

DOES LEAN CONSTRUCTION RENDER COMMISSIONING OBSOLETE? A PRELIMINARY STUDY AND DIALOGUE.

Lincoln H. Forbes¹

ABSTRACT

Commissioning is a quality assurance practice that has been used in the ship-building industry for decades because of the high risk of life lost, should systems or equipment fail (Agustsson and Jensen 2012). Building Commissioning (Cx) evolved from the ship-building industry and ensures that a facility and its technical systems meet the Owner's Project Requirements (OPR). As is done with ships, commissioning begins in the pre-design phase, and continues through design, construction, occupancy and use. (California Commissioning Collaborative 2006). Buildings that have been subjected to Cx experience less waste in life cycle performance such as reduced energy and operational costs. They experience fewer RFIs, change orders, and a greater likelihood of timely, on-budget completion. (Heinz and Casault 2004, Mills, 2009). Projects executed by the lean construction method have been shown to exhibit superior quality characteristics such as fewer RFIs, change orders, and rework (Ballard G. and Yong-Woo, K. 2007).

The purpose of this paper is to begin a dialogue that compares the merits of lean construction (LC) and Cx procedures. A number of questions explore i) whether Cx adds value to a project, or if its cost represents waste; and ii) whether Cx should be considered obsolete in lean projects. Preliminary findings suggest that Cx is not well understood by the industry, and is underutilized despite its potential for performance optimization. Research questions need to be investigated further with sample sizes adequate for testing hypotheses that may yield statistically valid results.

KEYWORDS

Lean construction, commissioning, sustainability, LEED, ROI, life cycle cost.

INTRODUCTION

DEFINING BUILDING COMMISSIONING (Cx):

Commissioning (Cx) is a quality assurance mechanism that reduces waste through facilitating the correctness of the design and construction of facilities, as well as optimizing energy usage into the future. The National Conference on Building Commissioning (NCBC) has officially defined 'Total Building Commissioning' as: A "systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation

¹ lhforbes@gmail.com

personnel”. (The NCBC unifies experts in green building design, construction, and operations.) Building Commissioning (Cx) evolved from the ship-building industry where it has reduced the high risk of life lost,

should systems or equipment fail (Agustsson and Jensen 2012). In the construction environment it ensures that a building and its technical systems meet the needs and requirements of the Owner’s Project Requirements (OPR). As a cradle-to-grave systematic process, Cx is optimally applied to all phases of a construction project – programming/pre-design, design, construction/installation, acceptance, occupancy and post-occupancy. (California Commissioning Collaborative 2006). (ASHRAE Draft guideline 0-2005. Very importantly, the term Commissioning Agent (CxA) represents a team of professionals of different skills that provide Cx services.

EXPLAINING WHAT CX IS NOT:

Cx enhances and adds to prevailing quality inspection procedures, and does not replace them. Cx does not increase the number of phases in a construction project; it operates in concurrence with them. Cx does not involve the testing of a single piece of equipment, and is not intended to be used for testing, adjusting, and balancing (Grontzik 2009, California Commissioning Collaborative, 2006). Those are functions performed by others.

SIGNIFICANCE OF THE SUBJECT OF CX TO THE LEAN COMMUNITY:

In an article titled “Building Commissioning: What Can Denmark Learn from the U.S. Experience?, Agustsson and Jensen 2012, recognize the US as a leader in Cx practices, and point to the life-cycle and operational benefits of Cx as a motivation for other countries to adopt it. An increasing demand for Cx results from its role as a prerequisite for LEED NC® certification by the US Green Building Council (USGBC); LEED has become the predominant sustainability standard in the USA. (Kibert 2007). As more facilities are built for environmental sustainability, the more likely it will be to have Cx in lean projects. Cx is a paid service, costing 0.5% to 1% of new construction cost (US Department Of Energy 2010); this raises the question of whether Cx represents a waste.

