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An improvement strategy for the defects and rework management process within an SME: An action research

AN IMPROVEMENT STRATEGY FOR THE DEFECTS AND REWORK MANAGEMENT PROCESS WITHIN AN SME: AN ACTION RESEARCH APPROACH

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Irish construction reported strong growth towards the end of 2013, after years of industry recession. Following a property led economic collapse which started in 2007 construction output fell by circa eighty percent. Many construction companies went out of business; those remaining are strongly focused on their bottom line and increasing efficiency to ensure survival. Defects and rework, common in construction, are both wasteful and a cost that can be avoided, thus presenting an obvious target for improvement. A regional SME main contractor collaborated on a project to improve the efficiency of their current processes for the identification, management and elimination of defects and rework in their supply chain. An action research strategy was employed on several field projects, to investigate the problems faced by the company in this area and to develop an improvement plan. Action research involves a five stage problem solving cycle (1) problem diagnosing; (2) action planning; (3) action taking; (4) evaluation of results; (5) specification of learning. Action planning elements emerging from the cycle (at stage 2) are presented here. They are very wide ranging and include; process standardisation; sign off procedures; use of ICT as a collaborative platform; freeware information repository; cost modelling; benchmarks for improvement; planning workshops; root cause analysis of defects and subsequent development of learning materials. Preliminary results indicate a sophisticated understanding of the defects and rework process across the supply-chain, but a general lack of forum and opportunity to contribute to improvement. The results indicate a wide diversity of abilities and resources in SMEs, including human, capital and technological, meaning one size fits all solutions to efficiency improvements are difficult to attain. Prescriptions thus need to be both simple to implement and flexible. The results here offer detailed reflective insight into best practice in designing improvement plans of this nature.

Keywords: action research, defects, rework, supply chain management.

INTRODUCTION

Construction in Ireland, suffered a significant collapse following a property led bubble in 2007. Figures indicate the value of construction production declined by over 77% by 2013 (CSO, 2013). This situation led to a spiral of bankruptcy, unemployment and bad debt with the industry in recession for nearly five years (CSO, 2013). Data from 2014 shows some growth, but the recovery is patchy, geographically and by sector (Ulster Bank, 2014). The number of contractor's reduced by circa 40% by 2011. Those remaining are overwhelmingly SME with only 11 companies classified as large using EU classifications (EU 2003/361). As part of a wider PhD study, a collaborative

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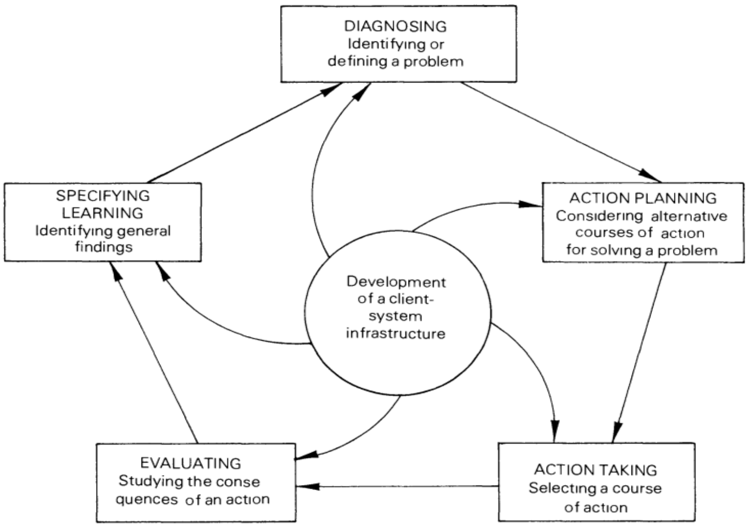
Action Research (AR) project is in progress with an SME regional contractor, who suffered substantial reverses of fortune during the downturn. The PhD research problem is focused on solving the contractor's ongoing problems with detection, management and elimination of defects and rework at the conclusion of projects. This phenomenon, known as 'snagging' in the industry, is a term little found in literature (Sommerville *et al*, 2004). A wider time view is however required as defects are both created and discovered at many stages of the production process, not just at project conclusion (Love and Edwards, 2004; Koskela *et al*, 2006).

