RICS COBRA 2018

23 – 24 April 2018

RICS HQ, London, UK

In association with

rics.org/cobraconference

RICS COBRA 2018

The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors

Held in London, UK in association with University College London

23 – 24 April 2018

RICS HQ, London, UK

ISBN: 978-1-78321-244-6
ISSN: 2398-8614

Royal Institution of Chartered Surveyors
Parliament Square
London
SW1P 3AD
United Kingdom

rics.org/cobraconference

BIM-ENABLED HEALTH AND SAFETY COORDINATION IN THE UK CONSTRUCTION INDUSTRY: ROLE OF THE PRINCIPAL DESIGNER

Dingayo Mzyece[1]

[1] *School of the Built Environment, Oxford Brookes University, Faculty of Design, Technology and Environment, Gipsy Lane, OX3 0BP, UK*

ABSTRACT

The coordination of Health and Safety (H&S) during the design/pre-construction phase is often perceived as significantly important because of the ability to influence a reduction in the possibility of accidents and injuries. In the UK construction industry, the construction design and management (CDM) regulations are best placed to achieve this vision. Most importantly, the role of the Principal Designer (PD) is crucial, given their pre-construction phase responsibilities. The aim of the study is to critically evaluate the duties placed on PDs and examine the extent to which implementation of Building Information Modelling (BIM)-enabled H&S coordination enhances the discharge of duties performed by PDs. Primary data considered for this study involved the use of a questionnaire survey, while secondary data in the form of Statutory Instruments were scrutinised, thereby applying content analysis and drawing comparisons with the extent of discharge of duties.

The findings reveal that over 90% (i.e. 12 of 13) of the duties placed on the CDM-C in the previous regime correspond with those placed on the PD in the current regime. Secondly, of the nine duties that stand out in terms of BIM interoperability at Level 2, the study shows that four duties of the PD immediately benefit from adopting the BIM-enabled H&S coordination approach, namely: Regulations 11(1), 11(2), 11(4), and 11(5). In summary, the study deepens the understanding of the implementation of the CDM Regulations, particularly highlighting the role played by PDs during pre-construction.

Keywords: CDM Regulations, BIM, Health and Safety, Principal Designer.

INTRODUCTION

The UK construction industry continually suffers from a poor reputation because of the reported fatal and non-fatal injuries resulting from construction activities. Figures published by the Health and Safety Executive (HSE), clearly show that accidents and injuries are still a common occurrence (HSE, 2015). For example, during 2014/15, the UK construction sector experienced some 35 fatal accidents and 69,000 cases of non-fatal injuries (HSE, 2015). This outcome invites significant attention into the management and coordination of Health and Safety (H&S) in the UK construction sector. It is therefore unsurprising that regulations perceived to be the most influential have undergone major review over the last two decades or so. These regulations, widely known as the construction design and management (CDM) regulations, place several obligations on five specific duty holders, namely: the client, designer, principal designer (PD), principal contractor (PC) and contractor, in the context of the CDM2015 regime. Of the five, the principal designer (PD), whose duties were

[1]dmzyece@brookes.ac.uk

formerly performed by the CDM Coordinator (CDM-C) under the CDM2007 regime, plays a significant role with regards to H&S coordination issues. Ideally, the role of PD involves management and coordination of H&S from the initial design phase, hereafter referred to as the pre-construction phase.

Furthermore, the PD role is typically executed by a designer with overall control of the pre-construction phase (see Regulation 5(1)(a)). It is therefore of no surprise that the incorporating the use of Building Information Modelling (BIM) is a likely option. Besides, it is widely documented that BIM plays a vital role in the management of construction projects (e.g. Zhang e*t al*., 2013; Wang and Chong, 2015), and its implementation is likely to majorly impact the pre-construction phase (Eadie *et al*., 2013). Indeed, the UK Government's construction industry strategy 2025 clearly endorses BIM (see BIS, 2013). Within the same strategy, it is expressed explicitly that by 2016, all major public projects were expected to incorporate BIM Level 2, as a tool to enhance procurement of construction projects. Additionally, in the Government Construction Strategy 2016-2020, it is reported that, to realise the full extent of BIM Level 2, departments need to develop the necessary skillset and capabilities (IPA, 2016). It is against such a background that this paper argues that BIM-enabled H&S coordination complements the role of the PD. Even a study conducted by Ganah and John (2015) supports this view, and concludes that BIM can enhance current approaches towards H&S planning for construction site personnel. However, the depth of research that draws a linkage between BIM and CDM Regulations is limited. This study therefore fills this gap by considering BIM-enabled H&S coordination. This is achieved by first mapping the duties performed by the PD in the context of BIM and then determining their extent of discharge.

