Confined site construction: An empirical analysis of factors impacting health and safety management

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INTRODUCTION:

On reviewing the construction industry in the modern era, there are a number of distinctive characteristics emerging. With the continuation of the global downturn, particularly in the construction sector, the need for optimal utilisation of potential development sites is becoming more important than ever. With the increased cost of development land, particularly in urban environments (Ellis, 2002), clients now insist on optimal utilisation of an acquired development site, particularly due to the increased cost of development land and the enhanced potential for an increased return on investment.

Because of the continued expansion of urban global centres, the need to facilitate the increased population influx is also a significant factor (Dixon, 2009). As a result, the increased development and brownfield reconstruction within urban site environments is quickly becoming the norm in the industry (Tindiwensi, 2000). Research has shown that urban centres are not expanding outwards towards green field sites, but are being redeveloped from within (Biddy, 2009). Thus, inner city, confined site construction is quickly becoming customary in today's construction industry (Singer, 2002).

In regard to the increased development of these urban centres, there too come additional managerial concerns. Due to the increased optimisation of the available space on-site, by architects and other members of the design team, many of today's modern developments envelope the vast majority of the overall site footprint. As a result, there is little room to accommodate the various resources required to successfully construct and complete these structures, often under strict time and budgetary schedules (Wideman, 1990; Remington *et al.,* 2007; Holroyd, 2003; Hinze *et al.,* 1994). Such resources as plant, materials, temporary facilities and other preliminary resources must be accommodated for, throughout the construction process.

One of the more prominent resources requiring effective management is the industries most important resource – personnel (Egan, 1998). Due to the increased complexity of construction projects coupled with the increased spatial restrictions present on-site (Wideman, 1990; Remington *et al.,* 2007), effective management of one of the most costly resources is essential, due to a significant percentage of a projects overall cost attributable to the personnel on-site (Winch, 2010).

Due to the spatial restrictions on-site, such adverse working environments for personnel can result in; high fatality figures (Mitropoulos, *et al.,* 2005; Sawacha, *et al.,* 1999; Pertulla, *et al.,* 2003), reduced productivity (Thomas, *et al.,* 2006; Enshassi, *et al.,* 2007), improper site layout planning resulting in increased travel time (Tam, *et al.,* 2002; Elbeltagi, *et al.,* 2004) and the requirement for effective scheduling and programming to reduce conflict (Long, *et al.,* 2004; Thomas, *et al.,* 2006; Faniran, *et al.,* 1999). The United Kingdom's Health and Safety Executive (2009a) outlines that in the last twenty five years, over 2,800 people have lost their lives in the construction industry in Britain alone. In addition, during the Health and Safety Executive's Construction Division intensive inspection initiative in March 2009, one in five construction sites inspected were deemed to be below the acceptable standard with regards to health and safety (Health and Safety Executive, 2009b).

These factors along with the ever increasing burdens of reduced project programme durations, reduced project budgets, compounded with the need for increased personnel management, lead to an amplified burden on the health and safety concerns of those made accountable for ensuring project completion (Mulholland *et al.,* 1999; Dulaimi *et al.,* 2001; Kerzner, 2006; Winch, 2009). Thus, the importance of this topic cannot be overemphasised, due to the increased health and safety risks that pertain with regards to confined site construction.

When reviewing the abundance of literature on the various issues in the management of personnel within the construction sector, there is a noted gap in the identification of the effects such issues have in a confined site environment. In the vast majority of cases,

authors identify the need to effectively manage personnel in their associated space but the emphasis is on sites where the space available is in vast quantities (Harris, *et al.,* 2006; El-Rayes *et al.,* 2005; Kartam, 1997).

On reviewing literature in search of a definition of a confined construction site, the majority of which only define a confined space on a construction site, but fail to acknowledge or differentiate between that and a confined construction site. For the purpose of this research, a confined construction site has been identified as a site where permanent works fit the site footprint, extending to levels above and/or below ground level, leaving spatial restrictions for other operations (e.g. plant and material movements, materials storage, personnel management and temporary accommodation etc.) and require effective resource co-ordination beyond normal on-site management input.

This research aims to fulfil this gap in knowledge by highlighting the need to identify the numerous issues regarding the implementation of health and safety, on a confined construction site. The various issues to the management of personnel's health and safety on a confined site will be highlighted and tabulated based on a mixed methods approach incorporating a literature review, case study analysis incorporating both individual interviews and focus group seminars along with questionnaire circulation throughout the industry.

In total, three case studies were selected, due to the confined environment in which they were being constructed along with the inherently difficult on-site personnel management issues evident. Based on the factors highlighted in the literature and from the case studies, a questionnaire survey was developed and piloted. In total, 216 questionnaires were circulated and 105 were returned with usable data, giving a return ratio of 48.6%. The resulting data was tabulated using mean, importance, frequency and severity indices with the various issues catalogued and discussed accordingly.

Where this research comes to the fore, is in aiding on-site management in the daily chore of effectively managing one of the more dynamic and integral resources in the construction industry. Through highlighting one or more of the numerous issues in the management of on-site personnel's health and safety in a confined site environment, on-site managers can proactively acknowledge the various issues and mitigate there effects, should they arise. As a result, the health and safety of personnel on-site is increased substantially, resulting in reduced accidents, reduced claims and increased productivity resulting in an overall increase in project performance and therefore, project success.

LITERATURE REVIEW

On analysing the various literature available on health and safety on construction sites, the majority of sources fail to acknowledge the increased managerial burden on health and safety in relation to confined site construction. The International Labour Office (1995), briefly illustrates the potential problems, as a result of working within confined sites, but only gives a concise summary of available strategies. There are numerous books and articles written on project management and managing the construction process. Levy (2006), Walker (2002) and Gould (2005), all outline the various obstacles with which management must overcome from project inception to completion and handover to ensure successful project completion, yet little information or guidance is given in regards to confined site construction.

