HEALTH AND SAFETY ISSUES AND MITIGATION MEASURES RELATING TO ADAPTIVE-RETROFITS PROJECTS: LITERATURE REVIEW AND RESEARCH IMPLICATIONS FOR THE GHANAIAN CONSTRUCTION INDUSTRY

Frederick Owusu Danso[1], Edward Badu[2], Divine Kwaku Ahadzie[3] and Patrick Manu[4]

[1] *Department of Building Technology, Takoradi Polytechnic, Takoradi, Ghana*

[2] *College of Art and Built Environment, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[3] *Centre for Settlements Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[4] *Department of Architecture and the Built Environment, University of the West of England, Bristol, UK*

Adaptive-retrofit projects (ARPs) are associated with dire health and safety (H&S) issues which are fragmented and scattered in the existing literature on retrofitting, refurbishment, renovation, rehabilitation, and repair and maintenance work (5R+M). To effectively guide the safe execution of ARPs, these fragmented and scattered issues together with their mitigation measures need to be identified and consolidated into a single unified coherent insight. Therefore this paper, as part of an on-going PhD research on ARPs in Ghana, reviews academic literature to identify and compile a comprehensive list of the H&S issues with their mitigation measures for ARPs. After performing electronic database literature searches and subsequent critical examination of the literature obtained, thirty-six (36) health and safety issues/challenges and twenty-six seven (27) mitigation measures relating to execution of ARPs were identified. These findings provide a sound preliminary basis for further empirical studies towards the development of a coherent and unified guidance for the safe execution of ARPs in Ghana while taking into account local conditions that could also induce additional H&S issues which may not be apparent in the extant literature.

Keywords: adaptive, health and safety, retrofit.

INTRODUCTION

Compared to regular construction work (i.e. new works), ARPs suffer from a relative dearth of literature on occupational H&S. The existing research on ARPs appear to mainly highlight the significance of H&S on ARPs or provide fragments of insights on the H&S challenges relating to ARPs without providing a comprehensive and coherent examination of the key H&S issues and their associated mitigation measures (cf. Langston *et al*., 2008; Bullen and Love 2011; Xu *et al*. 2012). A thorough identification of these issues together with their related mitigation measures could constitute the basis for the development of a comprehensive and joined-up H&S

[1] ofreddanso@yahoo.com

Danso, F O, Badu, E, Ahadzie, D K and Manu, P (2015) Health and safety issues and mitigation measures relating to adaptive-retrofits projects: Literature review and research implications for the Ghanaian construction industry *In:* Raidén, A B and Aboagye-Nimo, E (Eds) *Procs 31st Annual ARCOM Conference,* 7-9 September 2015, Lincoln, UK, Association of Researchers in Construction Management, 559-568.

guidance for the safe execution of ARPs. Therefore, the purpose of this study is to delve deep into the construction H&S literature to draw out a comprehensive list of the key H&S issues and their related mitigation measures for ARPs. To achieve this, this paper starts by highlighting the dangerous nature of ARPs. The paper subsequently delves into the construction H&S literature as well as literature on ARPs to elicit the H&S issues that are often encountered on ARPs and their related mitigation measures. A discussion of the implications of the outcome of the review for further on-going research on ARPs in the Ghanaian construction industry is presented

WHAT IS ARP?

Adaptive-retrofit is a joined-up word from adaptation and retrofitting as applied to existing built assets. Adaptation, according to Douglas (2006), Wilkinson *et al*. (2009) and Ankrah and Ahadzie (2014) is an all-in concept comprising of refurbishment, renovation, rehabilitation, and repair and maintenance work (4R+M) applied to existing built assets to improve their physical form to continue or take on new functions or uses. On the other hand, retrofitting, according to Xu *et al*. (2012) and Dixon (2014) embraces the additions of modern plumbing, heating, ventilation, air conditioning and telecommunication services to existing built assets to improve their mechanical services and energy consumption. Retrofitting also includes the addition of components or features (which were originally not part of an existing building) to the existing building (Douglas 2006). In an attempt to achieve low-carbon emissions from existing built assets and make them more energy-efficient while meeting the modern needs of occupants, society and infrastructure development, the concept of retrofitting is most often than not connected with adaptation (Dixon 2014) though it can be applied separately to existing built assets. Since these two concepts (adaptation and retrofitting) are closely linked together in terms of modern infrastructure development, it is reasonable to adopt a common name to represent their usage, hence the term adaptive-retrofit (AR).

