Kahler, D. (2018). “Innovative Quality Management in a Lean World” In: *In: Proc. 26th Annual Conference of the International. Group for Lean Construction (IGLC), González, V.A. (ed.)*, Chennai, India, pp. 963–972. DOI: doi.org/10.24928/2018/0515. Available at: www.iglc.net.

INNOVATIVE QUALITY MANAGEMENT IN A LEAN WORLD

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ABSTRACT

By strict definition, the appraisal of quality is waste. It consumes resources, but does not directly add value to the work that is being appraised. It indicates what the actual value is, and in many cases why the work might not have met the required value. However, the appraisal of quality is a necessary waste. Without the appraisal of quality, those who are ultimately accountable for the work do not know whether or not the work meets requirements before it is accepted and incorporated into the project. And, even though it does not add value to the work itself, it adds value to our confidence about the quality of the work, which is often necessary to be paid for the work, to warranty the work, to insure the work, or to even allow public occupancy of the work. So how can stakeholders reduce the resources necessary to appraise quality without reducing the level of their confidence? Can the right type of innovative practices reduce the expenditure of resources but at the same time actually increase the confidence in the quality of the work? This paper will discuss actual methods of innovative quality management that have been used on public infrastructure projects within the United States by licensed professional engineers.

KEYWORDS

Value, waste, process, quality, innovation

INTRODUCTION

DID YOU FILL OUT THE PROPER FORM?

For decades, the primary tool for documenting the quality of design and construction project delivery has been the paper form: forms for check prints, forms for checklists, forms for inspections, forms for sampling, forms for testing, forms for reporting measured quantities, and even forms to request more forms. Forms were a development of the industrial revolution, where information had to be collected in a standardized structure to allow for efficient filing and forwarding to the proper department. But, in spite of the new, enabling capabilities manifested by the information revolution, these legacy practices of filling out forms remain with us. Project delivery needs new practices better suited to collecting, managing, analyzing, and reporting actionable data.

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Many of these obsolete practices reflect the way traditional project delivery manages the quality of the constructed project. Which evolved in the world of industrialization and organization of work by task. Terms such as "Quality Control" (QC) and Quality Assurance (QA) are often used ambiguously. In many cases, it is difficult to determine exactly what the "QC" person is controlling, or exactly what the "QA" person is assuring. Worse yet was the all-encompassing term of "QA/QC"; regularly invoked as the culprit for any problems where the actual causes are not even known. In the pursuit of accuracy, the American Society for Quality (ASQ) has worked to replace these terms with 1) "Prevention", which is the activity which ensures value is incorporated into the work, 2) "Appraisal", which is the activity which determines what the value is, 3) "Internal Failure", which is the consequence of discovering defective work before it is incorporated into the project, and 4) "External Failure", which is the cost of undiscovered defects remaining latent until they fail during use. Each of these categories has a cost that is increasingly greater the further the work progresses before the defect is discovered. Prevention consumes some resources but is needed to create the value; Appraisal consumes additional resources but only determines value, Internal Failure consumes even greater resources (removing and replacing the faulty work) and only provides the value that should have been there in the first place, while External Failure can consume a catastrophic level of resources and threaten public health, safety, and welfare.

FASTER, BETTER, AND CHEAPER?

