**POSITION**	**RESPONSE**	**KEY**
1	MD	If you've got something to hide then that's when people start to worry, if you've nothing to hide then these people are generally not concerned. But I think that people will always be concerned that Big Brother's watching them leads to them believing that they are not trusted. With the adoption of AWSDs you can also measure their heartbeats So if somebody's got to continue resting heart rate of 50 against the guy that's got a heartbeat, that shows 50 to 100 and back down again you can see who is working and who isn't.	
2	PM	I think they would have concerns, but if you could manage those concerns and prove that if was for workers personal health and safety then I think they will accept it. Some people may be concerned if they have an underlying health issue they don't want their employer to know about. Generally, having worked in the construction industry if I could read what's going to happen to me before it does then I'm reading the future.	
3	SM	Yeah, of course they would. If at the end the day companies use the data in a negative way people will become disengaged, demoralised, and they will walk away. So, the younger generation if they've been brought up using technology they'll accept it.	
4	SPM	I believe they would, yeah. It goes back to my point about being monitored again, so I believe some people would definitely be asking questions about how is the data used? What does type of data is actually collected and why is it being collected?	
5	HOP	Absolutely. Will they see it as a threat to their job, if they're carrying out a task and it's showing that a person's a lot healthier doing this task than they are, there's going to be all those kinds of worries, isn't there? It is a threat too if they're showing bad health, are they going lose their job?	
6	PD	Yes I do, I think if you're on a large construction project or you know you're building a very large office or working on HS2 or doing something like that, you're there for a very long period and you can see what the information's being used for. I think the challenge here is you're collecting data and information which people see as personal and you're not really demonstrating what you're doing with that data?	
7	PD	It's a generational thing, ultimately. I think we have to start the journey somewhere, this should be with the right education, the right intent, and the right output, with the right control of the data and information and the right assurances to those that were maybe subject to a trial. They would need to know that the AWSD's were not Big Brother trying to find out if they've knocked off two minutes early or they went for a fifth cigarette break. That actually, we were really truly worried about their well-being, concerned about the well-being and wanted to help them maintain it.	
8	PM	Yes I believe they would be concerned, but I'm sure that could be managed. So, an employee would be allocated at unique number when starting onsite that not associated to anyone, meaning all the information collected is directly related to that employee; this could then be used in real time for health and safety purposes and for building a data base of information to allow improvements to be made.	
9	SM	There is always the risk of that. I think if you're collecting people's personal data, whether its heart rates, locations etcetera, people are always concerned as to being tracked or being monitored, they would worry about having their information potentially leaked or sold onto insurance companies, which would then maybe you cause them problem getting insured for doing something because they've identified certain issues with their health.	
10	HSM	Yeah, indeed. I'm sure people would be wondering if the data was safe, we've already had a breach of our personal data in the last month, it can happen. We don't know everything., nobody knows everything about every kind of data storage, and some people can be very devious and break into these systems. So, there would be a natural concern about that information being stolen, I would imagine.	
11	HOP	Yeah, I think people are already actually just generally in general life, there's that concern that organisations are allowed to monitor someone for every minute of their working day. Some people, it won't be for everyone, but some people see that as an overreach, they will rebel and push back against if there's something that's monitoring their performance on a minute scale like that.	

12	PD	Yes because the information being obtained relates to construction workers personal health and safety, they may not want to share that kind of information. Data collection and storage regarding having all that information on individuals, is another minefield, but I think it's possible just look at the likes of TikTok and all the information that they can store. I can see that collecting personal health and safety data could be a challenge legally, I think that's going to be something that's going to need sign off. We've got this technology, but then you're told it's not a product that's signed off and then all of a sudden, you can't use it even though it's the right tool. I believe this could be the situation when we're trying to bring technology into play.	
13	PD	Of course, they will. It would be interesting really to put a survey out there around for the employees around technology to determine the attitude and the buy in from employees towards this. That would be a really interesting exercise to speak to the employees through a survey and see if they felt there were any barriers. But it's great to get feedback from the shop floor as well from the individuals, do they see any issues or what concerns they have with that technology. But I do agree with you think that training, coaching, culture, and evidence that it works then you know opens the flood gates to this technology.	
14	MD	I think people will harbour concerns around how their personal data is collected, used, and stored, because when you look at things like GDPR, I think if you were introducing this theme what would come, I suspect, is that eventually there would be an updated legislation built around it. Because the data is not useless data, it'll have all the information on individuals, their location, and their health issues etc. People would be concerned, I'd be concerned if I was the one implemented, I'd think, alright I fully understanding the benefit, but you would definitely have to have something in place legally in regard to the storage of that data.	

Question 8: Do you believe construction workers having their site location monitored continuously will bother them? *If yes ask:* Can you explain why? *If no ask*: Can you expand on your response?

ID	POSITION	RESPONSE	KEY
1	MD	If they've got something to worry about they have got something to hide and they need to be worried, If they're shirking off the AWSD technology will catch them out. The other thing to consider is the information obtained will enable employers to monitor efficiencies and implement changes to improve outputs.	
2	PM	In terms of having their location and breaks monitored, I believe construction workers would be worried about this, they will be concerned they are being micromanaged and will not be able to work freely due to being monitored at every turn.	
3	SM	Absolutely, nobody wants to be monitored all the time, they would feel like Big Brother was watching them and that they were being micromanaged. They would then start being conscious about how long they took for breaks, how many breaks they may have had and how productive they are.	
4	SPM	Yes, you'll always get contractors who are slower than others, take a little bit longer with breaks, go off and have more tea breaks, that's across the board, it's always the same. I can see that it could cause some concerns from certain individuals or certain groups, if they are in that mindset, where they think I'll just take another tea break, I'll just go and do that. I'll that 45 minutes instead of half an hour for lunch or I'll leave a little bit earlier today.	
5	HOP	Yeah, there will be once it becomes the norm, then it's accepted, isn't it? This is very new to me, so it's going to be very new to most construction workers. Initially there's going to be a lot of issues with it, is it going to be seen as a way of I own you. There's got to be steps involved regarding the information, how much information is taken	
6	PD	Yes, we're using, photographic signings in and they don't like that, and this is much more Big Brother than that. I don't think anybody really want somebody to know where they are or all the time and I think it goes back to the type of work that we do as well where you're coming in, you're working on a site for a short period of time and then going off and working on another site.	

7	PD	Like is said earlier people would be worried about the Big Brother element. I do think there is opportunity for these new technologies to be deployed. Let's look at some of the access control biometric systems on sites, there were ground-breaking organisations out there that introduced them, and they had their purposes. I'm sure they can interpret when people clock on and clock off if they so wish, but ultimately the objective was to maintain a secure site and have on site people that were competent to be on the site and nothing else. We know biometric could be eye scanning, it can be palm scanning etcetera. If you had a ground-breaking scheme, be it a high speed two or something like that, where it was mandated from the start that this technology will be deployed, that's part of the participation there's your opportunity.	
8	PM	My opinion is if it is to their benefit to wear it and will enhance their health and safety in my experience, not that many people take a great deal of convincing. If you were to say to them for example, if you had the sensor type, Hi-Viz jacket that also gave a location convincing him to take it home, keep it in the boot of their car might be difficult because then there would think Big Brothers watching them. So, if the technology could be constructed in such a way that you take, for example the SIM card out, if it was a SIM card so that it is deactivated on leaving the site, then yes they would. But I think that would be the barrier anything that allowed you to them and track them in their vehicles, I think that would be something that would be a difficult one to convince people of.	
9	SM	Yeah, I think construction workers, they're always concerned, I think there's always been a bit of a stigma in the industry as to is the boss watching, construction workers generally do not want the boss following or tracking them, seeing where they're going, what they're doing. At the same time if you're wearing this equipment and there's an issue on site, maybe something collapses or someone falls, AWSD's could help quickly identify where you are and potentially rescue you and save your life. So, at the end of the day and from my perspective, if you're working on site then your management team should have the structure in place to know where you are anyway, I don't see there being an issue with it.	
10	HSM	It could well do; some people will be more bothered than others. Some people will just carry on and think, I've been doing this for 10 years and have always been a satisfactory worker and it's always been OK. I would have the confidence just to carry on as normal, but other people might get quite upset about it. It would be a period of adjustment so that whoever was analysing the data would have to take a fairly pragmatic approach to it and understand and not fly off on a tangent at the slightest thing, because that's just a recipe for losing half his staff.	
11	HOP	Yeah. I just think there's not a great deal of trust between site workers and management and never has been. If you've got something that's measuring when they're working, when they're not working, I could see them not wearing it even if they are told too. So, that's a real difficult one to buying too, but if it's a life safe thing and you need a locator perhaps if you have fallen or what have you, maybe it's not a location system, more of a siren system or something like that. So, there's no GPS in there. Probably be cheaper to produce.	
12	PD	Yeah, I think construction workers would have a big hang up about having their location monitored. I think it's a case of when they come on the site, they do the initial induction and then each individual would have to sign up to this, indicating that they are happy to wear this kind of equipment and have their data collected, they could do this by a simple tick sheet that they had to fill in and sign off, very much like clicking the button on a website. They would need to know how and what the data would be used for. If the tick box covered a time and motion study on the individual, I'm sure that 90% of them would say no to the information being used in that fashion.	
13	PD	Yes I believe they well, it's the use of the technology and convincing and proving to our employees that the data is used for the correct purpose, and you've got to be very, very careful with personal data that you collect. We have to invest and look after our people and do the right thing as well through the implementation of the technology. It's a brave company that instigates it and initiates it, but once you get onto the cycle then it will become more of the norm. As a business we need to be productive, we need to drive quality, but also we do need to be really mindful and conscious and sensitive of people's personal data.	
14	MD	Construction workers will not like having their locations monitored. I imagine the first question people are going to asked when presented with an AWSD, is this tracking me? If it is tracking them there will be resistance, construction workers don't like it. We introduced a system into the office a few years ago, the guys had a phone app that would track them, the first kickback for us was they didn't like that they were tracked. I	

