THE ROLE OF THE SUPPLY CHAIN IN ELIMINATION AND REDUCTION OF CONSTRUCTION REWORK AND DEFECTS: AN ACTION RESEARCH APPROACH

Martin Taggart[1] Lauri Koskela and John Rooke

The University of Salford, School of the Built Environment, Salford, Greater Manchester M5 4WT. UK

During the past six years Ireland suffered a catastrophic economic reverse that impacted disproportionately on the construction industry, leading to a circa 80% reduction in output. The results of this have been bankruptcy, unemployment and bad debt. The changed environment has spurred the contractors to attach ever greater emphasis to production efficiency and cost reduction as a means of survival. An Action Research (AR) approach was used in this research to focus on improving the strategies adopted by a SME contractor for the control of defects in its supply chain. It is conservatively estimated in the literature that rework typically accounts for circa 5% of total project costs. Such activity is clearly wasteful and presents an obvious target to address. The AR intervention is at the diagnosing stage and involved examination of work on a pilot site, analysis of contract documents, including drawings, snag lists and specifications and semi-structured interviews with supply chain members. The results indicate the potential for the supply chain participants to both identify the root cause of defects and propose solutions, in terms of best practice to avoid future reoccurrence. Another key finding was the lack of any collaborative forums to contribute to production improvement and cost reduction. Additionally the processes, used to collect, manage and disseminate data on defects were found to be unstructured and uncoordinated, indicating scope for development of more useful methods. The research indicates good understanding of the potential benefits for supply chain collaboration but suggests the tools and knowledge to collaborate are currently lacking in the Irish SME sector.

Keywords: action research, defect, rework, supply chain management

INTRODUCTION

This report provides an interim assessment of results from the diagnosing phase of an on-going Action Research (AR) project involving an SME building contractor in Ireland. Ireland, suffered a severe and on-going economic reverse in the period 2007 - 2012. Construction has borne a disproportionate part of the burden in terms of bankruptcy, debt and unemployment. Output declined by circa 80% in that period (Taggart *et al.* 2012). In the decade prior to 2007, the industry was at the forefront of a property led boom, its predominance, at 24% of GDP was seen as unsustainable by many commentators (DKM cost consultants 2009). The industry is undertaking a very

[1] martin.taggart@gmit.ie

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painful adjustment, shedding over half of its workforce and also adjusting to a reality, whereby tender prices reduced by circa 28% from peak (SCSI 2012). The end of 2012 saw some signs that the industry had reached the bottom of the economic cycle and some stability had been reached, albeit that any significant uplift in output was some way off (SCSI 2012).

Contractors have adopted a pronounced focus on lowering cost to gain workload and ensure survival. During the early part of the downturn, weaker companies resorted to below-cost bidding as a survival strategy (SCSI 2012). 2012 shows signs that this approach is moderating and there is some stability in tender costs (Davis Langdon 2011). The eradication of rework and defects in the construction process is an obvious target for cost reduction and efficiency gains by contractors, as it is the unnecessary effort of re-doing a process that was incorrectly implemented the first time (Love & Edwards 2004). In most instances contractors will not be paid for the rework. The defects involved can be discovered at various stages of the process, both during the construction period and after handover, during the maintenance period and beyond (Love & Edwards 2004).

The focus of this paper concerns defects that are associated with the period at or around the project completion stage. Rotimi *et al*, (2011) define these defects as 'snagging' a term common in the industry, but little used in the literature. Likewise Sommerville *et al,* (2004) without explicitly stating it, associate snagging as an activity whereby defects are captured at project end by terminal 'snag lists'. Prominent in the literature is the lack of agreed definitions. In later work, Sommerville (2007) speculated that many items that are not defects, often found their way onto sang lists. A common example is the adding of items that are missing or partially complete, essentially as a reminder. This paper aims to highlight the potential improvements in harnessing a collaborative supply chain, to eliminate defects and rework at the completion stage of projects.