OBJECTIVE OF THE PAPER:

It is to open the way to further study of LC and Cx by exploratory discussion with the lean community to (a) determine whether they think that LC would eliminate the need for Cx. (b) if they think the scope of Cx should be altered if it is applied to a lean project.

METHOD

An exploratory approach was used to determine the prevailing perceptions of the commissioning (Cx) process, and the likelihood of locating a sub-population of construction professionals that would provide adequate samples for statistical analysis. Initial responses can be used to formulate research questions for subsequent surveys. The survey questions explored the lean community’s perceptions of commissioning – a) Lean - does it eliminate the need for building commissioning? Cx is defined as a process throughout the project, starting at pre-design and continuing to acceptance

b) How should the scope of Building Commissioning (Cx) in a lean project vary from the scope in a traditional one? The project owner generally hires Cx services during both design and construction.

A matrix was developed to compare the main activities in a hypothetical lean project with typical commissioning activities in order to identify possible duplication. Observations from the matrix and responses to the preliminary study are used to develop a model that represents the interaction of both lean and commissioning activities in a construction project. The findings from the initial survey are reported in the Results section of the report

REVIEW OF COMMISSIONING AND LEAN PRACTICES

Lean construction and commissioning intersect in two significant ways: Lean seeks to reduce waste while “Green Construction” as represented in the LEED NC® certification seeks to reduce the environmental impact of buildings through the rational use of resources. (Carneiro et. al. 2012). Lauri Koskela (2002) described Lean Construction as a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value. Abdelhamid 2013, defines lean construction as “A holistic facility design and delivery philosophy with an overarching aim of maximizing value to all stakeholders through systematic, synergistic and continuous improvement in the contractual arrangements, the product design, the construction process design and methods selection, the supply chain, and the workflow reliability of site operations”. But a well designed and efficiently built facility may experience ongoing deficiencies; the building envelope may experience undesired moisture transmission, and electrical/mechanical and conveyance systems may underperform. With time, the initial budget and schedule savings derived from lean may be eroded by excessive energy consumption and recurring, expensive, system failures. Furthermore the customer may not necessarily identify operating cost and environmental impacts as values (Rothenberg et. al. 2001). According to Nicholson and Molenaar (2000), “The need for Cx does not stem from poor design and construction practices, but rather the fact that modern buildings are a composition of numerous complex systems...no longer can the architect or GC understand life cycle implications of all the systems”.

The scope of Cx varies with the OPR. Total or whole building commissioning may include the building envelope, (exterior walls, glazing, insulation, vapor barriers, and roofing), electrical/mechanical systems, Energy Management Systems (EMS), fire protection, fire alarm, smoke control, security alarms, telephone and intercom systems. The Commissioning Agent (CxA) should be the objective “eyes and ears” of the owner/client to ensure that construction delivery decisions do not diminish functional performance.

The cost of Cx varies by scope: whole building Cx costs 0.5% to 1% of construction cost; HVAC and automated controls systems Cx costs 1.5% to 2.5% of the mechanical contract cost, and electrical system Cx costs 1% to 1.5% of the electrical contract. The return on investment (ROI) for commissioning is significant; it can improve new building energy performance by 8% to 30%. Various studies indicate savings due to commissioning of \$4 over the first five years of occupancy as a direct result of every \$1 invested in commissioning (Whole Building Design Guide 2012). The University of Wisconsin’s (UW) Commissioning training program

recommends that the commissioning process should clearly document savings in the first year of occupancy by the end of design or early construction. For each \$80,000 paid for commissioning, returns have been as high as \$500,000. (Forbes & Ahmed 2010). Sustainable building performance, as measured through LEED NC, is greatly influenced by pre-design and design decisions (Azhar et al. 2011). The lean method may also improve sustainability and reduce costs when applied during the design phases (Bae and Kim 2007). The Cx function supports these endeavors throughout all project phases; verification at project completion is especially important for sustainability goals to be met. Cx optimizes costs in all phases of a project; is proactive in identifying potential problems before the design is finalized, and addresses construction phase issues before they affect the schedule. Cx reduces change orders, RFIs, schedule delays, deficiencies at substantial completion, and work hours in post occupancy for Operations & Maintenance. (ASHRAE HFC Guidelines 2010).