Numerous studies indicate and underline the importance of an appropriately designed and managed site layout, to ensure adequate levels of health and safety are reached (Elbeltagi *et al.,* 2004; El-Rayes *et al*., 2005; Sanad *et al.,* 2008). This design is mainly illustrated in cases where space is available to all concerned. Illingworth (2000) and Cooke *et al.,* (2004) highlight the importance of an effective and well designed construction site layout, but give little emphasis of the importance of such practices in confined site locations. In addition, Chan, (1991) outlines the various types of construction site with regards to spatial assignment, indicating that sites can be classified from very unrestricted sites to those which are very restricted in nature. Furthermore, Leung and Tam (2010) indicates the importance

of the site characteristics in relation to numerous points, one of which is the safety of those on-site and the resulting management of this parameter. To compound the point of the importance of health and safety within a spatially restricted environment, Lam, *et al.,* (2007) argues that site specific factors can have an adverse effect on the health and safety of those on-site and consideration should be given to this even in the design stage of a project.

Other such instances where health and safety issues arise are due to the close proximity in which personnel have to work (Sowman, 2006). Overcrowding of the workplace can be a risk factor, particularly in cases where the programme of works is accelerated or already congested. The Health and Safety Executive (2003) identify overcrowding of construction sites as a major factor and that better management is essential to overcome this issue. In external research commissioned by the Health and Safety Executive in July 2009, it furthers this point by highlighting that poor co-ordination can cause overcrowding on building sites which can result in operatives sustaining trips and falls in the workplace. An additional variation, onto which research has been conducted, is that of the construction site layout with respect to the surrounding environment and its effects on health and safety. Sanad, *et al.,* (2008) identifies the need for efficient on-site layout planning to ascertain an acceptable level of consideration with regards the surrounding environment along with safety considerations.

Various studies outline the importance of an appropriately designed and managed site layout plan, to ensure adequate levels of health and safety are obtained. This design is mainly illustrated in cases where space is available to all concerned. In today's environment, this is rarely the case, with land costs at a premium, even with the continuation of the global recession and a brief reduction in value to the majority of sites, the cost of development land is still at a premium. Property wire™ (2009) reports that after two years of a decline in development land values, prices are beginning to increase once more. Both Illingworth (2000) and Cooke*, et al.,* (2004) highlight the importance of an effective and well designed construction site layout, but give little emphasis of the importance of such practices in confined site locations, particularly in relation to health and safety.

Other such instances where health and safety issues arise are due to the close proximity in which personnel have to work (Thomas, *et al.,* 2006). Robinson, as cited in Cotton, (2009) outline that overcrowding of the workplace can be a critical factor, particularly in cases where the programme of works is accelerated or already congested. On exploring the various research papers, articles and literature on the effects of overcrowding in relation to health and safety, it can be concluded that articles are almost non-existent in this knowledge area. This area of concern is predominantly associated with that of confined construction sites and must be addressed accordingly.

As a result, it can be concluded that there is a vast amount of literature on health and safety on-site, but little information regards confined construction sites and the increased risk posed to employees and the associated public. On a number of occasions, a number of pieces of literature have identified key facets with regards confined site construction but failed to delve into the core issues pertaining to the relevant context in review. Thomas, *et al*., (2006) identified the importance and resulting consequence of overcrowding at work, Sowman, (2006) identifies the importance of overcrowding while Illingworth (2000) and Cooke*, et al*., (2004) argued the significance of an effective design site layout to maximise space on-site, but in each study, no emphasis was placed on that of confined site construction and the inherent link with regards their respective research. Therefore, on reviewing the literature on the subject, a number of authors identify numerous issues which relate to confined site construction but each fail to relate and discuss the resulting issues within this particular context.

METHODOLOGY

When conducting research into the topic proposed, a mixed method approach was adopted to ascertain an exhaustive list of attributes with regards the issues in the management of health and safety, not only on confined construction sites, but also in relation to the construction industry at large. Through including a comprehensive list of possible variables at the onset, it is then possible to eliminate any factor which is not relevant or encountered

on a confined construction site environment. To cumulate the list of factors, the following methodological approach was adopted.

Initially, an in-depth literature review was undertaken, to ascertain all of the various on-site project management issues to the management of health and safety in confined site construction. Through reviewing the literature by analysing various sources such as books, journals, conference proceedings and articles, it was possible to gain a thorough insight into the topic in question while also familiarising the author with the various aspects of the topic in review. Where possible issues were identified but required further clarity, each of the possible factors were documented and utilised in the individual interviews and focus group seminars, to affirm their validity and thus, their inclusion in the resulting analysis.

Secondly, to complement and clarify the various issues highlighted in the literature review, an extensive interview procedure was undertaken, to ensure that a comprehensive list of issues to the management of health and safety, were included for discussion. The interview process encompassed both individual and focus group seminars to gain a holistic overview of the factors required for discussion while also providing clarity, removing bias and introducing triangulation, thus aiding in the analysis of the resulting data. In order to acquire the relevant candidates for the case study while also providing an objective reality of industry specific confined site environments, various case study examples were sought, thus aiding the discussion with the interviewees and resulting identification of associated factors. The interviewees who participated in this research had a wide variety of industry exposure, many of which were obtained working on confined construction sites. The average experience of the candidates was thirteen years with a variety of professions, such as contracts managers, projects directors, site managers, and site engineers participating in the study.

To assist in the research, various professional member bodies were approached with the intention of identifying a number of possible case studies for consideration. The ASCE (American Society of Civil Engineers), ICE (Institution of Civil of Engineers) in the UK and

CIOB (Chartered Institute of Building) and RICS (Royal Institute of Chartered Surveyors) in Ireland and the UK were all approached in this regard. A number of possible candidates were identified and approached with the intention of inviting interested candidates to participate in the research. Resulting from this approach, a total of twelve possible case studies were identified and considered for inclusion in the study. In order to shortlist the required case studies, each of the possible candidates was reviewed based on the intricacy, nature and location of the proposed case studies along with the overall difficulties envisaged by the site management teams. From the list of twelve possible case studies, three were selected which fulfilled these criteria most appropriately. The three case studies chosen were located in the Republic of Ireland, the United Kingdom and the United States of America and were a low rise apartment block, a mid-rise hotel complex and a high rise condominium development respectively.