The literature is confused in terms of the cost of defects and rework. A consensus however exists that in many cases it is 5% or more of total project cost (TPC) (Love, 2002; Taggart *et al*, 2014). The phenomenon of defects and rework is enduring, costly, wasteful and avoidable, providing justification for the academic aims of the study. The work also contributes towards solving the contractor's practical issues of delay, extra costs and late payments resulting from defects and reworks in an austere economy. Governmental reports suggest growth potential of 100% is sustainable for the industry in the medium term (Forfás, 2013). Should the status quo endure, we may speculate that the level of defects and rework, will likewise 'recover' by 100%, representing a significant missed opportunity for the industry and wider economy. The study collaboratively seeks to help the SME with its immediate problems and contribute to theory by dissemination of the results (Robson, 2002; Baskerville and Myers, 2004).

RESEARCH STRATEGY

An AR strategy is appropriate since it is suited to complex social situations with many factors at play in terms of human, technological, information and social-cultural variables (McKay and Marshall, 2001). In many cases these variables are impossible to disaggregate in any meaningful way, mitigating against the use of more traditional research approaches (Seymour *et al*; 1997). The roots of AR are generally traced to Kurt Lewin who felt the most important aim of social science should be to contribute to change for the betterment of society and its institutions (Lewin, 1946). Engendering learning through change is a fundamental element of AR (Altrichter *et al*, 2002). AR should also assist practitioners in developing their own self-help competencies (Susman and Evered, 1978). Many contributors are concerned by a lack of relevance to industry in current traditional academic research, suggesting it promotes description and explanation at the expense of problem solving (AlSehaimi *et al*, 2013). AR seeks to redress this balance by linking new knowledge to practical situations (Bresnen and Marshall, 2001). AR is widely conceptualised as a 'cycle' or 'spiral'. A popular representation is shown in figure 1. Stages entail; (1) diagnosing, the problem scope; (2) action planning, an improvement plan; (3) action taking, implementing the plan; (4) evaluating, the implementation consequences; and, (5) specify learning from the process (Susman and Evered, 1978). If the achieved solution is not satisfactory, further iterations take place to refine the process. A common criticism of AR is that it sacrifices scientific rigour in pursuit of practical relevance. This argument, has diminished in recent years, but still ensues. Strong argument for the scientific validity of AR can be found in Susman and Evered, (1978) and Reason and Bradbury, (2001). This paper seeks to further that discussion by considering how theory and practice can be linked when analysis of emergent improvement data takes place in an AR cycle.

Figure 1 - The Action Research Cycle - Susman and Evered, (1978, p588)



The remainder of this paper focuses on the action planning stage (stage two) of the study. The initial diagnosing stage, (stage one) is fully described elsewhere (Taggart *et al*, 2014). To aid reader understanding a brief summary of stage one is given below. Future papers will report on the remaining, implementation stages of the AR cycle.

FIELD STUDY DISCUSSION

Stage one entailed understanding of the current processes used by the SME to identify, manage and eliminate defects. This involved participative involvement on a field project constructing a health board building value circa €1.4 million. A range of research methods were used including; (1) un-structured observation; (2) photographing activities; (3) semi-structured interviews with stakeholder; (4) informal conversations on site; (5) analysis of documentation; and, (6) group discussion (Taggart *et al*, 2014). Results indicated the process being used was sub-optimal when compared to best practice suggested by literature. Participants demonstrated a sophisticated understanding of the root causes of the defects and suggested simple, cost effective methods to avoid future repetition. However they were never typically invited to collaborate in any meaningful way in defects reduction initiatives. Participants also showed an understanding of the possible benefits and a desire for more collaborative ways of working. However they suggested that the processes needed to support this was not currently present (Taggart *et al*, 2014).

ACTION PLANNING (STAGE TWO)

Five improvement areas emerged from stage one; (1) adoption of collaborative supply chain approaches; (2) adoption of a standardised management process; (3) adoption of cost effective IT solutions appropriate to SME; (4) adoption of simple costs modelling; and, (5) a focus on learning and continuous improvement. Noting the perilous economic context, any initiatives were required to both reduce defects whilst being rigorously balanced against any increased management process costs (such as inspections for example). Thus solutions need to be simple to implement and flexible. Following stakeholder discussions, 13 specific suggestions emerged where snagging process improvement might be found (Table 1).

