ANALYSIS OF SUPPLIER QUALITY SURVEILLANCE IN EPC PROJECTS

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ABSTRACT

This paper reports on research conducted by a team of academics and practitioners supported by the Construction Industry Institute that investigated the relationship between rework and effective supplier quality surveillance practices (RT 308). Data confirmed findings from previous studies about project-based systems and the fact that the Engineer-Procure-Construct (EPC) industry and its suppliers share little to no lessons learned from one project to the next. A number of reasons for this behavior are discussed in the paper, including but not limited to lack of time to review past projects, fear of claims and litigation, and lack of structured methods to process and make lessons learned available to others. This becomes a systemic problem for the industry, which does not learn from past experiences accumulated from multiple contracts and continues to rely on lengthy specifications and hours of surveillance to assure that products conform to the design intent. The paper concludes with a discussion of the ways Lean concepts could be used to improve the current status of surveillance practices used in the EPC industry while addressing its peculiarities and the risk associated with different products and services acquired.

KEYWORDS

Supplier quality surveillance, inspection, lessons learned, criticality, engineer-procure-construct.

INTRODUCTION

This paper reports on research being conducted by a team of academics and practitioners supported by the Construction Industry Institute that is investigating how to achieve zero rework through effective supplier quality surveillance practices (RT 308). The paper continues the discussion about this topic started in an IGLC paper published last year (Alves et al. 2013) and adds new data and findings regarding the role of inspection in project-based systems in the Engineering-Procure-Construct (EPC) industry.

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The Lean community usually views inspection and supplier quality surveillance as wasteful activities; however, the risks and associated consequences of non-conformances (NCs) can be extremely expensive and even catastrophic in large EPC projects (Ahmad, 2013).

Non-conforming items and resulting corrective actions are handled differently depending on the criticality of the item or project. For instance, the nuclear industry has a well-defined set of procedures to deal with activities and products needed in their projects (Singer et al. 1989, 1998); also the type of contract used might influence how NCs are dealt with (Ferreira and Rogerson 1999). Handling NCs can also be regarded as rework (CII, 2005) that might include engineering or design changes. Documenting reasons for NCs and creating a feedback system or a lessons-learned program can help prevent making the same mistakes again (CII, 2007).

There is a consensus among researchers that no single quality management (QM) standard or certification by itself will yield the highest levels of quality (CII, 2010a, 2010b, 2005, 1998; Tommelein et al., 2003; Ferreira and Rogerson, 1999; Willis and Willis, 1996). High quality levels and competence are only achievable when the organization utilizes multiple QM standards, procedures, and strong management support for quality across all levels of the supply chain. Performing periodic audits, obtaining certifications (such as ISO 9001) and conducting inspections without any other considerations for quality are simply not enough (Soltani et al., 2010). Furthermore, Alves et al. (2013) argue that the inspection process is considered as a non-value adding process from a Lean Construction perspective and that simply conducting inspections does not ensure quality. “Rather, processes could be designed to prevent errors at the source with the use of poka-yoke devices, standard operational procedures and standardization to quickly detect deviations, and peer inspection to avoid an additional layer of inspection” (Alves et al. 2013, p.834).

Engineered to order (ETO) materials usually have more detailed requirements, which influence their procurement, design, fabrication, and installation. ETO items are typically very expensive and must be carefully engineered, transported, and installed to prevent any rework. However, less-complex (in terms of engineering and design) items such as fabricated to order, assembled to order, bulk, stock, or commodity items should not be underestimated. DODIG (2012), Melo and Alves (2010), Tommelein et al. (2003, Ch.9; 1998), Thomas et al. (1999), and Tommelein (1998) provide case studies for cables, wooden doors, pipe supports, structural steel, and pipe spools exemplifying the difficulties involved in managing these kinds of items. Keeping in mind that a typical project might involve the purchase of hundreds or thousands of similar items, these case scenarios provide examples of problems including, NCs, matching and standardization problems, fabrication errors, and tracking and delivery methods unique to these types of items and material.

