
REQUIREMENTS OF AN INTER-PROJECT DIGITAL INSPECTION SYSTEM

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ABSTRACT

Mobility, project orientation and the set-up of new organisation in every project are characteristics of the construction industry. The products are one of a kind and seldom develop beyond the prototype phase. This is often suggested as reasons for the low development of productivity in the construction industry, and continuous improvement and experience feedback becomes harder to accomplish from project to project. The production results are handed over from contractor to client through different inspections. The inspector creates a "punch list" with all detected defects, and the contractor then is to fix these before the construction work can be finally accepted. These often lengthy lists on documented faults are full of information that can be useful for the contractor company's learning and experience feedback process. A previous study shows that contractors acknowledge this potential use, but they may need some sort of IT system to support the inter-project management of the inspection information collected. The aim of this study is to identify benefits for different project roles in a construction project from an inter-project inspection information system (IPIIS), e.g. what kind of information or data they would like to be able to extract, in order to enhance learning and feedback in their organisations. Semi-structured interviews were carried out with professionals representing different common project roles of construction projects, and regulatory demands for inspection as a part of project handover in Sweden has been studied. These results are analysed to form recommendations to the design of a future IPIIS. The requirements of a digital IPIIS are analysed, both from a regulatory point of view and from the perspective of making the inspection data useful for knowledge mining.

Keywords: experience feedback, information technology, inspection, quality

1. INTRODUCTION

The construction sector is often considered to have a poor reputation concerning learning and improvement. Latham (1994) describes that construction industry practitioners believe that approaches promoting the management of the corporate memory of their organisation would help to overcome many of the constraints inherent to their sector. It has however been found that feedback and learning loops are often broken in project-based organisations (Gann and Salter, 2000) and that project-based companies lack the organisational mechanisms for the knowledge from one project to be transferred and used by other projects (Prencipe and Tell, 2001; Dubois and Gadde, 2002). People generally tend to ignore feedback processes (Sterman, 2000) and as the project-based organisation is decentralised (Lindkvist, 2004) and loosely coupled the challenge to share knowledge effectively becomes even bigger (Orton and Weick, 1990). The focus is on projects rather than processes, which is a key difference to the manufacturing industry culture (Riley and Clare-Brown, 2001).

From a Quality Management perspective defects are signs of lowered product quality and must be detected in order not to reach the customer (Feigenbaum, 1991). Johnsson and Meiling (2009) investigate the severity of defects in industrialised house construction. They suggest that existing defect notations are a neglected source of

quality improvement information. Contractors need to work with continuous improvements and it is suggested that many of the improvements would come from knowledge about common defects.

An ordinary Swedish construction project usually goes through several different tests, audits and inspections, many described in the contractor's *Quality Plan*. The construction phase finishes with a final inspection, a compulsory step in which the question about approval of the total works between contractor and client is settled by the inspector as absolute judge. Two years after approval (if not otherwise decided) a Guarantee Inspection is held. This paper only studies aspects of these two compulsory inspections.

The inspection report gives the parties information about defects in the projects. A recent study by Lundkvist, Meiling and Vennström (2010) shows that many contractors actually recognise inspections as more than a compulsory step towards project handover, but rather as a good source for experience data for continuous improvements. Still, most of them only use them for correcting defects before handover to the client (ibid).

One possible reason for the big distance between that ambition and reality could be that inspection data is mostly manually collected on paper, leading to double work, a lack of standardisation, difficulties with monitoring the correction of defects, poor communication between on-site contractors and trades, an absence of systems for analysis and verification of causes of defects, statistics of defects rates, etc. and that there is also no feedback system. Cox *et al.* (2002) and Kim (2008) focused on technical solutions to an inspection system.

Construction, being a project-based industry, could categorise such a system as a part of a *Project Knowledge Management* (PKM) system. The support by information technology has proven to be a necessary but not sufficient factor for the quality of PKM. Without good IT-tools PKM is difficult, but the tools themselves are not sufficient if the corporate culture itself does not encourage the use of them (Hanisch *et al.*, 2009).