CxA qualifications require proven technical expertise in all the foregoing building systems, and should meet the requirements of at least one of several certifying organizations. Ten years' experience would be desirable, with Cx on two or more projects of similar size and equipment, as well as commensurate project management experience. As a separate service, continuous Cx involves ongoing monitoring and adjustment to optimize building performance and life cycle costs.

DETAILS OF THE INITIAL SURVEY

Questions were posed on construction-related LinkedIn websites. The framework for these questions was a definition by the National Conference on Building Commissioning that describes commissioning (Cx) as a concurrent activity throughout a project.

- Lean - does it eliminate the need for building commissioning?
- How should the scope of Building Commissioning (Cx) in a lean project vary from the scope in a traditional one? The project owner generally hires Cx services during both design and construction.

Over the course of a 7-week period, very few response posts were provided. Follow-up questions were asked to keep the issue alive, also with very few responses.

- Should the scope of commissioning services in both the design and construction phases be less in a lean project than in a traditional project?
- Some professionals feel that extensive collaboration in lean projects covers the gaps that commissioning would cover. Do you agree or disagree?. Please provide your reasons for your opinions.

The questions posed in the exploratory study and the responses of the study participants are listed in Tables 1 and 2 below. They have been paraphrased for brevity and confidentiality.

Hal Macomber of Lean Project Consulting (LPC) offers the following insight: "You ask a great question. I've made the case that if we know the Cx conditions of satisfaction, then we can significantly reduce the involvement and duration of Cx. There is circumstantial evidence to support my claim. However, there are cases where

good upfront work was done and Cx was needed because installation didn't conform to specs, specifically balancing of HVAC. I consider most of Cx to be waste. Some of it is necessary waste, but most of it has to do with stuff that wasn't done quite right.” (Email communication March 28, 2013).

Table 1: Initial responses

Question: Lean - does it eliminate the need for building commissioning? Cx is defined as a process throughout the project, starting at pre-design and continuing to acceptance

Lean processes don't hinder Cx, but collaborative and open, honest communication enhances it – the earlier, the better. Commissioning should begin at the beginning. Too often the decision is made along the way and as such, gets sacrificed when key decisions are made.

Absolutely not - Lean is a process to improve productivity and eliminate waste on a jobsite but would not have any impact on the need for commissioning the building.

No, "lean" doesn't eliminate the need for Cx, but would significantly change how it is performed. A "lean" Cx process would be integrated into the designer's and constructor's work and would involve a continuous QA.

A follow up question elicited the following answers in Table 2.

Table 2: Follow up responses

Question: How should the scope of Building Commissioning (Cx) in a lean project vary from the scope in a traditional one? The project owner generally hires Cx services during both design and construction.

With IPD it shouldn't really matter who hires the CxA, as everyone clearly is working for the interest of the owner in this delivery model. Perhaps the role of the independent CxA shifts to one of external auditing only, while true performance and functional testing is performed by the project team.

The customer of commissioning should be identified, and what value it adds. The collaborative team process could improve or eliminate it if possible. Does collaboration automatically cover the gaps unless there is a focused on them?

In the lean project delivery system (LPDS) commissioning should be more collaborative and integrative in a lean project. In terms of scope, Cx is a bridge ensuring a smooth flow from lean assembly to lean use; Cx should commence from the procurement of logistics through installation to handing over and operation.

Cx scope may not change much. One approach requires less back-end work after completion, but more up front work in collaborating during design and construction. The actual work should be similar, but the former may have better outcomes and performance relative to design expectations and likely better.