Incorporating quality in the production process, such as stopping the production line when a problem occurs, will prevent defective material from advancing in the production line and also help detect similar problems that could occur in the future. The concept of *poka-yoke* developed by *Toyota* (and implemented by Lean Construction) is a method of incorporating quality in the production process in order to minimize behavior/worker related mistakes. Poka-yoke can be interpreted as a fool-proof, mistake-proof, or fail-safe device that help reduce mistakes caused by incorrect performance by workers (Santos and Powell, 1993; Sadri, 2011). Although poka-yoke devices yield good fail-proofing results, Santos and Powell (1993) concluded that the construction industry rarely uses poka-yoke devices to reduce variability. Deming (1982) suggests that companies should stop depending on inspection to improve quality because inspection is expensive, unreliable and does not guarantee that a high quality product will be produced. Deming argues that quality should be built into the production process and not achieved through the activity of massive inspection. However, even after stating all the deficiencies of inspection, Deming suggests that inspection remains a necessary activity because it is required to maintain control over the production process, and even under certain circumstances, 100% inspection might be required.

RESEARCH METHOD

In this paper, the relationship between supplier quality practices deployed by owners and contractors in suppliers' facilities and the criticality of the products supplied is examined using data from collection of detailed data on specific purchase orders, focus groups, and interviews with CII member companies and their suppliers. Validation of the findings was done throughout the research effort by sharing data with practitioners who are part of the team, incorporating their comments and addressing their concerns throughout the data collection and cross-analysis.

DATA COLLECTION – PURCHASE ORDER INSTRUMENT

The Purchase Order (PO) Instrument consisted of an online data collection instrument that was anonymously answered by owner-companies, contractors, and suppliers. As indicated by its name, the information used to complete the data collection instrument came from purchase orders for four different types of material; tagged/engineered equipment, fabricated goods (structural steel and pipe spools), and manufactured/bulk goods (non-engineered/bulk valves). Subject matter experts (SMEs) believed that these products provided a fair representation of the various material types found in EPC project, with respect to the product design, transportation complexity, cost, criticality, and distinct levels of inspection and surveillance. A copy of the PO instrument was not included here due to space restrictions but can be found in Neuman (2014).

The PO Instrument was designed to collect data on current supplier quality practices at different phases of the supply chain, and determine how these practices help deliver high quality products and minimize rework. The PO Instrument used the supplier quality process map (SQPM) described by Alves et al. (2013) as a baseline to address the different phases involved in the process of procuring materials from the supplier's shop to the project site. The phases include an assessment of criticality, supplier selection, execution of the work, delivery to the job site, installation, and acceptance at mechanical completion. This team did not consider the portion of the project after mechanical completion because of the availability of data. Certain quality concerns might not surface until a later stage. The quantitative data collected allowed for statistical assessment of the practices employed. Practices of interest include resources (cost and hours) spent inspecting, implementation of a quality control plan, communication (meetings) with suppliers, assessments of supplier performance, and use of registered/certified suppliers amongst others.

An online version of the PO Instrument was developed and thoroughly tested for system bugs, correct preferences, and navigation options. RT 308 industry members were asked to share and circulate the PO Instrument with other companies and their personal connections as an effective way of encouraging people to participate in the study. Participating companies provided confidential data in the PO Instrument; therefore, keeping all the information confidential throughout the data collection and analysis process was of utmost priority. Submissions were reviewed, modified by the participant when incomplete information was detected, approved, extracted from the online database, and placed in a local database. All identifying information was stripped before any statistical analysis or observation was performed. The software used for statistical analysis was IBM SPSS V.21 (IBM, 2013).

DATA COLLECTION – SUPPLIER FOCUS GROUPS

Academics from RT 308 conducted focus groups with suppliers to gather their perceptions about Supplier Quality Management (SQM). The academics asked the SMEs to refer organizations that supply products and services to the local and global construction market and contacted the suppliers by email to arrange the focus groups.

