

# SUPPLIER QUALITY SURVEILLANCE PRACTICES IN CONSTRUCTION

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## ABSTRACT

Construction processes require the marshalling of resources to install components of the intended structure into the desired location based on design documents, with all the necessary structural and service connections. Construction management activities are often conceived as the facilitation of having the right labor and equipment in the proper location with the correct components, at the proper time, to allow safe and cost effective progress of the work. To avoid rework associated with the installation of project components that turn out to be deficient, general contractors deploy a number of efforts to assure the quality of components procured for the project. This paper will provide a summary of Supplier Quality Surveillance (SQS) practices in common use in major construction companies, primarily in Engineer-Procure-Construct (EPC) delivery projects in the process chemical industry. At present, SQS practices are rooted in an inspection culture, with a series of largely adversarial interventions conducted most commonly either at the supplier's manufacturing or fabrication facility, or at the construction site itself. The SQS practice will be analyzed from a lean perspective to suggest potential alternative processes to assure supplied components can be installed into the project in an acceptable condition to provide expected client value.

## KEYWORDS

Supplier quality surveillance, Engineering-Procure-Construct (EPC), value stream, manufacturing, supply chain management, lean construction.

## INTRODUCTION

Construction processes require the marshalling of labor and equipment resources to install components of the intended structure into the desired location based on design documents, with all the necessary structural and service connections. Construction management activities are often conceived as the facilitation of this process, or in

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other words the facilitation of having the right labor and equipment in the proper location with the correct components, at the proper time, to allow safe and cost effective progress of the work. If there are quality deviations of the component to be installed, then no matter how well designed the installation effort may be, the result will be deficient, and rework of some sort will result. This rework could consist of replacement or repair of the deficient component, engineering rework to design a work around, or client acceptance of a less-than-desired component. Any of these cases represent waste, either in effort or in diminution of the client's expected value.

To avoid rework associated with the installation of project components that turn out to be deficient, general contractors deploy a number of efforts to assure the quality of components procured for the project. This paper will provide a summary of these Supplier Quality Surveillance (SQS) practices in common use in major construction companies, primarily in Engineer-Procure-Construct (EPC) delivery projects in the process chemical industry.

At present, SQS practices are rooted in an inspection culture, with a series of largely adversarial interventions conducted most commonly either at the supplier's manufacturing or fabrication facility, or at the construction site itself. SQS practices introduce a number of stoppages in the production process via so-called hold points and witness points, focused on the identification of non-conformances. In some cases, the identification of non-conformances triggers a process improvement effort, but at present, project-based consideration of non-conformances often limits cross-project learning, thus the cycle of rework may continue. The SQS practice will be analyzed from a lean perspective to suggest potential alternative processes to assure supplied components can be installed into the project in an acceptable condition to provide expected client value.

## **SUPPLIER QUALITY SURVEILLANCE IN EPC PROJECTS**

Surveillance is defined as “(t)he continual monitoring of a process; a type of periodic assessment or audit conducted to determine whether a process continues to perform to a predetermined standard” (Quality Progress, 2002, p.59). Quality surveillance is defined as “(o)ngoing monitoring and verification of the status of conditions, methods, procedures, and products, and analysis of associated records to ensure that the established requirements are being complied with.” (www.businessdictionary.com, 2013). SQS is a process that not only crosses the boundaries of different organizations in a supply chain (SC), but also crosses geographical and cultural boundaries that directly influence how products are inspected, organizations are audited, and products are delivered.

The inspection process is usually considered to be a non-value added process by lean practitioners. It may be a required step per the contractor, but inspection itself 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.

However, the one-off nature of EPC projects require that organizations develop SQS plans capable of dealing with unique features specified by different owners and contractors in industries with various levels of criticality requirements (i.e., the more critical the product supplied, the more surveillance will be required). Often times,

plans are defined to address single products that have been engineered for a particular project and are not fabricated in large quantities (Singer et al. 1988). Based on an ongoing data collection effort about the SQS process in EPC projects, the authors estimate that product costs might be increased by as much as 25% given the requirements related to SQS. This number represents an immense potential for improvement as the surveillance process could be streamlined to match the needs of demanding clients and projects in areas such as oil and gas, nuclear, and petrochemical industries where mitigating large risks far outweighs the cost of surveillance.