CAUSATION AND COSTS OF REWORK

The defects literature is wide ranging as to suggestions of the root causes of rework. There is however general agreement that underlying cause often lays deeper than superficial blaming of the operative or their immediate supervisor (Atkinson 1999). In some cases they are of course the root cause. A small cross-section of suggested root causes of defects includes: Design issues, construction issues and product failures (Sommerville 2007). Poor understanding of drawings and specification, using superseded information, poor communications, poor co-ordination of sub-contractors, ambiguous working instructions, poorly trained operatives and inadequate supervision (Chung 1999). Love *et al,* (1999) differentiates between *common causes* that are linked to the process being followed, such as inadequate information flow in the supply chain and *special causes* that arise outside of the process of work, these can emanate from unilateral client changes or adverse weather conditions for example. Rotimi *et al,* (2011) note that aesthetics play a part in determination of acceptable standards. What is of an acceptable level in one project may be rejected upon inspection in another project having higher perceptions of quality. Atkinson (1999) providing a comprehensive review, covers the more mundane causation drivers found elsewhere in the literature, but extends the discussion further to include global issues such as organisational culture, time, economic, political and societal pressures. Josephson & Hammarlund (1999) again find commonality with the literature, but additionally emphasise client impact, in terms of the stability of client personnel in ensuring information flow and the impact of late changes instructed by clients and end-users / occupiers. Several attempts have been made to gather this long and broad list of suggested causation into a coherent conceptual framework, with Josephson et al, (2002) worthy of mention. The authors usefully apportion approximate cost percentages to their model, taken from extensive field studies. They suggested the principal headings of causation and their contribution to rework costs were: design related 26%, production management related, 25%, workmanship related 20%, materials related, 17%, client related, 6% and machine or plant issues, 3%.

Whilst there is some literature commonality in terms of causation, the area of defects costs is confused with many suggested cost estimates and a variety of disparate models for calculating costs, together with a range of variables as to what is or is not included in each model. Most estimates are generally expressed at a percentage of the total project cost (TPC) given over to rework. Love (2002) discusses the difference between direct costs, which are related to additional labour, materials and plant needed for rework and indirect costs, stemming from return visits, extra plant hire, waiting time etc. Love cautions that in some cases the indirect costs may be many multiples of the direct costs. Both Love (2002) and Sommerville (2007) find that snagging and defects are entrenched in the industry and are discussed as a normal and acceptable part of the process. Indeed in an Irish context a book on the subject was published during the recent boom entitled *'The Irish Home Buyer's Guide to Snagging'.* As this phenomenon is treated as a routine occurrence, we may speculate that the supply chain reflect these costs in their pricing models. Thus there is the potential for this inefficiency to be passed along the supply chain to the ultimate client. Common standard forms of contract confirm the ‘acceptable’ nature of defects in construction, by laying out methodologies whereby monies are retained, subject to completion of the inevitable list of defects. The Irish public works contracts are an example of this phenomenon.

Josephson et al, (2002) note that the act of managing reworks is in itself inherently inefficient as it requires a degree of supervision and co-ordination, involved in appraisal costs. This includes the collection of data via snagging inspections and collation and distribution of the resultant documents. Thereafter several cycles of checking and sign off are typically required. Return visits are likewise an inefficient practice and require additional indirect costs (Love & Edwards 2004). The literature does not agree on how much such activity costs but many suggestions have been made: Love *et al*, (1999) noted claims in the literature that a holistic cost of rework could range as high as 12.4% of TPC. Love & Li (2000) cited two projects where rework costs were 3.15% on one project and 2.4% on the other. Love *et al*, (2004) noted a range of reported rework costs ranging from 3% to 23%. Josephson & Hammerland (1999) reported on a large longitudinal study that suggested rework costs were 2% - 6% during the project and additionally 3% - 5% during the maintenance period. Hwang *et al*, (2009) suggest that rework costs are typically 5% of TPC in the United States. Applied to Ireland the 5% figure equates to circa €375 million in 2012. However at the height of the recent boom, (2007) this extends to €1.89 billion annually. Should the industry recover to sustainable levels suggested by DKN cost consultancy (2011) then rework would cost €850 million per annum. These figures alone justify further research into this area in search of methods to eliminate and reduce rework and defects.

