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CHALLENGES OF UK/IRISH CONTRACTORS REGARDING MATERIAL MANAGEMENT AND LOGISTICS IN CONFINED SITE CONSTRUCTION

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ABSTRACT

The aim of this paper is to identify the various managerial issues encountered by UK/Irish contractors in the management of materials in confined urban construction sites. Through extensive literature review, detailed interviews, case studies, cognitive mapping, causal loop diagrams, questionnaire survey and documenting severity indices, a comprehensive insight into the materials management concerns within a confined construction site environment is envisaged and portrayed. The leading issues highlighted are: that contractors' material spatial requirements exceed available space, it is difficult to coordinate the storage of materials in line with the programme, location of the site entrance makes delivery of materials particularly difficult, it is difficult to store materials on-site due to the lack of space, and difficult to coordinate the storage requirements of the various sub-contractors. With the continued development of confined urban centres and the increasing high cost of materials, any marginal savings made on-site would translate into significant monetary savings at project completion. Such savings would give developers a distinct competitive advantage in this challenging economic climate. As on-site management professionals successfully identify, acknowledge and counteract the numerous issues illustrated, the successful management of materials on a confined urban construction site becomes attainable.

KEYWORDS: Confined site construction, Logistics, Materials management, Strategic management, Urban development.

INTRODUCTION

In the last number of years, there has been a noted shift in the movement and growth of population densities around the world. In 2008, for the first time in history, urban and rural population were on par, with the trend highlighting that urban growth was set to surpass rural expansion (United Nations, 2008a). In the last decade there has been a significant surge in population growth in urban centres (Bidy, 2009; Li, *et al.*, 2007) and in 2009, this trend resulted in urban population exceeding rural growth. Furthermore, this expansion is set to increase significantly over the next decade (United Nations, 2010).

With this continued global expansion, there comes a need to develop and rejuvenate existing urban centres, to accommodate such population influxes (Jones and Evans, 2008). Over the next twenty years, the built environment is expected to increase by 40% in order to meet this growth in demand (Li, *et al.*, 2007). With the redevelopment of urban centres, significant reconstruction is required (Roberts and Sykes, 2000) and the redevelopment of brownfield sites is one of the more attractive options available. This is due to the city centre location and potential for increased revenue and return on investment, coupled with other market incentives available in these central locations (Thornton, *et al.*, 2007).

Increased construction activity comes with this redevelopment, often within limited available spaces. The redevelopment of these urban centres poses additional problems when compared with greenfield rural construction projects, due to a number of reasons. With the increased management interface required in the coordination of the various resources, the likes of personnel management, public relations, health and safety, and overall project performance are all increased concerns when developing in urban centres. One of the most significant reasons is the difficulty in the management of material required in constructing projects in these urban, spatially restricted surroundings.

Many authors have dealt with this topic under the realm of supply chain management (Ferne and Thorpe, 2007; Vrijhoef and Koskela, 1999), logistics management (Mossman, 2008) material management with regards to site layout (Sadeghpour, *et al.*, 2002) and overall waste management of materials on site (Formoso, *et al.*, 2002), to name a few. The vast majority of these authors focus on the management of materials on sites where space is plentiful but as illustrated, confined urban construction developments are quickly becoming the norm in the industry. Only fleeting references to urban material management has been suggested but in these cases the focus is on the overall management of the construction site at the inception or initiation stage (Lambeck and Eschemuller, 2008; Burch, 1985). There is a distinctive void in the literature with regards documentation highlighting the individual issues in the management of materials on a confined construction site.

With increased complexity in designs and countless materials required to construct these often intricate structures (Chan, *et al.*, 2004), endless quantities of materials are required at various times and in various locations, in order to complete a successful project (Kini, 1999). In addition, there is also an increase in the management of materials in urban developments, resulting in additional supervision by site management personnel (Li, *et al.*, 2005). In the case of a confined site construction, where space is a finite resource, effective management of materials on-site is becoming increasingly difficult (Thomas, *et al.*, 2005).

The main objective of this research is to unearth the various issues in the management of materials on a confined construction site and catalogue them according to the general perception of site management professionals as perceived in the industry. This is achieved through assessing existing research coupled with conducting case study reviews of confined construction sites in urban areas. In total, three case studies were analysed with a minimum of three site management professionals from each case study interviewed. From the various factors highlighted, a questionnaire survey was developed and administered throughout the industry. The results were analysed through means testing, anti image correlation and data reduction so that the fundamental issues in the management of materials on a confined urban construction site are established.