Problems related to the SQS in EPC projects include feedback between organizations, multiple audits, traditional construction practices of the industry rooted in inspection, and multiplicity of requirements and standards. Gathering information about the products supplied and their performance depends on feedback coming from relatively small samples making it difficult to understand how errors and failures occur and propagate throughout the SC (Singer et al. 1988). SQS practices reflect the lack of trust and collaboration among SC participants. Moreover, the multiplicity of standards adopted by participants in different industries and the language contained in contracts, design documents, and standards leave room for interpretation, which is detrimental to achieving a precise outcome (Singer et al. 1989).

### **DEVELOPING LEAN SUPPLIERS AND MOVING AWAY FROM SQS**

Womack et al. (1991, p.145) point out characteristics of the ‘mass-production supply system’ which could as well describe the EPC environment:

*“The suppliers are brought in late in the design process and can do little to improve the design, which may be hard and expensive to manufacture. They are under intense cost pressure from a buyer who does not understand their special problems. As a result, implausible bids win contracts, followed by adjustments, which may make the cost per part higher than those of realistic but losing bidders. This process makes estimating costs accurately difficult for the assembler. Moreover, the effort to play bidders off against each other makes them very reluctant to share ideas on improved production techniques while a part is in production. In other words, they have no incentive to merge their learning curves.”*

In contrast, suppliers working in a Lean environment operate within a different set of rules. Selection criteria are often based on suppliers’ past performance and the relationship they established with clients, their willingness to work with the client to track the causes of problems and prevent their recurrence, the sharing of production costs and quality issues with the client, and ultimately, the ability to develop collaborative relationships over the long run (Womack et al. 1991). Liker (2003, p.40) summarizes the treatment given to suppliers in a Lean environment as one of the principles of the Toyota Way: *“Respect your extended network of partners and suppliers by challenging them and helping them to improve.”* According to Liker (2003) suppliers are viewed as extensions of businesses and are challenged and helped by the clients, and should be fully integrated into the product development system early in the life of the product (Morgan and Liker 2006).

At Toyota, suppliers are organized in tiers which depend on the products they supply and the type of relationship required to develop and manufacture these products. Partners are suppliers who have guest engineers at Toyota working collaboratively with Toyota employees for 2-3 years to design products. Mature suppliers are those who have strong capabilities but depend on Toyota’s guidance to

develop their products. Consultative suppliers are commodity suppliers who can also offer innovations to products currently used. Finally, Contractual suppliers provide “parts that do not require a major partnership (Morgan and Liker 2006, p.183-185).

Research in the construction industry has underscored the management of supply chain relationships as a determining factor of project performance (Meng 2012). When supply chain relationships deteriorate, project cost and time performance suffer. Quality defects can be reduced when problem solving mechanisms, which identify potential areas of concern early in the project life, are jointly defined and executed by the involved parties.

## **RESEARCH METHOD**

The study of SQS practices in the EPC industry is being carried out by Construction Industry Institute’s (CII) RT308, Achieving Zero Rework through Effective Supplier Quality Practices. The research team includes approximately 20 people comprised of the authors of this paper and a team of industry practitioners including owners, contractors, and suppliers (Subject Matter Experts or SMEs) who work for CII’s member companies. The subject of this paper is organized around a Supplier Quality Process Map (SQPM) which was developed iteratively over a period of time by collecting information via a series of face-to-face meetings, site visits, and documents provided by members of RT 308. To confirm the accuracy of the map, face validity (i.e., industry practitioners who are part of the team reviewed the map and provided opinions) was used.