Adaptive-retrofit projects (ARPs) are thus built assets that have been subjected to refurbishment, retrofitting, renovation, rehabilitation, and repair and maintenance work (5R+M) to improve their physical form and energy consumption while continuing to perform their old function or new uses and also satisfy the needs of modern occupants, society and infrastructure development. Literature however signals that each of the 5R+M has their own confronting or peculiar H&S challenges. For example, previous report indicated that refurbishment work alone in the UK construction industry accounted for about 40.6% of the total number of construction fatalities (Anumba *et al*. 2004). Repair and maintenance work have also been reported to be responsible for a high proportion of 43% of the total number of fatal accidents in both building and civil engineering industry in UK (cf. Anumba *et al*. 2006). Hon *et al*. (2010) mentioned that the accident ratio of repair, maintenance, and alteration and additional works in the Hong Kong construction industry compared to new builds have significantly increased from 17.9% in 1998 to 50.1% in 2007. Also, fatal cases from these works in 2010 accounted for 66.7% of the total number of fatal cases in construction in Hong Kong (Hon *et al*. 2014). In a China-based study, Xu *et al*. (2012) through fuzzy theory identified eight key performance indicators (including a H&S indicator) that require consideration when adapting old hotel buildings. In order of importance, the H&S indicator ranked fourth ahead of other indicators such as energy consumption, resources saving, and stakeholders' satisfaction. Judging from the above, it is thus not surprising that there is the view that the application of 5R+M to existing buildings is likely to further worsen injury and illness statistics.

THE DANGEROUS NATURE OF ARPS

ARPs are generally described as dangerous projects (cf. Quah, 1998; Egbu *et al*. 1998; Egbu 1999; Anumba *et al*., 2004 and 2006; Douglas, 2006; Doran *et al*. 2009). The safety challenges ARPs present are either absent or minimal in new builds/works. Recent studies on the H&S impact of construction project features (cf. Manu, 2012; 2014) also provide insight of how demolition, refurbishment and new builds potentially influence accident occurrence on construction sites. Manu *et al*. (2014) reported demolition and refurbishment as having a higher potential to cause harm to workers than new builds. In terms of the likelihood of occurrence of harm (i.e. the risk of harm), Manu (2012) also reported that demolition and refurbishment are associated with a higher risk than new builds. Given that H&S control measures are supposed to be commensurate with risks (HSE, 2000; 2007), it is then without doubt that the H&S control measures that are needed for ARPs cannot simply be exactly the same as the controls used on new builds. Rather the controls that are used on ARPs should reflect the kinds of H&S risks/issues that workers are likely to be exposed to and thus ARPs will need some extra layer(s) of H&S defence in the form of measures and guidance to deal with the inherent H&S issues

LITERATURE REVIEW METHOD

The identification of the H&S issues of ARPs began with a detailed search from peer-reviewed journals that report on construction H&S. Zhou *et al*. (2015) researched and presented the top ten (10) journals that frequently report on H&S management and construction engineering issues. The peer-review journals as identified by Zhou *et al*. (2015) include: Safety Science (SS), Journal of Safety Research (JSR), Automation in Construction (AIC), Accident Analysis and Prevention (AAP), Reliability Engineering and System Safety (RESS), Journal of Construction Engineering and Management (JCEM), Engineering Construction and Architectural Management (ECAM), Journal of Management in Engineering (JME), International Journal of Project Management (IJPM) and Construction Management and Economics (CME). These peer-reviewed journals were selected to guide the review of literature for this study.