BENEFIT OF MATERIAL MANAGEMENT IN CONFINED SITE CONSTRUCTION

The benefit of effective material management within the construction industry has been widely acknowledged. Many writers have sought to detail the effects that site layout have on both materials and their waste (Formoso, *et al.*, 2002); Oglesby, *et al.*, 1989; Li, *et al.*, 2001; Tommelein, *et al.*, 1991). Material wastage amounts to a daily reduction in productivity of up to 40%t (Thomas, *et al.*, 2005); therefore effective management of waste is an essential factor in materials management.

In addition, the surrounding environment has a significant impact on the management of materials and the associated level of accidents that occur, with a third of accidents on-site attributable to poor material management (Perttula *et al.*, 2003). The constraints identified are many (Perttula, *et al.*, 2003), but the more significant constraint identified is the surrounding environment and its sporadic and dynamic nature.

Many studies have stated the significant importance to both material and waste management to that of the site layout. Those writing on waste (Thomas, *et al.*, 2005; Sanad, *et al.*, 2008; Formoso, *et al.*, 2002) highlight the significance of the on-site layout and many attribute it to one of the leading factors of waste on building sites today. However in contrast to confined construction sites, many of the researchers highlight that it is the larger, spatially rich sites that pose the biggest problems due to the long distances for which materials must be transported, coupled with the additional burden of monitoring materials. There is an abundance of literature on the management of materials on-site (Ala-Risku and Karkkainen, 2004; Enshassi, 1996; Ng, *et al.*, 2008; Navon and Berkovich, 2005), particularly where space is plentiful (Choo and Tommelein, 1999; Tommelein and Zouein, 1993), yet many fail to acknowledge the importance and the benefits of effective material management where space is a finite resource, requiring extensive management and the resulting benefits available to all. Many fail to take the aspect of confined sites into consideration when looking at material wastage, under such headings as;

- Lack of adequate storage space
- Lack of adequate room for the effective handling of materials
- Damage occurring due to poor material management, and
- Lack of adequate room to account for materials (e.g. materials becoming 'buried' on site)

The effective management of such aspects as delivery, off-loading, storage, handling, on-site transportation and on-site utilisation of materials is essential to the overall success of any development (Thomas, *et al.*, 2005), however this is even more accurate in the case of an urban construction site (Li, *et al.*, 2005; Poon, *et al.*, 2004a), where spatial restrictions are evident.

Various authors have covered on-site logistics management illustrating the benefits when implemented (Poppendeick, 2000; Caron, *et al.*, 1998; Proverbs, *et al.*, 1999). The majority of researches that focus on sites with little or no spatial restrictions, only hint at some of the potential issues that may arise (Chudley and Greeno, 2006a, 2006b; Ahuja, *et al.*, 1994). Due to spatial restrictions, effective logistics management should result in more proactive and productive utilisation of materials on confined construction sites.

When materials are not delivered to site as per the project programme, it results in delay in construction projects (Assaf and Al-Hejji, 2006). Therefore, where increased logistical management is required, as is the case in urban inner city environments, effective logistical management and supply chain management is essential in the overall material management process. The benefits of effective material management are well documented, resulting in significant monetary savings and schedule compression where implemented (Agapiou, *et al.*, 1998; Poon, *et al.*, 2004a). During such difficult economic conditions the need to acquire new contracts under difficult tendering practices further illustrates the benefits of effective material management, particularly in confined site environments.

If the findings of this research are acknowledged and implemented, there are significant savings attainable based on the following. In the majority of construction projects, materials amount to between 50-60% of the total contract cost, (Song, *et al.*, 2006) effective management of this resource can lead to a reduction in costs, resulting in a significant saving. A potential 6% saving on total cost through effective materials management is achievable (Bell and Stukhart, 1987), yet the construction industry invests only 0.15% in materials management and control (Navon and Berkovich, 2006). In addition, poor material management contributes to over a third of accidents on-site; a reduction would further lead to monetary savings to a project (Perttula, *et al.*, 2003). Based on the possible savings that are achievable, the potential for more competitive tendering and increased profit margins are evident and become increasingly beneficial in the current economic climate.

RESEARCH METHODOLOGY

In conducting this research investigation, a number of data collection techniques were utilised encompassing both qualitative and quantitative means. These processes are summarised in the following sub-headings.

Qualitative Data Collection

In order to identify the numerous issues in the effective management of materials on a confined construction site, a number of qualitative means of data collection were considered and implemented. The qualitative data collection was primarily based around two forms of qualitative data collection. The review of literature, paying particular attention to peer-reviewed publications and case studies for acquiring on-site feedback directly from site management professionals. With regards the literature review, interesting insights were gained of material management in the construction industry and other industries, such as manufacturing, retail and automotive industries. This holistic overview provided information/suggestions to the issues identified.

