ATTAINING ZERO DEFECTS WITHIN BUILDING SCHOOLS FOR THE FUTURE: A REALISTIC TARGET OR A SISYPHEAN TASK?

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Until its demise in July 2010 The Building Schools for the Future (BSF) programme represented the biggest single UK government investment in school buildings for more than 50 years. One of the key goals of the investment programme was the desire to ensure that pupils learn in High Quantity 21st-century facilities that are designed or redesigned to allow for educational transformation in historically underperforming schools who's pupils where often enshroud in depravation and social exclusion. This represents a major challenge to those involved in the delivery of the new or refurbished schools. The paper explores the extent to which schools completed under the umbrella of BSF lived up to the government's ideology of 'value for money' a key parameter of which is the delivery of high quality buildings. Drawing on an embedded case study methodology based around one local authority which completed nine secondary schools under the BSF funding model between 2006 and 2010. The findings portray the many challenges faced by constructors in the pursuit of zero defect construction. Critical to this, the authors argue, is the approach used by stakeholders to define and measure the presence of a 'defect'. Analysis of quantitative defect data reported in the paper suggests a large number of those defects identified related to mere cosmetic imperfections caused by inter alia the client team moving the school into the new building rather than serious defects caused by poor workmanship on behalf of the constructor. Findings from the research raise important questions about the use of 'defects' as a performance measurement for quality within the construction sector.

Keywords: building defects, quality, total quality management.

INTRODUCTION

In 2003 the Government launched the Building Schools for the future (BSF) programme with the aim of renewing all 3,500 English secondary schools over a fifteen year period with an initial estimated public spend of £52 to £55 billion (National Audit Office 2009) subject to future public spending decisions. The initial plan was to rebuild half the schools, structurally remodel 35% and refurbish the

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balance. The scheme's key aspiration was to ensure that pupils learn in High Quantity 21st-century facilities. That are designed or redesigned to allow for ‘educational transformation’ in historically underperforming schools, where pupils are often enshroud in depravation and social exclusion. The first schools BSF contract commenced in 2005; however in July 2010 the BSF programme which represented the biggest single UK government investment in school buildings for more than 50 years met its demise as austerity measures were introduced. Shortly followed by the James review in April 2011 which recommended that schools be constructed to "standardised drawings" which incorporate the latest thinking on educational requirements implemented by the new Education Funding Agency which still aims to deliver high quality state of the art educational facilities. This study seeks to explore the extent to which schools completed under the umbrella of BSF lived up to the government's ideology of 'value for money' a key parameter of which is the delivery of high quality buildings. The paper concludes by proposing further research into how stakeholders define quality.

THE LITERATURE

Theory of Quality

Following world War II and his ground-breaking work in Japan Deming (1986) in his seminal text “out of a crisis” produced a fourteen point plan which is considered to be a “complete philosophy of management’, which can be applied to small or large organisations in the public, private or service sectors” (Institute for Manufacturing 2009). Deming (1986) suggested that quality can only be defined in terms of customer satisfaction, management is key and quality can be achieved through continuous improvement. Deming differed from Juran (1989) who placed great importance and responsibility on statistical process control with ‘quality through continuous improvement’. Deming (1986) also believed that management is responsible for 94% of quality issues. Deming had a major influence in changing the way Japan controlled quality and stated to Japans chief executives; “improving quality will reduce expenses while increasing productivity and market share” (Deming, 1986).

Prior to the introduction of quality assurance, quality was predominantly measured by the finished product. Other than Deming there have been only a few quality champions who have advanced the theory. Juran (1989) albeit not the first master of quality but is believed to be of significant importance, looked further into quality linking it to value and the end user. Juran further defined quality as the ‘fitness for use’ and suggested that this could be linked to value management where unnecessary costs and products are removed. Juran’s theory brought the development of the quality trilogy: quality planning, quality control and quality improvement as a result of Deming's work and further development of Pareto’s principle; that 80% of the problem is caused by 20% of the causes. It is widely acknowledged and understood that the main aim for quality management is to provide customer satisfaction for all stakeholders. Harris and McCaffer (2006) suggest that this can only be achieved if all stakeholders directly contribute to achieve the objectives.