There are seven sections in this paper. After the introduction, a detailed literature review is provided which considers the role of BIM during the pre-construction phase and as a tool to trigger improved H&S outcomes; also highlighting the emerging gaps in knowledge. After a succinct discussion on the implementation of the CDM regulations in the UK construction industry, the research methodology adopted for the study is explained. The research results and findings are then presented and discussed, after which the conclusions of the study are outlined.

BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION AND HEALTH AND SAFETY

With the advent of BIM, it is reasonable to argue that the holistic management of construction projects across their life cycle, often triggers significant benefits (see Eadie *et al*., 2013). Perhaps, a more obvious benefit is the tendency for parties within the supply chain to engage at an early stage, thus triggering collaboration. For example, a study conducted by Eadie *et al*. (2013) based on ranking of BIM impacts by respondents who took part in a web-based questionnaire survey indicate that stakeholder collaboration was ranked highly. Bearing this in mind, it is unsurprising that there is a growing need to incorporate BIM on most projects and increasingly, it has become a major tool for collaborative project management as demonstrated on numerous occasions (e.g. Aranda-Mena *et al*., 2009; Zhang *et al*., 2013). It can even be argued that BIM triggers an integrated approach towards the management of construction projects (BIS, 2012), from inception to completion (BIS, 2012; Moulds, 2016), thus dealing with fragmentation challenges. Ideally, what this implies is that, stakeholders have the ability to work in an integrated manner at the earliest possible opportunity, which in turn influences decisions taken during the pre-construction phase.

Sebastian (2011) defined BIM as technology frameworks that complement integrated collaboration during and throughout the project design lifecycle. Whereas, other researchers have explained that BIM presents an opportunity to improve the overall outlook of project safety, given its planning and design integration abilities (e.g. see Benjaoran and Bhokha, 2010; Zhou *et al*., 2011). Further, BIM can also offer behavioural and procedural changes as noted by Joyce and Houghton (2014) and Olatunji (2014). For example, the integrated system for safety developed by Benjaoran and Bhokha (2010) based on a BIM model, enhanced safety awareness and in turn triggered informed design decisions and changes. These studies on one hand demonstrate that BIM implementation may yield tangible results and plays a significant role towards securing improved H&S outcomes. Typically, when deployed on most projects, BIM is likely to offer timely sharing of information at varied levels as the BIM object develops (RICS, 2015). It is clear from the foregoing that several authors define BIM differently. This study adopts the holistic view as explained by Khosrowshani and Aryici (2012, p.615), whereby the BIM model triggers collaboration, interoperability and interdependence among stakeholders. At its most advanced level, the BIM model offers real time benefits and analyses of complex issues during the early pre-construction phase (Khosrowshani and Aryici, 2012); and offers information exchange at various levels (see e.g. Abanda *et al*., 2015).

In the main, drivers for BIM adoption to reiterate, include: (i) a reduction in the cost of assets and achievement of significant operational efficiencies; (ii) improved construction supply chains; and (iii) improved industry growth and outcomes (BIS, 2012). From a commercial point of view, it simply means that the supply chain will feed information into the system at the most relevant time and similarly, extraction of such information is readily available at the most opportune time. As such, use of BIM on various construction projects has been commended (see Bryde *et al*., 2013) and the consensus reached by various commentators, practitioners and researchers, is that BIM unifies and streamlines the design and construction process. It is therefore reasonable to infer that indeed, BIM is an exemplar; a tool which brings together a number of project stakeholders with prospects to improve the overall management of construction projects. The view that BIM is capable of improving communication issues and advocates for better and consistent management of projects is commonplace. For example, Moulds (2016), reported that there was a significant reduction in time, owing to the streamlined approach for undertaking various processes. Similarly, key issues and impediments were identified and resolved expediently, unlike previous paper-based method(s). In terms of the practicality of the design, BIM offered the opportunity to simulate the construction sequence and where practicable, the rework of design. Furthermore, in the same case study, Moulds (2016) reported that the model was also used for purposes of H&S, thereby communicating to the site teams, the sequence of construction and so forth. Even a study conducted by Bryde *et al*. (2013) considered the interoperability of BIM and the extent of its usage. The conclusion reached based on secondary data collected from 35 construction projects which employed BIM, shows a significant reduction in time and cost throughout the project lifecycle, corroborating the conclusions derived in Mould's study. Whereas, Zanni *et al*. (2016) considered a BIM-enabled sustainable building design process. Their results, based on a developed framework, having undertaken 25 in-depth interviews indicated that a BIM-enabled approach, complemented the use of other design software that took into account sustainability issues. This outcome demonstrates the adaptability of BIM to complement user/project requirements and needs.