Electronic database search using keywords (e.g. adaptation, H&S, retrofits, refurbishment), was conducted on these journals. Titles and abstracts of peer-reviewed papers within those journals that could potentially contribute to the understanding of the topic were identified, read and selected. Further, relevant titles from references/bibliographic lists found in those peer-reviewed papers that could also contribute to the understanding of the topic were also selected. Through this, peer-reviewed papers from journals such as Structural Survey (SS1), Facilities (F), Building and Environment (BAE), Energy Policy (EP), Energy and Buildings (EAB), International Journal of Construction Education and Research (IJCER), International Journal of Injury Control and Safety Promotion (IJICSP) were also considered for the literature review. Electronic books on adaptation, retrofitting, renovation, refurbishment, rehabilitation and repair and maintenance work were also searched from Google Books and Directory of Open Access Books (Doab). Health and safety reports from the UK Health and Safety Executive (HSE) website (www.hse.gov.uk) and papers from conference proceedings that have major themes or titles as adaptation, retrofitting together with health and safety were also considered. Quite apart from using the research keywords alone for the search, Boolean connectors such as AND, OR, AND NOT were also used to connect the research keywords to form search strings such as *"adaptation AND health and safety"* and *"retrofitting AND health and safety"*. The reason was based on the idea that if a paper bears strong links to adaptation and retrofitting of existing built assets then it is likely that its H&S issues will be captured in that paper or report or book.

HEALTH AND SAFETY ISSUES ON ARPS AND POSSIBLE MITIGATION MEASURES

Through the systematic search and reading of the obtained literature, several health and safety issues (over 50) and mitigation measures (over 30) relating to ARPs were initially spotted and tabulated. Through subsequent careful scrutiny of these, multiple occurring (i.e. repeating) H&S issues and mitigation measures were excluded resulting in an eventual comprehensive list of thirty six (36) H&S issues and twenty-seven (27) mitigation measures. The detailed results from the review are summarised in appendix 1 below. The H&S issues are represented by HSI while the mitigation measures are also represented by MM. The repeated items of HSI and MM are presented in table 1 below.

From table 1, eleven (11) similar health and safety issues were spotted twice and five (5) similar health and safety issues were also spotted three times from different studies. For example, regarding safety signs (i.e. HIS 1), Anumba *et al*. (2004) and Doran *et al*. (2009) are of the same opinion that lack of warning signs or safety posters could affect the safety, health and the wellbeing of workers on refurbishment projects. The absence of safety signs or the lack of its understanding, according to Tam *et al*. (2003) are likely to cause injuries (fatal and non-fatal) on construction sites in general. On ARPs sites, where hazards are more commonplace than on new build sites, the lack of warning signs or safety posters could therefore further worsen the likelihood of occurrence of injuries.

Table 1: Recurring H&S Issues and Mitigation Measures

Health and safety issues and Mitigation measures	*Frequency of occurrence*
(HSI 1), (HSI 4), (HIS 5), (HSI 8), (HSI 9), (HSI 11), (HSI 13), (HSI 14), (HSI 16), (HSI 23), (HSI 26).	2
(HSI 15), (HSI 17), (HSI 24), (HSI 30), (HS34)	3
(MM1), (MM6)	2

Lack of/inadequate site supervision (HSI 5) was also noted from two different studies (see Anumba *et al*. (2004) and Doran *et al*. (2009)). Lack of site supervision has been identified by these authors as a major factor that could affect the safety of workers on ARPs. Inadequate supervision of construction operatives is also generally considered to be an inappropriate construction control that could lead to accidents on site (Suraji *et al*. 2001). Regarding the mitigation measures, MM1 (i.e. undertaking structural safety survey) and MM6 (i.e. provision of safety training (related to refurbishment and demolition) to workers) were spotted in two studies. Anumba *et al*. (2004) and Egbu (1999) share the view that specific safety training is needed for workers on refurbishment projects if injuries are to be prevented or minimised. Hallowell and Gambatese (2009) reinforced this view by mentioning that project-specific training is among the key/essential elements for reducing or preventing construction accidents on site.