Quality management could be defined as “the culture of an organisation committed to customer satisfaction through continuous improvement” (CIOB 2011). Quality management should have the same principles for all industries, although quality management evidently is more successful in the car industry than in other industries such as construction, which can be attributed to the early implementation of Deming’s methods.

Deflects as a Proxy for Quality in Construction

The International Council for Research and Innovation in Building and Construction´s (CIB) group W86 (Building Pathology) define a ‘defect’ as ‘a situation where one or more elements don’t perform its intended function and an anomaly is referred to as an indication of a possible defect’ (CIB 1993). A definition fully supported by one seminal quality theorist. Juran (1989) attests that quality is another term for fitness for purpose. Yet can quality really be measured in such a simplistic manner. When this definition was tested in the courts, the limitations of its suitability became quickly apparent. For example in Yarmouth v France (1887) and later in Tate v Latham (1897) the court held something not fit for purpose was defective. As a result of these cases, it quickly becomes apparent, that if a wall was constructed in concrete blocks rather than facing bricks yet is fit for purpose and therefore high quality. Although the architect may still declare it as defective, given the incorrect materials were used.

The international standard for Quality Systems (ISO9001) published by the International Organisation for Standards has widened Juran's initial definition of quality, suggesting the term quality is to be regarded as the delivery of a product at a set standard. This would appear to suggest that high quality would be indicative of a high level of attainment against that standard. It would be therefore plausible to argue that a defect is a measure of deficiency when it is compared, all be it in a subjective manner, against a predetermined minimum standard. In the case of construction, this would be the specification documents forming part of the contact. A definition which appears to align with the interpretation many of the construction standard forms of contact have implemented. For example, in clause 2.38, of the JCT Design and Build standard form, a defect is expressly defined as "materials or workmanship not in accordance with this agreement". Whereas the New Engineering Contract (NEC3) defines a defect as "part of the works which is not in accordance with the works information or a part of the works designed by the contractor which is not in accordance with the applicable law or contractor's design which the project manager has accepted".

As such defect can be accepted as a measure of underperformance against a standard allowing it to be adopted as a proxy for quality in construction. Consequently, high quality translates into a low number of defects and vice versa -quality is therefore reciprocal to the amount of defects

Latham (1994) and Egan’s (1998) seminal reviews of the 1990s collectively challenged the UK construction to have a greater focus on the quality of the assets it deliveries. The authors collectively suggested improvements in quality would foster improvements in the levels of client satisfaction achieved. Key strategies in the attainment of this ambitious target included Latham’s (1994) assertion that existing tendering procedures required significant transformation throughout the supply chain and Egan’s (1998: 22) call for continuous quality improvements through the targeted reduction and eventual eradication of primary building defects within five years.

Whilst Egan does not purport the adoption of the ‘defect’ as a singular measure of quality, it is nonetheless important to establish the suitability of a 'defect' as an indicator for quality within construction projects. Wolstenholme (2010) acknowledges in his review of progress since the Egan report, on behalf of Constructing Excellence, that industry has achieved its 20% year on year target for the reduction in the number of recorded defects since Egan first set the target in 1998. A critical part of the sectors continued attainment of this target must be a commitment to the identification of the principle causes of construction defects. Yet as Auchterlounie (2009) opines defects have continued to plague construction projects across the full spectrum of projects raising important questions as to the underlying causes of defects. Atkinson (1999) suggests there is a wide spread believe within the construction industry that defects are merely the result of both human error and a general lack of work ethic leading to poor workmanship standards. Yet countering this view, Atkinson (1999) also opined that these are often quite complex, with different active and latent errors interacting which eventually lead to human error and the occurrence of a visible defect (Douglas and Ransom, 2007) either way it is clearly in the interests of the construction industry to identify and combat the root causes of defects.