The main objectives of the supplier focus groups were to: gather suppliers' perceptions about the current state of quality assurance/quality control (QA/QC); identify best practices related to QA/QC currently used in the EPC industry; and develop a "supplier wish list" with practices conducive to zero rework. The questions asked in each phase of the meetings with suppliers were the following:

- Phase 1: How is QA/QC currently performed in your organization and your suppliers?
- Phase 2: What are the best practices related to QA/QC you commonly find in the industry (organizations you work with)?
- Phase 3: What would it take for you to meet all applicable requirements contained in an order without rework? (i.e., What suggestions do you have to help suppliers achieve zero rework at the site?)

Three focus groups were conducted, two in Houston and one in Tulsa, with eleven participants representing a total of nine suppliers. These suppliers have been active in the EPC industry for an average of 49 years. These nine suppliers range in size, with the number of employees ranging from 90 to 9,000, and annual sales raging from 60 million to 3 billion US dollars.

DATA COLLECTION – STRUCTURED INTERVIEWS

Interviews were conducted with six contractors from RT 308 on a voluntary basis using a structured interview data protocol. Three interviews were conducted face-to-face and the other three by phone. The interviewees have expertise in various quality management functions including procurement, project services and inspection, supplier quality and material planning, and operations and quality management. The main goal of the interviews was to learn about current SQM practices implemented by the contractors. The interview questions were grouped into seven sets comprising the following areas: Supplier quality organization, Supplier quality systems, Metrics for supplier performance management, Supplier performance documentation, Assessment of the SQM, Supporting documents to serve as evidence for the practices implemented, and Quality assurance for sub-suppliers. To see the complete structured interview instrument, refer to (include citation).

ANALYSIS OF DATA

Results from the survey, focus groups and interviews are discussed. Cross analysis is used for validation to synthesize and report on the main research findings.

RESULTS – PURCHASE ORDER INSTRUMENT

A total of 108 Purchase Orders (POs) were collected using the PO Instrument. The percentages presented in this section were derived from responses to questions in the PO Instrument. The percent response for each material was: tagged/engineered equipment 31%, structural steel 27%, pipe spools 21% and non-engineered/bulk valves 20%. Every PO was assigned by respondents a criticality level, which indicates the urgency or risk associated with the procurement of the PO. Each company assigns this criticality level differently; they typically take into account the cost, schedule, and quality of the product or material. The respondents were asked to map the criticality level that they had assigned to a 4-tier scale, with responses distributed to low, medium, high, and critical, by 16%, 38%, 27%, and 19% respectively.

Regarding the amount of time that a person was assigned to observe work in a supplier's facility, the PO Instrument results shows that the majority of the responses (39%) indicated that staff is assigned *occasionally, randomly, or periodically* for only a certain amount of time or days out of the whole fabrication process. This is different from a *part-time* (19%) assignment were a person might inspect the work every day only for a few hours, and *full-time* (14%) when someone is assigned as a resident inspector at the facility. When the material is low criticality, responses indicated that 53% of the time there is *no inspection at all* and never (0%) a *full-time* inspection. This result also corresponds to the low-criticality bulk valves, showing no (0%) *full-time* inspection and 36% for *no inspection at all*. When materials are medium, high, and critical levels, such as tagged/engineered equipment, structural steel, and pipe spools, the materials are evenly distributed around 40% under the *occasionally, randomly, and periodically* inspection category.

When a person is assigned to observe work, they can track the inspection effort by keeping track of the cost used for inspection, the hours inspected or both. Data shows that 53% of low criticality items are not tracked for cost or hours during the inspection effort and 41% of bulk valves are not tracked either. High criticality items are tracked for both, hours and cost, for 57% of the POs but still in 15% of the POs neither cost nor hours are tracked. This does not imply that an inspection was not performed, it only means that the inspection effort was not tracked. By not tracking, companies might lose the opportunity to learn how much is spent on their surveillance effort and to identify potential causes for more/less inspection.