Table 1-Suggested process improvement elements

Code	Suggested Improvement Element	Area of Interest
E1	Adoption of standard collection template for snagging data	2
E2	Co-ordination of the process across design team and contractor	1
E3	Requirement that Sub-cons sign off work as ready for next trade	1, 2
E4	Adoption of IT solutions for data collection and manipulation	3
E5	Issue snag lists sorted by responsible firm	2
E6	Use of electronic repository to share snagging data	3, 5
E7	Develop simple cost model to capture snagging costs	4
E8	Introduction of benchmark targets for defects reduction	1, 5
E9	Introduction stakeholder workshops to examine defect root causes	1, 5
E10	Develop visual communications materials as teaching aid	5
E11	Use of electronic repository as shared knowledge base	5
E12	Introduction of stakeholder workshops focused on avoidance	1, 5
E13	Introduction of toolbox talks / induction on quality issues	1, 5

At stage two of the AR cycle, the emergent improvement suggestions have direct relevance to the participants as they have contributed to their development. However significant methodological questions are posed concerning the validity of this output and nature of the knowledge being generated by these actions. Robson, (2002) found AR to be a very flexible approach and this very flexibility poses issues for claiming purely scientific or statistical validity. Schön, (1995) suggests a generalisation for AR that is not of the ‘covering law’ variety, but frames the problem and the strategies of actions for its solution, allowing both the problem and solution to be carried over to other similar situations, providing an analytic or theoretical generalisation (Robson, 2002).

Using an AR approach, typical research output creates a tested and grounded technological rule, its knowledge justification comes from a saturation of evidence that the rule actually works in practice (van Aken, 2004). AR emphasises the utility aspect of the future process from the participant's perspective, whilst generating new knowledge to guide practice gained from the act of modification of the current state (Järvinen, 2005). Susman and Evered, (1978) contend AR is a different type of science with a different epistemology, producing a different kind of knowledge. This knowledge is contingent to a particular situation and develops the capacity of participants to solve their own problems whilst contributing to theoretical knowledge. The goals of AR are to make the resultant improvement actions more effective while simultaneously building up a body of scientific knowledge (Coughlan and Coghlan, 2002). AR is essentially a pragmatic strategy, since its core paradigm is that the 'truth' to be found is based upon the utility of the research (Azhar *et al*, 2010).

Robson (2002) classified the three main threats to validity when using AR as; (1) lack of complete and accurate description; (2) researcher bias / pre-conceptions; and, (3) failure to consider alternative explanations or understandings. As a counterbalance to these it is essential to adopt coherent research frameworks to increase the rigour and hence the validity of the work undertaken. As part of the wider PhD methodological validation a guidance framework for AR developed by Eden and Huxham, (1996), was adopted. This provides twelve guiding contentions for the justification of AR. The contentions are in terms of internal, external (project) and external (wider generalisation) validity. At this planning stage (two) of the AR cycle, it is appropriate to consider their contention seven; 'A very high degree of method and orderliness is required in reflecting about the emergent research context of the involvement' (Eden and Huxham, 1996, p84). This wider theoretical consideration of proposed practice improvements guards against bias by forcing reflection from differing perspectives.

To address these threats, a theoretical model for systematic reflection upon the emerging improvement ideas in stage two (table 1) was followed, using 'four critically reflective lenses' (Brookfield, 1995). This model proposes critical reflection on the assumptions we make (in this case about the improvement suggestions). Brookfield arranged this refection using four lenses; (1) Our autobiography as teacher and learner; (2) Our students eyes (in this case, the research participants); (3) our (expert) colleagues experiences; and, (4) theoretical literature. Faced with problems, we often find that the foundations of our subsequent actions are laid in our autobiographies. Brookfield argues that all teachers make paradigmatic assumptions and have instinctive reasoning's and need to understand these when interpreting data from our students, colleagues and literature. Critical reflection is thus widely accepted in the literature as a critical component of good research, but is particularly relevant to AR (Baskerville and Myers, 2004).