		was saying it was there for their safety and it's not there to look at if you're going home early, it's for us to know your whereabouts. Obviously they pushed back indicating that didn't like being tracked and we were finding that the guys were actually going in and turning the settings off.	
Question 9: Do you believe the software and hardware solutions relating to the adoption of AWSD's is lacking standardisation resulting in limitations of the technology? *If yes ask*: Can you explain your thinking? *If no ask*: Can you justify your response?			
ID	**POSITION**	**RESPONSE**	**KEY**
1	MD	If we look at the technology that's already available to us, all were doing is utilising the same technology that's out there already, you're just putting it into one place, you can put a tracker on any car now, so that software is already in place and what you're doing is you're just putting that technology into AWSDs. So once that software is in place you can monitor what the guys are doing. It just needs to have a common data environment set up where all the information could be stored and distributed.	
2	PM	There seem to be many software solutions available but what I think is missing is a standardisation around a hardware common data environment for each site set up, that where improvements are needed. That will keep costs down and ensure data storage solution are in line with legislative guidelines.	
3	SM	If they can't get their own Internet to work, then this stuff won't work. Commercial constructions are mainly a metal framework that disrupts that sort of signalling.	
4	SPM	I believe there is a lack of standardisation of the technology, although in principle it's very good and valid, it can only be utilised properly by using standardised systems, primarily the hardware solution. This would then enable construction workers to login and relevant alerts could then be issued. I also believe there should be a standard for the software devices use to insure they are capable of providing and receiving the information required, these devices should have to be calibrated and check regularly to ensure compliance.	
5	HOP	I believe there's got to be some kind of standardisation put in place and some legislation put in place on how this is used. You've got standardisation of certain technology already in place, things like RF monitors, gas monitors, that kind of thing, this should follow that.	
6	PD	It would have to be a common data environment for the full benefits of this to be achieved, I'm not sure the technology is in place for standardisation to be achieved currently, but if we wait a bit and complete some research into this on a designed program, you could record accidents that are happening and seeing there is any link to the timeline on a construction program.	
7	PD	No not currently. I'd love to deploy technology on a construction site that is cutting edge or at least is following the latest trends. We talk about how our offices are occupied and how people interact and move around a typical office floor. It'll be very interesting to see how people move around the typical construction floor, construction area. But we'd have to have probably agreements already in place with suppliers or subcontractors that the data we collect won't be used in anger against them commercially. It's just there to protect and observe rather than, to get him to buy into it. I'm pretty sure then suppliers would see the benefits themselves of that health monitoring and health screening and safety.	
8	PM	Yeah, it's got to be a common access protocol somewhere. I would agree there is no evidence to support there is a standard, I've not seen it, so I'm not aware of it.	
9	SM	Potentially we're lacking in that. From a Wi-Fi and Bluetooth perspective that's pretty much everywhere these days, you can connect to most technologies one way or the other. The standardised items are probably going to be in the individual's manufacturing of different pieces of equipment. They're all going to want to have their own system in place for their equipment. You probably need to have a standard in place which says that this equipment should be able to communicate at a specific level and do certain things, be able to talk to a specific piece of equipment or another standard of equipment, so there's an open protocol and standardisation across the industry. That's where you need the standardisation so that you may have a different manufacturers piece of equipment, but it's still able to communicate and deliver the same information across to another product.	

10	HSM	I'm not an IT expert so I'll really struggle to answer that one.	
11	HOP	I don't know if they are standardised or not, if I'm honest, because I haven't seen any. So, I couldn't really answer that one. It's very similar to the devices that you can buy now that connect to Alexa or Google. They're varying different companies, different apps all connecting to those central hubs. And yeah, I mean, what are the standards? Who's recording or what? Yeah. It might do better if it's connected to a phone app, have your phone on you and stored in your phone so the person feels they have some control over the information, where you have a sort of principal download for every week or something, I don't know, we're designing it now.	
12	PD	I don't know enough about a site and adopting all of them solutions. We have mobile fire alarm systems around sites regularly now, I think the next stage will be mobile VPN solutions around construction sites, which could be just as easily adopted. Therefore, the adaption to incorporate that information would be really easy and I think were adopting solutions technology wise and construction is probably at the back end of where this innovation takes off. So, they've already gone through a lot of the standardisation of what needs to be done and we are just piggybacking off the back of it, whether we'll ever end up at the front of it, I don't know, but I think it could be easily standardised.	
13	PD	We have a working party that's looking at our total mobile solution, which is the avenue that we are likely to go down, a body of subject matter experts around health and safety. But in terms of gaps in technology I am not really familiar enough with the systems and I'm not expert enough to analyse them. I think you'll have a lot of competition out there with these providers who are designing their own systems and they'll have their own platform, to have those on a common platform they would then be selling basically the hardware element. I don't think in that they would volunteer up a common operating platform that these devices would all buy into.	
14	MD	Put it this way, if it isn't widely being used, then there's something amiss at the moment. I think there needs to be some changes here, I definitely think there needs to be some changes around that because I'm not aware of any form of standardisation and I do believe it is limiting the use of the technology.	

Question 10: In your opinion how do you think AWSD's can be used to improve construction workers personal health and safety? *Then ask:* In your opinion what are the positive and negative factors of adopting AWSD's?

ID	POSITION	RESPONSE	Key
1	MD	Mental health, and the stresses because you know it will all be about the heart rate and the recovery rates of monitoring the guys. I'm guessing it will also track blood sugars and it can let you know if they taking enough breaks, I think if you look it from the employee point of view, it could also assist them from the fact that it will demonstrate whether the employer was pushing them too hard to get jobs finished in an unrealistic time scales, you'll be able to get that feedback from their body by the information produced by using AWSDs and the associated software, it will indicate how they're feeling throughout the day.	
2	PM	Well, as I said to you at the start, I think the Hi-Viz and the watch will enable additional time to be given around warnings for safety issues. especially regarding the escape of toxic substances, I think that is really important. You're working on a construction site; you've got scaffold all the way around it and you've got a scaffold board that's weak. Is this technology going to tell you that the board is weak, and you might fall through it? That comes down to regular checks not down to digital technology. I suppose the negatives here is always the cost, it's always going to be the cost because life is about money.	
3	SM	It could be used to monitor and record peoples risk activities by identifying patterns of bad behaviour so they can be targeted and managed accordingly. A national data based could be held and shared so that these individuals can be identified.	
4	SPM	If the systems could pick up how the external environment is reacting on a person's body, then that would be an advantage because you be able to know, if their temperatures at this value then your body reacts this way which may mean you going to be less productive, so maybe we need to look at providing suitable work clothing relating to the environmental conditions.	

5	HOP	I think for loan workers something using AWSDs really is key to looking after that person, I know construction workers will accept this kind of thing, the key is giving them education, so I'm totally for it. There are a lot of positives I can think of but I'm struggling to think of any negative factors around this.	
6	PD	Using AWSDs will improve behaviours of people because they are being monitored, changing methods of construction rather than changing individuals will have the biggest impact of construction workers personal health and safety.	
7	PD	They could be used for monitoring heart rate, lung capacity and fatigue that kind of thing, and warnings issued when any adverse readings are identified. Construction workers just need to be aware of them and trained on the benefits of use.	
8	PM	I believe AWSDs could be used to improve construction workers personal health and safety by monitoring personal biometrics and warning them about personal health issues that they may not have been aware of.	
9	SM	Certainly, looking at individuals and the areas there working. Then looking at the exposure rates to the hours that you're working, there may be an exposure to gas within the atmosphere that you're only allowed to work for a certain period of time.	
10	HSM	These devices could measure an operative's biometrics in terms of heart rate, core temperature, stress etc. Sometimes we have a requirement to wear a personal oxygen monitor, these are very basic at the moment, but that could be much more enhanced I think to give the wearer more information, more warning from a low oxygen situation and then it could be monitored back centrally as well.	
11	HOP	By monitoring attendance and health issues. The positive is obviously save lives and dealing with risky behaviour on site, particularly if it can pick out the risky individuals by identifying patterns of bad behaviour so they can be targeted, and the risks managed. I think negative is around the buy in, if not everyone's using it then you're not really getting the real benefit, of the cost invested, I've often said with CDM regulations, is the cost of CDM implemented on a site, is that beneficial in lives saved compared to spending the same amount of money on the health service for example?	
12	PD	By monitoring all aspects of construction workers personal health and safety utilising biometrics as wearable technology and being able to provide early warnings, potentially saving lives. The most positive is being able to save one injured person from going to the hospital, absolutely, without a doubt. I'm trying to think of a negative, apart from costs and the customer accepting the cost, is that going to have an impact on the overall build costs in the UK?	
13	PD	By making them aware of any health issues as early as possible, giving them the best chance to get treatment before it becomes too serious. The positive factors are that lives could be saves the negative factors are related to cost.	
14	MD	One of the key things I think this would be good for would be fire safety. So, when you have a fire on site and everyone goes off to their muster point and you do a roll call to see where people are, if you add a device personal health and safety of workers could be enhanced by tracking their location, you will know if they were accountable, or they were missing. There would also be benefits for fire service so they know with certainty that everybody is out and accounted for and they would not be putting themselves at risk for no reason. The negative aspect is that with new technology, you got to get it into the market and the first thing the showstopper is always cost.	