T. Abdelhamid reports on projects conducted at MSU: “If Cx is performed solely at the end of a project, then I would agree that it leads to rework (waste) that could have been prevented. The Cx agent should/must be involved in the planning/design stage to give input. That is what we did on our first Lean/IPD project. The Cx phase itself was more of a check that systems performed as designed and intended - and we had to do it. The results were far better than normal projects because the Cx agent had already pointed out to the designers and contractors where the pinch points usually are in the end. The project involved a semi-formal OPR (Owner Program Requirement) and the MSU Cx agent led that. He is doing it on other projects, albeit

they are not Lean/IPD. While there is an internal Cx group at MSU, (they do commissioning, continuous commissioning, and retro-commissioning), an external Cx consultant was hired for the Lean/IPD project because the internal Cx group was overloaded with retro-Cx work. The external Cx consultant was still reporting to our internal Cx agent. We finished all punch list items within 30 days of substantial completion and a 2-3 items dealt with HVAC related items - it was mostly architectural interior issues (scuffed paint, drywall, window sills, etc). Again, this result is not typical for our campus projects which end up with a size-able punch list and dominated by controls and HVAC issues.” (Email communication, March, 2013)

DISCUSSION OF RESULTS

The responses to the questions about Cx suggest that there are widely differing views on its meaning and scope. Facility professionals with the American Society for Healthcare Engineering (ASHE) note that the word “commissioning” often means something different to different people depending on their background, education, and training. (ASHE Health Facility Commissioning Guidelines 2010). Some respondents thought that Cx should begin at the beginning of a project, the experience at the Michigan State University (MSU) project pointed to the benefit of early Cx involvement. By alerting designers to potential problems in a Lean/IPD project, Cx activity at the end of the project was reduced to mostly checking/verification. One response saw Cx as a bridge ensuring a smooth flow from lean assembly to lean use – essentially as an end- of project activity. Some responses saw lean and Cx as independent methodologies – lean was identified with improving productivity and eliminating waste on a jobsite; it would not influence the need for commissioning. This response was focused on the construction phase, and did not comment on the design phases. One response identified lean as being applied to the Cx process, resulting in a lean Cx, providing quality assurance for both the design and construction activities. Another response characterized Cx as “waste” although some of it was “necessary waste”

With regard to the scope of Cx when deployed in a lean project, the perceptions were mixed. One response did not visualize a significant change to Cx scope, but anticipated better outcomes and less corrective activity. Another response questioned the value provided by Cx, and implied that the lean process could improve it or possibly eliminate it. Cx scope was seen as being linked to conditions of satisfaction, which could reduce its scope, i.e., its involvement and duration. It is not clear how that could be determined beforehand – a project was referenced with an installation that did not conform to specifications. It may be argued that earlier Cx involvement could have reduced the non-conformities. The experience at MSU with an independent CxA pointed to superior project performance, with minimal punch list items that were all resolved within thirty days. While the survey responses did not refer to the role of Cx in sustainability initiatives, the USGBC recommends having an independent 3rd party CxA hired by the owner, although exceptions may apply depending on the size of the project. One response did not see the need for independence in an IPD project. With regard to a concern about Cx being a waste, past studies reveal short payback periods (4.2 yrs) for new construction with continuing benefits thereafter. (Mills 2009).

A TABULATION OF ACTIVITIES FOR LEAN AND COMMISSIONING

Table 3 displays a number of project activities as a prelude to developing a model for improving the design and construction processes. The table shows lean, LEED, and Commissioning activities separately. In fact, with the proper qualifications, the same facilitation resource could provide LEED and Cx services. Lean facilitation is shown as a separate function, but it can conceivably be combined with LEED support.