The interview process for each of the three case studies identified below was compiled of both semi-structured individual interviews and unstructured focus group seminars, to aid in the identification and clarification of the various issues in the implementation of health and safety of the respective confined site case studies in question. Each of the interviews was not recorded at the request of the participants but notes were taken in the form of written, diagrammatic format, to assist in the fluidity and coherence of the data identified throughout the interview process. The resulting data for each of the case studies was scrutinised based on cognitive mapping, thus aiding in the identification of underlying traits and resulting factors for inclusion on the quantitative aspect of the research. The aspects of the case studies identified are as follows;

Low rise apartment block - Republic of Ireland (Case Study 1)

The first case study identified was that of a six story apartment and office block in Limerick in the Republic of Ireland. This case study was chosen due to the site being surrounded on three sides by existing structures and on the fourth, by a busy road network. At the time of the interview, the project was approximately at 70% completion with the majority of the superstructure constructed and the finishing stages of construction underway. The company

responsible for the construction of this development had, at the time of the survey, over twenty year's management experience in the construction of inner city developments. Three on-site management personnel were approached and interviewed in isolation, in order to ascertain the relevant factors pertaining to the case study in question. The average confined site construction exposure of the interviewees questioned was in excess of fifteen years with the average confined construction site experience over this time being seven confined construction sites. The three individuals who were questioned in this case were the contracts manager, projects director and the site engineer, where the average interview time was forty-five minutes. To aid in the removal of bias and for triangulation purpose, each of the three interviewees along with additional participants from the case study undertook a focus group seminar, to ensure result validity and again to remove bias while also aiding in confirming the inclusion of possible suspect factors. The duration of the focus group was in excess of an hour with a ten minute break half way through for refreshments and to deal with on-site matters of urgency.

Mid-rise hotel complex – UK (Case Study 2)

The second case study identified from the possible list of confined site projects, was a mid-rise hotel complex. This example was chosen due to the location of the site entrance and the overall complexity of the operations and the amount of management interface required on a daily basis. The development was bounded on two sides by existing structures and on the remaining sides by a busy road network. The project was thirteen floors of mass concrete construction with the schedule illustrating that the substructure works were nearing completion at the time of the interviews. In this case, the site manager, site foreman and finishing foreman all participated in individual interviews to aid in ascertaining the various factors in the management of their respective portions of the project in question. The three interviewees had, at the time of the interview, twelve years' experience, many of which were spent on confined construction sites located within inner city developments. The individual interviews averaged thirty-five minutes with two of the three interviews conducted in the site office and the third, in a local coffee shop. The main contractor responsible for this development had already completed a number of previous

projects similar to the one in review; both the interviewees and the main contractor were knowledgeable in the area of inner city, confined site construction. To complement the individual interviews while also obtaining a holistic overview of the issues encountered by those directly involved in the construction of the project in question, a focus group seminar was also undertaken on-site. In this case, five personnel from the case study participated in the discussion ranging from the project architect to on-site operatives. The discussion proved fruitful and lasted almost an hour, where each of the participants provided amply points and discussion on the topics raised.

High-rise condominium and loft apartment development – Chicago, Illinois, USA (Case Study 3)

The third and final case study identified for inclusion in the research was located in downtown Chicago. This development was nearing completion during the time of the research where the finishing touches were being made to the remaining units. The property itself was bounded on three sides by a busy road network and on the fourth, by an existing low rise structure. This development consisted of a high rise tower constructed to thirty-five floors coupled with a neighbouring low rise structure of loft apartments up to six floors. Basement and ground floor units comprised of car parking and retail, culminating in a complex and diverse development located within an inner city environment. The three professionals approached on this development were the chief operations officer/director, senior site engineer and senior site manager. The average duration of the interviews was in excess of fifty minutes. Each of the participants had an average of twelve years' experience in the construction industry, many of which included working on inner city developments, both in the United States of America and in Europe. The developer responsible for the project had a wide variety of projects on its portfolio, but many of which were located in inner city environments and ranged in size from small service contracts to large towers. To supplement the individual interviews and again to provide clarity and further information on the issues relating to on-site personnel and health and safety, a focus group seminar was also conducted. Five individuals participated in the discussion which took over an hour to complete.

On assessing each of the case studies and identifying the factors highlighted, table 1 illustrates the dispersion of the factors with regards each of the case studies reviewed. Each of the factors identified were also identified in the literature review.

Table 1: Issues affecting Health and Safety Management across Case Studies

	Issues affecting Health and Safety Management in Confined Site Construction	Case Study 1	Case Study 2	Case Study 3
1	Difficulty in positioning temporary facilities to avoid accidents from falling heights	X	X	
2	Difficulty in controlling hazardous materials and equipment on site.			X
3	Difficulty in ensuring proper arrangement and collection of waste materials on-site.	X	X	X
4	Close proximity of individuals to operation of large plant and machinery.	X	X	X
5	Increased possibility of over-crowding the workplace due to lack of available space.	X	X	
6	Effective lighting of confined areas on site to ensure health and safety of all concerned.	X	X	X
7	Intersections and collisions of personnel in heavily travelled routes during construction operations	X	X	X
8	Difficulty in ensuring personnel getting to and from their area of work safely.	X		X
9	Difficulty in ensuring site is tidy and all plant and materials are stored safely.	X	X	X
10	Difficulty in providing temporary facilities on-site to cater for the needs of the site effectively.	X		
11	Difficulty in the management of on-site traffic.	X	X	X
12	Increased safety risk due to various tasks being executed in close proximity to each other.		X	X
13	Difficult to account for and manage personnel due to the restricted working conditions.	X	X	X
14	Difficulty to move materials around site safely	X	X	X
15	Workplace becoming over-crowded.	X	X	X
16	Lack of adequate room for the effective handling of materials.	X		X
17	Lack of adequate storage space.	X	X	X

From the resulting qualitative analysis incorporating the literature review, individual interviews, focus groups and subsequent cognitive mapping, a comprehensive quantitative study was undertaken through the use of an industry circulated questionnaire survey. The list of factors identified in the qualitative analysis was reviewed and, where appropriate, they were included in the questionnaire design. To complement the design process and to mitigate the possibility of any grammatical, structural or other errors along with reviewing the fluidity of the questionnaire, a draft was piloted to a number of industry and academic professionals. In total, five individuals (three industry and two academic professionals) were utilised in the piloting exercise and the process was repeated three times to ensure that the corrections made were appropriate and to address any changes made in the review process.