Question 11: Can you explain how AWSD's enhance construction workers environmental health and safety?

ID	POSITION	RESPONSE	KEY

1	MD	So, example, if there was a noisy area where you excess decibel levels requiring you to wear ear protection, you could be alerted by having a device on you like a watch that sends you a message saying you're about to enter a hazardous environment please take the appropriate precautions, or if you're working at heights it could warn you about any hazards related to that.	
2	PM	Warning of environmental issues, especially regarding the escape of toxic substances, I think that is really important. If you were wearing one of those Hi-Viz and it senses something and it alerts you before it's too late, I think that is that is a positive.	
3	SM	If it warns you about gas leaks and it says there's a gas leak that would be good. I was at Oxford Street when a bomb warning was announced, there's a bomb here. Nobody told us which way to go, and everyone was running around like headless chickens panicking, you can over give people information.	
4	SPM	Noise levels, because working on construction sites myself as a plumber and gas engineer I could be in a room where someone could be next to me chasing out the floor. I think I'm OK with the hearing, but AWSDs could pick up that the noise levels are too high, and I should be wearing hearing protection.	
5	HOP	It's just in terms of monitoring, we've already got RF monitors and gas monitors. If you're close to a hazardous condition like a falling from height condition, then they can send a warning to you.	
6	PD	I think when you feel you're being monitored or watched your behaviour is different and therefore you'll probably doing everything in a safer and more environmentally friendly way just because you're being watched. You know, where we put cameras on sites we would probably get much better behaviour, you're generally going to be more compliant in everything.	
7	PD	Well, not in terms of personal devices and I haven't had that exposure to that type of learning or that technology, but I do know technology we've deployed within our own offices to monitor the office environment in terms of CO2, carbon, air changes, temperature all help. So, I'm pretty sure that that science can be deployed to other areas within the construction industry, it could be recalibrated to be used in specific areas. I just wonder about if you're casting concrete on the 54th floor what type of environmental information can you receive that's going to impact you, maybe temperature outside is too hot and to put on sunscreen or you know this type of activity. But yeah it's difficult to know where it can be applied down to that sort of individual level.	
8	PM	So, depending on the device you wear, let's use the hat for an example the device on the back of the neck has a device going across an air quality sensor and suddenly the guy shouldn't be working in that environment because the dust levels of at a certain point, so get him out of there or get the right breathing gear on him, and a similar thing for noxious fumes. Now I know people working in confined spaces, again using that as an example or in a petrochemical environment would benefit from this. I have an interest in it anyway, and I have something about the size of a small Swiss army knife that can measure air quality, noxious fumes, temperatures and all the rest of it, and it weighs about two ounces. So, something like that feeding back, It's going to give you the air quality, you can monitor dust and sound levels because people don't, it's insipid, isn't it? You start talking and then the sound around you get louder. You start shouting at each other to carry on the conversation, but you don't realise you've gone past the warning level.	
9	SM	If you're doing groundworks or working in a confined space the ability to identify many different hazards within the atmosphere that you're working in, there's certainly a big potential there. Noise levels as well, going from different plant rooms or working in different environments. You can walk into those areas and you're not necessarily going to know what level of noise it you're being exposed too; you can have a device that monitors and then alerts you to the sound issue to say you need to be wearing ear protection or you now need to remove yourself from an area that potentially could result in permanent hearing loss.	
10	HSM	I suppose you could wear something that monitored certain chemical exposures, if you were working in a refinery, for example, you could wear something that analysed the exposure rate to volatile compounds and such like, ditto that for dust and noise as well, so not just for chemicals. If	

		somebody is laying a floor with a latex or undertaking an extension job, doing a bit of demolition, or even just using the cement mixer because obviously the dust created by tipping in the cement, technology developed to detect dust could be use in these situations.	
11	HOP	Gas leaks odours could be detected by these devises provide a warning. There might be some combined benefit of people who have different diversities or disabilities now this could be a challenging one, if you've got someone who's deaf who's working on the site you might have an extra sort of lighting systems on there to detect risks.	
12	PD	So, one thing for me, working in data centres, underground air quality and air freshness. If you had a sensor of on individual that was walking around the site that was approaching an area that was overpopulated for instance, because there was a concentration of effort in a particular room in relation to a time scale, then it would be I think fabulous to have. Some information that highlighted, maybe on a BMS dashboard back at the site main office, looking at your air quality of what you've got on the site. It could warm of areas that are a little bit overpopulated and you put measures in to feed the site with fresh air etcetera, then you could make changes or in your team get together in the morning you could start to assess if you've got the right amount of fresh air.	
13	PD	You could have temperature, high temperature, humidity, water all the environmental conditions could be picked up through sensors and then the information fed back. Ultimately, whatever technology the person is wearing and whatever information they're fed, they have got to have the right safety mindset and the on the right safety culture, you've got to be aware of the risks and the hazards and you've got to have that mindset to look after yourself and look after your colleagues and put safety first.	
14	MD	You know, we work in potentially explosive atmospheres as such we are limited on the technology you can take into these areas because there's DSEAR, any intrinsically safe developments to assist and warn people of environmental hazards that they are being exposed too would be very useful in this environment.	

Question 12: How do you believe AWSD's can be used to ensure compliance with legal Acts and Regulations such as The Working Time Regulations (1998) and the Health and Safety at Work etc Act 1974?

ID	POSITION	RESPONSE	KEY
1	MD	The easy one is the number of hours you're working on site; it could track how long you've been on there and whether you've had the required breaks to do the job safely and without you getting fatigued. It could be taken to the next level, you could put information training records onto the AWSDs, for example, if you were using certain types of hand tools, whether you'd had the prerequisite training for that. I think there's also elements we could expand this into having a database of what levels of training have you got on your chip.	
2	PM	AWSDs could be considered as part of any risk assessment that are undertaken to ensure compliance with CDM 2015. Improved safety for construction workers by using this technology will enable the requirements of the health and safety at work act to be met. I think in terms of the working time regulations, worker attendance could be monitored to ensure no breaches are experienced, there could be someone that goes the other way and don't work their hours, that could be picked up. There's some health and safety issues there, because if someone does excessive hours, then there's going to be fatigue involved and there's more likely to be additional risks associated with the tasks that they're carrying out.	
3	SM	I think the technology should be included in every risk assessment conducted to ensure compliance with CDM 2015. Implementing this technology can significantly enhance safety for construction workers, thereby fulfilling the requirements of the Health and Safety at Work Act.	
4	SPM	If it can monitor your working trends then that is a very good tool, especially because you know we've all been there, you decided I'm going to stay on a few hours and work past my working hours just try and get the job done. It would also benefit a company because if they are monitoring the times it takes somebody to do those tasks then they'll know in the future if they need to allow more time for it. If they are putting too much time straight down or if they are trying to push them too hard, which obviously does have effect on their health and safety. It also influences their mental well-being as well because they are then under pressure constantly to deliver outputs within the time identified.	

5	HOP	By the monitoring and collection of data you'll be able to prove companies are working in accordance with those Acts and regulations, if not something can be done to address the issue.	
6	PD	I have no reason to believe that it couldn't, you know, I think that you could almost get this to do whatever you want it to do, I think that's the challenge. If you're doing it to improve worker safety, you're doing it to improve worker compliance or you're doing it to keep them legal in everything that they do. Clarification is needed in that regard before you can ensure compliance.	
7	PD	They absolutely can, very much like biometrics at site entry points. If it's solely used the clocking on and clocking off, construction workers are clever enough to try and fix the system somehow, no different than swipe cards. I've seen activities in a previous job were shift workers that we're sharing swipe cards, it appeared that there was two people swiping at every location until we investigated via CCTV and we found that one guy had been led out the door to go home and one engineer was covering his shift while the other one either got on with private jobs or went back to bed, regrettably that's human nature will intervene and always cause you an issue to resolve. But on the whole if you can get a trustworthy workforce I think they're good too, but again not to be used by Tier 1 suppliers to beat up the tier twos. Certainly, to illustrate either attendance or lack of attendance, if could be used to address challenges from suppliers.	
8	PM	I think it could be because instead of people thinking they're complying; the technology is going to tell them that they are or they're not, quite literally. It should be as part of your CPP to say that it been considered, but not required for this particular activity.	
9	SM	Certainly, from the working time regulations, definitely. Some of the other acts I could see it being useful to gather data to make sure that we're not either working beyond or the limits that are set. It's quite often that you're here of contractors working long hours, longer than what they should do to get a job done. But then they're potentially putting themselves at risk by doing that, they get tired for example.	
10	HSM	You could consider the AWSDs in the hierarchy of controls when conducting risk assessments under CDM. If it was a fairly big construction company, it would be a very sensible thing to do that at least periodically, even if you didn't ask the person to wear it all the time. You could monitor one day every three months or something like that, I don't know whether that would be a fair representation, but it would certainly build up a picture. on a really big build project that was several years long, if you had a spate of people going off with a complaint, whatever it was, then you know to be able to monitor them closely might give you some answers to the problem that was occurring.	
11	HOP	Yeah, you got a tachograph in a truck to make sure people don't work or drive over a certain number of hours. You could do the same thing with an alarm system to monitor attendance or hours worked, it's a bit like a seat belt alarm on a car, it can be a bit of an inconvenience sometimes, but I think there's some benefit there, those that are self-employed may look to will bypass it.	
12	PD	I do, absolutely. Vibrate hand vibration and all those kinds of things. Attaching this kind of device to an individual is one thing, but there's no reason we couldn't extend that to attaching it to a piece of equipment. You know, if a piece of equipment is run for 8 hours, but then you've only got an individual login that they've used it on site, when you add it up, for 15 minutes, then there's obviously a gap.	
13	PD	Yes, I think there is, but as I say, we've got to be really careful around how we use the data that's collected and to make sure that these devices are used for the intended purpose and not used for productivity management or collecting specific data on personnel. I think when you look at working practices, the working practices are there to protect everybody. We have clocking in and clocking out systems, in terms of working time directives, it's a very crude system that's been in place for many, many years, so potentially AWSDs could assist with improvements. In terms of health and safety compliance, you know absolutely and compliance with the health and safety legislation, particularly when you look at the technology that you presented at the beginning in terms of the glasses.	
14	MD	They can assist the regulations because they're designed to ensure personal health and safety is improved, a lot of these acts they're forever being updated all the time, with technology this legislation needs to be adapted to ensure the knowledge and adoption is allowed for, this will	