Overall, there is compelling evidence which shows the tangible benefits of BIM adoption. In terms of BIM implementation in the UK construction industry, Eadie *et al*. (2013), considered BIM application across the project lifecycle. The conclusion drawn shows that BIM is most often used during the design and pre-construction phase, and to a lesser extent during the construction stage. This outcome demonstrates the influence of BIM in the early design stage. As such, it is viable to conduct a study interlinking BIM and CDM. This study therefore concentrates on the extent of discharge of duties performed by the PD given their likelihood to be performed during the pre-construction phase.

THE CONSTRUCTION DESIGN AND MANAGEMENT REGULATIONS

The construction, design and management (CDM) regulations were first introduced in the UK construction industry as the Construction (Design and Management) Regulations 1994 (CDM1994), on 31 March 1995, Statutory Instrument (SI) number 1994/3140. Briefly, they were introduced by the UK government because of two major reasons: (i) as a version of the transposition of a directive placed on EU member states (EU 92/57/EEC); and (ii) improvement of the performance of the construction sector in terms of H&S outlook.

However, after a decade, significant problems associated with the CDM1994 regime emerged and because of this, the CDM2007 (SI, No. 2007/320) replaced the CDM1994, with the intention to improve the overall implementation in practice, reduce bureaucracy and increase better understanding among others. The main concerns highlighted during the CDM1994 regime were: overly bureaucratic procedures; excessive paperwork; widespread misunderstanding of roles; and uncertainties across construction supply chains (e.g. Baxendale and Jones, 2000; Beal, 2007; Dalby 2007).

It is these concerns, as mentioned already, that ultimately culminated into introduction of the CDM2007 on 6 April 2007, to improve CDM implementation across the UK construction sector. In summary, the motivation for introducing CDM2007 was noted by Bomel (2007) as: simplification of the regulations; enablement of a flexible approach in terms of contractual issues; more focus on the planning and management of H&S issues; and simplification of competence assessment.

Although it was envisaged at the time that replacing the Planning Supervisor (PS) role with the CDM-C, would be beneficial, the results were not that impressive. It was reported on numerous occasions that CDM-Cs provided little input or in some cases no support in discharging H&S coordination responsibilities on most construction projects. For instance, a report prepared by the Specialist Engineering Contractors' Group (SEC), noted that the presence of the CDM-C on most projects was limited (SEC, 2010). Increasingly, the evidence on most occasions seemed to show that the same concerns still emerged under the CDM2007 regime (e.g. Dalby, 2007).

Whilst there were some improvements during CDM2007 regime era (Frontline Consultants, 2012a; Webster, 2013), a major evaluation still revealed numerous concerns because of industry commercial pressure (Frontline Consultants, 2012b). Additionally, it was observed that the CDM2007 was still surrounded with uncertainties in terms of: (i) misunderstanding of responsibilities (Dalby, 2009); and competency issues with regards the role of the CDM-C (ICE, 2011) and interpretation of the Approved Code of Practice (ACoP) (Frontline Consultants, 2012a). Following the Löfstedt report, which reviewed H&S legislation (Löfstedt, 2011), the main conclusions drawn recommended a complete overhaul of CDM2007, with the intention of: (i) ensuring that duties are expressed in a clearer manner; (ii) reducing bureaucracy; and (iii) providing appropriate guidance for smaller projects.

Most importantly, in response to Professor Löfstedt's report, the HSE replaced the CDM2007 regime with the CDM2015 (SI, No. 2015/51) regime in the autumn of 2015. Major changes included: replacement of the CDM-C role with the PD role; inclusion of more straightforward provisions for domestic clients; removal of the competence provision; and simplification and alignment of the regulations to the EU Directive (EU 92/57EEC).

