IGLC.net (/)

REGISTER (/ACCOUNT/REGISTER) | LOG IN (/ACCOUNT/LOGIN)

24th Annual Conference of the International Group for Lean Construction - Boston, USA - 2016

(/Papers/Conference/26)

Using Lean to Counteract Complexity

Antonio N. de Miranda Filho[1], Luiz F. M. Heineck[2] & Jorge Moreira da Costa[3]

[1]Civil Engineer, Ph.D., CEO, Construtora Santo Amaro Ltda., Fortaleza, Ceará, Brazil, anmirandaf@yahoo.com.br

[2]Civil Engineer, Ph.D., Senior Professor, Business Administration Department, Ceará State University (UECE), Brazil. freitas8@terra.com.br

[3]Civil Engineer, Ph.D., Associate Professor, Department of Civil Engineering, University of Porto (FEUP), Portugal, jmfcosta@fe.up.pt

Abstract

Based on a literature review and drawing from the experience of lean implementation in multiple construction projects, this paper explores the notion that simplicity and integrality might be crucial for any production system seeking to develop competences against variations derived from both internal and external sources. A discussion using different systems thinking approaches is conducted to provide a better understanding of the volatile behaviour of complex organizations. The aim is to encourage initiatives that address organizational simplicity and integrality in construction projects and, more important, to highlight the important role of lean tools and principles for this endeavour.

Keywords

Systems thinking, organizational complexity, production system design, lean tools

Files

Full Text (/Papers/Details/1355/pdf)

Reference

Filho, A.N.D.M. , Heineck, L.F.M. & Costa, J.M.D. 2016, 'Using Lean to Counteract Complexity' In:, *24th Annual Conference of the International Group for Lean Construction.* Boston, USA, 20-22 Jul 2016.

Download: BibTeX (/Papers/ExportBibtex/1355) | RIS Format (/Papers/ExportRis/1355)

(index.html)

Founded in 1993, the IGLC is an international network of researchers from practice and academia in architecture, engineering, and construction (AEC) who feel that the practice, education, and research of the AEC industry have to be radically renewed in order to respond to the global challenges ahead.

2015 © All Rights Reserved.

Miranda Filho, A.N., Heineck, L.F.M., and Costa, J.M. (2016). “Lean as a counterbalance to complexity.” In: *Proc. 24th Ann. Conf. of the Int’l. Group for Lean Construction*, Boston, MA, USA, sect.1 pp. 133–142. Available at: <www.iglc.net>.

USING LEAN TO COUNTERACT COMPLEXITY

Antonio N. de Miranda Filho[1], Luiz F. M. Heineck[2], and Jorge Moreira da Costa[3]

ABSTRACT

Based on a literature review and drawing from the experience of lean implementation in multiple construction projects, this paper explores the notion that simplicity and integrality might be crucial for any production system seeking to develop competences against variations derived from both internal and external sources. A discussion using different systems thinking approaches is conducted to provide a better understanding of the volatile behaviour of complex organizations. The aim is to encourage initiatives that address organizational simplicity and integrality in construction projects and, more important, to highlight the important role of lean tools and principles for this endeavour.

KEYWORDS

Systems thinking, organizational complexity, production system design, lean tools.

INTRODUCTION

The challenge of managing complex project organizations points to the importance of shedding light on the reasons why lean tools have been successfully applied in the construction environment while other so-called best practices have not. The current study puts forward that the perceived gains might come from organizational simplicity and integrality supported by lean tools. Simplicity is a desirable feature for a project organizational structure because the low degree of vertical and horizontal differentiation between participants helps to reduce the number of changes and events that cause dynamics (e.g., Baccarini 1996; Ashkenas 2007). Additionally, integrality is based on solutions that enhance organizational proximity in different dimensions and thereby improve interactions between participants (e.g., Voordijk et al 2006).

