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Making the Construction Industry Resilient to Extreme Weather: Lessons from Construction in Hot Weather Conditions

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Abstract

The construction industry is susceptible to extreme weather events (EWEs) due to most of its activities being conducted by manual workers outdoors. Although research has been conducted on the effects of EWEs, such as flooding and snowfall, limited research has been conducted on the effects of heatwaves and hot weather conditions. Heatwaves present a somewhat different risk profile to construction, unlike EWEs such as flooding and heavy snowfall that present physical obstacles to work onsite. However, heatwaves have affected the construction industry in the UK, and construction claims have been made due to adverse weather conditions. With heatwaves being expected to occur more frequently in the coming years, the construction industry may suffer unlike any other industry during the summer months. This creates the need to investigate methods that would allow construction activities to progress during hot summer months with minimal effect on construction projects. Hence, the purpose of this paper. Regions such as the Middle East and the UAE in particular flourish with mega projects, although temperatures soar to above 40°C in the summer months. Lessons could be learnt from such countries and adapted in the UK. Interviews have been conducted with a lead representative of a client, a consultant and a contractor, all of which currently operate on UAE projects. The key findings include one of the preliminary steps taken by international construction companies operating in the UAE. This involves restructuring their entire regional team by employing management staff from countries such as Lebanon, Palestine, Iraq, and their labour force from the sub-continent such as India and Pakistan. This is not only due to the cheap wage rate but also to the ability to cope and work in such extreme hot weather conditions. The experience of individuals working in the region allows for future planning, where the difference in labour productivity during the extreme hot weather conditions is known, allowing precautionary measures to be put in place.

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1. Background

The UK has faced various extreme weather conditions in the recent past, including flooding, heavy winter snowfall, heavy rainfall, extreme temperatures and heatwaves. Such extreme weather conditions are expected to increase in the UK and are likely to occur more frequently (Stern, 2007). Although frequent weather extremes, such as flooding and heavy snowfall, have grabbed the headlines during recent years, hot weather conditions and the possibility of heatwaves during the summer seem to be on the increase. Analysis of climate data has revealed that summer heatwaves (heat or anomalous hot weather that lasts for several days, usually accompanied by high humidity) (Tan, 2008) have become more frequent in the UK (Firth and Colley, 2006; Hulme et al., 2002), it is predicted that they will become more frequent in future due to climate change (Department of Health, 2007), thus creating more severe impacts. According to Hulme et al. (2002), hot summer days with daytime temperatures in central England exceeding 25°C have become more common, almost twice as many on average during the 1990s compared to the first half of the twentieth century. The Stern Review (2007) estimates that there will be more days of extreme heat (relative to today) and fewer very cold days in the future, due to the effects of climate change. Temperature extremes may create adverse impacts on human health and may also create adverse effects on businesses. Firth and Colley (2006) report that the hot summer of 2003 caused major business disruptions in the UK. Construction can be identified as a sector that can be vulnerable to such disruptions.

Hot weather/heatwaves can cause productivity to fall and projects to be delayed, specifically in the construction industry. Previous studies have identified that exceptionally hot summers and heatwaves have had a considerable impact on the UK construction sector (Brodoli, 2010; Wedawatta et al., 2011). The purpose of this study is to establish and identify management solutions to delivering construction projects in hot weather conditions. According to Brodoli (2010), the UK's warm summer in 2007 caused problems in the industry, such as delays in construction projects due to it being claimed by contractors as adverse weather conditions (Brodoli, 2010). As construction companies in the UK seek to catch up for winter disruptions by speeding up project progress during summer months, any disruption due to hot weather is likely to have a considerable impact on project progress, financial performance and business continuity (Wedawatta et al., 2011). Due to global warming and the likelihood of warmer temperatures occurring more frequently in the UK, the construction industry needs to adapt to this change in weather. The study looks at how construction projects in the UAE and the Middle East are managed, and seeks to establish how construction companies in the UK can effectively manage their projects during warm summer (heatwave) periods in the UK. By knowing the procedures and laws that allow construction projects to thrive and proceed under hot weather conditions in the Middle East, UK construction companies can learn from these procedures and adapt them for UK projects in hot climates or projects in the Middle East should they operate overseas.