IMPLICATIONS FOR FURTHER RESEARCH FOR THE GHANAIAN CONSTRUCTION SECTOR

As confirmed by the review, the extant H&S literature on ARPs mainly either appear to caution and highlight the significance of H&S on ARPs or provide fragments of the H&S issues encountered on ARPs and their mitigation. Given the significance of H&S to ARPs, it is thus important to systematically elicit and consolidate from the extant literature the various bits of reported H&S issues and mitigation. Through a thorough review, a comprehensive list of thirty-six (36) H&S issues together with twenty seven (27) mitigation measures has been developed.

Presently, in the Ghanaian construction sector, ARPs are increasingly becoming common and this can be linked to the need to meet the huge housing and infrastructure deficits within the country (Ofori 1995; Ahadzie *et al*., 2004; Bank of Ghana, 2007). This situation may not be dissimilar to other developing countries where a similar scale of housing and infrastructure deficits are to be addressed. Whilst the comprehensive lists that have been developed from this study could constitute valuable insight for ARPs execution, they have mainly been based on studies conducted in developed contexts. Therefore the list may still not be fully comprehensive or entirely responsive to some of the local context-specific conditions in developing contexts like Ghana. For instance Kheni *et al*. (2010) mentioned in their H&S study on Ghana that the construction industry is highly labour intensive with a majority of its site workers being illiterates with low skills. They also mentioned the use of poor traditional working methods on construction projects in the industry. Such local context-specific conditions/situations could either induce additional H&S issues or trigger the need for additional mitigation measures for ARPs that are not apparent in the extant literature. It is thus important that for the local Ghanaian context further research work is undertaken to elicit other H&S issues that are not apparent in the extant literature and also to devise commensurate adequate mitigation measures towards the development of a more holistic H&S management guidance for ARPs in Ghana. The further research work is expected to be addressed by three main steps of the on-going PhD study alluded to above:

1-development of a conceptual H&S management framework for ARPs in Ghana;
2-refinement of the framework; and
3-evaluation of the usefulness of the framework. These steps are elaborated below. The initial step is to develop a conceptual framework which coherently matches the list of H&S issues with their corresponding mitigation measures and then maps them onto the phase(s) of project life cycle at which the measures should be implemented together with an indication of the relevant project participant(s). To enable subsequent refinement of the framework (i.e. step 2) to take into account any context-specific issues for the Ghanaian construction industry, it is proposed that a Delphi method is applied. The Delphi method is an iterative process used to collect and distil the judgments of experts using a series of questionnaires interspersed with feedback (Skulmoski *et al*., 2007). The method can also be used when there is incomplete knowledge about a problem that does not lend itself to precise analytical techniques but rather could benefit from the subjective judgments of individuals who have a wealth of expertise/knowledge about the problem area (Adler and Ziglio, 1996; Delbeq *et al*., 1975). Whilst ARPs are becoming common in Ghana, they are still relatively less common than new works. As a result fewer construction professionals in Ghana are expected to have the expertise or knowledge about their execution and hence the inherent H&S issues. ARP execution in Ghana is thus expected to be