THE RESEARCH METHODOLOGY

The research methodology comprised the use of a questionnaire survey to investigate the extent of discharge of duties previously performed by the CDM-C, while an inductive inquiry was used to first: analyse the descriptions of the duties placed on the PD; then second, compare these duties with those formerly discharged by the CDM-C, given that they largely all align to the pre-construction phase. As such, a mixed methods research is conducted, whereby the results from the questionnaire survey partly inform those emerging from the inductive inquiry. In terms of the analysis, initially, the quantitative data is analysed using descriptive statistics, to determine the extent of discharge of duties. Further, the relative index (RI) analysis is used to rank the duties in terms of frequency of discharge. The content analysis is also performed to determine the extent to which the PD's duties resonate with BIM in terms of interoperability.

Briefly, content analysis is defined by Bryman (2012) as an approach that seeks to analyse documentary evidence or text into quantifiable predetermined categories, systematically. With this in mind, it is considered as a reasonable method of analysis in this study given that the evidence is based on secondary data. Moreover, combining this approach with the descriptive statistics ensures that, the methods complement each other. Initially, organisations likely to perform the role of CDM-C were identified through a readily available professional membership body. Further, the PD's duties were categorised according to the stage of discharge, in order to inform the level of BIM adoption and interoperability. A total of 48 responses informs the quantitative analysis, whereas the total number of duties considered across the CDM-C and PD is 26. AS such, use of the central tendency scores and the relative index analysis proved useful. It is however necessary to point out that employing parametric methods would have been possible if the data was less skewed. It was therefore determined that the central tendency scores would be useful at this stage.

RESULTS AND FINDINGS

Table 1 shows the extent of discharge of pre-construction phase coordination duties placed on the CDM-C, whereas, in Table 2, a comparison reveals the differences between duties placed on CDM-C those placed on the PD, of which there are no major differences in terms of description of duties. To clarify, CDM-C's duties: 20(1)(b), 20(1)(c) and 20(2)(e) where expanded to realign better with the PD's duties. The results show that, first, majority of the CDM-C's duties correspond with those placed on the PD and the same thing can be said inversely. Second, the primary data results show that there are variations in the extent of discharge of duties, of which it is worth taking note of duties discharged the least in terms of frequency (i.e. yielding a mean less than 4.00).

From the above, it can be observed that the PD's duties: 11(1), 11(2), 11(4) and 11(5), are discharged the least in relation to the primary data. Interestingly, they all invite improved collaborative working, therefore consistent with the BIM Level 2 ethos. Even, promptly providing preconstruction information is a duty which may strongly benefit from BIM adoption, although ranked 7 with a mean score of 4.04. The analysis further revealed that, of the 13 duties, some typically relate to the pre-construction phase, while others relate to the construction phase as noted in Table 3. Again, the same four duties placed on the PD highlighted above appear in the pre-construction phase, which confirms that the role of the PD can be enhanced with BIM adoption.

Table 1: Extent of discharge of preconstruction coordination duties

Reg.	Description of duties	Median	Mean	Std. Dev.	Std. Error	Relative Index (RI)	Rank (R)
21(1)	Ensure notice is given to the Health and Safety Executive (or Office of Rail Regulation)	5.00	4.83	0.433	0.063	96.60	1
20(1)(c)	Liaise with the Principal Contractor regarding information required for the preparation of the Construction Phase Plan, contents of the Health and Safety File and any design development that may affect the planning and management of construction work	5.00	4.29	0.824	0.119	85.80	2
20(2)(f)	Handover the Health and Safety File to the Client at the end of the construction phase	4.00	4.23	1.016	0.147	84.00	3
20(2)(a)	Take reasonable steps towards identifying and collecting preconstruction information	4.00	4.10	0.881	0.127	82.00	4
20(2)(e)	Prepare where none exists the Health and Safety File and update/review for subsequent construction work	4.00	4.10	1.115	0.161	82.00	5
20(1)(a)	Give suitable advice and assistance to the Client regarding compliance with the Clients' duties under the Regulations	4.00	4.04	0.967	0.140	80.80	6
20(2)(b)	Promptly provide preconstruction information to	4.00	4.04	0.988	0.143	80.80	7