2. Effects of Hot Weather Conditions on the Construction Industry

Extreme weather conditions affect industries as well as the economy as a whole. However, the construction industry is one that is most vulnerable due to the nature of how construction companies operate and the industry's heavy reliance on manpower. Mills (2003) mentions that the construction industry is one of the most vulnerable to climate change. Therefore, due to the construction industry's high vulnerability to any climate change or extreme weather event, hot weather conditions would affect the construction industry while many other industries may flourish in warm climates (Biparva, 2010). Therefore, construction during hot weather conditions creates challenges in construction projects. Some of these challenges that affect construction projects as a direct result of heat are as follows:

2.1 Site

Brodoli (2010) mentions his experience in delays due to dry subsoil caused by hot and dry weather. The dry subsoil can be changed to dust, as dust is associated with hot and dry weather. Crissinger (2005) states that dust due

to dry subsoil creates large clouds of dust to settle in neighbouring properties. The Health and Safety Executive (n.d.) states that exposure of workers to substances from dust can cause long-term health issues, such as diseases, mentioning the most prevalent of those dust-related diseases being in the construction industry. These diseases include chronic pulmonary disease, occupational asthma and silicosis. The law further states that it is the employer's responsibility to control the dust causing those respiratory diseases by means other than personal protective equipment (PPE), for example, through water suppression or the extraction of dust (Health and Safety Executive, n.d.).

2.2 Equipment

Crissinger (2005) states that, due to hot weather conditions, filters on vehicles, machinery and equipment, both inside and outside, are exposed to dusty conditions. If those filters are not regularly checked and changed, premature breakdowns can occur (Crissinger, 2005). Depending on the project and machine, this may have severe impacts on a project. Chamberland (2014) further mentions that, due to dry and hot weather conditions, construction equipment is mostly affected by large amounts of dust clouds, which are formed around construction sites. The dust generates dirt, which causes unnecessary complications and breakdowns to machinery as well as risks to the health and safety of workers (Chamberland, 2014).

2.3 Concreting

According to the American Concrete Institute (ACI 305), hot weather is defined as: "Any combination of the following conditions that tends to impair the quality of freshly mixed concrete by accelerating the rate of moisture loss and the rate of cement hydration or otherwise causing detrimental results" (L&M Construction Chemicals, 2008). Crissinger (2005) states that hot and dry weather conditions can cause the water in concrete and masonry to evaporate too fast. This rapid evaporation produces concrete with a lower compressive strength and a finish that tends to curl upward and spall. Portland Cement Association (2014) mentions the effect of high ambient temperatures and high temperature concrete component materials have on the setting time of concrete mixtures due to the reduced time in which concrete must be placed, consolidated and finished. These increase the potential for plastic shrinkage cracking and thermal cracking. This further increases the potential for strength reduction due to high water demand and high curing temperatures (Portland Cement Association, 2014).

2.4 Workers

Workers affect the construction industry during hot weather conditions in two main ways, which are interrelated: these are from a fall in labour productivity and an increase in health and safety procedures to minimize workers' exposure to heat-related risks and illnesses. These factors are examined below.