SUPPLY CHAIN IMPROVEMENT POTENTIAL

For various reasons, including geographical, historical and language, construction processes in Ireland are similar to the UK (Thomas & Hore 2002). The production model is generally of shell main contractors, arranging the work of numerous and fragmented sub-contractors selected on the basis of lowest cost. Taggart *et al,* (2012) noted that on the one hand the economic climate in Irish construction was highly adversarial, whilst on the other the industry showed a sophisticated understanding of collaborative approaches and felt that collaboration and cooperation were essential elements of success.

A significant study by Karim *et al*, (2006) noted that sub-contractors viewed the main-contractor as their 'customer' and showed little concern for and often had little direct communication with other sub-contractors with whom they were interacting. This means that problems were pushed onto the next part of the supply chain, until they were detected on terminal or interim snag lists. Koskela *et al,* (2006) supports the assertion that problem detection is often found in a later stage of the supply chain than problem creation. A Supply Chain Management approach to the problem of defects at handover would entail an agenda of stopping to fix the problems as they occur (Liker 2004), this of course means earlier detection in the process and by extension a new means of trapping errors, suggesting greater sub-contractor involvement and collaboration. Improved efficiency over time can be gained by attention to continuous improvement, but to achieve this better metrics to measure defects and rework are needed, allowing reduction targets to be set. (Lee & Amaral 2002).

In recent years the emergence of affordable information technology (IT) at the site level offers potential for significant improvement in supply chain collaboration in the area of defects elimination and management of the defects and rework process. Significant literature contributions have been made by; Bowden et al. (2006) Kim et al. (2007) and Craig & Sommerville (2007) who all describe attempts to collaborate the site processes involved in collection and management of defects data using mobile IT devices, that link back to database systems. The accounts however focus on larger projects and contractors. The quality appraisal costs (Rosenfeld 2009) involved in purchasing equipment, on-going technical support and staff training described are relatively modest for such contractors, but are more challenging for the plethora of SME contractors found in Ireland, particularly the many small sub-contractors. Essentially a balance needs to be struck between costs of ensuring quality and costs of non-quality (Rosenfeld 2009). The literature would benefit from more study pertaining to the use of affordable mobile IT by SME companies and it is planned that future reports from this study will address that area.

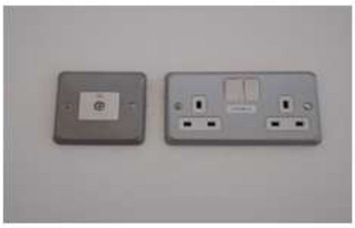
PILOT CASE STUDY OVERVIEW

As part of a wider PhD study, a pilot field study using an AR approach was undertaken to gather knowledge about Irish construction practices and attitudes concerning the management and understanding of defects, particularly in and around the project completion phase. AR adopts an inductive research approach based on a cycle involving diagnosing of a problem, action planning, action taking, evaluation of results, and specification of learning in a manner that is readily usable by participants (Susman & Evered 1978). A key factor is the notion of collaborative problem solving between researcher and organisation. In this study the 'problem' to be resolved is the on-going costs and disruption of rework on the main contractor's projects. AR thus directly promotes organisational change as well as the more normal research outputs of description, understanding and explanation (Robson 2000). This study utilised several data collection methods including analysis of project drawings, specifications and written reports including snag lists, semi-structured interviews with key participants including design team, main contractor and sub-contractors (10 No) and visual observation of defects on the project. At the completion of the project a number of reflective discussions with participants also took place.

The project involved construction of a health department project in Ireland, valued at circa €1.5 million. The project was let by two-stage tender to a local SME contractor, appointed using a 'traditional' version of the Irish public works contract with separated design and construction elements. Interviews with participants found consensus that they felt the project was generally successful and completed in a co-operative manner.