Josephson and Hammarlund (1999) attempted to identify these underlying causes in their four-year research study based on the detailed observation of seven Swedish construction projects over a four to six month period. Identified that defects could not be attributed to either a single stakeholder or phase in the project but to the overall motivation of the project organisational team, suggesting improvements in the motivation of the construction team would lead to a reduced occurrence of construction defects. Love *et al.* (1999) used a system dynamics framework to evaluate two Australian projects, the first a residential tower block and the second an Industrial warehouse facility, from commencement of the construction phase, to the end of the defects liability period. The researcher concluded that a paradigm shift in project management strategy was needed to reduce the occurrence of defects. At the centre of their calls for improvement, was the implementation of a collective, joined up approach to the management of the project with a single point of information and responsibility. Kim *et al.* (2008) concluded a ten-project study, consisting of 700 apartments in multi-storey buildings, and they suggested an Information Communication Technology (ICT) solution for managing defects in large construction projects. They tested and suggested real-time data collection and processing of defects, and the study reported significant efficiency improvements. Hassan *et al.* (2011) reviewed the occurrence of defects across four design and build hospital projects constructed for the Malaysian department of Health. From their quantitative analysis of secondary defect data together with stakeholder interviews, the researcher's analysis of 1343 and 5483 defects per hospital reaffirmed the earlier findings relating to the breakdown in the management of the project. The researchers suggested the management of quality on the project should be a continuous process, overseen by the employment of an independent third party organisation. Yet such approaches are already utilised in the UK construction industry but do not appear to have led to a reduction in the occurrence of construction defects.

The research reviewed so far appears to advocate a relatively project focused approach to the causation of defects, yet another body of evidence has argued the need for a more long term strategy for the reduction in construction defects, based around the theory of organisational learning. Schön, the leading organisational learning theorist argued that people and organizations should be flexible and incorporate their life experiences and lessons learned throughout their life through a process of double–loop learning, where the organization adjusts its operations to both keep pace with changing market conditions but also to create new and better ways of achieving business goals (Fulmer 1994). A number of researchers have argued, such an approach would allow organisations to proactively reduce and eventually eliminate defects and improve the quality of their projects (Love *et al.* 2000).

In later research, Love *et al.* (2002) examined how the extent to which change management or the potential lack of change management processes within the project management system affected the overall quality levels attained. The research again adopted a case study approach, with data collected through both observation and stakeholder interviews. The research identified that change occurrences had a significant impact on the management of the project, inevitably leading to an increase in the number of observable defects. As a result, the researchers concluded that the reduction in defect occurrences required the project manager to learn from and develop mechanisms to proactively anticipate project change, and on occurrence deal with the effects of those changes.

Yet as Lundkvist *et al.* (2010) quantitative survey of forty-one Swedish project and site managers suggested Love *et al.*'s (2000) calls for the adoption of organisational learning strategies as a part of enhanced quality management have been largely ignored. The survey revealed that although the majority of respondents understood the benefits associated with the detailed analysis of defect data from past projects, in practice very few tried to use it for experience feedback and continuous improvement. The majority did little more than correct the defects. Although evidence from two of the UKs largest contactors Laing O'Rourke (2009) and Bovis Lend Lease (2010) appears to suggest this lack of reflection or organisational learning, could be a symptom of the construction teams eagerness to move to the next challenge. A problem which Peach (2010) opines must be addressed if overall quality is to improve and the industry is to close in on achieving zero defects.

If Auchterlounie (2009) is to be believed, the finding of these studies have thus far failed to identify the principle route causes of construction defects raising the question, is zero defects truly a Sisyphean task. Deming (1986), the world authority on quality, appears to suggest this to be the case, arguing efforts to remove all defects would be an excessive waste of time and money. Instead Deming asserted that the client and manufacturer should establish an acceptable level of defects for the project prior to commencement. Looking to the literature, Aagaard *et al.* (2010) have developed a theoretical framework for the identification of the optimal level of defects based around economic theory of optimisation. The model suggests it is possible to identify an acceptable number of defects based on the economic cost associated with defects. Fundamentally the model suggests the decision to attempt to deliver a zero defect building is principally economic. The fewer defects the client is willing to accept, the more the project will cost, whereas the more defects the client accepts the less the project will cost. Yet the complexity of construction procurement would appear to suggest that the model is overly simplistic, especially given the excessive use of price based competition (Wolstenholme 2010). In reality, the cost of defects are borne by the contractor, who has little prospect of transferring these back to the client in the form of additional transaction costs. Bovis Lend Lease (2010) suggests, defects can be up to 1.7% of the projects total value. On an £80million project, this would translate to an additional expense of £1.4million wasted on the correction of poor workmanship. However, Fagbenle's (2010) recent large scale quantitative survey of over eight hundred Nigerian construction firms suggests these costs and the total number of defects could be reduced significantly if contractors proactively managed their supply chain. Analysis of the data from the questionnaire revealed a strong positive correlation between time and quality performance of labour only subcontractors. Suggesting labour only subcontractors compromised on quality to complete the work in the quickest time possible.