The case studies involved 12 possible confined construction sites that were selected based on several parameters including size, location, number of personnel on-site and the overall complexity of the respective project. For the purpose of this study, a confined construction site has been identified as exhibiting an increased managerial burden on material management, due to reduced presence of space in which to manage this resource effectively. After careful consideration and consultation with industry experts, the number of case studies narrowed down to three. The selection process permitted comparisons and deducing differences between the case study projects chosen.

The three case studies 1-3, selected were a high rise condominium development (Chicago, Illinois, USA), low rise office block (Limerick, Ireland) and an underground water services contract (Derry, Northern Ireland).

To supplement the information obtained from the case studies, a comprehensive interview procedure followed, so that an exhaustive list of managerial issues was included for discussion. This interview process was divided into two facets; individual interviews and focus group seminars. The individual interviews were with at least three on-site professionals from the three separate case studies. In total 12 interviewees were approached, with an average of 15 years experience within the project management profession.

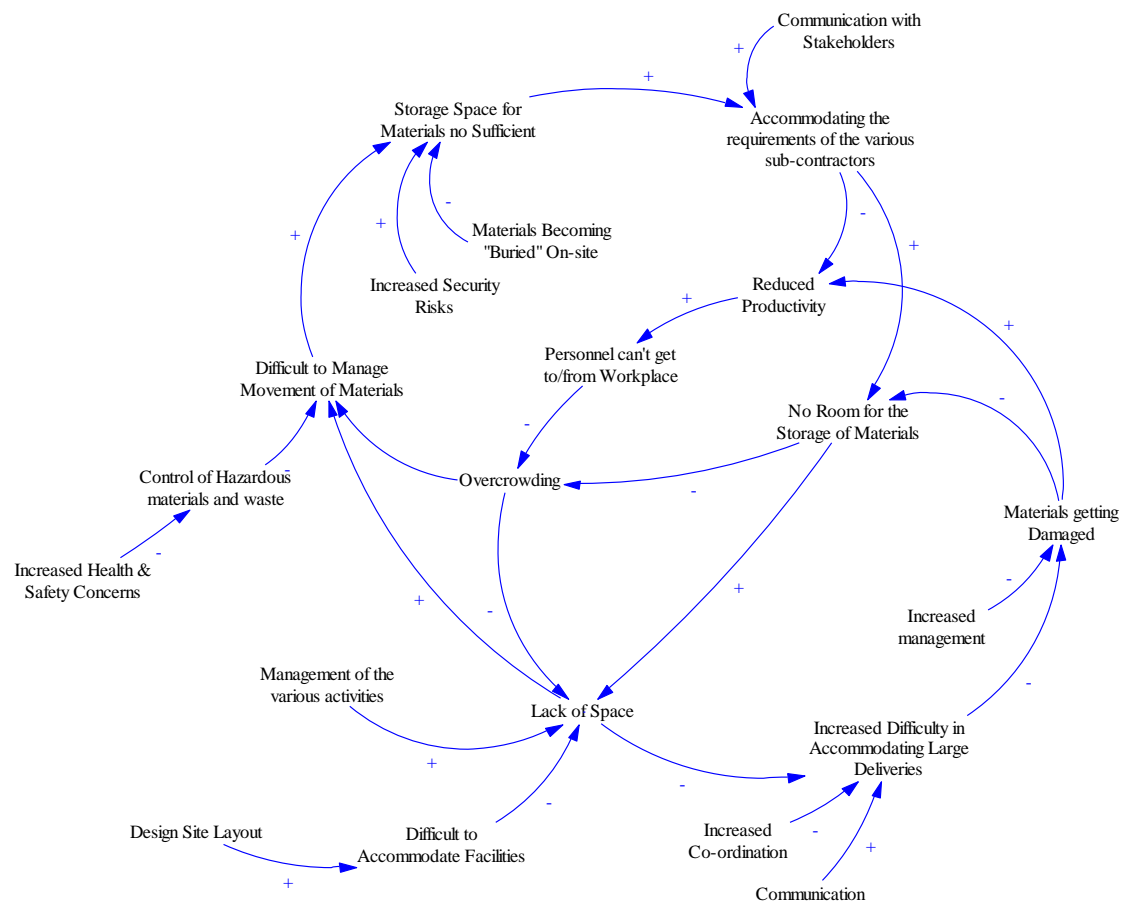


Figure 1: Causal loop diagram - Issues with material management on confined construction sites

From the case studies, cognitive mapping and causal loop diagrams were used to depict and decipher the various factors highlighted by the interviewees, thus aiding in the dissemination of the data and the extraction of the factors for further study. Figure 1 illustrates graphically, the combined causal loop map showing the various core issues documented throughout the qualitative analysis investigation, where each of the core issues identified in the qualitative analysis are documented. In conjunction with illustrating the numerous variables, the interrelationships are also documented with positive [+] and negative [-] signs, thus aiding the portrayal of the factors and how they interlink in the overall scheme with regards to issues in the management of materials on confined construction sites.