Reg.	Description of duties	Median	Mean	Std. Dev.	Std. Error	Relative Index (RI)	Rank (R)
	all Designers, Contractors and the Principal Contractor.						
20(2)(d)	Take all reasonable steps during the construction phase to ensure cooperation between Designers and the Principal Contractor in relation to any design or design change	4.00	3.67	0.996	0.144	73.40	8
20(2)(c)	Take reasonable steps to ensure Designers comply with their duties and provide sufficient information about aspects of the design to assist other Designers, Clients, the CDM Coordinator and Contractors	4.00	3.67	0.996	0.144	73.40	9
20(1)(b)	Ensure that arrangements for coordination of health and safety measures during planning and preparation for the construction phase are implemented	3.50	3.54	0.898	0.130	70.80	10

Table 2: Comparison of the main duties of the CDM-C and PD expanded

CDM-C Coordinator duties		**Principal Designer (PD) duties**		**RIR**
Reg.	*Description*	Reg.	Description	
20(1)(a)	Assist the client in complying with his duties under these regulations	9(4)	Adequately assist the client	6
20(1)(b)	Ensure coordination of H&S issues	11(1)	Planning, management, and monitoring of the pre-construction phase and coordination of H&S issues	10
20(1)(b)(ii)	Application of the general principles of prevention	11(2)	Carefully take into account the principles of prevention	10
	**Not Applicable(N/A) to the CDM-C*	11(3)	Where reasonably practicable, the PD must identify, eliminate and control any foreseeable risks to any persons	
20(2)(c)	Ensure designers comply with their duties specified in regulations 11 and 18(2)	11(4)	Ensure that all designers comply with their duties as specified in Regulation 9	9
20(2)(d)	Ensure cooperation between the designers and the principal contractors	11(5)	Ensure all persons working during the preconstruction phase cooperate with the client, principal designer and each other	8
20(2)(a)	Identify and collect preconstruction information.	11(6)(a)	Assist the client with provision of preconstruction information.	4
20(2)(b)	Promptly provide preconstruction information.	11(6)(b)	Provide preconstruction information to the designer and the appointed contractor.	7
20(1)(c)(iii)	Liaise with the PC regarding the design development, which may likely to affect planning and management of construction work.	11(7)	Liaise with the PC during the construction phase as well as share all the necessary information such as planning, management, and control of H&S issues during construction.	2

CDM-C Coordinator duties		Principal Designer (PD) duties		RIR
Reg.	*Description*	Reg.	Description	
20(1)(c)(ii)	Assist the PC regarding preparation of the CPP.	12(3)	Assist the PC when preparing the CPP by providing necessary information.	2
20(2)(e)	Prepare the H&S File	12(5)	Prepare the H&S File.	5
20(2)(e)	Update, review and revise the H&S File.	12(6)	Review, update and revise the H&S File	5
20(2)(f)	Pass the H&S File to the client.	12(8)	Pass the H&S File to the PC.	3
21(1)	Ensure that notice is given to the HSE		**Not Applicable (N/A) to the PD*	

*duty either not directly applicable or placed on a different dutyholder

In terms of BIM Level 2 interoperability, nine duties standout and are considered to be highly linked with early design decisions, that is:

- planning, management and monitoring the pre-construction phase (Reg. 11(1))
- taking into account the principles of prevention during the preconstruction phase (Reg.11(2))
- eliminate foreseeable risks (Reg. 11(3))
- ensure designers comply with their duties (Reg. 11(4))
- ensure all persons working during the preconstruction phase cooperate with the client, principal designer and each other (Reg. 11(5))
- assist the client in providing preconstruction information (Reg. 11(6)(a))
- provide preconstruction information to all designers and contractors (Reg. 11(6)(b))
- prepare the health and safety file during the preconstruction phase (Reg. 12(5))
- review, update and revise the health and safety file (Reg.12(6)).

However, of the nine, as demonstrated from the content analysis and the descriptive statistics, four PD duties clearly stand to benefit from BIM Level 2 adoption, that is:

(i) planning, management and monitoring the pre-construction phase (Reg. 11(1));
(ii) taking into account the principles of prevention during the preconstruction phase (Reg.11(2));
(iii) ensure designers comply with their duties (Reg. 11(4)); and
(iv) ensure all persons cooperate with the client, principal designer and each other (Reg. 11(5)).