The literature reveals that although defects are costing contractors nearly 2% of the project value to put right (Bovis lend lease 2010). Significant progress has not been made against Egan's fourteen year old target of delivering defect free construction. The literature evidences that whilst defects are the result of human error, a highly complex interrelated set of factors lay behind this. Yet the major contactors in the sector appear dismissive of the academic models developed. Suggesting instead that the pivotal reason for the number of defects recorded at handover is simply the low priority construction management professionals assign to the rectification of sub-standard work immediately prior to the critical hand over stage of the project. Yet this hypothesis appears to be untested in the literature. This paper is drawn from a larger PhD study which is aiming to develop a theoretical framework to allow major contractors to monitor defects as an indictor of performance.

RESEARCH APPROACH

Yin (2008) defines case study research as "an empirical inquiry that: investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident". Yin identifies several points within this definition, which typify case study research. First, the case study is involved with empirical inquiry and therefore relies on the collection of evidence on what is going on. The case study focuses on a phenomenon in context, typically in situations where the boundary between the phenomenon and its context is not clear. It is useful to this study when a how or why question is being asked about a contemporary set of events over which the investigator has little or no control (Yin, 2008). In the case of research into defects, earlier researchers appear to have favoured the single case study as a tool for the collection of empirical data.

In his seminal work on case studies Yin (2008) asserts the use of a single case study is justifiable in any one of the following five situations (a) the case is critical, testing a well formed theory; (b) the case is extreme or unique; (c) the case is representative or typical; (d) the case is revelatory or of finally (e) the case is longitudinal. As all BSF programmes and centrally funded and controlled the researchers feel the programme evaluation is typical of projects completed under this funding model. The adoption of a single study design also allows the researcher to undertake a more detailed scrutiny of the organisation thus strengthening the research whilst improving the studies validity (Proverbs and Gameson 2008).

Data Collection

The paper reports the initial exploratory phase of the case study research, based on analysis of defect data from the case study programme is reported. Identification of both the levels of defect occurrence and any specific trends with the identification of defects is an important stage in determining how BSF project stakeholders interpret quality and how this interpretation evolved through the three phases of the project. As the case study projects selected were constructed over three phases, between 2006 and 2010. The researchers have dismissed the use of primary data collection. This called for a research design making use of existing data held by both the client's professional team and the main contractor. The use of secondary data analysis is supported by Gilbert (2008:287) who argues the use of document analysis as an appropriate data collection approach when the researcher wishes to start with a generic question, or a statement from which the main research will evolve. Whilst Proverbs and Gameson (2008) opine that, the use of document analysis is wholly appropriate, if used as part of a fully triangulated research design.