Quantitative Data Collection

The results obtained from the qualitative investigation were reviewed, compiled and included in a questionnaire survey, the basis of which was to categorise the prevalence and importance of the various issues identified. The questionnaire survey designed, was piloted to three individuals who had an average of 15 years project management experience in the industry. Through piloting the questionnaire, the length, order and feasibility of the questions were tested under real life circumstances in which it was designed to measure. The questionnaire incorporated a dual response rating for each of the factors posed. Both the 'Importance' and the 'Frequency of Occurrence' were polled, to determine the 'Severity' of the factors included. Adopting a dual ranking system, helped to decipher the results and provide more detailed and concise result for discussion. The questionnaire was administered to on-site construction professionals where 106 respondents completed and returned the questionnaire, giving an approximate response rate of 49%.

Table 1: Case study comparison based on factors identified

	Factors	Case Study 1	Case Study 2	Case Study 3
1	Contractors material spatial requirements exceed the available space	X	X	X
2	Difficult to coordinate the storage of materials in line with the programme	X	X	X
3	Location of the site entrance make delivery of materials particularly difficult	X		X
4	Difficult to store materials on-site due to the lack of space	X	X	
5	Difficult to coordinate the storage requirements of the various sub-contractors	X	X	X
6	Increased management intervention required throughout, due to the lack of space		X	
7	Difficult to transport material around site because of the lack of space on-site	X	X	X
8	Time consuming to coordinate the movement of materials on-site	X	X	
9	Confrontation among sub-contractors due to the lack of storage space on-site	X	X	X
10	Difficult to coordinate the movements of contractors materials on-site	X	X	X
11	Difficult to facilitate materials required in line with the programme	X	X	
12	Increased manual handling of material on-site due to the confined environment	X	X	X
13	Material storage locations inhibiting the progression of the works	X	X	X
14	Difficult to get materials from the storage space to the location where required		X	
15	Materials getting damaged on-site due to the lack of space	X	X	X
16	Difficult to provide safe and secure storage of material on-site	X	X	X
17	Close proximity of personnel to large stockpiles of material on-site	X	X	
18	Difficult to accommodate the safe storage and removal of material waste on-site	X	X	X

DATA AND RESULTS

18 factors emerged from the qualitative analysis which were then included in a questionnaire survey. The communality of the factors in relation to each of the factors is given in table 1. 61% of the factors identified, emerged from all three case studies (11 from 18) and 28% of the factors were identified in at least two of the case studies (5 from 18). 11% of the factors occurred in only one of the case studies (2 from 18). A high degree of communality among the case studies assessed, illustrate the transferability of the factors to other confined construction sites.

With the aid of the causal loop diagram in Figure 1, it is also possible to document the majority of the factors and also graphically illustrate how each of the factors does not occur in isolation but as an integral part of an overall issue, which is material management and logistics in confined site construction. From the data acquired in the questionnaire survey, it was possible to catalogue the 'Importance', 'Frequency of Occurrence' and resulting 'Severity' based on the following formulae as derived from Chan and Kumaraswamy (2002).

$$\text{Importance Index (II)} = \left(\frac{\sum(i)}{NI} \right) \times 100\% \dots\dots\dots \text{Equation 1}$$

$$\text{Frequency Index (FI)} = \left(\frac{\sum f}{NF} \right) \times 100\% \dots\dots\dots \text{Equation 2}$$

$$\text{Severity Index (SI)} = \left(\frac{\sum(if)}{NIF} \right) \times 100\% \dots\dots\dots \text{Equation 3}$$

Equations: Importance, Frequency and Severity Index

Where 'i' and 'f' are importance and frequency rating respectively, which correspond to the ratings identified by each of the individual respondents to the survey, and range from 1 to 5. 'I' and 'F' are the highest importance and frequency ratings possible respectively, which in the importance and frequency scales, is 5. 'N' is the total number of responses for that particular factor, that is 105. From the resulting formula, it was possible to tabulate the factors based on their severity indices.