RESULTS - REFLECTIONS ON STAGE TWO

This descriptive results summary is necessarily truncated by the paper space but illustrates reflective data which may change and improve the plan, emanating from the four lenses reflective process. Coughlan and Coghlan, 2002, suggest AR researchers need a prior breadth of situational understanding. The field researcher (author 1) has extensive experience as a construction manager, balanced by additional academic and business management experience, enabling a broad range of reflective contributions. Caution is however needed not to simply import the researcher's assumptions about what context is relevant to this situation (Silverman, 2000). Extensive field notes were kept by the researcher, allowing systematic personal reflection on the development of the improvement plan ideas as they emerged. However Schön, (1995) notes significant limitations on the degree of rigour that can be achieved by purely autobiographical reflections and strongly advises extensive reflections using the remainder of the reflective lenses.

To assess the participant's reflections (Lens 2) a semi-structured interview template was prepared by the author, seeking opinions and insights on the ideas listed in table 1. Supply chain Interviewee's (9) included architect, quantity surveyor, engineer, site management staff and sub-contractor supervisors. Additionally to address Lens 3, discussions took place with a senior quality manager (QM) from a major contractor unconnected to the SME, using the same interview template. Finally a summary review of literature pertaining to the thirteen elements was undertaken (Lens 4).

Using an AR approach the review of existing literature was thus partly driven by the emerging practice, rather than the more traditional research sequencing where practice normally follows an examination of theory.

In regard to collaboration; participants espoused support for more 'collaboration' as an improvement tool, but were not uniform in what form this would take. A coordinated snagging process across contractor and design team (E2) found agreement that this would be beneficial. The site manager agreed in principle, but felt it would be very difficult, due to contractual practicalities, a view shared by the QS who felt an 'attitudinal' change was needed for this approach to work. Sub-contractors signing off their own work as ready for the next trade (E3) also found general support. Some participants had experience of this and noted in principle it is a good idea, but, two factors disrupt its use; firstly a congestion of sub-contractors towards the end of most projects meaning numerous sign-offs that are difficult to manage and secondly; if there is programme pressure sub-contractors will 'cheat' saying they are finished when they are not. Workshops focused on the prevention of defects (E12) and root cause analysis of defects (E9) also received support in principle, many participants had previous experience of such workshops. Their overall reflection on these was however mainly negative. Comments included; 'The focus from the main-contractors is always programme, not quality'; 'You can never get everyone important in the same place for workshops', The nature of construction procurement also means that sub-contractors are appointed at different times in the process, meaning meetings at the appropriate time are often impossible. Participants generally supported 'collaboration' which concurs with literature (Akintoye *et al*, 2000). Björnfot and Torjussen (2012) found that collaboration by SMEs is mainly informally arranged, resonating with this study. Literature mainly discusses collaboration as a far more formal concept, usually involving larger companies. Love *et al*, (2004) noted resistance by designers to collaboration as it erodes their traditional powers. Designers here displayed a more open-minded attitude towards collaboration, which can be tested in stage 3 of the cycle.

Adoption of a standardised method of data collection (E1) received strong support. Some operational concerns were however noted. Respondents agreed that it was a good idea to have a 'checklist' when snagging, they were concerned about the large size of any potential database of snag descriptions and felt any checklist would have to be very simple in use to find favour. The architect noted inexperienced staff may miss defects that were not on the standard list / template. Issuance of individual snag lists to sub-contractors showing only their own defects (E5) split the group without any consensus. Opinion ranged from avid support to those who noted that defects rectification often has a collaborative element. To those who thought seeing the 'big picture' was beneficial to the supply chain. One sub-contractor made the startling admission that he often 'left some snags for the architect to find'. Explaining his rationale, he stated that if things were 'too perfect', it encouraged the architect to become 'picky' in adding inconsequential items to the snag list, whereas some obvious snags found during the inspection would satisfy both the inspector and the process.