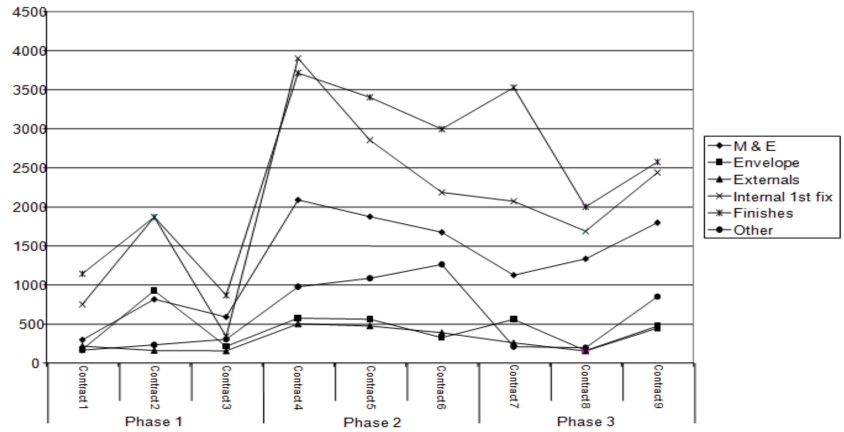
DEFECT DATA ANALYSIS

The first round of results has been analysed using descriptive statistical techniques in order to determine:

- Defect occurrence trends across the full programme to establish if organisational learning is taking place;
- To establish defects occurrence patterns across works packages for the three phases;
- To appraise how defects are managed between key milestones in the contract.

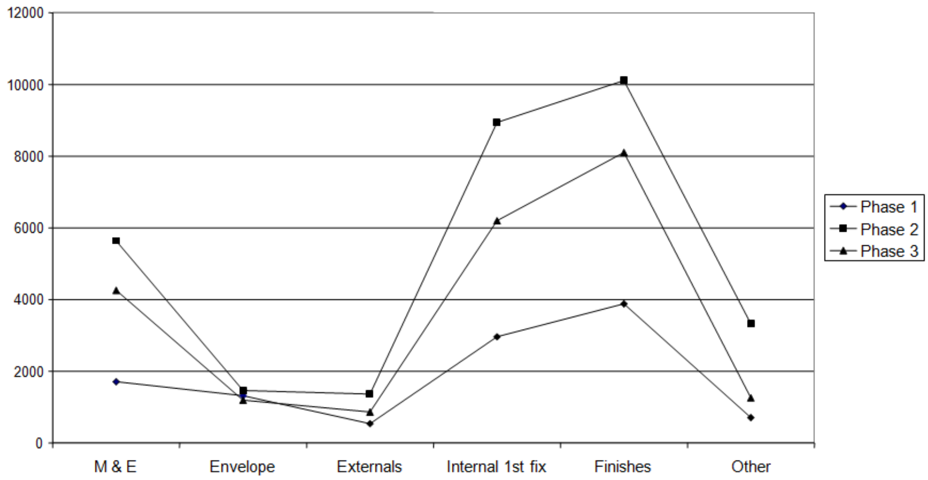
Figure one illustrates a positive trend in the number of defects recorded across the three phases consisting of nine projects. The figure shows a significant fluctuation after phase one which albeit recovered within the final phase but did not return to the previous lows seen in phase one.

Figure1: Defect occurrence across the programme



Further analysis of the data in figure one and figure two illustrate both the external works and the main structural envelope delivered a constant level of quality across all nine projects.