characterized by relatively limited knowledge and expertise amongst professionals. In view of this, it is prudent to use a Delphi method as this method enables the use of the collective judgment of a group of experts in investigating such phenomena or problems (that are characterized by limited insight) and coming up with workable solutions (see Adler and Ziglio, 1996; Delbeq *et al*., 1975). The application of Delphi method in construction management research and more specifically H&S studies is not uncommon as can be seen in several studies (e.g. Chan *et al*. 2001; Yeung *et al*., 2007; Hallowell, 2009; Hallowell and Gambatese, 2010). This also reinforces the suitability of the Delphi method for this research. In applying the Delphi method, a team of construction professionals who have expertise regarding execution of ARPs in Ghana will be assembled to participate in two or more rounds of Delphi surveys, the aim being to employ their collective expert judgment to refine the framework into a practical guidance for the management of H&S of workers on ARPs in Ghana. The experts will ascertain the relevance of the H&S issues and the mitigation measures (listed in appendix 1) to the Ghanaian context. More importantly, they relying on their local expertise and experiences of ARPs and the Ghanaian construction industry in general, they will also contribute to the research process by identifying other H&S issues (together with their mitigation measures) that are more context-specific and as such may not be not covered by the H&S issues and measures in appendix 1. It is envisaged that through this process of inquiry a practical ARP H&S guidance will be developed to address the H&S challenges accompanying the growing ARP sub-sector in the Ghanaian construction industry. For the final step (i.e. step 3) the practical utility of the developed ARP H&S guidance will be evaluated from practitioners' perspectives

CONCLUSIONS

Due to several drivers including sustainability and the need to meet housing and infrastructure demands, ARPs are increasingly becoming common. ARPs are however more dangerous and carry risks that are significantly different from those on new works/builds. As such is it evidently clear that the H&S control measures that are needed for ARPs cannot simply be exactly the same as those used on ARPs. Whilst there is a body of literature on the H&S issues associated with ARPs and their mitigation measures, these have been reported in fragments and as such scattered across the literature on ARPs and construction H&S. As such there is not a comprehensive and consolidated understanding of the H&S issues and mitigation measures relating to ARPs. Through a systematic review of the existing literature a comprehensive list of the H&S issues and mitigation measures is drawn. In order for this generic list to be of practical use to the Ghanaian construction sector, further empirical work is needed to ascertain their relevance and more importantly to elicit other context-specific issues regarding ARPs that are not featured. Three main steps have been proposed to advance this: (1) to develop a conceptual framework which coherently matches the list of H&S issues with their corresponding mitigation measures and then maps them onto the phase(s) of project life cycle at which the measures should be implemented together with an indication of the relevant project participant(s); (2) apply a Delphi method to refine the conceptual framework into a H&S management guidance for ARPs in Ghana; and (3) evaluate the practical utility of the guidance from practitioners' perspective. Through this 3 step process, it is expected that the fragmented and scattered H&S issues of ARPs will be consolidated into a single unified coherent framework to reflect the project life cycle of ARPs.

Furthermore, the gap of the relative dearth of literature on H&S management on ARPs especially in the context of developing countries like Ghana will be bridged

REFERENCES

Adler, M. and Ziglio. E. (1996) *"Gazing into the oracle: The Delphi Method and its application to social policy and public health"*. London: Jessica Kingsley Publishers.

Ahadzie, D.K., Proverbs, D. G. and Olomolaiye, P. (2004) Meeting Housing Delivery Targets in Developing Countries: The project managers contribution in Ghana, In Ogunlana *et al* (Eds): *"The Construction Industry in Developing Countries, International Conference on Globalization and Construction"*, Asian Institute of Technology (AIT), Bangkok, Thailand, 17-19 November, pp. 620-630.

Ankrah, N.A. and Ahadzie, D.K., (2014) Key challenges of managing building adaptation and retrofit projects. *"Structural Survey"*, **32**(5).

Anumba, C., Marino, B., Gottfried, A. and Egbu, C. (2004) *"Health and safety in refurbishment involving demolition and structural instability"*. Suffolk: HSE Books.

Anumba, C., Egbu, C. and Mukesh, K., (2006) *"Avoiding structural collapses in refurbishment. A decision support system"*. Suffolk: HSE Books.

Bank of Ghana, (2007) *"The Housing Market In Ghana"*. Bank of Ghana.

Bullen, P. and Love, P., (2011) A new future for the past: a model for adaptive reuse decision-making. *"Built Environment Project and Asset Management"*, **1**(1), pp.32–44.

Bullen, P.A. and Love, P.E.D., (2010) The rhetoric of adaptive reuse or reality of demolition: Views from the field. *"Cities"*, **27**(4), pp.215–224.