Table 3: A comparison of design and construction support activities (adapted from Forbes & Ahmed, 2010)

Project phase	Architectural/engineering (A/E) design	LEAN FACILITATION	LEED SUPPORT	Commissioning (Cx) – Multiple disciplines
1 Pre-design	A/E Designers: Clarify owner’s value proposition Lead design charrette with support of Lean, BIM, Cx, LEED facilitators... Clarify sustainability standards	Clarify owner’s value proposition Evaluate proposed facility use & size/configure for lean operations. Promote lean practices as a procurement strategy. Implement the IFOA	LEED AP support Evaluate site feasibility with respect to sustainability standards	CxA undertakes services with owner Review decisions on OPR, BOD Provide input on design decisions. Develop pre-design Cx outline.
2 Design	A/E Designers: Perform design activities. Target Value Design with aid of Lean facilitator, BIM/ICT manager. Collaborate with CM/GC for constructability, process design	Target Value design – provide best facility that meets owner’s budget. Collaboration between stakeholders to harness best ideas. Guide process design	Track incorporation of sustainability in design – e/g, LEED categories – sustainable sites, water efficiency, etc	Develop a preliminary Cx budget Perform I review Provide VE and O&M recommendations Finalizes Cx plan for the project.
3 Construction	A/E Designers: Maintain technical support throughout construction, May provide Construction oversight as an extra service	Continuous learning and improvement through PPC tracking and analysis	Enhanced commissioning Closely monitor materials and equipment provided for the project for sustainability compliance.	CxA leads Cx team, views contractor submittals Attends jobsite mtgs. Participates in problem resolution. Requests/reviews applicable tests
4 Acceptance	A/E Designers: Ensure finished facility meets Owner’s Project Requirements (OPR).	Conduct Commissioning for project acceptance	Meeting of LEED targets is a requirement for acceptance	Verify functional performance tests Review test/balance activities. Ensure O&M staff training performed by contractor
5 Post Construction/warranty	A/E Designers: Evaluate overall performance, owner satisfaction	Conduct Retrospective – learn lessons Conduct Post Occupancy Evaluation – learn lessons from users	Monitor building performance in specific categories – energy usage, water usage, etc.	Track warranty issues Perform semi-annual, seasonal testing. Revise/submit final Cx report. Initiate Continuous Commissioning CCx

The construction phase involves the CxA in progress reviews, submittal reviews, problem resolution, and functional tests reviews as may be appropriate. At acceptance, the CxA provides more input than other disciplines to ensure that all various systems function as intended. The earlier Cx involvement significantly reduces the scope of the work that is needed to meet the owner’s conditions of satisfaction.

There may be a degree of duplication of these activities, especially if separate entities are used for Lean, LEED, and Cx facilitation. A meaningful estimation of this duplication should be the subject of a more detailed survey.

A PRELIMINARY MODEL

The following model (Figure 1) incorporates the responsibilities documented in Table 3. Using the Lean Project Delivery System as a foundation (Ballard 2000, 2008), five phases are represented – project definition, lean design, lean supply, lean assembly, and use. Commissioning is shown as an activity throughout the entire project. Sustainability initiatives such as LEED, Energy Star, etc are shown on a horizontal bar throughout the entire project, and continuing during use until alteration or decommissioning takes place in the future. ICT and BIM are also represented as ongoing activities during the project.

The vertical element at the left side of the diagram represents a support structure with facilitation for lean activities, sustainability, and Cx. The scope of these services is unspecified in the preliminary model. Further research would establish reference scopes of work for the respective facilitators. Duplication would be reduced by exploring the use of multi-skilled facilitators. In the case of the Cx responsibilities, the integrity of the function would be maintained as an owner-support function. However, activities that overlap with lean collaboration activities could be investigated as candidates for scope reduction.