Using quantitative analysis of the data, the top five issues in the management of materials on a confined construction site was established using the severity index (SI) ranking. Therefore the top five issues identified are:

1. Contractor's material spatial requirements exceed the available space
2. Difficult to coordinate the storage of materials in line with the programme
3. Location of the site entrance makes delivery of materials particularly difficult
4. Difficult to store materials on site due to the lack of space
5. Difficult to coordinate the storage requirements of the various sub-contractors

Each of these top five factors in the management of materials on a confined construction site are addressed and scrutinised further, paying particular attention to existing literature to compound the points noted.

Table 2: Material management factors and associated attributes

Factor	II	I Rank	FI	F Rank	SI	S Rank
Contractors material spatial requirements exceed the available space	79.0%	3	72.8%	1	60.4%	1
Difficult to coordinate the storage of materials in line with the programme	84.2%	1	58.5%	5	51.7%	2
Location of the site entrance make delivery of materials particularly difficult	77.0%	4	63.2%	2	51.1%	3
Difficult to store materials on-site due to the lack of space	75.2%	6	60.4%	3	47.7%	4
Difficult to coordinate the storage requirements of the various sub-contractors	72.0%	11	59.0%	4	44.6%	5
Increased management intervention required throughout, due to the lack of space	71.8%	13	58.3%	6	43.9%	6
Difficult to transport material around site because of the lack of space on-site	82.3%	2	50.9%	13	43.9%	7
Time consuming to coordinate to movement of materials on-site	73.9%	10	55.6%	7	43.2%	8
Confrontation among sub-contractors due to the lack of storage space on-site	74.3%	9	52.6%	9	41.0%	9
Difficult to coordinate the movements of contractors materials on-site	75.0%	8	51.8%	10	40.8%	10
Difficult to facilitate materials required in line with the programme	72.0%	11	53.5%	8	40.5%	11
Increased manual handling of material on-site due to the confined environment	76.4%	5	50.1%	15	40.2%	12
Material storage locations inhibiting the progression of the works	75.2%	6	49.1%	16	38.8%	13
Difficult to get materials from the storage space to the location where required	71.4%	15	51.4%	12	38.6%	14
Materials getting damaged on-site due to the lack of space	70.1%	17	51.8%	10	38.1%	15
Difficult to provide safe and secure storage of material on-site	71.8%	13	50.5%	14	38.1%	16
Close proximity of personnel to large stockpiles of material on-site	71.0%	16	46.7%	18	34.8%	17
Difficult to accommodate the safe storage and removal of material waste on-site	68.4%	18	47.8%	17	34.3%	18

II = Importance Index; I Rank = Importance Rank; FI = Frequency Index; F Rank = Frequency Rank;
SI = Severity Index; S Rank = Severity Rank

Contractor's material spatial requirements exceed the available space

The result of the qualitative analysis identified material spatial requirements of contractors as the top most issue of concern in confined site construction. The 'Importance' rating assigned by the respondents to the survey ranks this factor 3rd, but it occurs at such a high level of frequency (rank 1st) that it was identified as the most prominent factor discussed. Spatial requirement require thorough attention due to the likelihood of this issue occurring, considering that construction materials make up an average of 40% to 50% of a total project cost (Vainio, 1999; Vrijhoef and Koskela, 2000). With the increase in the utilisation of sub-contractors and third parties to the average construction project (Langford and Male, 2001; Holt, *et al.*, 2003), the amount of on-site management and co-ordination is set to increase dramatically (Winch, 2009, 2010).

With the increase in contractor involvement coupled with the continued compression of many of today's project schedules (Chang, *et al.*, 2005; Nepal, 2006), the need for on-site management to successfully accept delivery and accommodate the numerous material requirements of these subcontractors grows in complexity with the number of contractors on-site. In order to provide for and aid in the movement of required material, the space required must be documented, managed and allocated accordingly. Scenarios where the spatial requirements for material on-site exceed the availability of space on site require proactive management to be introduced to mitigate the resulting effect. Where such instances are mitigated, there is a propensity for reduced accidents (Spillane, *et al.*, 2011), increased productivity (Thomas, *et al.*, 1989) and ultimately, a greater possibility of achieving project success. In order to alleviate the issue, the vast majority of authors agree that the most advantageous strategy to adopt is one of proactive mitigation through early contractor involvement (Proverbs and Holt, 2000; Trigunaryyah, 2003; Khalfan, *et al.*, 2004; Song, *et al.*, 2009) coupled with continuous communication among the parties (Emmitt and Gorse, 2003), both horizontally and vertically, on and off-site with the various internal stakeholders associated with the project.