Use of IT solutions to make collection and distribution of snagging data (E4) was firmly supported by all. Comments typically included 'It will happen anyway' and 'it is a given'. Concerns voiced typically focused on practical issues such as older workers learning technology; cost; security; training issues; and device reliability. The painting sub-contractor noted his workforce was largely transient in response to supply and demand peaks, so his training costs would be repetitive without any obvious benefit. The QM commented that companies were often discussed under common headings such as 'SME' whereas SMEs in reality were very variable in terms of their expertise, ranging from the technologically sophisticated, to those making little use of IT.

Electronic repositories, so that information could be easily shared in terms of both snagging data (E6) and learning (E11) were also popular, with all stakeholders stating they were prepared to use them. Surprisingly none of the interviewee's had previously used them. The architect was concerned about ownership of the materials / data in repositories, further noting that post contract reviews are now a common requirement in quality management systems, but 'are rarely done in any detail or well'. Reflecting on literature Harland *et al*, (2007) found SMEs tend to play a watching game, their horizon is short-term, and in terms of IT integration / use they tend only to respond to customer demand, rather than be innovators (Fink, 1998). Harland also notes the dominant role of SME owner managers, particularly in regard to IT purchase and the desire of SMEs to maintain close personal direct contact with their customers in preference to e-business or electronic communication methods.

Capturing the cost of defects and rework in this process with a simple cost model (E7) produced a consensus of sorts. A large majority of respondents felt this would be very interesting and useful information to have. They also stated it would be almost impossible to gain a true understanding / model of cost given the typical contractual arrangements. Responses included; 'A very difficult thing, very complicated'. 'You are up against the secret nature of the QS and commercial sensitivity' 'People will not share that kind of information'. The interviewee's were asked their opinion of typical defects and rework costs as related to total project costs? Many responded that they had no idea as it was outside their area. The painter said it would be between 10% / 12% of his tender cost on this project; the site manager suggested 5% but much more in many cases and the SMEs QS did not know for sure. Subsequently the researcher and SME have commenced field trial experiments to test various templates to capture defects and rework costs. These insights help to demonstrate why the literature in this area is very confused with no obvious standardisation of metrics (Fayek, *et al*, 2004). Reported defects costs range from 3% to 23% of total project cost (TPC) (Love *et al*, 2004). Love (2002) also suggests that many costs are hidden in the operational process and in some cases defects and rework costs range up to 25% of TPC. Given the opinions of the Irish construction community, expressed here, his suspicions may indeed be well founded.

Finally learning and continuous improvement (CI) was reflected upon. Benchmarking improvement targets (E8) caused some difficulty in that none of the participants had any personal knowledge of them. When their use was explained some people gave guarded support, but were otherwise unsure about their use. Use of visual management techniques (E10) was again a mystery to most, however they all clearly understood their use in a health and safety management context and were open minded in its potential for improving quality and prepared to try it out. Creating a knowledge data base (E11) was widely supported. Many interviewees had experience of similar defects problems being repeated from job to job and felt learning from such problems must be possible. The site manager noted that the SME had carried out two similar projects previously but he has not been aware of any learning from them. He felt a 'lessons learned' review would be very useful if presented in a suitable and usable way. Although continuous improvement was a key factor of the SMEs quality assurance system, little feedback learning was ever seen recycled into the field. Use of toolbox talks for quality (E13) found wide support. All participants had experienced such talks in relation to health and safety, feeling that they worked well, but none had experienced them for quality matters. The architect particularly felt that toolbox briefing is an excellent way to avoid defects and was always willing to provide briefings if asked, stating 'fixing it never gives the same finish as doing it right the first time'. Barker and Naim, (2008) found UK house builders could readily identify and solve common problems - then typically repeated them, as the improvement information was not captured and reused. Bresnen and Marshall, (2000) suggested that contractors support CI, but found it hard to achieve in practice and found clients had unrealistic expectations from it. In regard to benchmarking against Key Performance Indicators (KPIs) Ireland does not use any comparable system to those in common use in the UK (Beatham *et al*, 2004). This means that benchmarking is very difficult to achieve, save some internal benchmarking, without comparable available industry data. Interestingly when benchmarking has been introduced to new territories, metrics for defects and rework is often one of the first KPIs to be introduced (Alarcón *et al*, (2001). Costa *et al*, (2006) discuss the variations in benchmarking metrics, finding most allow 'post-mortems' to inform future learning, but few allow for evasive action to be taken during live projects. Dave and Koskela, (2009) suggest that re-use of organisational knowledge greatly reduces time spent on problem solving and increases quality. The challenge here is to design a cost effective solution for the SME. The QM noted his experience that useful CI data was often lost or poorly captured in normal quality management systems, agreeing with the literature and field research. He also agreed that traditional quality systems engendered a 'post-mortem' approach and were often not very useful in avoiding defects, only at detecting them once created. His suggested solution concentrated on early stage inventions to assess and identify potential issues before they became defects.