		enhance the regulations still further. If you look back at, say, the health and Safety at Work Act and the umbrella of that sitting over lots of other legislation, I think as it finds its way in, it will definitely improve things.	
Question 13: You previously stated that the main barriers to adopting AWSD's by construction workers are, Barriers 1,2,3,4 etc. *Ask:* In your opinion what can construction companies, technology developers, educational bodies and training schemes do to solve these outstanding problems?			
ID	**POSITION**	**RESPONSE**	**KEY**
1	MD	I think these companies need to make their employees aware of this via their internal training mechanisms such as e-learning. The technology developers should maybe partner up with the construction companies and come and do demonstrations to promote the benefits of using AWSDs. The education bodies and training schemes, they just need to have relevant content within their courses so that people understand what is available to them. In terms of implementing them, I believe they should be part of the hierarchy of controls. They should be considered when they need to make an assessment against them, in terms of the time, the cost, the hassle, those type of things to see if there's justification to use them	
2	PM	I think technology is massive and as you say it is expanding rapidly, construction companies need to implement internal training programmes around the benefits and use of AWSDs, manufactures need to heavily promote their products and team up with construction companies to come to site and physically demonstrate these devices. I think education authorities and training schemes need to be led by policy change, where they are instructed to ensure technology awareness and data management is included in the training.	
3	SM	I think all of those organisations have a responsibility to make construction workers aware of AWSDs through various different types of medium, training courses, in-person demonstrations, literature, promotion etc and this should be supported by any required legislation change. I believe this because ultimately we're talking about improving workers personal health and safety and potentially saving lives.	
4	SPM	I believe awareness and training will solve a lot of the problems. I believe they should provide training courses, especially at the infancy stage that they're going through at the moment, they should be fully aware of it and really pushing this technology .	
5	HOP	With the companies themselves, it is about education, it's about providing orientations. It's that education that's going to come from the construction companies, perhaps, probably working with the developers and to provide examples of the available devices and showing workers evidence of real-life scenarios where the technology has helped construction workers, they could do this via in person visits or videos to promote the benefits of using AWSDs. The education authorities could also include modules in the training to provide relevant knowledge of AWSDs and data storage, to cover all demographics they could include content in apprenticeship training and renewable schemes such as CITB construction training, it would be good if this was supported by some kind of legislation change.	
6	PD	Yes, you know, of course everybody has a responsibility. I think there's responsibility for people to be aware of the products but also what they're trying to get out of those products. I think that one of the reasons why this is probably not broadly looked at across the industry is that it's probably still going through the phase of what are the benefits that we're going to get out of this? I suspect the tier one contractors are all looking at this going I know we're going to get benefit out of it, but I don't really know, they can't granularized what that benefit is yet and therefore we are getting some benefit, but how big is it going to be? It's almost the same as any PPE that you bring in, the logic of it works well but the practice of it is yet to be established. And I think there is a responsibility across the whole industry including industry bodies to be looking at this. It's so broad as well you know this isn't one bit of kit that we're that we're looking at. It's a much wider thing, and my view with a lot of these things is that I think I've said before let's have less people working on construction sites. You have less people working on construction sites you're going to have less accidents. It's going to be safer and you pre-manufacture everything in a factory environment were.	
7	PD	Yeah, education is always important on site. We can't just assume that our obligations with your very basic site safety, it has to extend into world of well-being and I'm quite passionate about that. It has to embrace new technologies and innovations because more and more of our own	

		customers are seeking that innovation from us because they nether have the time nor the access to the marketplace to find it. So, one of the agenda items on many of my senior leadership team meetings are, what innovation is out there in the construction industry that will help us offer our customers more services, which then drives digital revenue or allows us to be efficient in what we do and improve relations with the customer and safety is a huge one of those. We should be starting in the boardroom with this type of innovation and technology, we should appreciate it when it's proven and has benefit, at that point we can deploy. Then there is a further second round education as it transitions from the boardroom to the plant room or the drying room or the mess room.	
8	PM	If they want to give added value to any training course, you've got the SMSTS NEBOSH all the rest of them, but why not bolt on an hour and put in a module that makes people aware of AWSDs, it should be a legal requirement to teach this because it's a life saver. I think internal organisation training should also be included this and the manufacture should also undertake demonstrations so workers can see the technology first hand.	
9	SM	I think so, because if you can get the operative to understand the benefits of this equipment and how it could protect them or safeguard them, then you're going to get there by into that equipment and from the actual companies. I can see them looking at the cost perspective, they'll look at this thinking, that's going to potentially cost a lot more money in relation to the traditional PPE that's been available, so they'll be looking at this from a financial viewpoint. When it becomes an industry best practice, this then becomes the best method to protect your workers while doing a certain task, then that's what they should be looking for. All stakeholders in the technology development and use have a responsibility to ensure construction workers understand the benefits of using AWSDs.	
10	HSM	If they are on the market now and widely available and are indeed a valuable add on to the health and safety for construction workers, then tell everybody about them. All organisations have a responsibility for health and safety as such should implement training and relevant promotions to enable construction workers to be aware of the technology. It's just how it's introduced, it'll be a massive education to tell everybody about these things, a massive job. I don't see why not include it in all construction training for awareness.	
11	HOP	Yeah, I think it's not just moral. I think it's to do with protecting their own interests as well as, you know, the interests of the individual themselves. I mean, there's the whole nobody wants an accident on their side, the implication of that to a company as we know is reputational, financial as well as moral. So, there's a whole aspect of reasons why this should be considered. If it's a genuine tool that proves to work, then I think there would be a natural buying, especially from the larger companies.	
12	PD	Number one is, let's talk about it, nobody's talking about it. Sometimes it's too far a stretch for any one person to deal with, and I think it's a collaboration of the higher companies the contractors, the customers, and getting them all together to talk about it. I think once that solution comes around it's a journey again, training will then they end up in the NEBOSH courses and educational courses and the university is to say, this is what's going on around that kind of thing. I see it as another positive that we talked about earlier is that people might be fearful of going into the construction industry, we have massive suicide rates. When you look at accidents and incidents around the construction industry, it's quite up there, isn't it? Knowing that these things are coming around, it might bring more talent into our industry.	
13	PD	I think there is an ownness and a responsibility on all organisations to share the information and to train people and make sure that we provide the right product. What would be really beneficial is to see a really good weighting around health and safety and in the decision-making procurement process rather than a very heavy weighting on just price and quality. If we can encourage businesses to bring in, technology and health and safety performance into that waiting and into the decision-making that will drive the right behaviours from companies.	
14	MD	I know we're kind of focusing on construction, but I think this could be used in any industry in general because every employee's got a duty of care to their employees. If it got within that kind of implementation within the employment laws then all employers, technology developers and educational bodies would have a responsibility to pass on knowledge, then I think this would definitely take off.	
Question 14: Do you think AWSDs, and innovative digital technologies should be a compulsory training element for construction workers? *If yes ask*. How do you think this could be achieved. *If no ask:* Why do you think this.			