Table 3: Main duties of the PD categorised and expanded

Regulation	RIR	Description
		Duties discharged during the pre-construction phase

Regulation	RIR	Description
11(1)	10	Plan, manage and monitor the pre-construction phase
11(2)(a)	10	Plan and manage items or work stages that are likely to take place concurrently or sequential
11(2)(b)	10	Estimate the duration for discharging duties to complete the work stages and take into account the general principles of prevention
11(3)	*N/A	Eliminate any foreseeable risks to persons: undertaking construction work, maintaining the structure, and using the structure.
11(4)	9	The principal designer to ensure all designers comply with their obligations
11(5)	8	Ensure all persons cooperate with the client, principal designer and each other
11(6)(a)	4	Assist the client in providing preconstruction information
11(6)(b)	7	Provide preconstruction information in a prompt manner to all designers and contractors
12(5)	5	Prepare the health and safety file during the pre-construction phase
12(6)	5	Review, update and revise the health and safety file
12(8)	3	Pass the health and safety file to the principal contractor (PC) if appointment ends before project completion
Duties discharged during the construction stage		
11(5)	8	Ensure all persons cooperate with the client, principal designer and each other
11(6)(b)	7	Provide preconstruction information in a prompt manner to all designers and contractors
11(7)	2	Liaise with the principal contractor (PC) during the construction phase
12(3)(a)	2	Assist the PC in preparing the construction phase plan by providing preconstruction information from the client
12(3)(b)	2	Assist the PC in preparing the construction phase plan by providing information obtained from the designers
12(6)	5	Review, update and revise the health and safety file
12(8)	3	Pass the health and safety file to the principal contractor (PC) if appointment ends before project completion
12(10)	3	Pass the health and safety file to the client at the end of the project

*duty either not directly applicable or placed on a different dutyholder

DISCUSSION

The evidence so far shows that there are a number of PD duties which may benefit from BIM implementation and adoption, particularly at Level 2 in the context of H&S coordination. Although all duties placed on the PD may benefit from a BIM-enabled approach in one way or the other, nine duties standout (i.e. *11(1), 11(2), 11(3), 11(4)*, *11(5)*, 11(6)(a), 11(6)(b), 12(5), and 12(6)) given their likelihood to trigger early design decisions. Whereas, the four duties that would most benefit from BIM adoption are shown in italics, given the argument that they are the least to be discharged in terms of frequency. Moreover, the themes drawn from the regulations are consistent with the overall ethos of BIM, which is to trigger integrated collaborative working as re-echoed by IPA (2016). Indeed, this work complements the findings established by Mzyece (2015), which revealed a lack of collaborative working during CDM implementation. This study therefore proves that BIM adoption with regards to the duties placed on the PD may yield major tangible results; which in turn argues for a BIM-enabled H&S coordination approach. Crucially, the analysis also shows that over 90% (12/13) of the PD duties align with those placed on the CDM-C in the previous regime, which shows the reliability of the inferences drawn.

CONCLUSIONS

This study deepens the understanding of BIM adoption, particularly in relation to the role of the PD. Interesting insight considering the plausibility of the BIM-enabled H&S coordination approach is established. Results from the analysis indicate that BIM-enabled H&S coordination during the pre-construction phase is viable, and most importantly may improve the extent of discharge of duties in terms of frequency. Crucially, four main duties placed on PDs stand out which may strongly benefit from this approach. However, this is not to say that other duties do not stand a chance to benefit. As such, the importance of this study cannot be emphasised given central government's clear construction strategy. The next stage of this study will be to develop a framework incorporating CDM regulations implementation in their entirety, while considering the role of BIM and testing the developed framework in industry.

REFERENCES

Abanda, F.H., Vidalakis, C., Oti, A.H. and Tah, J.H.M (2015) A critical analysis of Building Information Modelling systems used in construction projects, *Advances in Engineering Software*, 90, 183-201.

Aranda-Mena, G., Crawford, J. and Chevez, A. (2009) Building information modelling demystified: does it make business sense to adopt BIM? *International Journal of Managing Projects in Business*, 2(3), pp.419-433.

Baxendale, T. and Jones, O. (2000) Construction design and management safety regulations in practice--progress on implementation, *International Journal of Project Management*, Elsevier, 18(1), pp. 33–40.

Beal, A. N. (2007) CDM Regulations: 12 years of pain but little gain, *Proceedings of the Institution of Civil Engineers - Civil Engineering*, 160(2), pp. 82–88.