Companies can perform inspections via two different types of inspection personnel: contract or staff. They can also have both types of personnel or not conduct any type of inspection at all. When the inspection personnel are parsed by criticality level and by material type, the highest percentage under the *no inspection* category is for low criticality (53%) and bulk valves (36%). Another interesting result is that a significantly higher percentage (48%) of responses for tagged/engineered equipment fall under the category *for both (contract and staff)* personnel. This might be related to the fact that tagged/engineered equipment is often more complex and/or critical in nature and requires a greater number of qualified inspectors that belong in both groups in order to be built and installed when compared to the other materials analyzed in the survey.

The preceding discussion examines different inspection and surveillance practices and how they differ with criticality and material type. Next, the level of communication between owners, contractors, and suppliers is examined by analyzing the amount and type of meetings held between parties during the project.

According to subject matter experts (SMEs), there are typically five different types of meetings related to the quality function that occur at different times along the lifespan of a purchase order. The list below shows the types of meetings indicated by SMEs and the percentage of POs that reported this type of meeting. Note that the percentages add up to more than 100% since respondents could select more than one meeting for each PO.

1. Pre-award meetings related to the quality function (46%)
2. Post-award, pre-execution meetings related to the quality function (29%)
3. Pre-inspection meetings (65%)
4. Meetings during execution related to the quality function (53%)
5. Lessons learned meetings after execution to discuss quality outcomes and potential improvements (17%)

These data regarding meetings are used to indicate the level of communication between clients (contractors and owners) and suppliers. More meetings implies there is more communication between parties.

It was surprising to learn that on 10% of the POs, respondents indicated that no meetings were conducted at all. SMEs explained that when products had low criticality levels and/or when suppliers had been previously employed with successful delivery, there might not be a need to schedule meetings to discuss quality; the reputation and in-house quality overseen by the suppliers might be sufficient to achieve a high quality product. Figure 1 shows the responses regarding meetings parsed by criticality level. Notice that the highest percentage for the *No Meetings* category corresponds to the lowest criticality items, which validates the explanation provided by the SMEs. Furthermore, it should be noted that in Figure 1 less than 10% of the responses under the *No Meetings* category are for medium criticality and there are no responses for high or critical items here, meaning that at least one type of meeting was conducted for high and critical items.

SMEs argued that meetings during execution are typically conducted when there is a problem with the item being procured, such as scheduling or cost-related problems, and problems related with the specifications or plans. Figure 1 shows that the amount of *meetings during execution* increases as the criticality level increases. This is also true when the meetings are parsed by material type (Neuman 2014). More complex and higher criticality items such as tagged/engineered equipment and structural steel also have a higher percentage of *meetings during execution* than pipe spools and bulk valves, which typically have lower criticalities.