Difficult to coordinate the storage of materials in line with the programme

The second most significant issue in relation to material management on a confined construction site was that of the difficulty in coordinating the storage of materials, particularly in line with the project programme. The respondents collectively viewed this issue as the most "Important" but the 'Frequency of Occurrence' identified that this issue is below the remaining points noted, coming in at 5th. Interestingly, Thomas, *et al.*, (2005) identifies storage as the first step in materials management and failure to accommodate materials results in poor productivity and waste (Thomas, *et al.*, 1989). The effect of unsuitable storage locations is also an issue in poor labour productivity (Enshassi, *et al.*, 2007), thereby indicating that not only is the presence of adequate storage space essential, but correctly located storage is also a factor in the overall on-site productivity. The negative effect of inadequate/inappropriate material storage is an issue with various trades on-site, such as masonry productivity (Sanders, *et al.*, 1991). The mismanagement of material storage is a leading factor in spatial congestion and results in reduced levels of productivity on construction projects (Thomas, *et al.*, (2006). Therefore effective measures must be taken to counteract such instances on-site.

Ensuring an adequate stockpile of materials on-site is essential in the management of production (Horman and Thomas, 2005). Where there is a lack of storage space, this inventory may become compromised, resulting in further negative results in productivity and materials management. Effective site and space utilisation is fundamental to the management of materials (Chau, *et al.*, 2004). Where space is limited, additional management of the available space is essential to accommodate the various material requirements of a project.

On reviewing a number of the interviews and the literature (Yang and Mahdjoubi, 1999; Yang, *et al.*, 2003; Mohamed and Anumba, 2006; Soltani and Fernando, 2004), a number of authors identify the experience of the management in the successful allocation of material and its associated storage on-site. This is based on intuition and experience gained through knowledge obtained in the industry. The knowledge gained is tacit and takes years to develop through experience and interaction in the industry. Koskela, (1999) aptly concludes by outlining that projects are very often constructed in 'sub-optimal conditions'. In addition,

congestion was highlighted as being ‘one facet of a wider phenomenon’ where extensive management is necessary to accommodate such working conditions on site.

Location of the site entrance makes delivery of materials particularly difficult

The third material management issue is the difficulty in the transportation of materials, particularly in relation to the location of the site entrance. The questionnaire results identify the ‘Importance’ of this factor by ranking it 4th overall but the ‘Frequency of Occurrence’ indicate a ranking of 2nd, elucidating the likelihood of such an issue arising on-site. Resulting from this, materials become damaged, require double handling and are misplaced, due to inadequate management of the limited available space on site. This happens predominantly in the vicinity of the site entrance. This is mainly attributable to bottleneck effects, where multiple deliveries can result in increased management intervention to alleviate any issue that may arise. This may be classified and detailed under the title of material flow, an important topic in the management of materials on-site. In a study conducted on material management, material flow management was classified as the second most critical factors in project management’s level of satisfaction in construction logistics (Jang, *et al.*, 2003).

Inadequate working conditions can ultimately lead to increased material handling, resulting in possible injury to personnel (Mitropoulos, *et al.*, 2005a). Mitropoulos, *et al.*, (2005b) also outlines that the “unpredictability generates hazardous situations” results in “chaos and confusion”. Furthermore, the benefit of an effective site layout and thus, the location and number of site entrances, contributes to the flow of materials. The provision of adequate spatial considerations has been considered by a number of authors (Elbeltagi, *et al.*, 2004). This is highlighted further where adequate planning is required to avoid excessive movement of materials on-site, thereby, reducing the probability of double handling materials in adverse conditions. Through effective identification and location of site entrances, the possibility of increased handling of materials is mitigated. Thomas, *et al.*, (2002) concludes that interruptions to the normal flow of materials will cause serious degradations to performance and labour productivity. From the aforementioned it is evident that improper location of the site entrance, resulting in inadequate room for the effective handling of materials, is a significant issue in materials management in confined site environments.

The site layout is directly connected to the management of materials (Elbeltagi and Hegazy, 2003; Tam, *et al.*, 2002; Sadeghpour, *et al.*, 2002), and where such management is implemented, monetary savings are attainable (Osman and Georgy, 2005). One of the primary functions of an adequate designed site layout is to aid in the movement of materials, unto and around site, as is necessary in the completion of the various tasks (Elbeltagi, *et al.*, 2004). The supply of materials is fraught with difficulties, not only onto site, but also in getting materials to site (Agapiou, *et al.*, 1998). With many urban confined site environments, the location of the site entrance or the site itself can be an issue. The role of logistics management and supply chain management are essential in the management of materials and the location of the site entrance, both prior to arriving on-site and during the delivery and unloading process.