During the development of the SQPM, five main areas of the process were identified: **Planning and Selection, Execution, Release from Shop, Received at Site, and Mechanical Completion**. SMEs emphasized the need to study these five stages for several reasons. These areas are important steps in the SC for EPC projects and they also act as gateways where observations are made and/or problems are detected along the value stream. To support the development of the SQPM, documents were collected (e.g., purchase orders, non-conformance reports, corrective action reports, daily reports) which illustrate activities developed in each of the stages depicted in the map. The first two stages of the SQPM focus on the supplier selection process, and the development and execution of a quality plan. The subsequent three stages are designed to track a package (i.e., product purchased) from the shop, to the site, and after mechanical completion. In this context, Mechanical Completion can be defined as “Unit is essentially complete for start-up operation and test run. All major work is completed. Minor work not interfering with operation may not be completed, such as punch list and minor touch-up work.” (Dictionaryofconstruction.com, 2013). Obviously, the client’s primary interest is in the performance of the element after startup and during the service life; this project focuses only up until mechanical completion as a first study of the issues largely because of the availability of performance data up to that point in the process.

## **SUPPLIER QUALITY PROCESS DESCRIPTION**

This section provides a summary of research findings to date regarding the SQS in the EPC industry. Figure 1 depicts key elements of the SQPM including all five major stages of the overall process. These are boxed and numbered for easy reference. First, the assessment of criticality stage is briefly discussed. Next, stages 1-2 illustrating the

supplier selection process and the development of a quality plan are presented followed by stages 3.1-3.3, which pertain to important milestones where the measurement of production process quality occurs.

### **ASSESSMENT OF CRITICALITY**

For the purposes of this discussion we will assume that the process starts for a given project in the upper left-hand corner of the process map, with an assessment of criticality. For elements of a project, make or buy decisions are made by the contractor, and some (typically large) fraction of the project will be purchased. That portion of the project which will be purchased will be divided up into a large number of packages. For each package that must be purchased, a level of criticality will be determined. This assessment may be designated using a variety of different scales, such as Critical, High, Medium, or Low. Higher levels of criticality would typically be assigned to packages based on an assessment of characteristics such as the impact of late or nonconforming delivery on the project schedule, the cost of the package, the importance of the package to the overall functioning of the finished project, the perceived sophistication of the available suppliers of the package, among other factors.

### **STAGES FOR SUPPLIER SELECTION AND QUALITY PLANNING**

Once the levels of criticality are defined, the process progresses as illustrated in Figure 1 and described in the following sections.

#### **1. Planning and Selection**

Once a criticality assessment has been made for each package, the available supply base for the package can be assessed. If the supply base is deemed to be large enough, then selection can move forward. This would occur when the contractor has experience with a sufficient number of suppliers they deem capable of providing that package at an acceptable level of quality. Sufficient numbers in this context would usually be determined on the basis of the likelihood that competition among the suppliers will produce downward cost pressures.

If the supply base is not deemed to be large enough, then it is necessary to qualify new suppliers (the arrow labeled “Yes” on the left side of the figure). The supplier’s financials will be reviewed, in an attempt to protect the project from the potential of a business failure in the supplier organization interrupting the supply chain for the project or the ability of the supplier to warrant the package. The supplier’s quality control practices will be assessed, in order to determine if they are capable of achieving the quality needed. The packages that a given supplier is capable of producing will be listed, and matched against the needs of a given project. Additionally, the supplier’s available capacity must be assessed, in order to determine if they can provide a sufficient quantity of the package to support the project, without overburdening their production resources and putting undue pressure on their quality assurance systems. If the contractor has experience with this particular supplier on past projects, this will provide additional data for use in qualifying a given supplier.