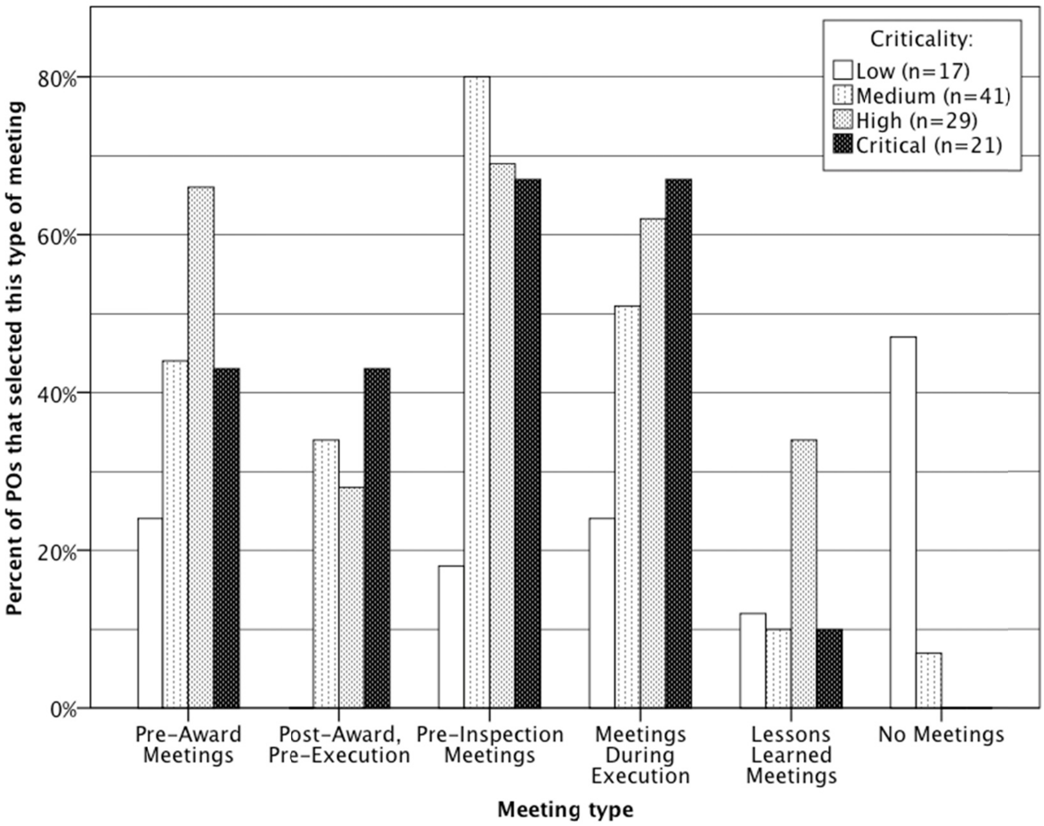

Figure 1: Meetings related to the quality function (parsed by criticality)

SMEs argued that lessons learned meetings are typically conducted for higher criticality items and especially when a lot of problems occur in the project, but they can also be conducted to document effective practices that helped improve the project. In theory, the findings and issues discussed during the lessons learned meetings are thoroughly documented and easily accessible in the future by others to prevent the same problems from occurring (or to implement effective practices) in future projects. However, SMEs argued that this is not what occurs in reality. SMEs highlighted that issues or problems found and discussed during a lessons learned meeting are not typically shared with other parties outside their own company, out of fear of potential future litigation.

SMEs also pointed to the lack of documentation or ease of accessibility of any information emerging from lessons learned meetings (or post-project completion assessment) in the future, even within the same company. SMEs argue that the only people that benefit from any findings or conclusions from a lessons learned meeting are the individuals who worked on the project (they refer to this as "tribal knowledge") that is kept only by these individuals as they work and gain more experience through the years. When these individuals retire from the company they take their "tribal knowledge" with them without the possibility of sharing their knowledge with the succeeding individuals that will replace them. CII (2007) provide details on how to design and implement lessons learned program to address the problems just mentioned.

RESULTS - SUPPLIER FOCUS GROUPS

The results from the supplier focus groups were arranged into three main categories, current practices of supplier quality, current state-of-the-art practices (best practices) in the EPC industry, and practices that suppliers believed would help them achieve zero rework.

For *current practices of supplier quality*, suppliers described current practices of supplier quality in the EPC industry. Suppliers indicated that project specifications and POs are received from different sources, including the project owner and contractor, and sometimes the information and requests contained in these documents do not match. With regards to feedback, suppliers reported that in some cases NCs are only known after the product has already been shipped. In addition, suppliers mentioned, the personality of inspectors may affect the feedback process, as some inspectors might be combative and not immediately share with suppliers when problems are discovered delaying the process to correct problems and avoid rework.