Lundkvist, Meiling and Vennström (2010) suggested that contractors would benefit from a digitalized inspection system. The aim of this paper is to identify which of the project roles in a typical construction project could benefit from an *Inter-Project Inspection Information System* (IPIIS), and what type of information or data they would like to get from the system, in order to enhance learning and feedback in their organisations.

2. THEORETICAL FRAMEWORK

2.1. Quality in construction

Quality management within the construction sector has been intensified in recent years through customer demands and government legislation and attention. Laws and regulations have been sharpened in order to emphasise the importance of quality work and the introduction of the quality concept, e.g. in the Swedish General Conditions of Contract of 1994 (AB 94) the concept Quality Plan was introduced, and Plan for Inspections was then later introduced in the regulation of 2004 (BKK, 2005). A Final Inspection is compulsory, as well as a 2-year Guarantee Inspection. The client appoints the person he or she feels "is competent" for the job (ibid), usually a construction engineer consultant specialising in the profession of inspector. Many of the inspectors are educated by the Swedish National Federation of Construction Engineers (SBR) and certified by SP SITAC in cooperation with SBR, even if there's no requirement of a certification. The inspector ends the inspection by writing an inspection report including a defects list (punch list) which is sent to both contractor and client, the contractor can now start to correct the defects. In the view of the General Conditions of Contract of 2004 and 2006, AB 04 and ABT 06¹, the final inspection is merely seen as a compulsory point where the project is accepted by the client and legally handed over from the contractor. The 2-year guarantee inspection audit if any new defects have surfaced since the final inspection. (BKK, 2005; BKK, 2007)

The values of Total Quality Management (TQM) is summarised in five cornerstones or core values; (1) focus on the customer, (2) base decisions on facts, (3) focus on processes, (4) improve continuously, and (5) let everyone be committed (Dale, 1999). The cornerstones are supported by a set of techniques i.e Six sigma, QFD, QC circles, Benchmarking, Supplier partnership, Process management, Self assessment and tools i.e. Design

¹ There are two different General Conditions of Contract, AB being for general *Building and Civil Engineering Works and Building Services*, and ABT being for Design and Build contracts.

matrix, Pareto diagram, Quality house, Tree diagram, Ishikawa diagram, Process map, Control charts (Bergman and Klefsjö, 2003), many of which are also used within the Lean production system (Arnheiter and Maleyeff, 2005). Low and Peh (1996) suggest a framework for implementing a Total Quality Management (TQM) quality system in construction, though the impediments are also summarized by Low and Teo (2004), who state that the success of TQM is yet to be proven in construction.

Barriers to quality improvement efforts are numerous e.g. failure to correctly understand customer requirements, both internal and external, failure to understand the capability of the production system, failure to track defects, failure to repair sub-optimised processes and failure to track quality costs (Sower *et al.*, 1999). This is to blame on management and deficient communication (Deming, 1986; Industrifakta, 2007; Josephson and Hammarlund, 1999).

2.2. Inter-project learning

Construction, in general, is a project-based industry. The ability for project-based firms to capitalise on knowledge acquired during the execution of one project and transfer that to other projects or parts of the organisation was studied by Prencipe and Tell (2001). They understood the project-based firm as a population of projects, where specific project traits may get transferred via various mechanisms from one project to another. They also proposed a framework to analyse and interpret firms' approaches to project-to-project learning, defining the project-based firm's learning landscape.

If knowledge can be codified and commodified, the ease of knowledge transfer will increase and costs associated with such transfer will decrease (Cowan and Foray, 1997). According to Zollo and Winter (2001) it is not sufficient to consider knowledge codification only as an outcome. The literature on knowledge codification is characterised by a tendency to think that the costs of codification activities are justified by their outcomes rather than by the cognitive implications of the codification process as such. It seemed that project-based firms also focused their efforts on *outcomes* rather than on the *process* of codification in developing technical devices and organisational mechanisms for learning between projects. Also, little evidence was found of direct incentives, such as monetary benefits, associated with the codification of knowledge. Rather, the codification of knowledge into reports, minutes, lessons learned, etc. is based on a presumption of good behaviour among members in the organisation (*ibid*).