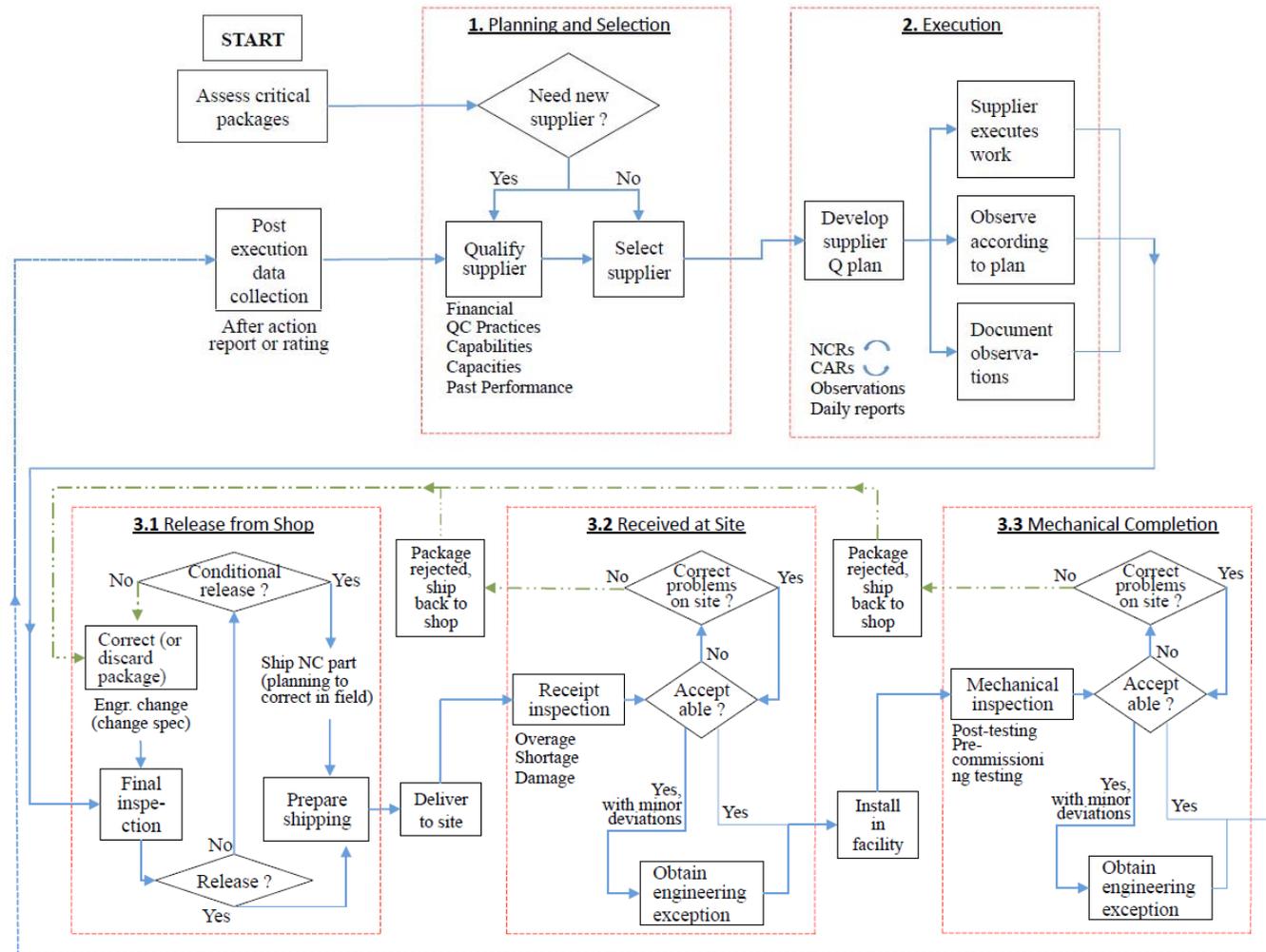


Figure 1: Supplier Quality Process Map

A few notes should be provided for the qualification process. The process is ongoing for many types of packages. New suppliers may approach the contractor for the purpose of obtaining a new client, and this contact is not necessarily spurred by the recognition of a particular upcoming project on which their products might be used. Contractors perform these assessments regularly for the purpose of building, broadening, and diversifying their supply bases.