For *current best practices in the EPC industry*, suppliers provided examples of best practices, currently adopted by some of the organizations in the EPC industry which suppliers believe that have a positive impact on SQM. Since these practices are not widespread among EPC contractors some of them might also show up in the suppliers' wish list. For instance, regarding project specifications, several contractors provide clear specifications to their suppliers. These contractors also have effective supplier quality management (SQM) systems and use NCs as a learning opportunity to develop and train the suppliers, ensure top management involvement, and establish strong supplier partnerships. These contractors use examples from other industries that have effective SQM practices such as automobile manufacturing to develop their current practices.

For *practices that would help suppliers achieve zero rework (suppliers' "wish list")*, suppliers identified a number of practices that would help them achieve required levels of quality. A basic request from suppliers is that they would like the PO to match the request for quotation (RFQ) and receive only the relevant product specifications up front so that the bids they submit can be more accurate and reflect the desired levels of surveillance and final quality of products desired by customers. In addition, standardized and updated specifications are critical for the success of projects. They reported that some contractors use specifications that are more than 30 years old. With regards to feedback, suppliers believe that avoiding delays in feedback will improve the quality of their work. To improve the Quality Management System (QMS) they use, the suppliers determined that they need to conduct joint quality planning with contractors and owners.

RESULTS – STRUCTURED INTERVIEWS

The effectiveness of the supply chain organization in managing the supplier quality process (SQP) was examined with contractors during the structured interviews. A short summary of the most important findings is presented here and additional details can be found in AlMaian (2014). In general, contractors who effectively manage the SQP indicated that they place importance on the supplier selection process and have more involvement from top management in supplier-related decisions. In addition, these contractors mentioned that they have clear plans for supplier inspection efforts based on the criticality of items being supplied (i.e., more resources are used to inspect critical items). Effective contractors also use databases to track supplier performance, constantly measure supplier quality, and provide suppliers with feedback as quickly as possible. These practices improve communication with suppliers, increase transparency, and result in shorter cycle times between detection of NCs and corrections, and the propagation of waste throughout the SQP.

With regard to the difficulties in managing supplier quality, contractors reported that managing low cost suppliers in the global market is challenging due to many issues including, but not limited to, cultural differences. This difficulty increases if there are multiple tiers of suppliers. Some contractors reported that they assume that suppliers are responsible for managing their sub-suppliers. One approach that contractors use to alleviate the problem with multi-tiered and geographically dispersed supply chains is providing training to suppliers and sub-suppliers. Additionally, contractors try to make sure that the project specifications are clear and known to all the tiers of suppliers involved in the project (i.e., contractual clauses and specifications flow down to sub-tiers).

CROSS ANALYSIS

One of the principal topics discussed in the focus groups and structured interviews is the topic of implementing an effective feedback system such that, lessons learned, post-project completion assessments, reasons for NCs, and effective practices can be shared and used as a learning tool. The PO Instrument results show that *lessons learned* meetings were conducted for only 17% of the POs submitted, yet participants in the focus groups and structured interviews stressed the importance of conducting lessons learned meetings. Suppliers reported that feedback provided by contractors and sharing the results of the performance ratings and lessons learned conducted would help suppliers improve their work.

According to discussions held in the focus groups and structured interviews, an effective inspection effort and tracking and documenting the results of the inspection effort are also important aspects of a good feedback system. The PO Instrument results show that high criticality items were tracked for both, hours and cost, for 57% of the POs but still in 15% of the POs neither cost nor hours are tracked; keep in mind that if hours or cost are not tracked it does not imply that an inspection was not performed, it was simply not tracked. Furthermore, when the material is low criticality, over 50% of the POs were not inspected at all and never (0%) inspected full-time. Suppliers argued that highly effective companies put together workable packages of standards and specifications and determine the required level of inspection based on the criticality of the item. During the inspection efforts, these companies not only focus on tracking the hours used for inspection but they also make the inspection effort a learning opportunity for the suppliers. The PO Instrument results, and the discussions that occurred during the focus group and interviews advocate a need to revise the inspection methodology and track it as a feedback tool for learning.