2.4.1 Labour productivity

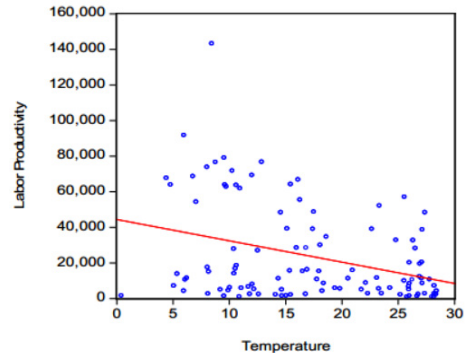
Palmer and Creagh (2013) state that the increase in humidity as a result of climate change are reducing labour productivity, and it is likely to get worse over time. In addition to this, an article published by Dunne et al. (2013) estimates that environmental heat stress has reduced labour productivity to 90% in peak months over the past few decades, and further projects' labour capacity to reduce to 80% in peak months by 2050 around the world. Furthermore, Figure 1, which is based on the findings of Yildirim et al. (2009), shows a negative association between an increase in temperature and labour productivity.

Furthermore, Figure 1 adds to the prediction by Dunne et al. (2013) of further reduced labour productivity due to an increase in global temperatures in the future. Yildirim et al. (2009) state that, according to their findings, temperature can be adversely affecting per capita income level of a country via reducing the labour productivity level in that country. This would mean that countries with high temperatures, such as the UAE, would have a much lower labour wage rate due to lower labour productivity when compared to the UK, where cooler temperatures would mean higher labour productivity and therefore a higher labour wage rate.

2.4.2 Health and Safety Procedures

According to Crissinger (2005), due to the physical activity associated with construction work, construction workers lose a fair amount of body fluids when performing these activities in hot weather conditions. The hazardousness of hot weather to outdoor construction workers has been alarming and has drawn the attention of the government, government bodies and the construction industry, since many of the verifiable deaths due to heat stress have been reported from the construction industry (Chan et al., 2011). Therefore, construction workers’ welfare needs to be well assessed when constructing in hot weather conditions or moving to construct in a hot weather climate. This is due to extreme hot weather conditions not only increasing the health and safety risk to construction workers through the increase in the likelihood of workers suffering from heat-related illnesses, but also workers’ absenteeism and turnover will increase while productivity will fall during such extreme hot weather conditions or sudden changes in temperature (Hollingsworth, 2013; Intergraph Corporation, 2012).

Figure 1: Relationship between Temperature and Labour Productivity (1997-2006)



3. Research Method

The chosen primary data collection methods for this paper utilize a qualitative approach through interviews and a case study. Kirton (2011) notes that qualitative research uses investigative approaches that produce results in the form of descriptive textual information. Kirton (2011) further states that in general terms a qualitative approach is for investigating the following: opinions, feelings and values; people’s interpretations and responses; behavioural patterns; process and patterns; and case studies, including critical incidents. According to Levin (2005) in his project subject and methodology table, the subject of the study (construction in hot weather conditions) is an issue/problem. Therefore, the methodology recommended is through exploring the issue and, if possible, to resolve it. Levin (2005) further notes that information gathered for projects involving exploring and resolving issues is best done through people who can be interviewed. Therefore, three interviewees in three different company roles with experience of working in hot weather conditions in the Middle East have been selected (see Figure 2). The interviews conducted were exploratory, semi-structured interviews.

Figure 2: Profile of Research Participants

Interviewee	Company	JOB TITLE	COMPANY ROLE
A	A	Project Manager	Client
B	B	Resident Engineer	Consultant
C	C	Projects Manager	Main Contractor

4. Findings and Analysis

The analysis section of this paper will discuss the findings from the interviews with the findings in the secondary data in regards to the project management aspect of construction in hot weather conditions.

The differences in the health and safety regulations in Dubai, UAE, compared to that of the UK are mainly due to the extreme hot weather in the UAE, and that this is mostly likely to cause differences in the way projects are managed in the UAE compared to the UK. Interviewee B noted that the continuous need for the supervision and control of sub-contractors and their labour force is something that is needed to be carried out by the main contractor, noting that this is something that is unusual in UK construction firms. Interviewee B also mentioned that, in the UK, sub-contractors are expected to manage their staff on their own and fulfil their duties with no managerial

interference from the clients (main contractors). However, in the UAE, main contractors are expected to manage the operations of sub-contractors.