ID	POSITION	RESPONSE	KEY
1	MD	I don't really know enough about whether it should be compulsory at this point in time. Again, it depends on the environment, maybe for specific high risk construction activities initially, like I said earlier, I think there's ways and means and places for its use. I believe that it probably needs to be examined a little bit further. I'm not sure I understand enough about the technology to agree it should be compulsory at this point in time. I can definitely see the benefits of it without a doubt.	
2	PM	Not so much compulsory, go to the HSE and be led by them because they're the governing bodies that in place, this could be a good thing, not just for construction, for quite a lot of things. So those governing bodies need to embrace that and once they've embraced it, then they can move forward with construction.	
3	SM	Yes I do believe that is should be included when you go and do your CSCS card, your SMSTS and your NEBOSH, your IOSH and any other construction training. I'm saying that it should be a compulsory element to make people aware of it, once they're aware of it and they see the benefits and you've got some evidence to support those benefits, then they might be some more buy in towards it and gradually change the attitude from being negative to a more proactive approach to adopting these things. But it's all about knowledge, knowledge sharing and being able to see the benefits of use.	
4	SPM	Yeah, I believe all construction training should incorporate specific content into their courses to enable awareness of the technology and promote the benefits of use through knowledge sharing.	
5	HOP	With the companies themselves, it is about education, It's about providing orientations. It's that education that's going to come from the construction companies, perhaps, probably working with the developers and to provide examples of the available devices and showing workers evidence of real-life scenarios where the technology has helped construction workers, they could do this via in person visits or videos to promote the benefits of using AWSDs. The education authorities could also include modules in the training to provide relevant knowledge of AWSDs and data storage, to cover all demographics they could include content in apprenticeship training and renewal schemes such as CITB construction training, it would be good if this was supported by some kind of legislation change.	
6	PD	I think all construction related courses should include relevant health and safety training. It should include details on all the latest legislation, products, benefits of used and address how the data collected is used and stored. Manufactures of the technology should arrange demonstration to showcase their products and answer any question. The attending construction workers will then spread the word about these devices when discussing it with the co-worker, educating others through knowledge sharing.	
7	PD	I'd be interested to see what HSE's view of technology would be to be honest with you before I could determine whether it should be a corporate mandatory statement or position to be in. If the HSE are seeing technologies improving safety and they've got these statistics and the data to prove it, well then it becomes unequivocal and then it's easier to test and deploy on an organisation. Again, I am concerned about the type of device utilised to make sure it's not a distraction as opposed to a benefit. I'm not reticent, but I'd like to see more fact around us.	
8	PM	Whilst it's been introduced and it's still in the stage it's at now, where nobody really knows about it, I think it's difficult to make it compulsory because what do you teach? because there's no standard yet. I think an introduction to up-and-coming technology is something. But to make it compulsory, you are teaching something that's not yet across the board.	

9	SM	Yes, I do think there should be an area that covers that now purely because there is so much technology available.	
10	HSM	Yes, I don't see why it should not include it in the training for awareness.	
11	HOP	Yeah, because the other point to this is actually by demonstrating they've got this monitoring equipment, their behaviour will change anyway, even a body camera they know that it's recordable what they do, but construction worker will and get round it.	
12	PD	Yeah, I'm thinking of our business, we have our talent coach and there's masses of information and masses of training there. I think a simple course of awareness of what technologies there is out there that they could adopt within their construction sites, so each individual is taking an ownership and responsibility for sending everybody home safe and sound, then that can only ever be a good thing. I know we have training courses, but so do all the other big players, it wouldn't be too hard to implement.	
13	PD	I think it's difficult, because to train people and educate people around the technology the expectation is then that the company has adopted that technology. I think you probably need to take a step backwards and say what is the incentive for the companies to adopt that technology, is there an incentive, a tax benefit from the government? Is there an incentive from a procurement from the customers? I think it's only at the point that a company adopts the technology that they will then educate and train out the staff. I think it's really difficult to kind of impose on a company an education program until you've adopted that technology. Where you could go this is that education on this subject could be delivered by all construction training providers.	
14	MD	I do, and obviously CITB we implement that in the company, so we use the SSSTS and the managers course, and all the guys have CSCS cards and to be honest, yeah I think a little portion on this technology because then that goes out to the key people within them in the construction industry. So, I definitely think that because they're the people you educate.	

Question 15: Due to the rapid expansion of technology and its inevitable increased use to maximise construction workers personal health and safety, do you think there should be improvements made to current legislation to manage this. *If yes ask:* What legislation amendments do you believe should be implemented? *If no ask:* How do you believe technology advancements should be managed?

ID	POSITION	RESPONSE	KEY
1	MD	You are talking about potentially industry changing initiatives that I'm not sure people are ready for. I think introducing it now maybe too much, maybe it needs to be slowly brought in and trials run. As the use of AWSDs evolves I believe there will then be a requirement to implement legislation to encourage and promote a shift change to enable negative attitudes and behaviours to develop into a positive by educational content being introduced into all construction related training; this should include AWSDs in the Health and Safety at Work etc. Act 1974 and the CDM 2015 regulations, electronic health and safety processes should be included in the hierarchy of controls and the use of these should be considered in any process of elimination considerations. I also believe that current legislation should be amended to include details on how the data collected, that relates to the use of AWSDs, is managed and stored.	

2	PM	I think once it's future proof, then that's when the legislation should be put in place. you do your homework to start with, you covert all avenues so that you've got a policy fit for purposed, once confident that everything is covered then at that point it's time to change legislation.	
3	SM	Absolutely, legislation should be in place it enables confidence to use technology and not having to worry about how the information is stored and used. I think it was the GDPR regulations that were an EU standard that we needed to adhere to. Now we've out of the EU I think we've got the Data Protection Act is 2018. But we are now in 2023 and in terms of technology advancements, five years is a long time, so I'm not sure that the regulations are keeping pace with the change of technology and the additional things that are out there.	
4	SPM	I believe it needs to be reviewed and developed to move with the times and to consider this technology. It's out there and it's been developed at the moment to give the best working environment that we can. I'm not aware of any regulations related specifically to new technologies.	
5	HOP	I don't believe you can make it compulsory now, I believe it will be compulsory in the future, but right now it should a suggestion or recommendation. Then over a period time you can actually make it compulsory.	
6	PD	I think things work better without legislation, rather than with legislation, I think legislation is a way of dumbing things down to make it compliant rather than it being a really strong way of enforcing something, and the construction industry has a history of self-regulating and them when that doesn't work legislation is put in. I'd much rather see an industry that is a leading force in health and safety and then the legislation kind of follows rather than the other way around.	
7	PD	Absolutely, and as consumers we've become guilty of wanting commodities and products. Now we default to the path of least resistance to grab those commodities and products that we want to consume, we go to the large warehousing providers to get those and quite often they come through when you're dealing with inferior products. So, for me we certainly need statutory regulations to be deployed, applied to the technology that we're utilising. This needs to consider data collection, storage, and use and everything else to make sure that it sits firmly within the British standards. The BSI will be quite important to be able to deploy a piece of technology, it meets our criteria, it meets our CE markings because there will be a demand for power sources or battery sources. You don't want some piece of technology clipped to somebody's belt bursting into flames then causes another type of hazard. So, I think you need that overlap of statutory obligations and British standard deployments. Then you can start to talk about whether it's a statutory requirement across the business.	
8	PM	If the legislation it's being outstripped by the speed that the construction industry data is moving then that's probably required as a review, but the Data Protection Act is there as an act across all industries, so any updates will need to consider them as well.	
9	SM	I can't think of anything specific from the legislation perspective, but maybe there should be guidelines or Approved Codes of Practice on how these technologies should be used and the data is captured on them. Things move on rapidly these days and what was in place five years ago we've moved dramatically from that now and documents and these processes and procedures or standards need to be updated to comply and meet today's needs.	
10	HSM	It depends, not every company's going to have the ability to provide that training to the staff, so a big company would, but a little company might not. The legislation would have to be flexible initially and then refined as it became more and more widespread. The HSE teams will probably be looking at a resource issue at this point in time, every single government department I speak to at the moment is under extreme pressure, but that's not to say that won't change.	