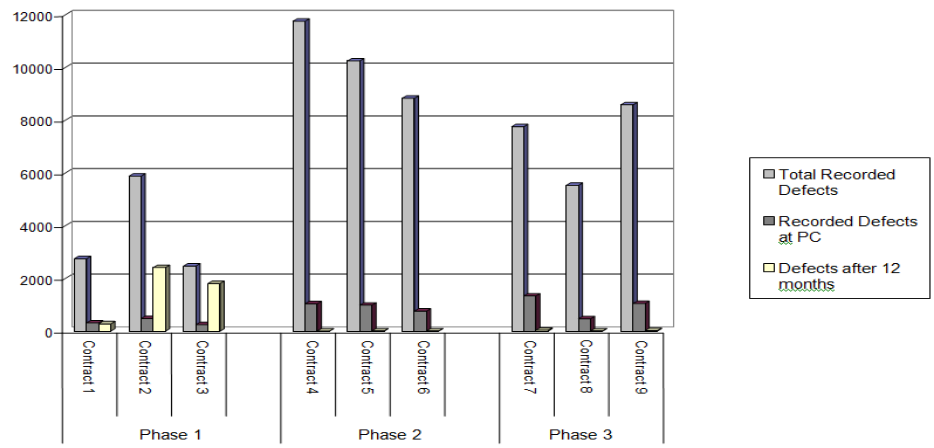
Figure2: Defect Occurrence Patterns



This is suggestive of the implementation of effective management systems, workmanship control and quality standards. However mechanical and electrical, the internal first fix and finishes all recorded significant fluctuations in quality both between phases and within the phases. Leading researchers to hypothesise that the significant fluctuations may be triggered by inter alia (i) lack of specialists knowledge within the management team; (ii) the operatives consider that unseen work albeit needs to be functional does not need to be aesthetically pleasing and finally (iii) finishes are generally more scrutinised and prone to damage thus leading to stakeholders perception that there is a increase in the number of defects recorded.

Figure three illustrates the number of defects identified at three key stages within the project life cycle. The data suggests albeit the clients feel that construction quality is poor typically they are unaware of the contracts commitment to quality control. This can clearly be seen in figure three where column one records the total number of defects observed by the main contractors site management team upon completion of the various packages. The second column records the number of latent defects observed by the designer at practical completion where a marked improvement in quality can be observed. The data in figure three further demonstrates an improvement in achieved quality at phase one with a complete eradication of latent defects in the subsequent phases.

Figure3: How defects are managed



DISCUSSION OF RESULTS

Through the evaluation of defect data collected from nine case study projects, completed over a four year period by the same project team revealed an unexpected positive trend in the number of defects identified. Over the three phases of the programme the number of defects recorded at both pre completion and practical completion stages increased significantly from phase one to two. The CIOB (2011) assert that one of the key facets of quality management is to strive for continuous improvement. For this to be attained on the BSF project analysed the number of defects should reduce. Potential reasons for the none achievement have been identified in the work of Love *et al.* (2000) and Lundkvist *et al.* (2010) who have both assert the construction team should learn from their past experiences, build on them and subsequently reduce the number of defects identified. Yet the data appears to suggest that a limited amount of organisational learning had taken place which is evident through the fall of the number of latent defects recorded.

More extensive observation of the data suggested that only certain works packages followed this trend. Typically the packages recording the higher levels of defects were the specialist mechanical and electrical or packages where quality was deemed less important. This would appear to align with Labbad (2010) who suggests the importance of quality is not understood by the operatives completing the work. However if this was the case we would have expected to see similar levels of defects across all works packages within all nine contracts. This may add weight to Douglas and Ransom's (2007) suggestion that the cause of defects is often quite complex with various active and latent errors interacting which eventually lead to human error and a visible defect. A further contributory factors maybe the lack of experience of the site management team such as the work of Farrell and Gale (1999) evidences the career path of the construction manager which shows younger inexperienced staff often supervise smaller or less important work. Although it may also simply be that some aspects of the work are subject to more scrutiny than other by the various stakeholders.

CONCLUSIONS

This paper raises a number of important questions about the use of 'defects' as a performance measurement for quality within the construction sector. The literature identified that poor management practices together with a disregard towards organisational learning has resulted in the adoption of a weak approach to the management of quality within the construction sector. The literature further identifies a number of contributory factors including (i) the lack of personal ownership of quality (ii) procurement driven by price not the wider parameters of value and (iii) the construction teams eagerness to move on to the next project. This collectively prevents the sector attaining the levels of quality Egan (1998) observed in other industries.

The initial baseline analysis of defects appears to support the initial view developed from the literature review. The research identified that the number of recorded defects has not reduced over the three phases. This suggests organisational learning is not taking place within the team. Secondly, the defect data appears to suggest that that certain works packages appear to be more prone to the occurrence of defects than others. Yet these packages appear to exhibit two common traits. Either they were highly complex in nature, for example the M&E package or where more visible at building handover for example floor finishes. A number of possible explanations for this exist within the literature. These include inter alia: the assigning of these packages to the less experienced members of the supervisory team or simply the desire to leave site for the next challenge.

The next phase of the PhD research is to undertake exploratory interviews with project stakeholders to establish if the initial observations are valid.

REFERENCES

Aagaard, N.J: de Place Hansen, E.J: Nielsen, J. (2010).CIB 55 Building Economics W055 - Special Track 18th CIB World Building Congress, May 2010 Salford, United Kingdom Conference Salford.