In order to ascertain a more in-depth and concise overview of the factors included, the questionnaire respondents were asked to rank each of the factors on a sliding scale of 1 to 5 on “Importance”, where 1 was “Not Important” and 5 was “Most Important” but also on the “Frequency” of occurrence, where 1 was “Not at all” and 5 was “Always”. This provided the possibility of gauging the importance and the frequency of the factors identified but also the “Severity” of the overall issue, based on the cumulative score of the former scales used. The results of each of the factors highlighted and the corresponding scales are documented in tables 1-4 with the following formulas adopted based on adaptations identified from Okpala and Aniekwu (1988) and Field, (2005) in the identification of the resulting Indices. On completion of the questionnaire design, the survey was circulated to a total of 216 industry professionals located in Canada, United States of America, Ireland, Australia and the United Kingdom with eleven, three, twenty-five, five and sixty-one completed responses recorded respectively. On reviewing each of the responses in relation to geographical location, it emerged that in a geographical context, each of the core issues to health and safety management emerged in a similar order when reviewed under the severity index. To further identify if any anomalies exist within the dataset with regards to geographical location, each of the factors identified in table 5 is reviewed using the Kruskal Wallis test of one way analysis of variance in SPSS. The Kruskal Wallis ANOVA test is utilised as there are four parameters or locations in review. Where the resulting significant level is $\leq \alpha = 0.05$, there

exists enough evidence to conclude that there is a difference in the severity of the issue as perceived by those in various geographical locations which is beyond the possibility of occurring by chance alone. When each of the seventeen factors is reviewed, all except one factor identified in table 5 meet this requirement ('Close proximity of individuals to operation of large plant and machinery', with a $\alpha = 0.05$), therefore it is possible to conclude that the issues identified are not bias in relation to geographical location. Hence, this indicates that variations due to practice and environmental differences respective of the geographical location, did not adversely affect the overall order in which each of the variables were listed. In total, 106 individuals responded to the survey, as outlined, with one survey omitted due to incomplete data. As a result, a return ratio of useable data of 48.6% was achieved.

Data Obtained:

$$\text{Importance Index } (II) = \left\{\frac{\Sigma(i)}{\text{NI}}\right\} \times 100\%$$

.....Equation 1

$$\text{Frequency Index } (FI) = \left\{\frac{\Sigma(f)}{\text{NF}}\right\} \times 100\%$$

..... **Equation 2**

$$\text{Significance Index } (SI) = \left\{\frac{\Sigma(if)}{\text{NIF}}\right\} \times 100\%$$

.....Equation 3

In the three subsequent index equations, *i* is the importance weighting and *f* is the frequency weighting assigned by the respondents in the questionnaire, rating from one to five. I and F are the highest ratings possible for each of the assigned factors; in both cases, this being five. N is the total number of respondents with usable data to that particular factor, which is 105. From the resulting factors highlighted in the interviews conducted from the participants in each of the case studies reviewed, it is possible to identify and exhaustive

list of factors. Each of the factors identified were utilised in a questionnaire survey where industry professionals from a wide variety of specialised backgrounds, completed the questionnaire survey. The resulting data was accessed based on a dual scale as prescribed, thus aiding in the analysis of the inherent characteristics, therefore obtaining a more diverse and detailed overview of the numerous health and safety issues with respect to confined site construction.

Table 2 – Importance Index (II) ranking of factors identified

Factor	Score Assigned					Mean	II%	Rank
	5	4	3	2	1			
Lack of adequate storage space	5	41	16	2	1	4.21	80.2	**1**
Difficulty to move materials around site safely	41	44	17	2	1	4.16	79.3	**2**
Workplace becoming over-crowded	9	6	5	3	2	4.11	78.4	**3**
Intersections and collisions of personnel in heavily travelled routes during construction operations	41	38	18	6	2	4.05	77.1	**4**
Close proximity of individuals to operation of large plant and machinery	37	40	19	7	2	3.98	75.8	**5**
Difficulty in ensuring site is tidy and all plant and materials are stored safely	28	47	24	3	3	3.90	74.2	**6**
Lack of adequate room for the effective handling of materials	24	51	22	7	3	3.86	73.5	**7**
Difficulty in ensuring proper arrangement and collection of waste materials on-site	31	36	31	4	3	3.84	73.1	**8**
Difficulty in controlling hazardous materials and equipment on site	31	36	31	4	3	3.84	73.1	**9**
Increased possibility of over-crowding the workplace due to lack of available space	4	53	16	9	3	3.82	72.7	**10**
Difficulty in providing temporary facilities on-site to cater for the needs of the site effectively	29	40	23	7	6	3.75	71.5	**11**
Difficult to account for and manage personnel due to the restricted working conditions	18	51	30	3	3	3.74	71.3	**12**
Difficulty in positioning temporary facilities to avoid accidents from falling heights	32	35	20	12	6	3.71	70.7	**13**
Difficulty in the management of on-site traffic	20	45	27	9	4	3.65	69.5	**14**
Difficulty in ensuring personnel getting to and from their area of work safely	24	34	34	7	5	3.63	69.0	**15**
Increased safety risk due to various tasks being executed in close proximity to each other	16	44	35	7	3	3.60	68.6	**16**
Effective lighting of confined areas on site to ensure health and safety of all concerned.	7	25	34	29	10	2.90	55.3	**17**

Table 3 – Frequency Index (FI) ranking of factors identified

Factor	Score Assigned					Mean	FI%	Rank
	5	4	3	2	1			
Difficulty to move materials around site safely	25	36	32	10	2	3.69	70.2	**1**
Lack of adequate room for the effective handling of materials	22	32	33	13	5	3.50	66.8	**2**