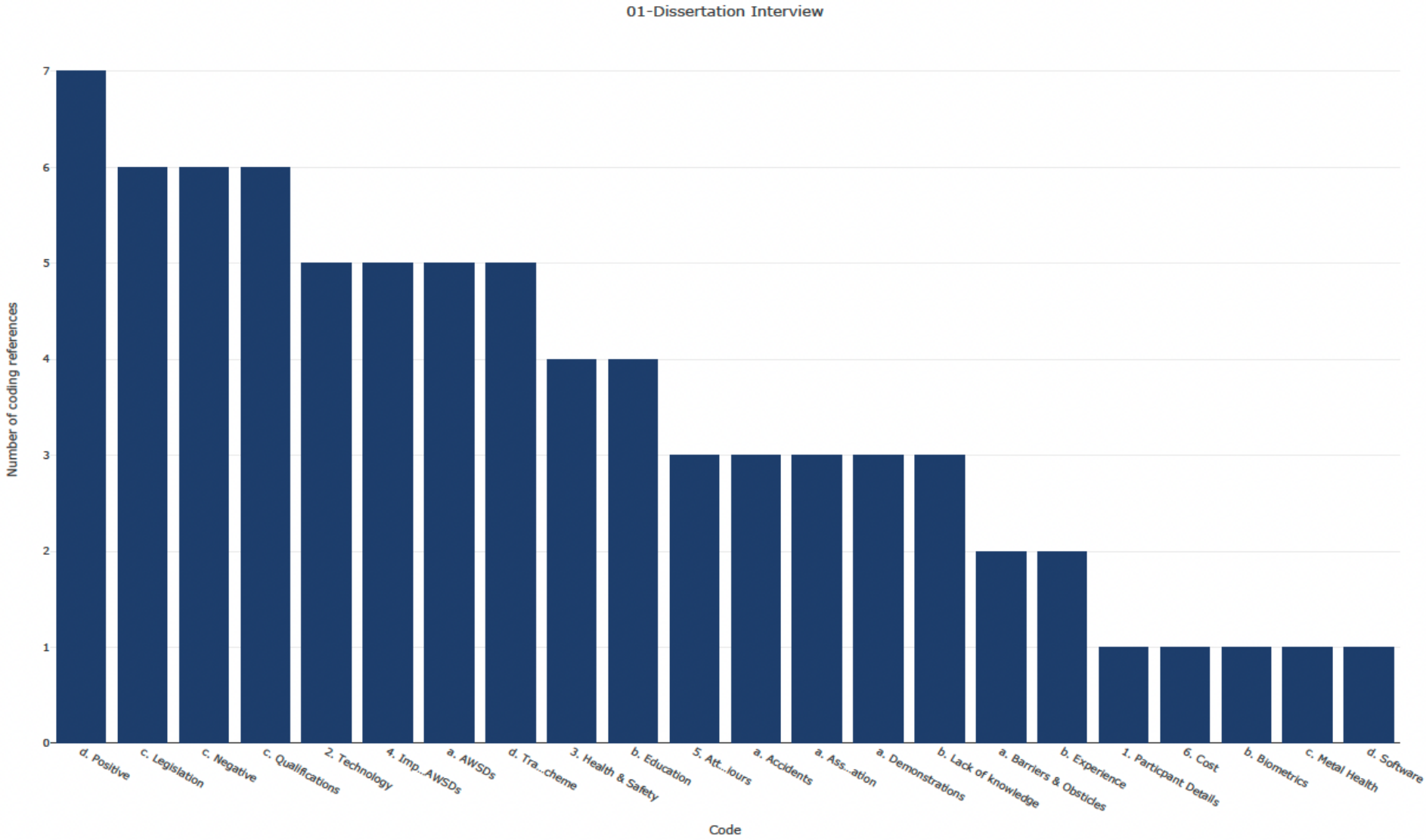
11	HOP	Yeah, you've already got protection against personal data, this would include that personal data in terms of someone's personal movements. you know you've got these things like Google and Alexa that are listening all the time and there's robots AI that's monitoring the data that comes out of it the same with phones. We don't know how that information is used and some of it can be personal and not to be shared and or security related to a company, this should be regulated I think, but that's not my decision obviously that's the government.	
12	PD	I do believe legislation should be kept in line with advancements, I think technology and data are advancing so rapidly, but I'm not close enough to know how long it takes to even review a document such as that and get it through the right processes to get it approved, it could take years to get it through the system.	
13	PD	Yes I believe so, if you want people to adopt this technology then you need to ensure legislation change regarding, health and safety, data protection, and education content in construction training schemes are enhanced so that they are fit for purpose, they will need to be regularly checked and updated to ensure they kept in line with advancements.	
14	MD	I think because technology is moved so fast, yeah. I just think if you look at all the Acts that are in place, they do get amended and they do get updated. I think there is definitely a gap with regards to using technology across the board. If you look at all the legislation, I think there's definitely a gap.	

Question 16: *If yes to Q15 ask:* How do you think this should be undertaken.

ID	POSITION	RESPONSE	KEY
	MD	Implementing these changes might be a bit difficult, there would need to be a phased approach to the implementation. So initially you could highlight mega constructions sites, Tier 1 contractors and high-risk construction environments and implement some legislation around that, the outputs can then be monitor that and the positive outcomes promoted before pursuing a slow phase introduction into other areas of construction.	
2	PM	I know construction sites are dangerous, in a mine you're working below ground, you don't know what you're coming up against and when working on oil rigs your exposed to an explosive environment, so yes I greed with the phased approach starting in the areas you mentioned.	
3	SM	I think what'll happen is you'll get big construction companies and people doing work in high-risk environments that are encouraged to implement this technology first, they'll be the ones that initially legislation will be aimed at.	
4	SPM	I believe a phased approach, maybe for the top guys, the tier ones should be asked to implement this initially. This can then be monitored and if beneficial implemented further in differing areas of construction.	
5	HOP	I agree this should be introduced into large construction sites and mining and high-risk environments, I'm sure there's already a list of high-risk construction environments like radio frequency, gas, working in confined spaces, asbestos, old buildings etc. So definitely I think it's concentrated on those areas first and edge to making them compulsory across all construction projects.	
6	PD	I think there are other ways of doing it, maybe not as good. I'd much rather see an industry response to this rather than a legislation response if that makes sense.	
7	PD	The same will happen for any technology that will be deployed in the construction industry. Your big scheme, your big tier ones will embrace this, will adopt this, will pioneer this, but it will filter down to the man in the van, you know eventually. After a product comes out it can be reproduced cheaper. So, there will be iterations of the technology that was made.	

8	PM	I believe any legislation should be introduce via a trial approach, with results monitored and analysed, they can then be used to support and promotion further integration into construction. So, there'll be some areas because the very nature of what we're talking about will involve the radio transmission of sorts, Bluetooth, wireless, radio. So, there'll be certain areas that that will become very difficult, for example, an area where you have to use an intrinsically safe torch, so the risk of anything that's got a battery in it because, somebody falling over and cracking that little case, forming very small spark in that environment could cause an issue.	
9	SM	There's lots of different companies out there and some of them wouldn't initially be able to take the cost of implementing all of that if it was forced on them. If you can have a phased process of implementing these new systems, you then start to see the benefits with these companies using them, there's then better practices for the storage of data that's been gathered, better use for that and then gradually that will filter down throughout the industry and so on. Initially implementing the new technology will allow the construction industry to become more aware of it, maybe the technology manufacturers should discuss implementation with companies that are working in these different areas of construction and agree a planned approach.	
10	HSM	I believe it should be a phased approach. I think you could draw a parallel with the emergency services because the police didn't used to wear anything, the fire brigade didn't used to wear anything and neither did the ambulance service, but now I think they're wearing cameras and recording devices. I know it's for a slightly different aspect, but for the police particularly it is a personal safety thing, it probably took a while to transition, but now I guess there's people that probably wouldn't go out without their cameras on.	
11	HOP	I think once you get the big contractors to undertake AWSDs and the legislation initially, to take this on board it then becomes more accepted and can be introduced via a gradual implementation approach, one sector at a time maybe, I think it could work then.	
12	PD	Yeah I agreed the technology should be introduced via a phased approach. I think you need to understand who's going to store that information? Does it become government information? How do you give people the comfort that he's not going to get thieved?	
13	PD	Starts off, by covering very high-risk activities and then filters down in that scheme of things, yes, it probably needs to be embedded at a very high-risk level and then see the benefits and the data and then see how it flows down. I think that would be a sensible approach, once the data is analysed and the statistics are out there in terms of how this benefits people first and foremost, then organisations from a safety perspective, it's then easier to sell it or incorporate it in legislation. Further down the chain.	
14	MD	I get involved in lots of things that get implemented in the industry and there's a lot of, I use the word, donkey work in the background. So, you're trying to build a foundation first, so yes, you would have to probably pick key sectors such as electrical as working in high voltage because there is lone work in there, so I think that would be a key area to look at. You could also look at explosive atmospheres like oil rigs, once you start building up the case studies that's when you see the benefits of them, obviously push it into other sectors.	