Atkinson, A. R. (1999). "The Role of Human Error in Construction Defects." Structural Survey, 17(4), pp.231-236.

Auchterlounie, T (2009),"Recurring quality issues in the UK private house building industry", Structural Survey, 27 (3) pp. 241 – 251.

CIB (1993) "Building Pathology - a state of the art report", Van den Beukel (eds). Rotherdam.

CIOB. (2011)-last update. A Competitive Future for UK Construction. Available online at: http://www.atypon-link.com [15/01/2011, 2011].

Demming, W, E. (1986) Out of the Crisis. Cambridge, England: MIT/CAES Press.

Douglas, J & Ransom, B. (2007) Understanding Building Failures. Third Edition. Oxon, England: Taylor & Francis Group.

Egan, J (1998) *Rethinking construction: the report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction*, London: Department of the Environment, Transport and the Regions Construction Task Force.

Fagbenle, O.I. (2010) a comparative study of the time and cost performance of labour- only subcontractors in the construction industry in south western Nigeria. Journal of Building Performance. **2** (1) pp 94-101.

Farrell, P and Gale, A (1999) The influence of site manager career progression paths on the successful outcome of construction projects. In: Hughes, W (Ed.), Procs 15th Annual ARCOM Conference, 15-17 September 1999, Liverpool John Moores University. Association of Researchers in Construction Management, **1**, 133-42.

Gilbert N (2008) Researching Social Life 3rd Ed. London: Sage Publications Ltd.

Harris, F & McCaffer, R. (2006) Modern Construction Management. 6th Ed. London: Blackwell Scientific Publications.

Institute for Manufacturing (2009)-last update. University of Cambridge. Available online at: http://www.ifm.eng.cam.ac.uk/dstools/process/deming.html [06/01/2010].

Josephson, P.-E. and Hammarlund, Y. (1999) The causes and costs of defects in construction, a study of seven building projects. Automation in Construction, **8**, 681-687.

Juran,J M. (1989) On Leadership for Quality New York: Jossey Bass.

Kim, Y S, Oh, S W, Cho, Y K and Seo, J W (2008) A PDA and wireless web-integrated system for quality inspection and defect management of apartment housing projects. Automation in Construction, **17**(2), 163-179.

Laing O'Rourke. (2009)-last update. Quality Construction. Available online at: http://laingorourke.com/pages/quality.aspx [15/01/2011].

Latham, M (1994) *Constructing the team: final report of the government/industry review of procurement and contractual arrangements in the UK construction industry*, London: HMSO.

Labbad, D. (2010)-last update. Lend Lease Magazine. Available online at: http://www.thehive.com [27/01/2011].

National Audit Office (2009) The building schools for the future programme: renewing the secondary school estate. London, HMSO.

Love, P. E. D, Mandal, L, P: Li, H. (1999): Determining the causal structure of rework influences in construction, Construction Management and Economics, **17**(4), 505-517.

Love, P E D, Irani, Z and Faniran, O (2000) Total quality management and the learning organization: a dialogue for change in construction. Construction Management and Economics, **18**(3), 321–31.

Lundkvist, R, Meiling, J and Vennström, A (2010) Digitalization of inspection data: a means for enhancing learning and continuous improvements? In: Egbu, C. (Ed) Procs 26th Annual ARCOM Conference, 6-8 September 2010, Leeds, UK, Association of Researchers in Construction Management,829-838.

Peach, T. (2010))-last update. Quality Matters. Available online at: http://www.thehive.com/quality [04/02/2011].

Proverbs, D. and Gameson, R. (2008) Case Study Research. In: Knight, A: Ruddock, L (eds) (2008) Advanced Research Methods in the Built Environment. Oxford: Blackwell.

Wolstenholme, A (2010) Never Waste a Good Crisis: A review of progress since rethinking construction and Thoughts for our future. London: Constructing Excellence.

Yin, R.K. (2008) Case Study Research Design and Methods, 4th Ed. London: Sage Publications Ltd