CONCLUSIONS

A review of Table 3 points to the potential for duplication between various project support activities – lean, sustainability (LEED), and Cx facilitation. These activities are reflected in Figure 1. Further studies should determine the appropriate scope and price of Cx services. The following issues should be evaluated further:

- The lean methodology should be applied to the Cx procedures to minimize waste and ensure their effectiveness and efficiency.
- In projects that have ongoing lean training, consider training the CxA.
- Investigate with the USGBC a possible combined role for lean and Cx facilitation that meets the LEED criteria without a conflict of interest.
- Clarify the role of the Cx function in projects - Add system performance to the Conditions of Satisfaction (COS).
- Develop the Cx plan in concert with a lean facilitator to minimize duplication and improve collaboration on time-dependent issues.
- Where appropriate – identify handoffs that depend on functional performance in predecessor activity; synchronize Cx with the Last Planner® System.
- Develop a reduced fee structure for Cx services in the lean environment
- Establish minimum qualifications and experience of the Cx function.
- Consider Continuous Commissioning (CCx) into the future.

PROPOSAL FOR FURTHER STUDY

Future studies should address the following possible research questions:

- Do lean practices duplicate Cx activities?

- If yes, quantify the hours utilized.

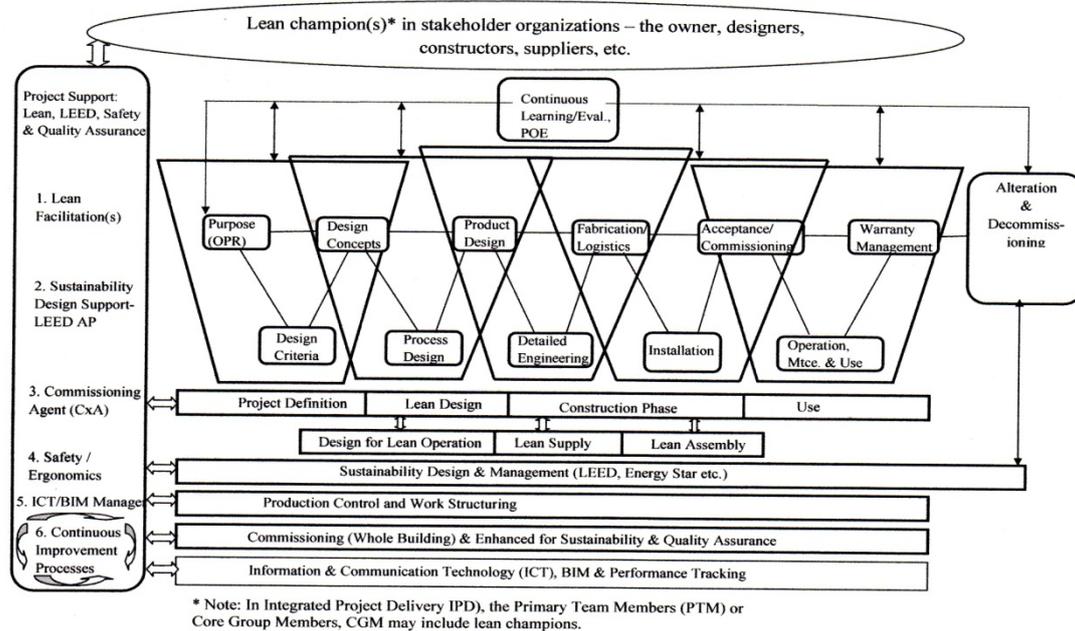


Figure 1: Preliminary model of the modified Lean Project Delivery System adapted to Ballard 2000, (From Forbes and Ahmed 2010)

- Does Cx add measurably to the outcome of lean projects?
- Is there a correlation between Percent Planned Complete (PPC) values and the time spent on Cx activities in a project?
- What is the optimum mix of LC and Cx facilitation hours on a project?

Various construction industry groups will be used as the survey population – IGLC, LCI, American Institute of Architects, (AIA) Associated General Contractors (AGC).

The findings should be used to formalize updates to Cx support in the LPDS framework, and develop operational procedures. The lean tenets demand that clarity.