APPENDIX C – EXAMPLE DATA SET

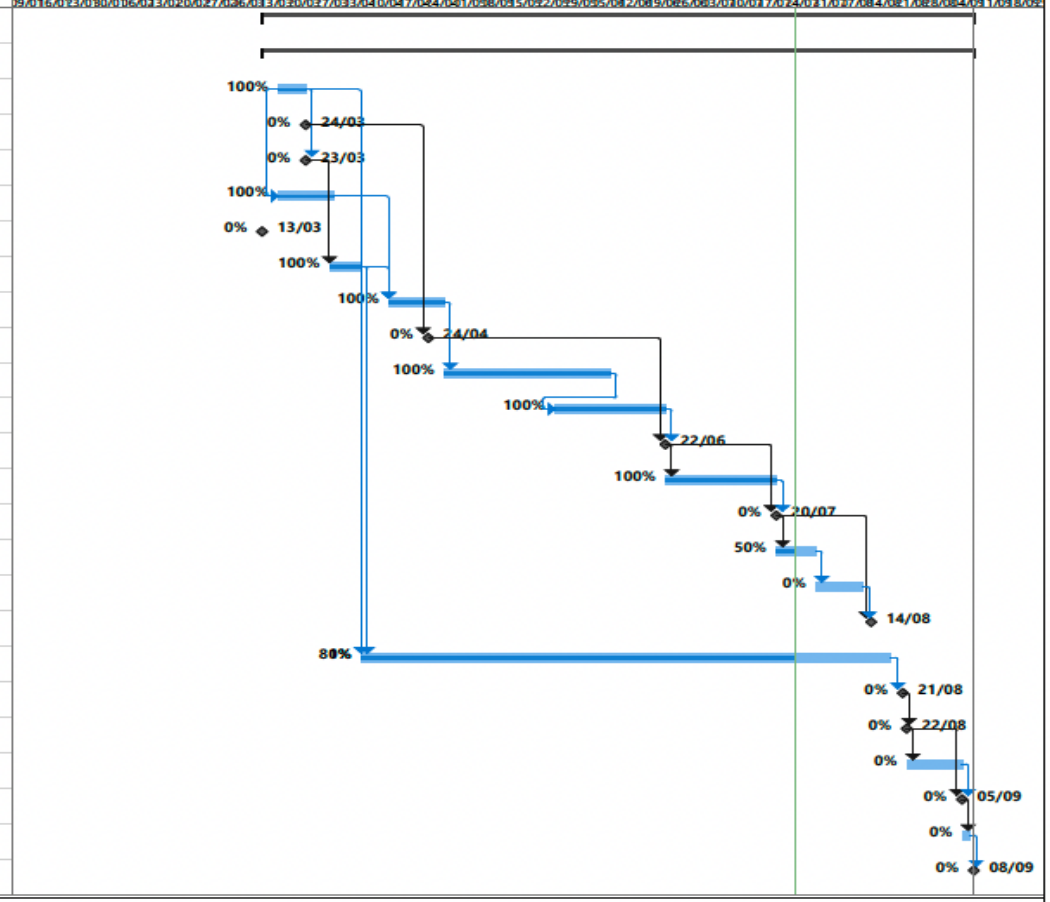


APPENDIX D - DISSERTATION PROGRAMME

Constructed by Steven Rose 20.01.2023

MSc CONSTRUCTION PROJECT MANAGEMENT DISSERTATION PROGRAMME

ID	Task Name	Duration	Start	Finish
1	Constructipn Project Management Dissertation	130 days	Mon 13/03/23	Fri 08/09/23
2	Dissertation	130 days	Mon 13/03/23	Fri 08/09/23
3	Complete Ethics Review & Risk Assessment	5 days	Fri 17/03/23	Thu 23/03/23
4	Supervisor Meeting 4	0 days	Fri 24/03/23	Fri 24/03/23
5	Submit Ethics Review & Risk Assessment	0 days	Thu 23/03/23	Thu 23/03/23
6	Plan Interview Questions	10 days	Fri 17/03/23	Thu 30/03/23
7	Supervisor Webinar 4	0 days	Mon 13/03/23	Mon 13/03/23
8	Gain Approval For Ethics Review & Risk Assessment	6 days	Thu 30/03/23	Thu 06/04/23
9	Arrange interview meetings	10 days	Fri 14/04/23	Thu 27/04/23
10	Supervisor Meeting 5	0 days	Mon 24/04/23	Mon 24/04/23
11	Undertake Interviews	30 days	Fri 28/04/23	Thu 08/06/23
12	Analysis Research Information	20 days	Fri 26/05/23	Thu 22/06/23
13	Supervisor Meeting 6	0 days	Thu 22/06/23	Thu 22/06/23
14	Explore Research Gaps Further	20 days	Fri 23/06/23	Thu 20/07/23
15	Supervisor Meeting 7	0 days	Thu 20/07/23	Thu 20/07/23
16	Complete Conclusion, Recommended & Improvement Measures	10 days	Fri 21/07/23	Sun 30/07/23
17	Identified Limitations, Gaps & Recommend Further Areas of Study	10 days	Mon 31/07/23	Fri 11/08/23
18	Supervisor Meeting 8	0 days	Mon 14/08/23	Mon 14/08/23
19	Write Dissertation	96 days	Fri 07/04/23	Fri 18/08/23
20	Present Draft Dissertation	0 days	Mon 21/08/23	Mon 21/08/23
21	Supervisor Meeting 9	0 days	Tue 22/08/23	Tue 22/08/23
22	Update Dissertation	10 days	Wed 23/08/23	Tue 05/09/23
23	Supervisor Meeting 10	0 days	Tue 05/09/23	Tue 05/09/23
24	Update Dissertation	2 days	Wed 06/09/23	Thu 07/09/23
25	Present Dissertation	0 days	Fri 08/09/23	Fri 08/09/23



Project Programme
Updated: 26.07.23

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Page 1

APPENDIX E - CERTIFICATE OF ETHICAL POLICY

UNIVERSITY OF PORTSMOUTH

Certificate of Ethics Review

Project title: Attitude and behaviour change in adopting advanced wearable sensing devices by construction workers to improve personal health and safety.

Name:	Steven Rose	**User ID:**	2083615	**Application date:**	28/03/2023 08:02:19	**ER Number:**	TETHIC-2023-105330

You must download your referral certificate, print a copy and keep it as a record of this review.

The FEC representative(s) for the **School of Civil Engineering & Surveying** is/are **Brett Martinson, Sepehr Abrishami**

It is your responsibility to follow the University Code of Practice on Ethical Standards and any Department/School or professional guidelines in the conduct of your study including relevant guidelines regarding health and safety of researchers including the following:

- University Policy
- Safety on Geological Fieldwork

It is also your responsibility to follow University guidance on Data Protection Policy:

- General guidance for all data protection issues
- University Data Protection Policy

Which school/department do you belong to?: **School of Civil Engineering & Surveying**
What is your primary role at the University?: **Postgraduate Student**
What is the name of the member of staff who is responsible for supervising your project?: **Dr Quan Phung**
Is the study likely to involve human subjects (observation) or participants?: Yes
Will you gather data about people (e.g. socio-economic, clinical, psychological, biological)?: No
Will you gather data from people about some artefact or research question (e.g. opinions, feedback)?: Yes
Confirm whether and explain how you will use participant information sheets and apply informed consent.: A demographic form will be issued with the consent form. The demographic form will collect data regarding education, age, sex, and ethnic background to enable an understanding of the groups of construction workers who are most likely to be resistant to the adoption of advanced wearable sensing devices. The consent form will be issued to ensure a full understanding is in place of the interview process and that participants are aware of how their data will be collected and stored; this form will also highlight that any information published will be done with full anonymity unless permission is acquired to detail specific individuals or organisations.
Confirm whether and explain how you will maintain participant anonymity and confidentiality of data collected: Any data collected in relation to personal or organisational information will be stored confidentially within a password protected computer file, this will be backed up on Apple's encrypted password protected i-cloud platform. No direct mention or indication of any individual or organisation will be detailed in the publish research unless permission is obtained to do so; the information produced will be presented in a numerical format.
Will the study involve National Health Service patients or staff?: No
Do human participants/subjects take part in studies without their knowledge/consent at the time, or will deception of any sort be involved? (e.g. covert observation of people, especially if in a non-public place): No
Will you collect or analyse personally identifiable information about anyone or monitor their communications or on-line activities without their explicit consent?: No
Does the study involve participants who are unable to give informed consent or are in a dependent position (e.g. children, people with learning disabilities, unconscious patients, Portsmouth University students)?: No
Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants?: No
Will blood or tissue samples be obtained from participants?: No
Is pain or more than mild discomfort likely to result from the study?: No
Could the study induce psychological stress or anxiety in participants or third parties?: No
Will the study involve prolonged or repetitive testing?: No

Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?: No
Are there risks of significant damage to physical and/or ecological environmental features?: No
Are there risks of significant damage to features of historical or cultural heritage (e.g. impacts of study techniques, taking of samples)?: No
Does the project involve animals in any way?: No
Could the research outputs potentially be harmful to third parties?: No
Could your research/artefact be adapted and be misused?: No
Will your project or project deliverables be relevant to defence, the military, police or other security organisations and/or in addition, could it be used by others to threaten UK security?: No
Please read and confirm that you agree with the following statements: I confirm that I have considered the implications for data collection and use, taking into consideration legal requirements (UK GDPR, Data Protection Act 2018 etc.), I confirm that I have considered the impact of this work and and taken any reasonable action to mitigate potential misuse of the project outputs, I confirm that I will act ethically and honestly throughout this project

Supervisor Review

As supervisor, I will ensure that this work will be conducted in an ethical manner in line with the University Ethics Policy.

Supervisor comments: **The student completed all required documents.**

Supervisor's Digital Signature: **quan.phung@port.ac.uk** Date: **07/04/2023**

Faculty Ethics Committee Review

Ethics Rep comments:

Faculty Ethics Committee Member's Digital Signature(s): **brett.martinson@port.ac.uk** Date: **13/04/2023**

APPENDIX F - RISK ASSESSMENT

Student No. 2083615

UNIVERSITY OF PORTSMOUTH **UNIVERSITY RISK ASSESSMENT FORM**

RISKS TO PERSONAL HEALTH AND SAFETY

HIGH
MEDIUM
LOW

Calculate: **Probability** multiplied by **Severity** for No/Post control scores. **NB:** For scores of 12 (High), or more contact the Health & Safety Office for further advice. Due to the seriousness of the 'Permanent Disability / Sight Loss and Fatal / Fatalities' factors this has been given a medium rating on the 'Unlikely' probability.

Site/Department: Technology

Task/Activity/Area: Conduct interviews via a video conference call, the interview is to be recorded and transcripts produced. The interview will be conducted in a working environment or at home outside of working hours.

Notes: This section of the risk Assessment related to personal injury risks.