The qualification process could be triggered by a particular project, however. For example, work in a given country may require that particular portions of the work, or some fraction of the work, be locally sourced. This requirement may compel a contractor to qualify new suppliers in that specific geographic area, if their portfolio of projects in that area is limited. Alternatively, a given project may involve packages associated with new process technologies to be used in the completed facility. That said, the qualification process may or may not be specific to a given upcoming project.

The depth or intensity of the qualification process can vary dramatically depending on the level of criticality of the packages that will be provided by a given supplier. More critical packages will involve much higher levels of scrutiny. A supplier who provides low criticality packages may be asked to provide documents, and to comply with certain industry standards. Critical package suppliers would receive much greater scrutiny, including perhaps site visits, lengthy and detailed discussions of their quality processes, and more.

Suppliers are selected using processes developed by the contractor over a lengthy period of time. Selection is usually made on the basis of a combination of the price offered by the supplier and the contractor's assessment of the data unearthed during the qualification process. It is outside the scope of the research to provide guidance on this portion of the process, but certainly the expected quality performance of the supplier must be a part of the selection criteria.

## **2. Execution**

Once the supplier has been selected for a given package, the contractor and the supplier will work together to develop a Supplier Quality Plan (SQP). The more critical the package, the more time it may take to develop the SQP. An Inspection and Testing Plan (ITP) will also be developed to lay out the specific processes to be deployed by the two parties. The ITP will commonly describe the contractor's intended level of scrutiny (e.g., full-time in-shop observation, regular part-time observation, periodic visits, random visits, etc.), inspections and tests that must be performed at different points in the process, certifications that must be provided, and the standards that must be met before elements of the package can be released to ship from the supplier's facility. The ITP will often describe points in time at which production might be halted so that inspectors can examine activities and verify characteristics. "Inspection points" may be specified, which are stages in the production process where the supplier must wait for the contractor to make an inspection of the partially completed package before they may continue production. "Hold points" are stages at which production may be held for the contractor to observe the partially completed package. "Witness points" are points in the production that may not go forward without providing the contractor an opportunity to witness the next stage of production. Typically, a more invasive ITP will be developed for more critical packages.

Once the ITP has been developed, the supplier is permitted to begin production at an appropriate point in time to allow the production of the package to meet the scheduled delivery of the package to the project site for installation. The supplier executes the work to complete the package. Observation and testing is conducted according to the ITP. The contractor documents their observations along the way. A number of documents are produced during this stage of the process. Observations are summarized whenever contractor personnel (whether direct-hired or third-party) are present in the facility for the purpose of observing or testing the package, up to daily reports in the case of full-time observations. Non-Conformance Reports (NCRs) are detailed documentation of any non-conformances identified during the production process. A non-conformance is defined as non-fulfillment of specified requirements, defects, or imperfections. NCRs often trigger a Corrective Action Report (CAR), which explains how the non-conformance was resolved and, if appropriate, suggests changes to the production process to avoid repetition of the same problem. Thus, a feedback loop can develop at this stage of the production from which learning and improvement may occur.

### **Stages to Measure the Production Process Quality**

The following three stages of the SQPM represent groups of activities which have their output closely monitored by inspectors. At the end of each of the following stages a major milestone is reached and related indicators and documentation are tracked and matched against the project's requirements.

#### **3.1 Release from Shop**

A final inspection is conducted and three possible results will follow: approve for delivery to site, approve conditionally, or correct problems. Upon successful completion of production and fulfillment of the ITP, the package is approved for release, prepared for shipping and delivered to site. If the package is not approved for release a decision can be made to conditionally release the non-conforming package with plans to correct the problems in the field, seek to accept in its current condition, or correct the problems at the shop. In the case that a package must be corrected at the shop, a series of corrective actions are triggered until the problems are resolved, the package then loops back for a final inspection again were the process of approving for release is repeated. If the problems cannot be resolved the package can be rejected and discarded.