Chan, A. P. C. , Yung, E. H. K. , Lam, P. T. I. , Tam, C. M. and Cheung, S. O.(2001) Application of Delphi method in selection of procurement systems for construction projects', *"Construction Management and Economics"*, **19**(7), pp. 699-718.

Delbeq, A., Van de Ven, A., and Gustafson, D. H. (1975) *"Group techniques for program planning: A guide to nominal group and Delphi processes"*. Glenview, USA: Scott, Foresman and Company.

Dixon, T., (2014). Commercial property retrofitting. *"Journal of Property Investment and Finance"*, **32**(2), pp.443–452.

Doran, D., Douglas, J. and Pratley, R., (2009) *"Refurbishment and repair in construction"*, Scotland, UK: Whittles Publishing.

Douglas, J., (2006) *"Building Adaptation"*, Second Edition, Butterworth-Heinemann.

Egbu, C.O., (1999) Skills, knowledge and competencies for managing construction refurbishment works, *"Construction Management and Economics"*, **17**(1), pp.29–43.

Egbu, C.O., Young, B. A. and Torrance, V.B., (1998) Planning and control processes and techniques for refurbishment management. *"Construction Management and Economics"*, **16**(3), pp.315–325.

Hallowell, M.R. and Gambatese, J. A., (2009) Construction Safety Risk Mitigation. *"Journal of Construction Engineering and Management"*, **135**(12), pp.1316–1323.

Hallowell, M, R. and Gambatese, J. A. (2010) Qualitative Research: Application of the Delphi Method to CEM Research, *"Journal of Construction Engineering and Management"*, **136**(1), pp. 99-107.

Hein, M. and Houck, K.D., (2008) Construction Challenges of Adaptive Reuse of Historical Buildings in Europe. *"International Journal of Construction Education and Research"*, **4**(2), pp.115–131.

Hon, C.K.H., Chan, A.P.C. and Wong, F.K.W., (2010) An analysis for the causes of accidents of repair, maintenance, alteration and addition works in Hong Kong. *"Safety Science"*, **48**(7), pp.894–901.

Hon, C.K.H., Chan, A.P.C. and Yam, M.C.H., (2014) Relationships between safety climate and safety performance of building repair, maintenance, minor alteration, and addition (RMAA) works. *"Safety Science"*, **65**, pp.10–19.

HSE (2000) *"Management of Health and Safety at Work Regulations 1999 Approved Code of Practice and Guidance"*. 2nd ed. Suffolk: HSE Books.

HSE (2007) *"Managing health and safety in construction- Construction (Design and Management) Regulations 2007 Approved Code of Practice"*. Suffolk: HSE Books

Isnin, Z., Ahmad, S.S. and Yahya, Z., (2012) Awareness and Knowledge of the Hidden Killers in Building Adaptation Projects. *"Procedia - Social and Behavioral Sciences"*, **68**(November), pp.43–52.

Kashyap, M., Anumba, C.J. and Egbu, C.O., (2005) Towards a Decision Support System for Health and Safety Management in Refurbishment Projects. In *"4TH Triennial International Conference Rethinking and Revitalizing Construction Safety, Health, Environment and Quality"* Port Elizabeth – South Africa. pp. 151–163.

Kheni, N., Gibb, A.G. and Dainty, A.R.., (2010) Health and safety management within SMEs in developing countries : A study of contextual influences. *"ASCE Journal of Construction Engineering and Management"*, **136**(10), pp.1104–1115.

Langston, C. *et al*., (2008) Strategic assessment of building adaptive reuse opportunities in Hong Kong. *"Building and Environment"*, **43**(10), pp.1709–1718.

Lind, S., Nenonen, S. and Kivistö-Rahnasto, J., (2008) Safety risk assessment in industrial maintenance. *"Journal of Quality in Maintenance Engineering"*, **14**, pp.205–217.