Lean Construction, found in various forms and stages of maturity in an increasing number of non-traditional project delivery models such as Integrated Project Delivery (IPD), Integrated Form of Agreement (IFOA), Public-Private Partnerships (PPP), Design-Build (DB), etc, is improved if we can work towards the elimination of the obsolete quality management philosophies. Postma et al. (1998) documented the requirements for ISO 9000 certification by the contractor on the I-15 design-build project in preparation for the 2002 Winter Olympic Games in Salt Lake City, UT. Gargione (1999) argued for the implementation of Quality Function Deployment (QFD) on middle class apartment units. This was focused primarily on QFD in the design phase. Goh et al. (2001) argued for the use of the Internal Quality Audit (IQA) within an overall Quality Management System (QMS), and also argued for the benefit of a company obtaining ISO 9000 certification. Marosszeky (2002) argued for a more process-focused approach to quality management. By concentrating primarily on process, an organization can avoid the negative effects of trying to impose the document-focused ISO 9000-1994 philosophy onto construction projects. The paper also argued for improved deviation detection, as well as shorter cycle times from detection to correct. Thomas (2002) argued that the traditional market focus of quality is too heavily focused on error detection, but a "clan" approach to quality will focus on error prevention. Misfeldt (2004) argued that the quality control systems that are an integral part of lean manufacturing were still maturing in lean construction. Walsh et al. (2004) found evidence for a relationship between delays and failed inspections (internal failure), which would indicate a failure of prevention. Marosszeky (2005) argued that quality control mechanisms can help to prevent construction defects. Saha (2005) argued that certain cultures might be incompatible with the concept of total control. Tilly (2005) argued that deficiencies in design and construction documents are a key contributor to errors in construction. Hofacker (2008) argued that the leanness of quality on a project could be measured in a systematic model. Lima et al. (2008) argued for the use of visual displays and QFD for low-cost construction. Tommelein (2008) argued for the incorporation of mistake-proofing so that appraisal would be unnecessary. Sullivan (2011) argued that quality could be found by selecting the most qualified constructor through best value. Fireman, et al. (2013) argued for more integration between production and quality control. Bjornfot (2013) argued for a QFD based on human experience rather than technical requirements. Leao (2014) argued for integrating production with quality control using information technology; this focused on the type of work being performed, such as “making-do.” Ibarra (2016) continued the argument for the integration of production and quality control.

Clearly, the subject of how to improve systems of quality in the built environment has a wide spectrum of theories about the problems and the best practices to address them. However, regardless of the type of quality management philosophy, the basic fundamental concepts of responsibility and control still apply. These concepts assert that the *entity in the best position to control a process should be responsible for it, and that an entity assigned responsibility for a process should be allowed to control it without unnecessary interference* (Fischer, 1999).

To assist in the analysis of innovative quality management methods, we can separate the concepts into a taxonomy of five key categories: Requirements, Design Process Control, Design Appraisal, Construction Process Control, and Construction Appraisal (Kahler, 2012).

INNOVATIONS IN REQUIREMENTS

Requirements Management comes from Systems Engineering, which is an engineering discipline developed during the Cold War that educates engineers in the integration of multiple disciplines into complex systems. Requirements management is a process to objectively document requirements so they can be agreed upon and controlled. One of the keys to modern requirements management is the relational database.

Traditional construction contracts usually communicate requirements in narrative-style scenarios that are intended to be read and interpreted by the person responsible for producing the work that needs to meet requirements. In systems engineering, requirements are structured in a relational database that links each requirement to other requirements that affect it or depend on it. This relational database of requirements is modified by the negotiating parties until agreement is reached, at which time the data becomes the contract document. This approach of developing the contract as a relational database makes it easier to manage the communication, fulfilment, and verification of requirements in a structured system.

A number of innovative delivery projects have attempted to extract legacy, narrative-style construction contracts into a requirements management system. However, a weakness of extraction is that formal changes to contracts are done in the source document, causing any extracted data to become quickly obsolete. A requirements management system that only points to sections in the contract without mirroring the actual text would mitigate the problem of requirements not being current, and allow some minimal automation of quality management data.

If nothing else, communicating specifications in traditional civil engineering contracts as structured requirements can help with the disparity between narrative-style writing and automated requirements management. The general characteristics of good requirements, as defined by the International Council on Systems Engineering (INCOSE), are:

Necessary –must be necessary for performance of the system;

Appropriate - must be regularly re-evaluated to make sure it's still needed;

Unambiguous - must have only one interpretation;

Complete - must contain all the information needed to define it;

Singular - must address a single characteristic;

Feasible - must be reasonably achievable;

Verifiable - must be capable of being measured;

Correct –must accurately represent the desired outcome;

Conforming – must be consistent with an overall style;

Consistent - must support and not contradict other requirements; and

Comprehensible –must be written in understandable language.

Focusing on the development of good requirements can reduce the need for the "tribal knowledge" that is so prevalent in the traditional project delivery model. This "tribal knowledge" consists of things that practitioners know in the design and construction process that are critical for project success, but remain undocumented in the official contract documents. In traditional project delivery, the same design and construction professionals are often used for the same agency or geographic area, so this knowledge can be retained and applied even in the absence of writing. But in modern global project delivery, design and construction engineers are often pulled together from all over the world, and can only rely on the written contract documents for the standards and specifications necessary for performance.