Benjaoran, V. and Bhokha, S. (2010) An integrated safety management with construction management using 4D CAD model, *Safety Science*, 48(3), pp. 395–403

BIS (2013) *Construction 2025*, Department for Business, Innovation and skills, London: BIS.

BIS (2012) *Building Information Modelling*, Department for Business, Innovation and skills, London: BIS.

Bomel Ltd (2007) *Improving the effectiveness of the Construction (Design and Management) Regulations 1994, Establishing views from construction stakeholders on the current effectiveness of CDM*, [online] Available from: http://www.hse.gov.uk/research/rrhtm/rr538.htm

Bryde, D., Broquetas, M. and Volm, J.M. (2013) The project benefits of Building Information Modelling, *International Journal of Project Management*, Elsevier, 31(1), pp. 971–980.

Bryman, A. (2012) *Social Research Methods*, 4th ed., Oxford, Oxford University Press, UK.

Dalby, S. (2009) CDM 2007 two years on: survey reveals widespread misunderstanding, *Proceedings of the Institution of Civil Engineers - Civil Engineering*, 162(4), p. 149.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. (2013) BIM implementation throughout the UK construction project lifecycle: An analysis, *Automation in Construction*, 36, pp. 145–151.

Frontline Consultants (2012a) *Evaluation of the Construction (Design and Management) Regulations 2007*, London: HSE.

Frontline Consultants (2012b) *London 2012: The Construction (Design and Management) Regulations 2007 Duty holder roles and impact*, London:HSE.

Ganah, A. and John, G.A. (2015) Integrating Building Information Modeling and Health and Safety for Onsite Construction, Safety and Health at Work, 6(1) pp. 39-45.

HSE (2015) *Health and safety in construction sector in Great Britain, 2014/15*, London:HSE.

ICE (2011) *CDM 3 years on*, London: ICE

IPA (2016) *Government Construction Strategy 2016-20*, Infrastructure and Projects Authority, IPA:London.

Joyce, R. and Houghton, D. (2014) Briefing: Building information modelling and the law, *Proceedings of the ICE - Management, Procurement and Law*, 167(3), pp. 114–116.

Khosrowshahi F. and Aryci, Y. (2012) Roadmap for implementation of BIM in the UK construction industry, *Engineering, Construction and Architectural Management*, 19(6), pp. 610-635.

Löfstedt, R. (2011) *Reclaiming health and safety for all: An independent review of health and safety legislation*, London, Department of Works and Pensions (DWP), [online] Available from: www.dwp.gov.uk/policy/health-and-safety.

Moulds, A. (2016) Meeting the mandate-the Mott MacDonald story, In: *NBS and RIBA Enterprises* (eds), National BIM report, pp. 16-21.

Mzyece, D. (2015) *An investigation into the implementation of the Construction (Design and Management) regulations in the construction industry.* University of Wolverhampton: Unpublished PhD thesis.

Olatunji, O. A. (2014) Views on building information modelling, procurement and contract management, *Proceedings of the ICE - Management, Procurement and Law*, 167(3), pp. 117–126.

Sebastian, R. (2011) Changing roles of the clients, architects and contractors through BIM, *Engineering, Construction and Architectural Management*, 18(2), pp. 176–187

SEC (2010) *Experience of working with the Construction (Design and Management) Regulations 2007*, London: Specialist Engineering Contractors' Group.

Wang, X. and Chong, H. (2015) Setting new trends of integrated Building Information Modelling for construction industry, *Construction Innovation*, 15(1), pp.2-6.

Webster, M. (2013) The use of CDM 2007 in the London 2012 construction programme, *Proceedings of the Institution of Civil Engineers - Civil Engineering*, 166(CE1), pp. 35–41.

Zanni, M.A., Soetanto, R. and Ruikar, K. (2016) Towards a BIM-enabled sustainable building design process:roles, responsibilities and requirements, *Architectural Engineering and Design Management*, pp. 1-29.

Zhang, S., Teizer, J., Lee, J., Eastman, C.M. and Venugopal, M. (2013) Building Information Modelliung (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules, *Automation in Construction*, 29, 183-195.

Zhou, W., Whyte, J. and Sacks, R. (2011) Construction safety and digital design: A review, *Automation in Construction*, 22(1), pp. 102–111.