(Including details of previous accidents/incidents)

Risk Assessment Team: Steven Rose

(People completing the risk assessment)

Probability ↓ / Severity →	Minor injury 1	Lost time/ Ill Health 2	Major / >7 days 3	Perm. Disability/ Sight Loss 4	Fatality/ Multiple fatality 5
Highly Unlikely 1	1	2	3	4	5
Unlikely 2	2	4	6	8	10
Possible 3	3	6	9	12	15
Probable 4	4	8	12	16	20
Certain 5	5	10	15	20	25

Risk assessment start date: 28th April 2023

Highly unlikely: Slight chance of an accident happening	**Unlikely:** An unusual combination of factors would be required for an accident to happen	**Possible:** Not certain to happen but multiple additional unforeseen factors may result in an accident happening	**Probable:** Not certain to happen but one additional unforeseen factor may result in an accident happening	**Certain:** A high probability of an accident happening
Minor injury: Injury requiring basic first aid i.e. Plaster or cold compress	**Lost time / Ill health:** Injury that requires medical treatment at hospital or GP	**Moderate/ > 7 days off work:** An injury or work related illness reportable under *The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013*	**Perm Disability / Eye Sight loss:** Likely permanent disability Acute/ Chronic health effects	**Fatality / Multiple fatality:** An injury/ Ill health that results in a fatality or fatalities

Dept. Manager (Print Name):	Quan Phung	**Signature:**	
Review Date:	26/04/2023	**Reviewed by:**	

Reason for review: To ensure suitable the identification of associated hazards and the implementation of relevant risk reducing measures.

Dept. Manager (Print Name):		**Signature:**	

Student No. 2083615

Ref No or Task-step	Identified hazards or Injury causes, highlighting risks	People at risk i.e., Staff, students, visitors, contractors, or the public	Score -No controls (Probability Severity = calculation)	Controls/Procedures/Key Behaviours (Existing controls, information, training etc.)	Score-Post Controls (Calculation)	Further action required	Action Priority (H/M/L)
1	Musculoskeletal Injuries, resulting in stiffness or seizing of muscles or permanent joint pain and discomfort.	Student and interview participants.	6	Suitable office furniture that allows individual ergonomic adjustments to be made is to be used. Ergonomic training is to be completed.	3	Visual checks to be undertaken.	L
2	Dehydration resulting in lack of poor concentration levels which in turn will produce poor responses to the interview questions.	Student and interview participants.	8	Drinking water is to be made available throughout the interview and the environment is to has sufficient heating, cooling, and ventilation.	2	Adjust climate controls to suit.	L
3	Electrical Shock, poor electrical installations or faulty equipment could result in burns or electrocution.	Student, interview participants, visitors, and contractors.	10	Electrical equipment is to be portable appliance tested and a fix wiring test should be completed. Visual inspections of the equipment and installation should be undertaken, any defects should be identified, and a suitably qualified person should be appointed to complete the remedial works.	5	Ensure there is no over loading of any extension leads used with items such as electric heaters, all extension leads should be unwound fully.	H
4	Poor lighting could lead to eye strain.	Student and interview participants.	5	Suitable lighting is to be supplied and any required prescription eye wear is to be worn, alongside this, a suitably size computer screen is to be made available.	1	Lighting is to be set to the required levels and the computer brightness and screen font size is to be set to the user's requirements.	L
5	Impact Injuries from falling objects could result in cuts, bruises, broken bones or even fatality.	Students, interview participants, visitors, and contractors.	10	Any items placed on shelves, work surfaces, tables and desks are to be positioned centrally and securely and should not be of sufficient weight to cause a collapse.	2	Visual checks to be undertaken.	M
6	Slips, trips, and falls resulting in impact injuries, cuts, bruises, broken bones and even fatality.	Students interview participants, visitors, and contractors.	10	A visual inspection is to be undertaken to identify any hazards, any identified hazards are to be removed or barriered off and where required suitable signage is to be displayed.	3	Suitable cleaning materials are to be supplied to manage and contain any spillages, i.e., drinking water.	M

Student No. 2083615

Ref No or Task-step	Identified hazards or Injury causes, highlighting risks	People at risk i.e., Staff, students, visitors, contractors, or the public	Score - No controls (Probability x Severity = calculation)	Controls/Procedures/Key Behaviours (Existing controls, information, training etc.)	Score-Post Controls (Calculation)	Further action required	Action Priority (H/M/L)
7	Fire could result in breathing problems, burns or fatality.	Students interview participants, visitors, and contractors.	10	The interview environment is to have an appropriate fire detection system installed and this is to be fully operational and tested regularly.	2	Suitable fire extinguishers are to be provided and located in agreed locations; these need to be inspected to ensure they are operational.	H
8	Blocked or restricted emergency exit routes resulting in delayed exit and exposure to fire and fumes; injuries could include burns, lung damage or fatality.	Students interview participants, visitors, and contractors.	10	Ensure a fire risk assessment has been completed and all actions relating to entry and exit routes have been undertaken.	2	Complete a visual inspection of all entry and exit routes.	H

Student No. 2083615

UNIVERSITY OF PORTSMOUTH

UNIVERSITY RISK ASSESSMENT FORM

HIGH
MEDIUM
LOW

Calculate: **Probability** multiplied by **Severity** for No/Post control scores. **NB**: For scores of 12 (High), or more contact the Health & Safety Office for further advice.

Risks To Dissertation Research Information

Site/Department: Technology

Task/Activity/Area: Conduct interviews via a video conference call, the interview is to be recorded and transcripts produced. The interview will be conducted in a working environment or at home outside of working hours.

Notes: The section of the risk assessment related to the risks associated with obtaining and storing the research information.

(Including details of previous accidents/incidents)

Risk Assessment Team: Steven Rose

(People completing the risk assessment)

Probability ↓ / Severity →	Lack of Knowledge 1	Non-Attendance 2	Loss of Individual Data 3	Equipment Failure 4	Loss of All Data Collected 5
Highly Unlikely 1	1	2	3	4	5
Unlikely 2	2	4	6	8	10
Possible 3	3	6	9	12	15
Probable 4	4	8	12	16	20
Certain 5	5	10	15	20	25

Risk assessment start date: 28th April 2023

Highly unlikely: Slight chance of an accident happening	**Unlikely:** An unusual combination of factors would be required for an accident to happen	**Possible:** Not certain to happen but multiple additional unforeseen factors may result in an accident happening	**Probable:** Not certain to happen but one additional unforeseen factor may result in an accident happening	**Certain:** A high probability of an accident happening
Lack of Knowledge: Insufficient knowledge of the research topic resulting in a lack of quality responses.	**Non-Attendance:** Unable to complete the number of interviews targeted resulting in diluted results.	**Loss of individual data;** Due to user error which will weaken the equality of the results obtained.	**Equipment Failure:** Unable to complete further interviews which would affect the quality of the output results.	**Loss of all data collected.** Unable to complete the research.

Dept. Manager (Print Name):	Quan Phung	**Signature:**	
Review Date:	26/04/2023	**Reviewed by:**	

Reason for review: To ensure suitable the identification of associated hazards and the implementation of relevant risk reducing measures.

Dept. Manager (Print Name):		**Signature:**	

Ref No or Task-step	Identified hazards or Injury causes, highlighting risks	People at risk i.e., Staff, students, visitors, contractors, or the public	Score -No controls (Probability x Severity = calculation)	Controls/Procedures/Key Behaviours (Existing controls, information, training etc.)	Score-Post Controls (Calculation)	Further action required	Action Priority (H/M/L)
1	Not obtaining sufficient information due to lack of knowledge on the research topic, this will significantly weaken the research analysis.	Student.	10	Researched the proposed interviewees and the companies they work for. Undertake pre-interview discussions before identifying the people you would like to take part in your research study.	2	The dissertation participant schedule is to be completed and returned with the letter of consent.	H
2	Interview non-attendance resulting in diluted results being obtained, and a less accurate data analysis being produced.	Student.	9	Confirmation of the interview date is required; an electronic meeting invite is to be issued. Send a reminder email and text to the interviewees at an agree time to ensure the interview date is still suitable.	3	If the interview is being completed in working time ensure the interviewee has the permission of their employer to attend.	H
3	Loss of data through user error impacting the data analysis and output produced.	Student and interview participants.	10	A thorough understanding of the equipment to be used is to be in place by undertaking any relevant training and completing practice runs. A back up facility should be used i.e., voice recorder, hand drive or cloud storage.	3	Checks on the equipment and programs to be used are to be completed. i.e., data storage capacity, licences, battery life etc.	H
4	Faulty equipment resulting in loss of information impacting the data analysis and outputs produced.	Student and interview participants.	12	Checks on the equipment and programs to be used are to be completed. i.e., data storage capacity, licences, battery life etc.	2	Spare batteries and IT leads are to be available	H
5	Unable to complete a data analysis due to fire damage resulting and the loss of research data collected.	Student.	15	The interview environment is to have an appropriate fire detection system installed and this is to be fully operational and tested regularly. All data collected is to be backed up on an encrypted cloud storage facility.	3	Suitable fire extinguishers are to be provided and located at agreed locations; these need to be inspected to ensure they are operational.	H

Student No. 2083615

Ref No or Task-step	Identified hazards or Injury causes, highlighting risks	People at risk i.e., Staff, students, visitors, contractors, or the public	Score -No controls (Probability x Severity = calculation)	Controls/Procedures/Key Behaviours (Existing controls, information, training etc.)	Score-Post Controls (Calculation)	Further action required	Action Priority (H/M/L)
6	Unable to complete the dissertation by the completion date due to poor time management.	Student.	15	Ensure a dissertation programme is produced and milestone dates are achieved.	3	Ensure interviews are booked and confirmations received.	H
7	Unable to complete the dissertation by the completion date due to unforeseen personal circumstances.	Student.	15	Inform the university as soon as you are aware of any personal issues that may affect you completing and presenting your dissertation by the agreed date.	3	Complete the relevant paperwork requesting an extension of time.	H

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