Innovations in Design Process Control

Traditional design process control is based on legacy technologies, namely ink and mylar plans sheets and paper calculation pads. These were the primary documentation tools of the profession until about mid-1990's. However, even with the enabling technologies developed in our digital age, design quality management for process control is often still based on the *old methods of the checkprint and checklist*.

The checkprint was originally a design quality management tool that allowed engineers to control the quality of the mylar plans sheet without having to come in physical contact with it. The checkprint was a cheap, expendable reproduction of the mylar that allowed the professional to check the drafting quality, and communicate additional changes that the drafter needed to make to the original plans sheet. The archived checkprints also served as an audit trail of each element that was designed, drawn, checked, and approved.

Digital design environments have made the old methods developed around ink and mylar technology obsolete. These enabling technologies make the checkprint, even those produced as a an electronic PDF, unnecessary for the purpose of allowing the engineer to review, comment on, and direct changes to, the master design. The reviewing design professional can reference the source 2D or 3D design models in real time, and make their comments in separate 2D or 3D design models that give the production design professionals nearly instant feedback. Archived 2D or 3D review models also provide an unlimited audit trail of how the design evolved and comments were implemented.

The checklist is also a holdover from legacy production methods. Often checklists will ask drafting-based questions as a proxy for issues that are really about design. This may have been useful back in the days of preparing graphical information on mylar, but are not effective in a modern design process. A more innovative approach would be to have process check points that ask questions customized for that particular level of development, so they ask questions relevant to the requirements for that part of the process.

Innovations in Design Appraisal

Even in innovative project delivery where control of the design is transferred to the project delivery team, the owners, owner's representatives, and other key stakeholders demand some early proof of whether or not the evolving design is meeting their needs and requirements, even if those needs and requirements are subjective or not in writing. In traditional project delivery this was usually accomplished by labor-intensive interim submittals of the in-progress design in the format of the final construction documents. However, on innovative projects, even with all design in digital form, we still see legacy contract requirements for the project delivery team to submit these interim documents for review as if they had still been created in ink on mylar sheets.

Owners and stakeholders often mandate the legacy processes. Many do not have access to, or training in, the same technologies that firms use to create the design. There are ways to ease the anxiety of owners and stakeholders faced with modern design information. Design firms can, and have, sponsored regular design reviews where no physical document is produced for review. Instead, the live design is projected on the wall and all interested parties are walked through each design element.

While this may require some investment in time and technology on the part of the design firm, this cost can be more than offset if the stakeholders will *then relieve the design firm from producing interim construction documents*. An additional benefit, which is often more powerful than the design review itself, is the fact that the reviewing stakeholders are in the same room, where they can work out differences in real time, instead of *using conflicting comments to the design firm as an indirect form of resolving different design opinions*. The practice of various reviewers fighting each other with the design team in the middle not only adds time and cost without adding any value, but often introduces easily avoidable errors and omissions that would not have been created if the design team received consistent direction.

Innovations in Construction Process Control

In innovative project delivery, the construction team has greater access to the digital design information than in traditional project delivery. This can provide opportunities for construction process control that would be more difficult to achieve using only information obtained from traditional construction documents. Some of these innovations include automated machine guidance based on certified design models, tailoring of the design model to take advantage of specific digital production technologies preferred by the contractor, customization of specifications to focus on better indicators of construction quality in lieu of traditional metrics, and real-time response for redesign caused by unforeseen conditions. While the traditional goal of construction process control has been to merely conform to the contract requirements, an improved digitally-enabled goal can focus on the fundamental performance characteristics from which those requirements were derived in the first place. requirements, particularly in an era of long-term maintenance warranties being introduced into delivery systems such as Public-Private Partnerships.

Innovations in Construction Appraisal

Similar to the design process, innovations in construction process control will have limited return on investment if they are still constrained by traditional appraisal and acceptance. *This area probably has the greatest potential for innovation in the entire construction process.* Because one of the key goals of innovative project delivery is to quickly produce work that meets performance requirements, the appraisal and acceptance must be *nimble enough* able to react to constantly changing plans and specifications, *productive enough* to stay ahead of the construction process control, and *accurate enough* to give stakeholders that are funding a project solid data to continue to manage their major capital investment.

Facilitating Further Innovation

Further innovation can be supported by structuring quality management processes the same way a writer structures a good story - by asking the six basic questions of *Who, What, When, Where, Why, and How.*

Who?