It is more likely that a NC found early in the manufacturing process, in the supplier's shop, will cost less to correct than if the item is found defective in the field. One way of finding NCs earlier is to implement a proactive approach to quality instead of a reactive approach to quality. The results show that 46% of POs included pre-award meetings and 29% included post-award, pre-execution meetings related to the quality function with the supplier. During the interviews, suppliers emphasized their preference of holding upfront meetings for joint quality planning with the goal of improving the quality of products and services. Suppliers also welcome the idea of holding quarterly reviews. Upfront joint quality planning is a proactive approach to deal with NCs, which can significantly reduce the cost of finding and correcting NCs. In the end, one must manage the delicate balance of cost, schedule and quality, as the three are highly interdependent.

POTENTIAL USE OF LEAN CONCEPTS TO DESIGN EFFECTIVE INSPECTION SYSTEMS

Implementation of widely known Lean Construction practices such as the use of poka-yokes, and principles such as increasing transparency, reducing cycle times, reducing the share of non-value-adding activities, continuous improvement and increasing value by systematically considering client's requirements (Koskela 1992) can be used to design effective inspection systems. It is not expected that inspection activities will be entirely banished (especially in-process), but they could be reduced, made more efficient by design, and surveillance would be used to assure the quality of critical items where the likelihood of failure can yield serious consequences. By systematically considering the client's requirements during fabrication, inspection plans can be customized to specific materials and criticality levels, and be designed jointly by the client (owner/contractor) and supplier.

Some Lean practices to design effective inspection systems would include a proactive approach instead of a reactive approach to deal with NCs by implementing poka-yoke strategies and front-end quality planning. As suggested by suppliers, and confirmed by the interviews and the PO instrument results, transparency can be increased in different ways by: implementing constant and open communication between suppliers and clients; removing non-relevant sections from specifications provided to suppliers and only including sections relevant to the supplier's work; making sure that documents and POs received by the supplier from the owner or contractor do not contradict each other; and making sure that POs reflect the same information as the original request for quotation (RFQ) and clearly reflect the desired levels of surveillance and final quality of products desired by the client. Improving communication directly increases transparency in dealing with suppliers and would also contribute to shortening the cycles of correction and detection of NCs, and the time suppliers waste dealing with cumbersome specifications, thus reducing non-value adding activities throughout the entire supplier quality process. This would also be conducive to continuously improving the supplier quality process as those involved would constantly learn about their performance and how well they are meeting client requirements. Continuous improvement can be achieved with effective feedback systems, e.g., implementation of an effective lessons learned program were problems such as reasons for NCs and effective practices are carefully documented and shared between parties without fear of claims and litigation (see CII (2007) for details).

CONCLUSIONS

This paper continued the discussion started in Alves et al. (2013) and adds new data and findings regarding the role of inspection in project-based systems in the EPC industry. Research findings were augmented by comparing results obtained with the PO Instrument, focus groups, and interviews involving owners, contractors, and suppliers. The paper concludes that although activities associated with inspection and supplier quality surveillance are seen as wasteful activities by the Lean community, they are necessary, especially for critical items. Additional findings suggest that supplier quality surveillance (SQS) practices investigated in the EPC industry vary across the industry. Moreover, a great deal of waste found in the supplier quality process can be attributed to miscommunication (e.g., documents with unnecessary information, lacking information needed for fabrication, or outdated/mismatched specifications) and lack of feedback systems (e.g., lessons learned systems/meetings, tracking and sharing timely data about performance). In this environment, several Lean principles can be used to design effective inspection systems including the implementing poka-yoke strategies, increasing transparency, reducing cycle times, reducing the share of non-value adding activities, and improving value through systematic consideration of client requirements as discussed.

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