Fewings (2005) stated that, in the UK, large and complex projects usually appoint executive project managers with direct leadership of the project team. Interviewee C stated that project management structure with all major clients in the UAE is similar to that of the UK. However, clients usually have their own in-house development department with a project manager, i.e. project management is carried out in-house, rather than by a project management company. Interviewee A mentioned the same, stating his current job position as project manager for the client, currently working for the project department of the client's organization. Interviewee B noted an important point, stating that the hot weather conditions that had occurred in the UK are normally unplanned for. However, in the UAE, these extreme hot weather conditions are planned for. Interviewee C noted that planning for such weather events is considered right from the bidding stage for a project. These two key points need to be considered when analyzing the differences. Key findings of the interviews will be discussed under the topics of procurement, contracts, laws and regulations, and workers, as detailed below.

4.1 Procurement

AECOM (2013) states that construction management and design only, then construct as the procurement option, would result in the best outcome for a project with regard to time, cost, risk and reputation. Interviewee A stated that standard procurement methods are the safest in terms of cost and time to the contractor, as they involve few changes and are currently the most common in the region, whereas design and build is the least used form of contract. This is opposite to the UK, where design and build contracts are the most common forms used (Chartered Institute of Building [CIOB], 2010). Moreover, Kerr et al. (2013) state that any international contractor that is engaged to undertake a project in the UAE must establish a local presence. This is done by recognizing the importance of local and international experience. The importance of local knowledge was mentioned by all three interviewees, with Interviewee B mentioning the importance of special relations with local sub-contractors. Furthermore, Interviewees A and B mentioned that there is not much difference in the procuring method between the UAE and the UK, adding that competitive bidding is the same. However, preference is always given to construction companies with experience of working in the Middle East region.

4.2 Contracts

Interviewee C mentioned that the forms of contracts used are FIDIC. The project he was currently working on was an FIDIC 4 form of contract. Interviewee B mentioned that contracts in the UAE are similar to those in the UK, stating that FIDIC 4 is the one most commonly used. This is similar to that stated by AECOM (2013). However, Interviewee A mentioned the use of NEC contracts, stating that such forms of contracts are starting to become more common. Furthermore, Theodore and Trauner (2009) state that it is common for construction contracts to specifically address how weather-related time extensions will be determined. However, this is applicable for unusual weather. Interviewee C noted that weather claims are specified in the contract. However, hot weather conditions are not unexpected in the UAE. Therefore, this is inapplicable in the UAE.

4.3 Laws and regulations

Turley (2010) states that construction companies in the UAE face challenges in ensuring compliance with the country's health and safety provisions. This had not been the case with any of the three interviewees. Interviewee A stated that these regulations and health and safety procedures are there to ensure the welfare and safety of the workers, and Interviewee C stated that, with forward planning, these regulations are complied with, with minimal effect on the construction project. Turley (2010) states that the most difficult piece of legislation to comply with is the labour law, due to the continuous changes and various origins. This was not mentioned by any of the interviewees. However, Interviewee C noted that the laws are clearly stated and requirements indicated by all the relevant government bodies, although confusion may sometimes be caused during complex projects, making it difficult to identify which piece of legislation complies with it. Interviewee C mentioned that different laws and

regulations apply, depending on where the project is located, stating that the laws and regulations are issued by Tarakhees if you are operating in a free zone area, such as the Jabil Ali Free Zone, and that the Dubai Municipality issues regulations for areas out of the free zone. This is similar to what has been stated by Palmer and Creagh (2013).

4.4 *Workers*

During the interview process, the findings on workers have been addressed in two broad categories: labour productivity and labour welfare in regards to health and safety. These are discussed below.