There are typically specific people who are accountable for a particular aspect of quality. In a digital design and construction environment that is data-intensive, the provenance of that accountability becomes even more important. Similar to the traditional craftsman's mark, but far more complex, the trail of quality, and who was in custody of it, from production all the way to acceptance can be tracked by the very data the processes produce. Even in a highly automated environment, it is important to know every time a process has been touched by a human.

What?

We need to ask the question: "What is the specific work whose quality is being managed?" Is the work made of concrete, steel, or soil? Is it something that must resist load, transmit electricity, or reflect light? Each element in a project has its own form, its own requirements, and its own place in the cost and schedule. If it does not have a specific function in the project, then we might question why its quality needs to be managed. We also have to ask what data we're collecting on it, and how that data is to be used.

When?

The date and time of activities are often important for quality management. Usually the date and time of quality management activities can be automatically generated by modern data collectors, but we also have to ask ourselves what we want to do with that information.

Where?

Where is a very important characteristic of construction projects. Everything in the built environment project has a place defined by the design, with location tolerances defined by the requirements. For some elements, the question of "where" needs to be answered with expensive survey-grade equipment, but most aspects of quality do not require that level of accuracy. Some quality management data could even be assigned general boundaries, such as an area representing the limits of construction for a particular schedule activity.

Why?

The "why" of our activities should be based on the written requirements. Asking this type of question becomes more important when new enabling technologies allow us to appraise performance by measuring different characteristics. These new developments need to be reflected in the written requirements if they are to be achieved.

How?

"How" addresses the means and methods we use to produce and appraise the work. While it may be a written requirement in older, method-based specifications, it should only be a means to an end in newer performance-based specifications. How becomes even more important for processes for which the performance is difficult to measure. The innovation in how we do things is probably the most fluid, given the rapid changes in the enabling technology.

Can We Innovate For Traditional Project Delivery?

Every one of these innovations, and more, can be applied to traditional, non-innovative project delivery. It is only the fast schedules of innovative project delivery that have forced engineers and constructors to quickly look for improved ways of doing things. However, traditional projects can have their own innovation drivers as well. Because many claims and delays are based on faulty plans and specifications, improving written requirements can become even more important for tight budgets and underbid projects. Contractors with low margins could benefit from the use of certified design models, eliminating the need to reverse engineer plans if they wish to take advantage of automated machine guidance. Inspection can be faster and more efficient, reducing the need for contractors to place contingency budgets in their bid to account for unknowns in the appraisal and acceptance of their work.

Innovations in quality management can be looked at to reduce certain things:

Reduce time – Time is money in project delivery and faster quality assurance means more profitable results. The key is to look for innovations that shorten schedules by reducing unnecessary or obsolete appraisal methods, as opposed to applying all of the pressure to the production methods.

Reduce cost – Resources cost money, so innovations that reduce the effort needed to assure quality, while maintaining the accuracy of its depiction of the actual work, can release these same resources into the production system, preventing defects and appraising quality at the time of production. Better prevention can further reduce the cost of projects by offering an opportunity to reduce the standard design factor of safety, which is based on the historical level of variability, not the variability of the actual work.

Reduce waste – Technically, anything that consumes resources without adding value is waste. Even an activity as traditionally sacred as inspection could be considered waste, because it does not improve the value of the thing being inspected; it only tells you what its value is. Innovation can be used to scour through the entire "value chain" to constantly ask the question of why an inspection, sample, or test is being done, and ensure the way it is being done is compatible with the latest production methods.

CONCLUSION

Innovative methods of delivering projects need equally innovative methods of managing quality. Forcing new project delivery methods and new methods of improving construction efficiency to conform to the constraints of traditional mass-inspection, after-the-fact based quality management removes much of the financial incentive to innovate in the first place. The licensed professionals who are ultimately accountable to the public for the quality of the delivered project need methods of quality management that take advantage of all the enabling technologies that are available, such as relational databases, digital models, and global positioning systems. By exploiting these new methods, the appraisal of management can cease to be a waste. By creating a continuous awareness of the quality of the work, combined with rapid feedback into the production process, the appraisal of quality can immediately add value to the work that is about to be performed. Then the appraisal of quality changes from a necessary waste to a value-adding process.

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