Hanisch *et al.* (2009) showed how the management of knowledge in temporary organisations is an increasingly important factor in many industries, examining knowledge management in and between projects. 27 structured interviews with project managers and knowledge management experts in different corporations were held. The prevalence, the organisation and the success factors of project knowledge management were analysed. Most interviewees stated an urgent need for a significant improvement of project knowledge management although a systematic approach existed only in a few of the companies. The success of project knowledge management was analysed to mainly be determined by cultural factors whereas technical aspects like information systems and project management methods are considered to serve as supporting factors only.

2.3. Experience feedback

The nature of experiences lays in their practicality that you need to do something to actually gain an experience. Therefore experiences, as well as knowledge, contain both tacit and explicit parts (Kamara *et al.*, 2002; Nergård and Larsson, 2009). It is not the whole experience that can be fed back but the more explicit parts that can be documented and easier explained, but if the person who had the experience participates in the feedback process some of the more tacit elements may be fed back (Foguem *et al.*, 2008).

According to Juran (1986) any production is charged with a current level of chronic waste, to be regarded as the level of opportunity for improvement. From a quality management perspective defects are signs of lowered product quality and must be detected in order not to reach the customer (Feigenbaum, 1991). From a Lean perspective defects are seen as one of the seven wastes in production resulting in lowered long term profit (Liker, 2004).

A contemporary defect study was conducted by Sigfrid (2007) and results were summarised in the report "Defects and deficiencies in new dwellings". The study was financed by the National Board of Housing, Building

and Planning in Sweden and thus implying its use for generalisation. Calculations within the study shows that the costs for correcting defects after project delivery in the country could be as much as 1 300 €M, calculations based on the 2005 years housing production. The report state that defects are indications of organisational shortcomings and insufficiencies in the construction industry.

Josephson and Saukkoriipi (2007) state that defects in different ways stand for as much as 10 % of the total projects costs in construction (e.g. costing for hidden and visible defects) and the cost for inspections. Estimates suggest that costs for correcting defects may account for up to 6% of the production costs, emphasising the important to gain knowledge about defects in order to prevent them from arise, this include both cost and causes (Josephson and Hammarlund, 1999).

Johnsson and Meiling (2009) investigate the severity of defects in industrialised house construction. The authors suggest that existing defect notations are a neglected source of quality improvement information, which can be used to help realise the benefits of off-site construction. The main reasons for investigating defects are to lower poor quality costs and improve production efficiency, product quality and customer satisfaction.

3. METHOD

This study covers the first step of identifying the requirements of an Inter-Project Inspection Information System (IPIIS). Semi-structured interviews were conducted with seven construction professionals on different positions in construction projects. All the interviews were recorded and transcribed. The interviewees were selected from a convenience perspective with an intention to cover the different project roles that are in touch with final inspections. Semi-structured interviews are characterised by having pre-established questions with opportunities for the respondent to answer from his/her point of view (Norman and Lincoln, 2000), but not being constrained to these as it allows for the interviewer to go into new interesting directions with the interview, modifying it according to the respondent or just having the possibility to ask follow-up questions, or to rephrase the question (Wallén, 1996).

An interview framework of major questions and prompts for topic coverage and probing of respondents was used. During the interviews additional questions were phrased, to adapt to the different project role of the interviewee or the individual respondent. The respondents, what role they represent and their background are summarized in Table 1. The HVAC consultant is also working as a building inspector on HVAC systems. The roles where chosen from the first author's idea about the common project participants and which could gain from an IPIIS, derived from the common roles in a construction project.

Table 1. Summary of respondent's background.

Inter-view #	Project role	Position	Years in company	Years in industry
1	Architect	Construction engineer	13	30
2	Client	Technical manager	2	30
3	Client	Project manager	7	20
4	Client	CEO	7	7
5	Trade engineer	Coordinator technical installations, self-employed	16	34
6	Trade engineer/ building inspector	HVAC engineer, self-employed	1	14
7	Building inspector	Partner of firm	11	35

As a validity measure, every interviewee was asked which other project participant/role they think would gain the most from having a database-based inspection system in the organisation or specific project? This way the list

of interviewees could be extended, if one of the respondents would name a project role outside the initial interview plan.

4. INTERVIEW RESULTS

In this section the results from the empirical study are presented, see Table 2. The results reference the interview numbers according to Table 1.