ANATOMY OF A SNAG

A considerable concern in the literature is the lack of root cause analysis of supply chain problems (Fellows 2012). An illustrated example of a typical snag is provided here. *(Photographs by author)* Photographs A, B & C show examples of snags taken from the site managers terminal snag list, No 21,42 & 62 all show co-located electrical plates / sockets which have associated defects, mainly of an aesthetic nature. An inspection found 15 locations where sockets / plates were co-located, many of them showed minor defects and were repetitively marked on the snag list. Discussions with the stakeholders including the site manager, electrical engineer, electrical contractor and decorator found that they all felt this was a 'normal' snag that they had encountered on many previous projects.



Photograph A (Top left) Surface mounted sockets on plaster wall. Photograph B, (Top Right) Recessed sockets with tile surround. Photograph C, (Left) Recessed sockets in painted and plastered wall.

Each required a return visit for rectification. Given the nature of rework required, several visits are needed to facilitate filling, redecoration and repair. It was noted via inspection, that the distance between the sockets influenced the likelihood of defects. Sockets that were closer together (0 - 50mm) exhibited many more defects than those further apart. Those with spacing above 50mm exhibited few if any snags.

A detailed discussion and consideration of the root cause of these snags yielded the following insights: Similar snags occurred with a variety of specifications, tile, and plaster, surface mounted and recessed. No two sets of co-located sockets (15 No found) had the same spacing. Spacing appeared totally random. A second project with co-located sockets was examined (11 No found) and supported the same conclusion. It was agreed during discussion that the individual electricians were randomly spacing the sockets. The electrical design drawings used CAD symbol notation to show the approximate position of sockets, no explicit dimensions were given leaving the individual electrician to decide the spacing. Further discussions found that follow on trades (plasterer, tiler, and painter) all found difficulty in working with the tiny elements of material found between sockets. Slithers of tile, small areas of plaster etc. leading to the defects. Larger pieces were easier to work with and yielded no defects.

The proposed solution is relatively simple and adopts a lean construction approach (Koskela 1994), by standardising the process. In the next iteration of the AR cycle the participants will use a standard spacing of 100mm for all conduits between co-located sockets. The propensity of defects will be checked to assess the success of the intervention. It is expected that the intervention will yield more consistent design and eliminate rework at no extra cost. If successful there is the possibility of conduit suppliers providing pre-sized and threaded conduit spacers thus speeding up the site element of the work whilst ensuring a standardised result.

The above example suggests that sub-contractors and suppliers can collaborate in the supply chain to eliminate common defects in advance, by joint contribution of their expert knowledge. However on this project none of the contractors or suppliers was asked to give any pre-construction input or critique of the design and report that to be normal practice. Part of the wider AR study will also provide a number of visual management tools to disseminate the knowledge to the supply chain so that learning can take place. It is also planned that workshops will be held in conjunction with the Construction Industry Federation (CIF) to further disseminate learning to the wider industry. It is also worth noting that the snags described above were listed for rework by sub-contractors who were not directly involved in the root cause of the problem, which is design related.

PILOT STUDY OVERVIEW OF MANAGEMENT SYSTEM

Using the AR approach the pilot study project was used to build up knowledge of the management systems for controlling rework and snags. This included site observation of work and semi-structured interviews with participants. Defects / Snag lists were scrutinised and synthesised daywork costs were added to gauge their impact. The following key points were noted.

The sub-contractors did not formally check their own work. The design team and site manager held periodic site walks and detected some issues. When interviewed all of the participants strongly supported the notion of 'collaboration' but agreed they had no formal forum or mechanisms to do so (on this project or elsewhere). Their efforts to avoid defects were thus informal and unstructured. Towards the end of the project the site manager, architect, electrical & mechanical engineers produced snag lists that were examined for this study. All were provided electronically either in Microsoft Word or in PDF format. The lists had idiosyncratic layouts. The two engineers worked for the same company but their lists had different layout. Interview data confirmed that participants generally worked separately on this task with no interdisciplinary or cross-organisational collaboration. No IT based information sharing systems was evident and only the Architect had any previous experience of working with collaborative IT systems.