CONCLUSIONS

This research has illustrated the use of Action Research as an approach to problem solving in SMEs. The results clearly indicate that homogenous categorisation of construction companies, for this purpose, using terms such as 'SME' is difficult, since they exhibit a very wide spectrum of intellectual, technical and financial abilities. This has implications for the development of improvement strategies at the process level, meaning that 'one size fits all' solutions are unlikely to be successful and are difficult to replicate in practice. AR provides a suitable vehicle for the development of situational solutions to socially constructed problems, permitting a deep understanding of the complex and interconnected variables involved. The results also indicate the particular complexity associated with the costs of defects, in terms of; (1) establishing the holistic cost of defects; (2) variable SMEs views on the costs associated with improvement strategies; and, (3) contextual realities of economic austerity.

The research also considered the argument made against AR, that it is a sacrifice of rigour, in favour of practical relevance. The research methodology applied a detailed theoretical framework to the work using twelve contentions of research validity as an overarching step-by-step checklist. The results of stage two (reported here), the emergent improvement plan elements, were also subjected to detailed critical reflection using four critical lenses of reflection. The results of reflection were to improve and tailor the emerging plan whilst aiding avoidance of researcher bias by forcing a consideration of other alternative meanings, views and solutions to the problems at hand. The knowledge gained is situational, but can contribute to understanding similar problems in similar situations.

REFERENCES

Abowitz, D. A. and Toole, T. M. (2009) Mixed method research: Fundamental issues of design, validity, and reliability in construction research, “Journal of Construction Engineering and Management”, **136**(1), 108-116.

Akintoye, A. McIntosh, G. and Fitzgerald, E. (2000) A survey of supply chain collaboration and management in the UK Construction Industry, “European Journal of Purchasing and Supply Management” **6**(3) 159-168.

Alarcón, L. F., Grillo, A., Freire, J., and Diethelm, S. (2001) Learning from collaborative benchmarking in the construction industry, In “Ninth Annual Conference of the International Group for Lean Construction” (IGLC-9).

AlSehaimi, A. Koskela, L. and Tzortzopoulos, P. (2013) Need for alternative research approaches in construction management: case of delay studies, “Journal of Management in Engineering”, (29), 407-413.

Altrichter, H, Kemmis, S. McTaggart, R, Zuber-Skerritt, O. (2002) The concept of action research, “The Learning Organisation”, **9**(3), 125-131.

Azhar, S., Ahmad, I., and Sein, M. K. (2009) Action research as a proactive research method for construction engineering and management, “Journal of Construction Engineering and Management”, **136**(1), 87-98.

Baskerville, R., and Myers, M. D. (2004) Special issue on action research in information systems: making is research relevant to practice--foreword, “MIS Quarterly”, **28**(3), 329-335.

Beatham, S. Anumba, C. Thorpe, T and Hedges, I. (2004) KPIs: a critical appraisal of their use in construction, “Benchmarking, An International Journal”, **11** (1), 93 – 117.

Björnfot, A., and Torjussen, L. (2012), Extent and Effect of Horizontal Supply Chain Collaboration among Construction SME, “Journal of Engineering, Project and Production Management”, **2**(1).

Bresnen, M and Marshall, N (2001) Understanding the diffusion and application of new management ideas in construction. “Engineering, Construction and Architectural Management”, **8** (5/6) 335-345.

Brookfield, S.D. (1995) “Becoming a critically reflective teacher”, San Francisco, Jossey-Bass.