To conclude, the ability to design and accommodate adequate logistics management plans, site layout plans and materials management plans are all essential in the management of the transportation of materials both unto and around site (Yang, *et al.*, 2003). Where such site layout plans are not implemented, the movement of materials on-site is significantly restricted, resulting in increased manual handling, double handling, waste, lost productivity,

increased health and safety risks and inevitably, at the extreme, project failure (Mawdesley, *et al.*, 2002).

Difficult to store materials on-site due to the lack of space

The fourth issue identified by the quantitative analysis was the difficulty with Storing materials on-site due to the lack of space. The 'Importance' rank of 6th illustrates that on-site management professionals are aware and counter-act this issue through effective planning and control, but with a 'Frequency of Occurrence' rank of 3rd, this illustrates that this issue is reoccurring on a frequent basis, hence its inclusion in the top five issues in the management of materials. One of the main reasons for a lack of storage space on-site is over-crowding or congestion of the workspace, which is directly correlated to poor project productivity (Thomas and Riley, 2006). An overcrowded construction site may lead to double handling of materials, again, reducing productivity and increasing damage to materials (Horman and Thomas, 2005) along with increased health and safety concerns (Huang and Hinze, 2003). Inadequate management of materials through over allocation also has been identified as impeding progress, workflow and overall productivity, due to overcrowding the limited work space available (Horman and Thomas, 2005) while also exasperating the issue of security of materials (Berg and Hinze, 2005). Planning is essential to overcome this issue and management of the critical space. Planning has been noted as being fundamental to site management, including spatial management (Winch and North, 2006) and reducing congestion on-site (Winch and North, 2006).

On confined sites, material waste may increase, resulting in significant increases in cost (Poon, *et al.*, 2004b) and additional project costs (Bell and Stukhart, 1987). It is estimated that on average, 1 to 10% of materials entering site, leave site as waste, due to improper management (Bossink and Brouwers, 1996). This shows the need for effective material management on-site. Formoso *et al.* (2002) considers the estimate conservative as they report that the range of material waste falls between 2-15%. Formoso *et al.* (2002) also highlight that the total building waste in urban areas could be as much as 30% in confined construction sites.

Lack of space is an inherent difficulty acknowledged throughout the industry, when constructing a development in an urban environment (Singer, 2002; Tindiwensi, 2000; Navon and Berkovich, 2006). In counteracting this issue, it has been noted that the strategies implemented can often prove problematic and cumbersome when trying to monitor and control a rigid project programme (Navon and Berkovich, 2006; Vrijhoef and Koskela, 1999; Lummus, *et al.*, 2001). As a result, the effective management of materials within a confined urban site cannot be over emphasised and must be acknowledged and implemented throughout any project, but in particular, a spatially restricted development.

Difficult to coordinate the storage requirements of the various subcontractors

The final factor identified as significant after the qualitative analysis was consider unimportant in relation to the other issues noted (with Importance rank of 11th) but again, the 'Frequency of Occurrence' (ranked 4th) is such that the 'Severity' of the issue requires redress. The co-ordination and movement of materials both onto and around site can be a cumbersome and time consuming task but one which is of paramount importance to site management (Soltani and Fernando, 2004). In cases where space is a limited factor, this task

becomes infinitely more difficult and requires extensive management interface in the co-ordination of the material storage requirements of the various sub-contractors (Winch and North, 2006). The co-ordination of materials on-site has been classified under a number of sub-sections, as follows (Thomas, *et al.*, 1989);

- Organisation and storage of materials,
- Housekeeping of materials and there waste,
- Planning of material deliveries,
- Material availability on-site,
- Material handling and distribution on-site.

The effective coordination and movement of materials is fundamental to the success of any project (Kini, 1999), particularly under then headings outlined previously. Where such steps are acknowledged and managed accordingly, increased savings are attainable, with some cases reporting saving of up to six percent in labour costs due to optimised schedules and improved productivity as a direct result of effective materials management (Bell and Stukhart, 1987).

The coordination of materials and other resources has been documented by numerous authors (Thomas, *et al.*, 2005; Nepal, *et al.*, 2006; Lu, *et al.*, 2007), illustrating that effective co-ordination of the various resources is essential to avoid waste or non-value adding activities in the industry (Formoso, *et al.*, 2002). Effective co-ordination of resources is essential in the management of the various resources on-site. To further this point, material waste is not always the result of poor co-ordination on-site. In some instances, waste occurs due to design faults and errors occurring during the design stage of a development (Enshassi, 1996; Love and Li, 1999). In the majority, waste on-site has been identified as being caused by poor co-ordination and communication in the management of materials which results in considerable additional cost in both monetary and schedule terms (Thomas, *et al.*, 2005).