Difficulty in ensuring site is tidy and all plant and materials are stored safely	20	34	28	17	6	3.43	65.3	**3**
Close proximity of individuals to operation of large plant and machinery	22	30	24	20	9	3.34	63.7	**4**
Difficulty in ensuring proper arrangement and collection of waste materials on-site	12	35	29	23	6	3.23	61.5	**5**
Difficulty in controlling hazardous materials and equipment on site	12	35	29	23	6	3.23	61.5	**6**
Difficulty in the management of on-site traffic	12	30	35	19	9	3.16	60.2	**7**
Difficult to account for and manage personnel due to the restricted working conditions	6	35	33	26	5	3.10	59.1	**8**
Increased safety risk due to various tasks being executed in close proximity to each other	4	29	39	24	9	2.95	56.2	**9**
Lack of adequate storage space	10	22	37	22	14	2.92	55.7	**10**
Intersections and collisions of personnel in heavily travelled routes during construction operations	10	26	28	25	16	2.90	55.1	**11**
Difficulty in positioning temporary facilities to avoid accidents from falling heights	10	14	31	28	21	2.65	50.5	**12**
Difficulty in providing temporary facilities on-site to cater for the needs of the site effectively	2	24	30	27	22	2.59	49.3	**13**
Workplace becoming over-crowded	3	18	28	40	16	2.54	48.4	**14**
Difficulty in ensuring personnel getting to and from their area of work safely	5	17	27	35	21	2.52	48.1	**15**
Increased possibility of over-crowding the workplace due to lack of available space	3	22	22	36	22	2.50	47.7	**16**
Effective lighting of confined areas on site to ensure health and safety of all concerned.	1	10	31	38	25	2.28	43.4	**17**

Table 4 – Severity Index (SI) ranking of factors identified

Factor	**Score Assigned**					**Mean**	**SI%**	**Rank**
	5	**4**	**3**	**2**	**1**			
Difficulty to move materials around site safely	33	40	25	6	2	3.92	64.43	**1**
Lack of adequate room for the effective handling of materials	23	42	28	10	3	3.68	56.78	**2**
Difficulty in ensuring site is tidy and all plant and materials are stored safely	24	41	26	10	5	3.66	56.09	**3**
Close proximity of individuals to operation of large plant and machinery	30	35	22	14	6	3.66	55.89	**4**
Difficulty in ensuring proper arrangement and collection of waste materials on-site	22	36	30	14	5	3.53	52.04	**5**
Difficulty in controlling hazardous materials and equipment on site	22	36	30	14	5	3.53	52.04	**6**
Lack of adequate storage space	28	32	27	12	8	3.57	51.69	**7**
Intersections and collisions of personnel in heavily travelled routes during construction operations	26	32	23	16	9	3.47	49.22	**8**
Difficult to account for and manage personnel due to the restricted working conditions	12	43	32	15	4	3.42	48.81	**9**
Difficulty in the management of on-site traffic	16	38	31	14	7	3.40	48.44	**10**
Increased safety risk due to various tasks being executed in close proximity to each other	10	37	37	16	6	3.28	44.64	**11**

Workplace becoming over-crowded	21	32	22	22	9	3.33	43.94	**12**
Difficulty in positioning temporary facilities to avoid accidents from falling heights	21	25	26	20	14	3.18	41.01	**13**
Difficulty in providing temporary facilities on-site to cater for the needs of the site effectively	16	32	27	17	14	3.17	40.83	**14**
Increased possibility of over-crowding the workplace due to lack of available space	14	38	19	23	13	3.16	40.18	**15**
Difficulty in ensuring personnel getting to and from their area of work safely	15	26	31	21	13	3.07	38.06	**16**
Effective lighting of confined areas on site to ensure health and safety of all concerned.	4	18	33	34	18	2.59	27.77	**17**

Table 5 - List of Issues in the Management of Health and Safety on a Confined Construction Site

	List of Issues in the Management of Health and Safety on a Confined Construction Site	% Importance Index (II)	Importance Ranking (IR)	% Frequency Index (FI)	Frequency Ranking (FR)	% Severity Index (SI)	Severity Ranking (SR)	Kruskal-Wallis Test	
								Chi-square	Sig.*
1	Difficulty to move materials around site safely	79.3	2	70.2	1	**64.43**	**1**	2.080	.556
2	Lack of adequate room for the effective handling of materials	73.5	7	66.8	2	**56.78**	**2**	1.999	.573
3	Difficulty in ensuring site is tidy and all plant and materials are stored safely	74.2	6	65.3	3	**56.09**	**3**	0.848	.838
4	Close proximity of individuals to operation of large plant and machinery	75.8	5	63.7	4	**55.89**	**4**	**7.800**	**.050**
5	Difficulty in ensuring proper arrangement and collection of waste materials on-site	73.1	8	61.5	5	**52.04**	**5**	3.272	.352
5	Difficulty in controlling hazardous materials and equipment on site	73.1	8	61.5	5	**52.04**	**5**	1.797	.616
7	Lack of adequate storage space	80.2	1	55.7	10	**51.69**	**7**	3.241	.356
8	Intersections and collisions of personnel in heavily travelled routes during construction operations	77.1	4	55.1	11	**49.22**	**8**	0.975	.807
9	Difficult to account for and manage personnel due to the restricted working conditions	71.3	12	59.1	8	**48.81**	**9**	3.512	.319
10	Difficulty in the management of on-site traffic	69.5	14	60.2	7	**48.44**	**10**	0.360	.948
11	Increased safety risk due to various tasks being executed in close proximity to each other	68.6	16	56.2	9	**44.64**	**11**	1.147	.766
12	Workplace becoming over-crowded	78.4	3	48.4	14	**43.94**	**12**	2.828	.419
13	Difficulty in positioning temporary facilities to avoid accidents from falling heights	70.7	13	50.5	12	**41.01**	**13**	0.850	.837
14	Difficulty in providing temporary facilities on-site to cater for the needs of the site effectively	71.5	11	49.3	13	**40.83**	**14**	1.164	.762
15	Increased possibility of over-crowding the workplace due to lack of available space	72.7	10	47.7	16	**40.18**	**15**	2.673	.445
16	Difficulty in ensuring personnel getting to and from their area of work safely	69.0	15	48.1	15	**38.06**	**16**	2.024	.567
17	Effective lighting of confined areas on site to ensure health and safety of all concerned.	55.3	17	43.4	17	**27.77**	**17**	2.945	.400

Footnote: * – Significant at 95% confidence Interval = 0.05.