Central Statistics Office (2013), Production in building and construction index, http://goo.gl/crz7An, accessed 2nd April 2014.

Costa, D.B. Formoso, C.T. Kagioglou, M. Alarcón and Caldas, C.H. (2006) Benchmarking initiatives in the Construction Industry: Lessons learned and improvement opportunities, “Journal of Management in Engineering”, **22**(4), 158-167.

Coughlan, P. and Coghlan, D. (2002) Action research for operations management, International journal of operations and production management, **22**(2), 220-240.

Dave, B. and Koskela, L. (2009) Collaborative knowledge Management – A construction case study, “Automation in Construction”, **18**(7) 894 – 902 .

Eden, C., and Huxham, C. (1996) Action research for management research, “British Journal of Management”, **7**(1), 75-86.

Fayek, A.R. Dissanayake, M. and Campero, O. (2004) Developing a standard methodology for measuring and classifying construction field rework. “Canadian Journal of Civil Engineering”, (31), 1077 - 1089 .

Fink, D. (1998) Guidelines for the successful adoption of information technology in small and medium enterprises, “International journal of information management”, **18**(4), 243 – 253.

Forfás (2013) Ireland’s Construction sector: outlook and strategic plan to 2015, Forfás, Dublin.

Harland, C. M., Caldwell, N. D., Powell, P., and Zheng, J. (2007) Barriers to supply chain information integration: SMEs adrift of eLands, “Journal of Operations Management”, **25**(6), 1234-1254.

Järvinen, P. (2005) Action research as an approach in design science, “The EURAM” (European), University of Tampere, Finland.

Koskela, L. Henrich, G. Owen, R and Vrijhoef, R. (2006) Theory based production and project management, “Proceedings of the 3rd International Salford Centre for Research and Innovation symposium” (SCRI), Delft, Netherlands.

Lewin, K. (1946) Action research and minority problems, “Journal of social issues”, **2**(4), 34-46.

Love, P. E. D. (2002), Influence of project type and procurement method on rework costs in building construction projects, “Journal of Construction Engineering and Management”, **128**(1), 18-29.

Love, P.E.D. and Edwards, D.J. (2004) Forensic project management: The underlying causes of rework in construction projects, “Civil Engineering and Environmental Systems”, **21**(3), 207 – 228.

Love, P.E.D, Irani, Z. and Edwards, D.J. (2004) A rework reduction model for construction. “IEEE Transactions on Engineering Management” **51**(4), 426 – 440.

McKay, J., and Marshall, P. (2001) The dual imperatives of action research, “Information Technology and People”, **14**(1), 46-59.

Reason, P., and Bradbury, H. (Eds.) (2001) “Handbook of action research: Participative inquiry and practice”, London, Sage Publishing.

Robson, C. (2002) “Real world research” (2nd Ed.), Oxford, Blackwell Publishing.

Seymour, D., Shammas-Toma, M. and Clark, L. (1997) Limitations of the use of tolerances for communicating design requirements to site, “Engineering, Construction and Architectural Management”, **4**(1), 3-23.

Schön, D. A. (1987) “Educating the reflective practitioner”, San Francisco, Jossey-Bass

Society of Chartered Surveyors Ireland (2014), “Construction sector outlook 2004”, Dublin, Society of Chartered Surveyors Ireland.

Sommerville, J. Craig, N and Bowden, S. (2004) the standardisation of construction snagging, “Structural survey”, **22**(5), 251 - 258

Susman, G. I., and Evered, R. D. (1978), an assessment of the scientific merits of action research, “Administrative science quarterly”, 582-603.

Taggart, M. Koskela, L J and Rooke J (2014) the role of the supply chain in elimination and reduction of construction rework and defects: an Action Research approach, “Construction Management and Economics”, DOI:10.1080/01446193.2014.904965

Ulster Bank (2014) Construction Purchasing Managers Index Feb - 2014, http://goo.gl/T9WTSe, accessed 1st April 2014.

Van Aken, J.E. (2004) Management Research based on the Paradigm of the Design Sciences: The quest for tested and grounded technological rules, “Journal of Management Studies”, **41**(2), 219 – 246.