For comparison purposes the lists were benchmarked against Sommerville *et al,* (2004) who investigated the commonality of headings on defects / snag lists and provided twenty-two items of information that may be found on such lists. Key concerns here were: 1) the lists had no revision number system, such that different versions of the list may be in circulation and lead to confusion as to which was the most up to date list. 2) The lists had no obvious updated 'status' process, thus without undertaking another full inspection one could not identify how many snags had been rectified at any given time. 3) Only one list (mechanical) had allocated a number to each defect, this makes it difficult to identify individual snags in an easy way and makes higher-level statistical analysis of the lists all but impossible. 4) The lists make no connection between sub-contracts works packages, thus 'shared' defects that may require collaboration to rectify is not identified. Also because of this factor lists cannot be sorted by sub-contractor name, they thus receive the whole list, not just their own list of defects. 5) No list provided any 'due date' by which the defect must be rectified. 6) The client was not consulted concerning this terminal inspection process. Subsequently they provided a short list of defects / snags of their own. This necessitated additional return visits accruing additional direct and indirect costs. The participants confirmed they generally used informal mechanisms to gauge client satisfaction with the finished product. No formal metrics that measured key performance indicators (such as quality / number defects) were used and was not normal practice.

The nature of the defects in terms of description and their location within the site was generally adequate for the sub-contractors to identify the defect and location. However this was not entirely the case, some general items were evidenced, such as *'touch up all marks on painted walls'* without any corresponding location, requiring the decorator to make a subjective judgement as to the amount of rework required. Other items listed (on all four lists) could properly be defined as being incomplete or missing entirely rather than defective.

The nature of the data provided and the media (Word / PDF) meant the data was of limited use for any further analytical purposes, unless data re-entry was undertaken. The management process was incoherent and not supportive of a collaborative approach to the defects issue, a lack of standardisation in the process and the lack of any analytical potential are obvious, but relatively easy to rectify, should the participants design and implement a more collaborative and robust system for identification, elimination and rectification of the defects. Interview data confirmed that none of the participants had any previous training in how to design and implement such collaborative working practices. They recognised that change in this area requires senior management support and generally felt that would be forthcoming from their organisation.

The literature strongly suggests that one reason that contractors have not historically addressed the defects issue is because they do not fully comprehend how much it truly costs them. To illustrate this issue to the participants, the site managers snag list was assessed on site and each snag was assigned an estimated number of work hours for rectification and appropriate estimate of new materials and plant costs. The figures were then multiplied through using hourly daywork rates verified by an independent senior PQS. The costs associated with the site managers' list corresponded to 1.3% of the construction cost of the project. Additionally there are costs associated with the other three defects lists, defects rectified during the project and defects that may arise during the maintenance period. We may thus speculate that added together a conservative figure of 5%, (supported by the literature) of construction cost would be spent on rectification of defects on this project, which is generally held by all participants as otherwise successful.

CONCLUSION

This study has considered the information gained from a scoping exercise using an Action Research approach to develop an action plan to address the defects and rework issued of an SME building contractor. Future work will provide reports on the implementation phases of this project. The information presented here allows several preliminary conclusions to be drawn that can be tested in future phases of the project. It has been demonstrated that there is potential for collaborative root cause analysis by supply chain members to identify and eliminate repetitive defects, contributing to a long-term continuous improvement process. Elimination is of course preferable to reduction in the longer-term. It has also been demonstrated that there is potential to refine the management process used to identify and rectify defects by adopting a collaborative and standardised process. This would be more data rich and thus user friendly at project level and provide analytical interrogation possibilities at the organisational level. The likely cost benefits and customer satisfaction possibilities of this approach have been outlined and can be expanded upon in future project phases. Finally the information suggests participants strongly support the need for formal collaborative or at least more informal co-operative approaches. They don't however currently adopt systems and processes at a collaborative level for mutual benefit.

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