DISCUSSION

On the findings of the research, the issues highlighted are various and diverse. Through conducting both qualitative and quantitative research, it is possible to highlight the leading issues in the management of health and safety within confined site construction, as follows;

(1) Difficulty to move materials around site safely

On assessing the responses from the questionnaire survey, the leading factor highlighted based on the "Severity Rank" was the difficulty in moving materials in and around a confined construction site safely. This leading factor identified, is due to having the highest combined importance and frequency of occurrence ratings (80.2% and 70.2% respectively), thus its level of overall severity is significant, at 64.43%. This concludes that the respondents to the survey highlighted that there is a strong possibility of this issue occurring coupled with the factor being classified as very important. During the discussions with each of the focus groups and with the individuals from the case studies assessed, each of the participants all expressed a concern with the movement of material around site safely. Each of the participants all acknowledged that due to the lack of space and the large amount of plant and equipment required on a standard construction project, there is an increased reliance on the various means by which to transport material delivered on-site to the workface, where required. Two of the fundamental methods adopted to facilitate material movement on-site include plant and machinery and/or manual handling. With regards to a spatially plentiful construction site, the difficulty in moving materials around site safely is not experienced, thus this factor is generally only related to that of a confined construction site where the lack of space on-site is a core characteristic.

With regards the movement of material using plant and machinery, spatial restrictions often hinder the effective implementation and utilisation of plant on-site. Effective material handling equipment is essential in the unloading and distribution of material around site. Where spatial limitations occur, this process can prove difficult and time consuming along

with increasing the health and safety concerns both to the machine operative and to the personnel on-site. The Health and Safety Authority (2011) echo this point and stress the importance of an effective transport management plan incorporating safe and suitable access ways to assist the movement of material coupled with effective segregation and monitoring of separate traffic and pedestrian routes on-site. In relation to manual handling of materials on-site, one of the core issues relating to this, as outlined by the Health and Safety Authority (2011), is the size and location of the site. Hampton (2004) further illustrates this point where spatially congested sites required additional logistical management in order to ensure the health and safety of personnel on-site while transporting materials. Where spatial restrictions are evident, additional planning is required to supplement the lack of space in the management of the movement and location of material being delivered, unloaded, stored and ultimately used on-site. Mossman (2008) furthers this point by arguing that space on-site is primarily about safety; the less space available, the more hazardous the environment becomes.

(2) Lack of adequate room for the effective handling of materials

The second most problematic issue in the management of health and safety on a confined construction site is the lack of room to facilitate the effective handling of materials on-site. When reviewing the responses to the questionnaire and more specifically, the responses regarding this issue, the respondents classified this issue as the 7th most important aspect but also identify the frequency of occurrence as coming 2nd, thus compounding its prominence in this subject area. On reviewing each of the interviews from the case studies selected, on a number of cases, the interviewees highlighted that the lack of adequate room hindered the effective handling and movement of materials on-site. On a number of occasions, interviewees indicated that this factor was one of the leading points in which on-site project managers had to identify and mitigate to ensure effective on-site management of health and safety. Bernold (2002) aptly outlines that construction activities will always require space to facilitate the movement, handling, storage, assembly of materials, within a complex environment, but in the case of confined site environments, this requirement is often difficult to achieve. Riley, (1994) indicates the use of predetermined “paths” to assist

in the movement of materials around site – a particularly useful strategy on confined site environments. Jang, *et al.,* (2003) argues that construction logistics, including material management and transportation, as one of the core aspects of on-site management. In relation to that of a construction site where space is plentiful, each of these factors also occur, but the level at which they effect the overall health and safety of personnel on-site is greatly reduced, due to the amount of space on-site in which to minimise the overall impact of handling large quantities of material on-site. Material flow from the site entrance to the workplace is of fundamental importance and thus, requires on-site management input on an on-going basis. Therefore, this may aid in identifying why the frequency rating of this issue resulted in a frequency rank of two, as on-site management are aware of the issue and also acknowledge the likelihood of its occurrence on a confined construction site. Consequently, Tommelein and Zouein (1993) argue that space is as an important a resource as personnel and other resources, which requires extensive and detailed management, hence the importance of a lack of space on-site.

As successful project completion is largely based on the successful ordering, delivery, transportation and relocation of materials to the job site (Kerzner, 2009), where such a scenario occurs where there is insufficient room to ensure easy of which to complete these tasks, the efficiency and ease at which the project can be completed is increased significantly. In order to mitigate this issue and the resulting possible health and safety issues which may result, the key management trait to assist in the management process is to ensure that the site management have a wide knowledge of the building material in question while also various approaches to supply chain management and an overall understanding of the holistic approach in managing materials successfully and safely (Sobotka and Czarnigowska, 2005).

Through effective material management on-site, it is possible to mitigate, transfer or eliminate the possibility of adverse health and safety risks occurring through proactive management of both materials and the personnel who interact and handle these resources (Lingard and Rowlinson, 2005). Direct site management interaction is essential to mitigate the emergence of accidents on-site with almost three quarters of site accidents preventable

through positive site management action (Sawacha, *at al.,* 1999). In order to alleviate accident causation in spatially restricted environments, it is essential for on-site management to document and control material flow, particularly in line with the project programme, thus identifying the possibility of any accidents or incidents occurring on-site (Jang, *et al.,* 2003).