Manu, P. A. (2012) *"An investigation into the accident causal influence of construction project features"*. PhD thesis, School of Technology, University of Wolverhampton, United Kingdom

Manu, P., Ankrah, N., Proverbs, D. and Suresh, S. (2014) The health and safety impact of construction project features. *"Engineering, Construction and Architectural Management"*, **21**(1), pp. 65 - 93.

Ofori, G., (1995) Construction technology development : role of an appropriate policy. *"Engineering, Construction and Architectural Management"*, **1**(2), pp.147–168.

Othman, A.E.A., (2012) Architectural Engineering and Design A study of the causes and effects of contractors' non-compliance with the health and safety regulations in the South African construction industry. *"Architectural Engineering and Design Management"*, **8**(3), pp.180–191.

Quah, L. K. (1988) *"An Evaluation of the risks in estimating and tendering for refurbishment work"*, Unpublished PhD thesis, Herriot-Watt University, Edinburgh, UK.

Skulmoski, G. J., Hartman, F. T. and Krahn, J. (2007) The Delphi method for graduate research. *"Journal of Information Technology Education"*, **6**, pp. 1-21.

Suraji, A., Duff, R.A. and Peckitt, S.J., (2001) Development of Causal Model of Construction Accident Causation. *"Journal of Construction Engineering and Management"*, **127**(4), pp.337–344.

Tam, C.M. *et al*., (2003) Relationship between construction safety signs and symbols recognition and characteristics of construction personnel. *"Construction Management and Economics"*, **21**(7), pp.745–753.

Wilkinson, S.J., James, K. and Reed, R., (2009) Using building adaptation to deliver sustainability in Australia. *"Structural Survey"*, **27**(1), pp.46–61.

Xu, P.P., Chan, E.H.W. and Qian, Q.K., (2012) Key performance indicators (KPI) for the sustainability of building energy efficiency retrofit (BEER) in hotel buildings in China. *"Facilities"*, **30**(9/10), pp.432–448.

Yeung, J. F. Y., Chan, A. P. C., Chan, D. W. M. and Li, L. K. (2007) Development of a partnering performance index (PPI) for construction projects in Hong Kong: a Delphi study. *"Construction Management and Economics"*, **25**(12), pp. 1219-1237

Zhao, D. *et al*., (2013) Electrical deaths in the US construction: an analysis of fatality investigations. *"International Journal of Injury Control and Safety Promotion"*, **21**(3), pp.278–288.

Zhou, Z., Miang, Y. and Li, Q., (2015) Overview and analysis of safety management studies in the construction industry. *"Safety Science"*, **72**, pp.337–350.

Appendix 1: Health and Safety Issues on ARPS and Possible Mitigation Measures

Health and Safety Issues (HSI)

(HSI 1) Lack of safety warning signs or safety posters

(HSI 2) Inappropriate use of tools

(HSI 3) Lack of demolition sequences and procedures

(HSI 4) Absence of temporary structures to support unstable elements

(HSI 5) Lack of or poor site supervision during demolition activities

(HSI 6) lack of demolition method statements

(HSI 7) Lack of site investigation

(HSI 8) Presence of asbestos materials

(HSI 9) Presence of deteriorating materials and structural elements.

(HSI 10) Presence of dropping or falling objects

(HSI 11) Presence of moving transport vehicles (with excessive speed).

(HSI 12) Presence of irregular surfaces

(HSI 13) Presence of spilled or leaked liquids or

(HSI 14) Presence of debris/ working in an untidy site

(HSI 15) Presence of uncovered openings

(HSI 16) Presence or use of unidentified faulty equipment

(HSI 17) Presence of loose and bare/live electric cable(s)

(HSI 18) Presence of pollutants such as noise, smoke, and hazardous chemicals

(HSI 19) Improper handling of materials

(HSI 20) Presence of operating machine(s)

(HSI 21) Working with hot processes such as welding, flame cutting, laying asphalt

(HSI 22) Presence of protruding sharp objects

(HSI 23) High presence of dust particles from breaking, cutting grinding or drilling cementitious and other particulate materials.