#### **3.2 Received at Site**

Before a package arrives at the receipt inspection point possible damage or problems might have occurred during the actual shipping to the site, or issues could have been missed at the shop inspection. At this inspection point, overage, shortage, or damage (OSD) will be assessed and three possible results will follow: approve for installation in facility, correct any problems on site, or reject the package and ship it back to the shop to correct any problems. If the problems are corrected on site, the package will still loop back for approval until it is ready for installation on site or until the option of correcting the problems on site fails and the package must be shipped back to the shop. The package can still be acceptable with minor deviations and be approved for installation after obtaining an engineering exception.

If a package is delivered back to the shop for correction it will arrive in the “Correct Problems” point where a corrective action will be triggered and the package will have to be approved for delivery again. Assuming that the package is deemed acceptable at site receiving, it will be stored until needed for installation. At the appropriate time, the package will be moved into position and connected in to the facility, achieving mechanical completion. At this point the device is physically attached and installed, but not yet operating. During installation, a non-conformance could also be detected.

### **3.3 Mechanical Completion**

The Mechanical Completion stage assumes that the package has already been installed in the facility, physically connected and wired, and is ready for use. Just like the second stage, a quality inspection loop has to assess the package and determine if it is approved for use in the facility, correct any problems on site, or reject the package and ship it back to the shop to correct any problems. During the mechanical inspection, some packages may be subjected to testing before commissioning. Once again, the package can still be acceptable with minor deviations and be approved for use in the facility after obtaining an engineering exception.

Mechanical Completion is the end stage for the purposes of this research. After mechanical completion, there are a number of additional stages at which non-conformances could be identified. Non-conformances could still happen during commissioning and startup, during operations, when a shorter-than-expected service life occurs, during maintenance and repair operations, or during ultimate disposal. Mechanical Completion was selected as the end point for this research largely because it is often the point at which the contractor will be notified about non-conformances. After mechanical completion, efforts to correct non-conformances could be undertaken by the owner themselves, or by the supplier without the knowledge of the owner. Non-conformances identified after mechanical completion might also be subject to dispute as to whether the issue arose from the production process or use. Additional research may be needed after this project to evaluate a longer time horizon.

It is worth noting that in stages 3.1-3.3 a decision is made as to whether the package is acceptable, or if instead the package exhibits a non-conformance. If a non-conformance is identified at any of these three stages, it represents a failure in the production process. Some kind of corrective action will ensue. Corrective action could range from acceptance in spite of the non-conformance (typically after a design review concluding the non-conformance is not serious or identifying a means of making do), to repair, or to replace. Obviously the time and resource implications normally increase from one end to the other along that spectrum. Throughout all three stages and during delivery or installation, the package can be flat out rejected and discarded if deemed necessary. Although infrequent, the results from completely discarding a package can have substantial impacts and implications on the project.

Finally, data is collected once the production process has been completed. The contractor will commonly complete some sort of post-execution reporting. This may include a qualitative, narrative style description of the production process, or a quasi-quantitative rating. Documented performance then feeds back into the supplier selection process when another opportunity to consider this supplier develops.

## CONCLUSIONS

This paper presented key findings about the state of the supplier quality surveillance (SQS) process in the EPC industry. In its current state, the process could benefit from the implementation of Lean practices to streamline the process by eliminating the need for numerous and onerous inspections along the way. The literature on the subject when compared with the current state of process revealed that the SQS process bears a lot of similarities with the way this same process was carried out over 20 years ago. This shows that not much progress has been done to “lean out” the activities developed by suppliers, contractors, and owners. This might be a result of more global supply chains and projects interfacing at the SQS process in more complex projects with multi-cultural teams distributed around the globe. However, the review of the SQS process reveals numerous opportunities where the supply chain could work collaboratively to jointly develop products and inspection plans that eliminate the need for multiple inspections by different parties leading to a leaner and thereby less costly process. Future work considers opportunities to improve the SQS process through implementation of Lean concepts. Examples would include: stopping the process to fix problems as they are detected and acting on root causes of problems to build right at the first time (learning); increase transparency and improve communication between supply chain members and different projects; respect, develop, and help suppliers improve.

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