(3) Difficulty in ensuring site is tidy and all plant and materials are stored safely

The third issue in the implementation of health and safety on a confined construction site is that of ensuring that housekeeping is implemented with regards to plant and materials through effectively locating and storage protocol. From the mixed method approach adopted and the resulting analysis, an importance and frequency ranking of 6th and 3rd was achieved, respectively, thus documenting the severity of the issue in question (ranked 3rd most influential issue). Due to the effective and ease of which the issue materialises, the respondents to the survey ranked this issue as the 3rd most probable issue to arise, but due to the ease at which the issue can be mitigated or eliminated, it was ranked 6th in relation to the frequency or likelihood of occurring on-site. As slips, trips and falls are the leading cause of accidents on any construction site – spatially restricted or not, the single most proactive strategy in mitigating or eliminating this issue is through effective and on-going housekeeping of the construction site (Gibb, *et al.,* 2005; Haslam, *et al.,* 2005; Bentley, *et al.,* 2006; Health and Safety Executive, 2007). In addition, Sadeghpour, *et al.,* (2002) outlines that sufficient space must be provided for "paths" to aid the movement of plant, materials and personnel throughout the site. This point is further illustrated by Soltani and Fernando (2004), who argue that clear paths must be provided, resulting in a reduction in accidents on-site, due to effective spatial management. Where such site environments exist which limit the spatial assignment, there is an increased propensity for accidents as a result (Howell *et al.,* 1993; Akinci, *et al.,* 2002; Health and Safety Executive, 2003). In the context of standard construction sites where space is not a critical factor, the importance of this key issue also resonates throughout. The importance of avoiding slips, trips and falls on-site is evident and through adopting effective management of health and safety protocol and minimising such risks, the propensity of such accidents occurring is greatly reduced. The

differentiating factor with regards a construction site where space is plentiful and that of a confined construction site is that in order to achieve this in a confined construction site, greater management input is required to ensure that it is achieved and maintained at all times.

To aid in minimising the possibility of accidents thorough slips, trips and falls on-site, it is essential for on-site management to programme the works accordingly, including the ordering and delivery of the required resources to site, as required. Through eliminating or reducing, where possible, the amount of storage required for materials on-site, the additional space can be utilised by other resources and tasks as on-site management see fit, thus reducing the overall possibility of the construction site becoming cluttered and overburdened with excess resources (Niskanen and Lauttalammi, 1989; Abdelhamid and Everett, 2000).

The importance of effective allocation and storage of plant and materials on-site cannot be underestimated. As one of the leading contributing factors to accidents on-site (Jaselskis and Suazo, 1994), on-site management professional must ensure the proactive delivery of plant and materials to site, thus minimising the possibility of an untidy site. One of the key strategies in mitigating such instances and improving the delivery of material to site is through the use of just-in-time delivery, where the resources are delivered to site as necessary, thus minimising the site storage requirements. This process has been identified as one of the core attributes of successful site material management in conjunction with maximising the available space for the utilisation of additional workspace for subsidiary tasks on-site (Ballard and Howell, 1995). Sawacha, et al., (1999) furthers the spatial issue by highlighting that a site must be tidy and all materials and plant are stored safely, to benefit the health and safety of those on-site. The lack of space can have detrimental effects on a project, as can be clearly illustrated in the case of Chandigarh Airport in India. Dutt, as cited in Sharma, (2009) highlights the increased concerns due to the lack of adequate space management by those involved, particularly subcontractors in the effective management and segregation of resources as required by the project programme.

(4) Close proximity of individuals to operation of large plant and machinery

The fourth most influential issue in the management of health and safety on a confined construction site is the close proximity of personnel to large plant and machinery in operation. The importance and frequency ranking of 5th and 4th respectively, illustrate the significance and resulting severity of the issue in question. This point was voiced by a number of the interviewees questioned, coupled with a detailed discussion on the subject in a number of the focus groups – particularly machine operatives. Each of the interviewees highlighted that this issue is most likely to occur during the early stages of a project, particularly where basement construction is involved, due to the requirement of large plant and machinery to excavate and construct the basement and associated enabling works. The International Labour Office (1995), Varghese, *et al.,* (1995) and Harris, *et al.,* (2006) all emphasize that there is a health and safety issue with the close proximity at which individuals have to work with large plant and machinery. Loosemore, *et al.,* (2003) argues that 'the use of dangerous machinery within a congested work environment', can have an adverse effect on the health and safety of those in its immediate vicinity. Shapira, et al., (2007) furthers this point by illustrating the numerous difficulties with incorporating various types of large plant in a confined space. One of the resulting factors noted was an increase in the risk of accidents or incidents due to the lack of space on-site to accommodate the various pieces of plant required to complete the tasks required. In the context of construction site with plentiful open space, the possibility of this factor influencing on-site management protocol is reduced proportionately, due to the abundance of space available for machine operatives and site operatives to ensure that adequate space is maintained between both machinery and operatives on-site. Therefore, this factor, although present on every construction site, is only a significant factor where spatial restrictions are evident.

One of the core points articulated with regards this subject is that it invariably leads to severe injury/incapacitation or fatality, should it occur on-site. Gürcanli, *et al.,* (2008) clarifies the category of injuries likely to occur, due to personnel coming into contact with large plant in operation as entrapment, crushing and/or amputation. Due to the severity of this issue, all personnel on-site were aware and proactively managed the reduction or elimination of this factor, where possible, on-site. The interviewees cited a number of factors in the causation of such accidents, including an operatives reduced field of vision

while operating large plant, the lack of space to manoeuvre safely, increased pressure to perform the task faster due to a compressed project schedule and also due to overcrowding of the construction site, leaving little room for various trades and individuals to work in isolation. In addition, it has been confirmed that half of construction accidents incorporating large plant is attributable to human error on the part of the machine operative, thus further emphasising the need to identify and mitigate the risks associated (Bhide, 2006). To summarise, Gehlhausn (2007) identifies the following large plant as being primarily involved in on-site accidents; cranes, backhoes, bulldozers, skid steer loaders, front end loaders and haulage vehicles. The occupation most susceptible to risk generation on-site accidents has been acknowledged as "Labourers", "Material Movers" and "Heavy tractor / truck drivers" (Bureau of Labour Statistics, 2003; Bhide, 2006). Other factors which are also noted as contributing to the increased health and safety concerns with regards this aspect is the nature of the work, including the working environment. The Bureau of Labour Statistics (2011) argues that the surrounding environment can be a contributory factor in the prevalence of accidents with large plant on-site. Such aspects as the weather conditions and the surrounding environment including the spatial constraints are also taken into account. In addition to personnel on-site being struck by moving plant or machinery, there is also the risk due to noise and vibration of large plant being operated in close proximity to other operatives on-site. Again, this issue was expanded during the focus group seminars but each of the participants indicated that the risks are invariably mitigated or eliminated through implementing numerous protocol and contingency measures, therefore, this aspect was considered minor when compared to the former point raised.