(HSI 24) Presence of lead-based materials e.g. paints

(HSI 25) Materials containing asphalt, silica, mineral wool and formaldehyde found during the process of adaptation

(HSI 26) Working in (hot and cold) confined environments

(HSI 27) Lack of space around machinery

(HSI 28) Unknown accumulated gases

(HSI 29) Presence of pest infested component or elements

(HSI 30) Presence or use of unprotected or unsecured scaffolding or unlit scaffolding

(HSI 31) Using inappropriate personal protective equipment

(HSI 32) Working on weak and slippery roofs

(HSI 33) Working with unsecured ladder

(HSI 34) The inherent structural risk (e.g. insufficient structural data, uncertainty of key structural elements, and uncertain structural condition of old buildings)

(HSI 35) Uncertain conditions of old equipment

(HSI 36) Working with reckless scheduling

HSI Sources: Sanvidoet et al. (1991), Egbu (1999), Anumba et al. (2004), Anumba et al. (2006), (Douglas 2006), Hein and Houck (2008), Lind et al. (2008), Langston et al (2008), Doran et al. (2009), Bullen and Love (2010; 2011b; 2011a), Othman (2012), Isnin et al. (2012), Zhao et al. (2013)

Mitigation Measures (MM)

(MM 1) Insisting and ensuring the use of qualified and competent structural engineer to undertake structural safety survey before demolition exercise

(MM 2) Providing accurate and detailed safety information for all workers on refurbishment projects

(MM 3) Ensuring that all tools and equipment for the refurbishment exercises have been assessed for that specific task

(MM 4) Preparing and maintaining an oriented H&S procedure for a particular task

(MM 5) Ensuring that workers are assessed based on their ability to understand work procedures and safety measures

(MM 6) Providing a specific safety training for workers assigned to undertake demolition aspect of the refurbishment project

(MM 7) Organising safety working procedures workshop at all levels and stages of a refurbishment process

(MM 8) Ensuring that adequate evacuation plans, procedures and means of escape have been clearly defined during construction phase

(MM 9) Providing a firm control and close supervision especially in hot working areas and activities involving flammable processes

(MM 10) Providing appropriate portable fire extinguishers in hot working areas and activities involving flammable processes

(MM 11) Ensuring a proper circulation of air around flammable materials and low-pressure gas cylinders and adequately securing them

(MM 12) Organising hazardous operation timely and separately to avoid disruption and nuisance with other construction operation

(MM 13) Ensuring the use of rated electrical equipment and earthing all of them

(MM 14) Providing red–white striped bands with warning stickers around scaffold poles when using it

(MM 15) Providing and insisting the use of personal protective equipment (PPE) by all workers especially those undertaking hazardous activities

(MM 16) Providing and ensuring the use of crawl boards to protect roof-workers, especially those working on fragile coverings

(MM 17) Arranging and undertaking brief and regular updates on safety precaution and emergency procedures to all parties in adaptation processes

(MM 18) Adopting a well-understood and recognised warning and safety signs

(MM 19) Ensuring debris is cleared from adaptation sites.

MM 20) Construction quality checks during adaptive-retrofitting of old buildings to ensure the safety of workers, materials and plants on sites

(MM 21) Providing and ensuring effective safety training in recognition of electrical hazards and its avoidance in workplace

(MM 22) Insisting on the use of non-conductive personal protective equipment (PPE)

(MM 23) Conducting a detail survey to identify potential electrical hazards and its mitigation measures before work begins

(MM 24) Insulating or de-energising all power lines before work begins

(MM 25) Ensuring that safety procedures for all works are followed

(MM 26) Maintaining regular safety site meetings

(MM 27) Adopting the system using warning signs for communicating electrical safety

MM Sources: Egbu (1999), Anumba et al. (2004), Douglas (2006), Langston et al (2008), Zhao et al. (2013)