Table 2. Project participants' view on experience feedback and the possibilities with an Inter-project Inspection Information System.

Interview #	1	2	3	4	5	6	7
1. Where do you acquire new knowledge and experiences?	<ul style="list-style-type: none"> - From within the projects, daily routines in work, - People - Industry news service - Education in new software and similar 	<ul style="list-style-type: none"> - Site visits every day - Meetings with the project managers every now and then enables collecting new experience from the projects 	<ul style="list-style-type: none"> - From “real life” 	<ul style="list-style-type: none"> - Contacts in the industry - Colleagues - Industry newspapers & magazines - I hire the right people 	<ul style="list-style-type: none"> -People; both old and young employees have things to teach each other – fresh ideas against deep knowledge 	<ul style="list-style-type: none"> -From being Project Manager for the installations -Internet -From own experience in the projects 	<ul style="list-style-type: none"> -From the different missions - Information about new regulations, products, material, etc. - guarantee inspection tests new material
2. In what way do you get feedback? Is there a formalised system?	<ul style="list-style-type: none"> - Deviations are continuously reported back to the office during the project, where investigations about causes take place. Often contractor blames design companies for the problem 	<ul style="list-style-type: none"> - Debriefing meeting at the end of most of their projects - Gets feedback from designers and contractors - Ad-hoc e-mail reporting from site during construction 	<ul style="list-style-type: none"> - Debriefing meeting at the end of most of their projects - No technical system -Knowledge network 	<ul style="list-style-type: none"> - Good system for debriefing meetings before, during & after (debriefing) every project, preceded by internal meetings - Central organisation working on IT-based system 	<ul style="list-style-type: none"> - Debriefing meeting at the end of most of their projects 	<ul style="list-style-type: none"> -We get aware of problems & errors right away -The Construction Manager 	<ul style="list-style-type: none"> - Very little - Contr. thanking for a quick delivery of report/punch list and spreadsheet format
3. Use of inspections today	<ul style="list-style-type: none"> - Inspection report according to regulation’s requirements - Report regulates contractual responsibilities 	<ul style="list-style-type: none"> - Inspection report according to regulation’s requirements - Manually harvesting of data for statistics. Number of defects, type, responsible trade are common kind of reported data - Defects stored in Excel files 	<ul style="list-style-type: none"> - Inspection report according to regulation’s requirements - Tenants get copy of report 	<ul style="list-style-type: none"> - Tries to identify systematic defects 	<ul style="list-style-type: none"> - Get inspection report -Rectifies my defects - As a basis for debriefing meetings 	<ul style="list-style-type: none"> - Creates inspection reports according to regulation requirements 	<ul style="list-style-type: none"> - Creates inspection reports according to regulation’s requirements, but with a field-equipped laptop - Delivers documents digitally in spreadsheet + PDF.