5. **Difficulty in ensuring proper arrangement and collection of waste materials on-site**
5. **Difficulty in controlling hazardous materials and equipment on site**

The fifth factor listed from the results of the questionnaire survey resulted in a dual factor result. Both "Difficulty in ensuring proper arrangement and collection of waste materials on-site" and "Difficulty in controlling hazardous materials and equipment on site" resulted in a tie. For the purpose of this discussion, due to the similarities in the two factors, each will be taken in unison and discussed further. Each of the factors had an identical importance and frequency ranking of 8th and 5th respectively, thus illustrating not only the

high importance of each of the factors but more importantly, the increased possibility of the respective issues materialising on-site. As both factors deal with the issue of effectively managing of, and where required, efficient collection and disposal of hazardous waste from site, each factor will be discussed collectively.

Construction waste is a significant burden on any construction project. Whether the site in question is one where spatial restrictions are evident or not, the proper arrangement and collection of waste coupled with the control of hazardous materials and equipment are factors which require redress on an on-going basis. Construction waste can be divided into three primary categories; material, labour and machinery (Ekanayake and Ofori, 2000). For the purpose of this research, the classification of waste encompasses that only of material and not of the other categories. This classification of waste generally accounts for 15 to 30% of urban waste (Formoso, *et al.,* 2002) and its effective management is essential to ensure it is successful, and more importantly, removed from site promptly and effectively. In order to mitigate the possibility of accidents or incidents due to hazardous material or equipment, one of the primary solutions is to eliminate the risk prior to occurring (Keys, *et al.,* 2000). Where this is not possible, risk transfer followed by the effective mitigation of the issue is required. To assist in the supervision process, on-site management must first identify the hazardous waste prior to effectively managing and ultimately disposing the waste off-site (Lee, *et al.,* 1999). In order for this to occur, on-site management must intuitively and proactively manage these hazardous sources prior to arriving on-site, through ensuring that the means are in place to efficiently identify, collect, store and ultimately remove the waste from site, as required (Formoso, *et al.,* 2002). Due to the advent of increased acceleration of many project programmes (Li, *et al.,* 2000) along with the continuous burden of excessive material required (Winch, 2010), the effective management of hazardous and waste material only becomes more apparent, in the strive for increased project performance and ultimately successful project completion.

IMPLICATION FOR PRACTICE

To summarise, based on the findings of the research, the issues highlighted are various and diverse. As Biddy (2009) outlined, urban areas are not expanding, but instead, they are being redeveloped, with a large majority of construction in urban areas occurring on brown field, inner city sites. Furthermore, the number of urban developments is increasing; suggesting that confined site construction is rapidly becoming the norm within the industry. Tindiwensi, (2000), continues by highlighting that "increasing population has put a premium on inner city sites. The building that occupies virtually the whole site area is now commonplace". Dixon (2009) argues that eighty percent of the population of the United Kingdom is spread over just nine percent of the country and this is further illustrated by Li, *et al.,* (2007) who has noted a "surge of population influx to urban centres", further exasperating urban growth.

Furthermore, the Director General of the International Labour Organisation (ILO) (2005) outlines that "there has been progress on many fronts in the world of work. But work-related deaths, accidents and diseases, are still major causes for concern". This is illustrated in a figure of over ten thousand construction site deaths occurring annually, around the world. The construction industry employs six to ten percent of the workforce yet accounts for up to forty percent of fatal accidents at work, thus further emphasising the increased health and safety risks present on-site (ILO, 2005).

As the results highlight, it is evident that in undertaking a development within a confined environment, increased health and safety concerns will inevitably arise. With the increasing cost of both time and money in relation to accidents on-site along with the morale issue, it is beneficial to all involved, particularly on-site project management, to envelop the proactive practices that aid in the management of these inherently hazardous working conditions. Through management identifying the numerous issues highlighted, on-site management can mitigate and counteract, the health and safety issues acknowledged in relation to confined site construction.

CONCLUSIONS AND RECOMMENDATIONS

Based on the research, it may be noted that confined construction sites, by their very nature, illustrate characteristics that are likely to increase the health and safety concerns, over conventional, open plan construction site environments. When reviewing the literature on standard, open spaced construction projects, many of the factors noted herein are also identified (Dedobbeleer and Béland, 1991; Sawacha, *et al.,* 1999; Mohamed, 2002). Furthermore, the difficulties noted with regards confined construction sites result in these factors being exasperated and thus the consequential effects being compounded, resulting in significantly more onerous health and safety issues for on-site management to contend with. Due to the prevalence and size of many of today's modern confined construction site environments, coupled with the increasing health and safety concerns, the need for project management professionals to acknowledge and utilise the research findings, become more apparent.

On reviewing the interviewee's comments with the data from the questionnaire survey, it is evident that health and safety in confined site environments, is an issue for all involved. Through analysis of the questionnaire survey, the issues were summarised as, (1) 'Difficulty to move materials around site safely', (2) 'Lack of adequate room for the effective handling of materials', (3) 'Difficulty in ensuring site is tidy and all plant and materials are stored safely', (4) 'Close proximity of individuals to operation of large plant and machinery', and joint fifth (5) 'Difficulty in ensuring proper arrangement and collection of waste materials on-site' and 'Difficulty in controlling hazardous materials and equipment on site'. On re-evaluating the case studies adopted, coupled with the interviews, these core issues emerged in each of the interviews, regardless of the case study discussed. As a result, it can be concluded that these issues are of paramount importance in the management of health and safety within confined construction site environments.

The identification of the numerous on-site project management issues in the co-ordination of health and safety within a confined site environment and acknowledging their existence, management can reduce proportionately, the various health and safety concerns that can and do arise, often on a daily basis. Based on the literature review on health and safety in confined construction site environments, coupled with the concerns voiced by the interviewees approached, it is evident that further detailed research within the area of confined site construction is required. Confined site construction must be acknowledged as an important aspect of project management in today's modern construction. As a result, the void of knowledge within the realm of confined site construction requires redress, due to its prominent nature within today's construction industry. It is suggested that further research be conducted in this vast area, to benefit present and future developments within the industry.

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