Koskela (1999) shows that almost 40% of the total cost of materials on-site is made up of purchasing and controlling the movement of materials on-site. Where this task is made more efficient, there are significant savings available (Koskela, 1999). Project co-ordination, including material co-ordination was highlighted as one of the key issues in projects failing to meet the predetermined project programme (Muholland and Christian, 1999). Through acknowledging the requirement to facilitate effective material co-ordination with the other various tasks and resources on-site, such programme slippages could be mitigated or eliminated as the project progresses.

Coordination and communication are often taken collectively due to each generally occurring in unison. Where both facets are taken jointly, the cause of delay and disruption between resources and stakeholders is vastly reduced (Assaf and Al-Hejji, 2006). In addition, co-ordination is fundamental in the management of the allocation of stakeholders to resources - an integral part of the management of the movement and allocation of materials on site (Koskela, 1999). Therefore, the co-ordination of materials is an essential facet in the management of materials on-site, but where spatial limitations occur, this point is significantly more evident (Thomas, *et al.*, 1989).

DISCUSSION

As many of the authors outline, materials management is core to the successful management of a construction project (Kini, 1999; Formoso, *et al.*, 2002). Where environments are restricted as in the case of confined construction sites, the difficulty and importance of materials management increases significantly due to the numerous issues outlined. Bidy, (2009) emphasizes that, contrary to belief, urban areas within the United Kingdom are not increasing but much of the new developments are being built within the existing urban environment.

Furthermore, Bidy (2009) outlines that there is a drop in the transformation of green field sites to development land by two thirds when compared to 1975. This has been aided by government policies that are encouraging inner city development of brown field sites and thus, increasing the urban density of many cities around the country. The United Kingdom is also one of the most populated countries in the world, with a population density of 246 people per square kilometer (Home, 2009), further emphasising the need for continuous urban development.

The increasing number of urban developments suggest that confined site construction is rapidly becoming the norm within the industry. Therefore, confined site construction must be acknowledged as an important aspect of project management in today's modern construction industry and therefore given adequate research to effectively manage this spatially restricted environment accordingly.

With the high percentage costs material attribute to the total cost of projects, effective management is paramount, to ensure their viability and profitability, particularly in the case of confined site projects, where increased management interface becomes essential. The need for management to acknowledge and counteract the issues highlighted is of paramount importance.

This study has documented and illustrated the key importance of the issues highlighted. With the increasingly competitive industry set to continue for the foreseeable future, the need for companies to acknowledge and adopt counteractive strategies in the management of the issues highlighted, is of significant importance. Through acknowledging the benefits of effective materials management on-site, companies can reduce the effects of a lack of space, additional material handling, distribution, increased waste, unproductive activities, etc. resulting in increased productivity and profit margins.

CONCLUSIONS AND RECOMMENDATIONS

Increasing urban development trends (United Nations, 2008a, 2008b, 2010; Dixon, 2009; Bidy, 2009), both in the United Kingdom and around the world is a reality. Confined site construction are becoming inevitable for the majority of developer projects around the globe. Based on the extensive literature reviewed and the opinions of the interviewees from the case studies coupled with the data obtained from the questionnaire survey, the issues to the effective management of materials on confined construction sites are many and diverse. It is possible to summarise the issues in order of importance as follows: (a) Contractor's material spatial requirements exceed the available space, (b) Difficult to coordinate the storage of materials in line with the programme, (c) Location of the site entrance makes delivery of

materials particularly difficult, (d) Difficult to store materials on-site due to the lack of space, and (e) Difficult to coordinate the storage requirements of the various sub-contractors.

It is evident that effective management is the core of the issues highlighted. Identifying and understanding the numerous issues, project management professionals can successfully mitigate the effects that the issues can have on project delivery.

With the continuation of the current difficult economic climate and the prolonged downturn in the construction industry, for companies to remain competitive and profitable, reduced tender prices and increased profit margins are necessary. In order to sustain such practices, companies need to become or maintain their competitive advantage. Through acknowledging and counteracting the numerous issues highlighted in the management of materials, particularly in confined urban site developments, it is of paramount importance that the issues outlined are acknowledged and sufficient strategies implemented to mitigate their effects. Where such practices are implemented, as previous literature have illustrated, significant savings are attainable, resulting in more competitive tendering and increased profit margins. There are significant financial and programme benefits present, to help ensure that a project whose environment mirrors that of a confined construction site, may be completed successfully.

To acknowledge and understand these restricted environments, it is recommended that further research be conducted into spatial management and confined site construction within urban areas, to distinguish and counteract the issues identified and formulate appropriate strategies to aid in the management of confined urban site construction.

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