<p>4. Which possibilities can you see with an IPIIS?</p>	<ul style="list-style-type: none"> - Contain mark deviations on digital drawings, take photos – useful for re-inspections and contractor’s correcting work - Sceptical about the use of inspection data for experience feedback - Possibilities for follow-up on reoccurring defects – for big contractors - System should focus on the whole quality management chain, not just final & guarantee inspections 	<ul style="list-style-type: none"> - Give feedback to contractors, how’s their quality of work? 	<ul style="list-style-type: none"> - Give feedback to contractors, how’s their quality of work? -Possibility to filter out statistics on specific building object, material, etc. - Contractor could use it while fixing defects - Compare statistics between, or get overview of different local offices - Use data in e.g. material tender 	<ul style="list-style-type: none"> - See total amount of defects - Statistics about time to fix the defects - Easily identify systematic defects - See patterns for contractors, suppliers - See cost for defect rectification 	<ul style="list-style-type: none"> - The inspection report - Experience feedback system - Get statistics before new projects - The systematic defects are the most important to attack - Use on first design meeting -To put focus in quality documents on target areas for improvement 	<ul style="list-style-type: none"> -Sorting defects lists to different trades, or on e.g. “easy” and “difficult” defects -Team of inspectors could concurrently work in the same database/project - Contractors could attest fixed defects directly into database, client can follow status change -Follow status on “design defects” investigations 	<ul style="list-style-type: none"> - Statistics functionality -Recording the character of the defect could be as important as the amount
<p>5. Which are the beneficiary project roles of such a system?</p>	<ul style="list-style-type: none"> -Construction management companies would benefit the most from it in their work, but the big clients will have the most to gain economically. 	<ul style="list-style-type: none"> - The client - The construction management company - The contractor (feedback) 	<ul style="list-style-type: none"> -The client -Contractors (for improvement) 	<ul style="list-style-type: none"> - The client -The Project Manager would have the most to gain 	<ul style="list-style-type: none"> - Project & Design Managers, - Clients 	<ul style="list-style-type: none"> National construction associations, schools, construction education institutes and consultants 	<ul style="list-style-type: none"> (Definitely) The general contractor - site and production managers - the client (in a certain way)
<p>6. What are the concerns one has to consider while designing such a system?</p>	<ul style="list-style-type: none"> - 	<ul style="list-style-type: none"> - We could never use defect statistics about a contractor against them in a tender process² 	<ul style="list-style-type: none"> - Have to keep project data & company secret to “the outside” - The public can’t know of the number of errors in buildings, - Can’t release sensitive company specific data to others than themselves 	<ul style="list-style-type: none"> - 	<ul style="list-style-type: none"> - 	<ul style="list-style-type: none"> -Those not invited to the inspection the first time should not get the data - Need for classification of the project and to anonymise project & participants if need for publication of data externally 	<ul style="list-style-type: none"> - A specific contractor/ trade must only be able to see its own defects -Filling in classification meta-data cannot take more time than today’s insp. procedure -Bonus systems that gets cancelled from too many defects is bad incentive

² This is a public client, meaning it has to abide by the public procurement legislation.

2.4. Where they are today

The first set of questions dealt with where the respondents find knowledge and new experience. All of the participants mentioned the social connection; people (e.g. colleagues, other project participants) as a main source for new knowledge. As #2 explains:

“We get experience from visiting the work sites almost every day. I have meetings with the project leaders every now and then, where we are able to collect new experience from the project”,

and #3:

“New experience is gathered every day from real life.”

Debriefing meetings, held after the projects are finished seem to be the main formal method of experience feedback, from the second sets of questions. Still, they are not always held, the private client (#3 and #4) was the dux, having a system of several meetings both prior, during and past the construction phase. Respondent #3 also recently helped initiate something in their New Production division they call *Knowledge Networks* with all their offices. The architect (#1) also responded that he gets new knowledge from an industry news service, as well as education in new software tools and similar areas of knowledge.

The third set of questions comprises how the respondents used the inspection reports today. Most respondents answered that it was mostly for checking of defects (#6 and #7 being building inspectors themselves), and the reports where all the standard documents required by the standard regulations. Respondent #2 used the reports for manually collecting of defects information for statistics and #5 used it as foundation before conducting *debriefing meetings*. Respondent #1 was overall sceptical that any good knowledge could even be pulled from the inspection reports, stating:

“It is unusual to find any new defects in a final inspection; those things should have been taken care of earlier in the process.”

2.5. Requirements on a possible future IPIIS

The fourth set of questions asked the respondents about their view of the possibilities of an inspection database, and what kind of information it could provide. This is the main research question for his study, and this seemed to be a question that the respondents struggled to answer. However, several mention that they would like to see the system being able to produce the formal inspection report of today, which is natural because that's what inspections have to do. Statistics is another important function most respondents referred to. The respondents all see advantage with the possibilities of automation of the work with statistics on defects.

Respondent #6 would like to see a multi-user system with possibilities to filter data-based type of defect, and on the different trades and inspectors. Furthermore, that the contractors are given possibility to undated defect data (e.g. after fixing the defect) given the possibility to see what defects are more common or which are more expensive. The codification should also reveal if the defects can be referred to as a client responsibility or contractor responsibility and that defects “fall down” to the responsible actor.

Respondent #3 thinks that a system should bring a better overview and be easier to filter defect data on defect type and recurring errors. Also the ability to link different projects from the entire company, to identify patterns in quality problems was a potential benefit. The client (#2) responded only that they are creating a project portal, for all their running projects.