4.4.1 *Labour productivity*

Palmer and Creagh (2013) noted that an increase in humidity results in a fall in labour productivity. This was obvious to Interviewee C, who stated that labour productivity falls by at least 2 to 3 hours per day. Moreover, Yildirim et al. (2009) state that, according to their findings, temperature can be adversely affecting per capita income level of a country via reducing the labour productivity level in that country. This would mean that countries with high temperatures, such as the UAE, would have a much lower labour wage rate due to lower labour productivity when compared to the UK, where cooler temperatures would mean higher labour productivity and therefore a higher labour wage rate. The low wage labour rate was noted by Interviewees A and B, whereby Interviewee B mentioned low productivity and skill rate on the sub-continental labour force working in the UAE compared to those working in the UK.

4.4.2 *Health and safety procedures*

Chan et al. (2011) note the hazardousness of hot weather to outdoor construction workers, mentioning that the government and the construction industry's attention has been drawn to focus on this issues. Interviewee B stated that the 'stiff' laws and regulations in place in the UAE are due to the high rate of fatalities in the industry, and that these laws are there to reduce such fatal incidents and protect workers' welfare. As mentioned earlier, Hollingsworth (2013) and Intergraph Corporation (2012) stated that workers' absenteeism and turnover will increase, while productivity will fall during such extreme hot weather conditions or sudden changes in temperature. This was addressed by Interviewee C, who stated that forward planning can reduce the effect of such low productivity and shorter working hours during the hot summer months in the UAE. The Construction Industry Council (CIC) (2008) states that contractors should establish safe systems for working in hot weather and should provide adequate training, information, instruction and supervision to workers and site supervisors in order to facilitate and ensure its adoption. Labour training was not mentioned by any of the interviewees. However, they all mentioned the importance of supervision. The CIC (2008) further states that client organizations should consider taking an equitable approach towards incorporating appropriate contractual provisions for granting extension of time. However, this is not applicable for hot weather conditions in the UAE, as they are frequent and are expected, as mentioned by Interviewees B and C.

5. **Conclusion**

The findings and analysis pointed out three key points to managing construction projects in hot weather conditions. These are: experience (local knowledge); the labour force; and forward planning. Construction during hot weather conditions can be managed without affecting project handover dates, as found in the UAE. As mentioned by Interviewee C, the hot weather conditions magnify the management and planning issues that exist and may go unnoticed during the lifetime of a project. Therefore, the experience of managing projects in such extreme hot weather conditions plays a vital role in future planning and scheduling of site activities in order to minimize labour intensive activities in the summer. This is done through controlling the labour force to allow for changes in shifts and to allow for work during night shifts. Scheduling such activities may seem simple on paper but managing a large labour force on a large-scale project can be a difficult and complex task, as explained by the interviewees.

However, this is the process adopted on construction projects in the Middle East, which is supported by the laws that allow for flexibility in working hours in order to minimize the effects of extreme hot weather and to deliver projects on time. The UK is now more susceptible to extreme hot weather events, which are expected to occur more frequently than in the past. They are further expected to last longer. The key to allowing UK construction projects to proceed during heatwaves is in the labour force and forward planning of construction activities. However, this is mainly restricted due to the British labour force not being used to working in such hot weather conditions and the extent of how accurate the prediction is of an extreme hot weather event to allow for future planning. The advantage in the UAE and the Middle East in this respect is the existence of a labour force from the sub-continent region that is used to and able to work in such weather conditions, as well as the predicted summer temperatures that occur every year during a certain known period. Therefore, the experience from the UAE can be used to assist in the future planning of projects during such hot weather conditions. However, the ability of the British labour force to adapt and accept working in such weather conditions, and the accuracy of extreme hot weather events in the UK, is questionable. Furthermore, British construction firms seeking to operate in the UAE will need to employ their labour force from the sub-continental countries or Middle Eastern countries in order to become competitive in the Middle East construction market. This would enable an experienced labour force, capable of working in such weather conditions. Although there is a lack in skills within the labour force compared to the UK labour force, it is compensated by the lower wage rate and the increase in the number of workers. However, it is essential that labour welfare and safety issues are attended to and that health and safety regulations are strictly adhered to while undertaking construction in hot weather conditions.

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