ACKNOWLEDGEMENTS

The author thanks Hal Macomber of LPC, Prof. Tariq Abdelhamid of MSU, and several other discussion participants for their valuable insights.

REFERENCES

- Abdelhamid (2013). "Lean construction," <https://www.msu.edu/user/tariq/Learn_Lean.html> (March 21, 2013).
- Abdelhamid, T., email on commissioning, March, 2013.
- Ágústsson, R. and Jensen, P. (2012). "Building Commissioning: What can Denmark Learn from the U.S. Experience?" *Journal of Performance of Constructed Facilities*, June 2012, Vol. 26, No. 3:pp. 271-278.

- ASHRAE Guideline 0-2005: The Commissioning Process, American Society Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- Azhar, S., Carlton, W., Olsen, D., & Ahmad, I. (2011). "Building Information Modeling for sustainable design and LEED rating analysis." *Automation in Construction*, 20 (2), 217-224.
- Bae, Jin-Woo, Kim, and Yong-Woo, (2007). "Sustainable Value on Construction Project And Application of Lean Construction Methods." *Proc. IGLC-15* Michigan, USA.
- Ballard, G. (2000). "*The Last Planner System of Production Control*." Ph.D. Thesis. Faculty of Engineering. School of Civil Engineering, The Univ. of Birmingham.
- Ballard, G. (2000b) "Lean Project Delivery System LCI White Paper – 8", Lean Construction Institute
- Ballard, G. and Yong-Woo, K. (2007). "Roadmap for lean implementation at the Project level. Research report 234-11." *Construction Industry Institute, 426 California Commissioning Collaborative (CACx)*. (2006). "California Commissioning Guide: New buildings." CACX, Portland, OR.
- Carneiro, S. B. M., Campos, I. B., de Olivera, D. M., and Barros Neto, J. P., (2012). "Lean and Green: A Relationship Matrix." *Proc. Twentieth Annual Conference of The International Group for Lean Construction (IGLC-20)*, San Diego, CA. USA
- Forbes, L. H., and Ahmed, S. M. (2011). *Modern construction: lean project delivery and integrated practices*. CRC Press: Taylor & Francis Group, Boca Raton.
- Grondzik, W.T. (2009). *Principles of Building Commissioning*, Wiley, Hoboken, NJ.
- Health Facility Commissioning Guidelines, 2010. The American Society for Healthcare Engineering, Chicago, IL60606.
- Heinz, J.A., and Casault, R.B. (2004). *The building commissioning handbook*, 2nd Ed. Building Association Assn., Portland, Oregon
- Kibert, C. J. (2007). *Sustainable construction: green building design and delivery*. John Wiley, Hoboken, NJ.
- Koskela, L. (2002). "The Theory of Project Management: Explanation to Novel Methods." *Proc. of the International Group for Lean Construction (IGLC-10)*, Tenth Annual Conference, Gramado, Brazil.
- Macomber, H., email on commissioning – March 2013.
- Mills, E.P. (2009). Building commissioning – A golden opportunity for reducing energy cost and greenhouse gas emissions. L. Berkely Nat.Lab. , CA.
- Nicholson, M and Molenaar, K. (2000)." Building Commissioning: ensuring Quality And Savings." [*Construction Congress VI*](#): Orlando, Florida pp 1074-1082.
- Rothenberg, S., Pil, F.K., and Maxwell, J. (2001). "Lean, Green, and the Quest for Superior Performance." *J. of Prod. And Oper. Mgmt.* 10 (3), 228-243.
- Scott, R. and MacPhaul, D. (2005) Pioneering Building Envelope Commissioning To Prevent Moisture Intrusion. *Structures Congress 2005*:1-12.
- U.S. Dept. of Energy. (2010). "Commissioning Phase." (<http://www1.eere.energy.gov/buildings/commercial/commissioning.html>). (May 10, 2010).
- Whole Building Design Guide (2012). National Institute of Building Sciences, Washington, DC.