Given that the respondents had information from an inspection system, the fifth set of questions comprised in what way they would use that information. They all replied that there are possibilities with such system:

“It's good to be able to give feedback to contractors, off course, or to suppliers.”

Connecting information from many projects provides the actors' possibilities to follow up problems with large delivery batches with defects. Accordingly, it creates the opportunity to work more together with the suppliers to help them improve their production

“They should have no problem receiving this feedback, if it’s constructive. I guess [every company] want to produce a good project.”

In the case of private clients, the information could also be used during tender for clients, to choose the best bid, a difference from the public client. Furthermore respondent #6 replied that

“Be able to follow the status of defects rectification”

And #5:

“I would use the statistics from the current project at the experience meeting. But also use earlier project’s records at a start-up experience meeting“.

The final set of questions covered what benefit other project members and stakeholders in the construction process could have of information from a feedback system, but also what concerns to consider regarding, for instance, privacy and integrity. The respondents had a similar view on this matter. The inspection reports should not be spread outside the project or the company, but the statistics for the industry could be useful for everyone. If the system filters out identity of the project and its participants it could be distributed to anyone interested. The information from the system could, furthermore, be used by design management, construction managers and clients in general. The respondents also identified organisations dealing with similar matters on national level as potential beneficiaries. Most of the interviewees believe that the system should be best off in the hands of a larger client.

5. CONCLUSIONS

This study aimed at identifying the requirements for a digital Inter-project Inspection Information, IPIIS, i.e. what type of information different roles in a typical construction project would like to extract from the system, in order to enhance learning and feedback in their organisations.

Defects in new buildings are signs of quality problems and the involved project participants therefore need to address this issue. To be able to measure an improvement the method for it needs to be systematic. Lundkvist, Meiling and Vennström (2010) indicated contractors’ lack of a system for supporting experience feedback through building inspection, while inspections was seen as an important source of information among the companies. Similarly, Prencipe and Tell (2001) proposed a framework to analyse and interpret firms’ approaches to project-to-project learning. The brief literature study of this paper supports the idea of a systematic approach to learning and quality improvement. Furthermore, there are existing routines in the Swedish construction process, i.e. compulsory final and guarantee inspections, which can serve as a base for collecting information.

However, this empirical study shows that the respondents have different views of how an IPIIS should be designed. The general view is that a great concern has to be taken about integrity matters and to not let company or project specific information follow the proposed defect statistics into the public. It was of important that the system can produce a formal inspection report and export defect data to an industry standard used today (for example a MS Word document).

In the case of who they think will benefit from the system, the common denominators are both the contractors and the clients, but some also mention the Construction/Project Manager, which usually is a private consultant in Swedish construction projects. In the case of the two out of three that mention C/PM as beneficiary, their company have that kind of business. It’s likely that this is because they know more about their own work than other project roles do, and that they see benefits for themselves that the others don’t.

Summing this up gives an impression that the companies all see benefits for themselves with this system. Interviewees #6 and #7 however, both inspectors, leave this path of the others, meaning they don’t think that this system would gain them more than it cost. It seems like it’s natural for them that others than the inspector itself will gain more from the system; their work is just about finding the defects. They do not think that the activity of inspection will be improved or simplified.

Further research will focus on how to design the IPIIS to address the above mentioned demands on output. As described there are no specific project roles that were identified as the biggest beneficiary of an IPIIS, giving further development a good degree of freedom. An important feature of a future system could therefore be an

ability to extract different kinds of information depending on the specific project role's interest. This also keeps the question of ownership and responsibility for a future system open, while it's important that any system is maintained and developed over time to be attractive to the users. A possibility of having an entirely independent system owner could also be investigated.

The overall impression of this study is that the respondents struggled answering some of the questions, mainly because they had difficulties to understand the whole scope of a database solution and the possibilities with an IPIIS. Most of the answers were based on what they do and know of today, but with some interest in the possibilities with improved statistics. Basically they suggested the use of the same statistics as today, but with improved potential for automation. Similar view is presented by Sower et al. (1999) that, among other things, failure to understand the capability of a system is a barrier to improved quality in construction. Further research in this area has to develop a better understanding between researcher and the identified beneficiaries from this study, and furthermore develop and eventually suggest a graphic model of the system.

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