In order to provide a deeper understanding, the discussion herein revisits the issue of complexity caused by the heterogeneity of project participants and their interaction difficulties. It is initially argued that a clear distinction between the complex and complicated aspects of project production is necessary to understanding the effectiveness of certain tools. With this directive the discussion focuses on nonlinear interactions

1 Civil Engineer, Ph.D., CEO, Construtora Santo Amaro Ltda., Fortaleza, Ceará, Brazil, anmirandaf@yahoo.com.br

2 Civil Engineer, Ph.D., Senior Professor, Business Administration Department, Ceará State University (UECE), Brazil. freitas8@terra.com.br

3 Civil Engineer, Ph.D., Associate Professor, Department of Civil Engineering, University of Porto (FEUP), Portugal, jmfcosta@fe.up.pt

within the project organization because these are the most obviously perceived problems associated with complexity. Variations in productivity rates, rework and other performance measures are herein described as the final results of nonlinear dynamics. Thus, ideas from several system thinking approaches are combined to comprehend how these dynamics originate and propagate within complex project organizations.

Two main guidelines for counter measuring dynamics that cause deviations in performance are identified. Related to system design and operation, these guidelines help to explain the efficacy of the existing lean tools and should contribute to new developments seeking to stabilize production systems. The paper concludes by putting forward the idea that the search for simplicity and integrality, in contrast to complexity, is what intuitively guides the successful renewal solutions in project production.

DISTINGUISHING COMPLEX FROM COMPLICATED

Inside the project organization, nonlinearities cause work efforts to be disproportionate to the results. The nonlinear interactions between project participants are behind what construction researchers (e.g., Koskela 2000; Ballard et al. 2001) call the variability of systems and subsystems. This means that variations in performance measures are the final result of nonlinear dynamics between participants. Therefore, regardless of having been started by an external or internal event, the dynamics are aggravated by flaws in the interconnections within the organizational structure.

This notion leads to a review of the common understanding of project complexity. To begin with, Snowden (2003) defines products (engine, refrigerator, car, house, etc.) as complicated systems, since their components are stable with time and can be improved by optimization. In this case the whole is equal to the sum of its parts. Differently, complex systems are complicated and unstable, which means they change shape and pattern with time (e.g., Ottosson and Björk 2004). A business organization is a good example of a complex system where small changes expressed through management decisions are amplified by other actors and disproportionately cause large effects. The more people involved the more probable it is that completely uncontrolled dynamic changes will occur. The nonlinear interactions among them make the whole differ from the sum of the parts.

For a long time, the common assumption was to interpret projects solely as complicated systems, as demonstrated by the use of transformation model concepts and tools like PERT/CPM and Line of Balance (e.g., Mendes Jr. and Heineck 1999). Afterwards there was a tendency to interpret projects exclusively as complex systems (e.g., Bertelsen 2003; Bertelsen and Koskela, 2003). However, both approaches need to be reconsidered and combined so as to visualize each project as a blend of complicated system (product) and complex system (organization). The two realms must be dealt with in different but complementary ways (e.g., Figure 1).

A product is characterized by a set of attributes like purpose, criteria, functionalities, components and value. These attributes establish the product's cost, quality standards and degree of constructability. Changes in attributes affect how simple or complicated will be a product. On the other hand, an organization is characterized by the policies, processes, strategic choices, resources, capabilities and competences that generate its robustness and constraints. Changes in these characteristics alter the system's robustness and transform the way the various subsystems interact routinely or when submitted to sporadic events.

There is no direct relationship between the product's level of complication and organizational complexity. A complicated product can be entirely designed and built by a small team if there is sufficient time and skills. This corroborates the notion that organizational complexity is not just a consequence of product type, but rather the cumulative result of decisions regarding business selection, structure and management (e.g. Gröbler et al. 2006; Ashkenas 2007). Therefore, a small project can be more complex than a large one if there is a great amount of uncertainty, either in product goals or in organizational methods, added to time and cost constraints (e.g., Williams 2002).

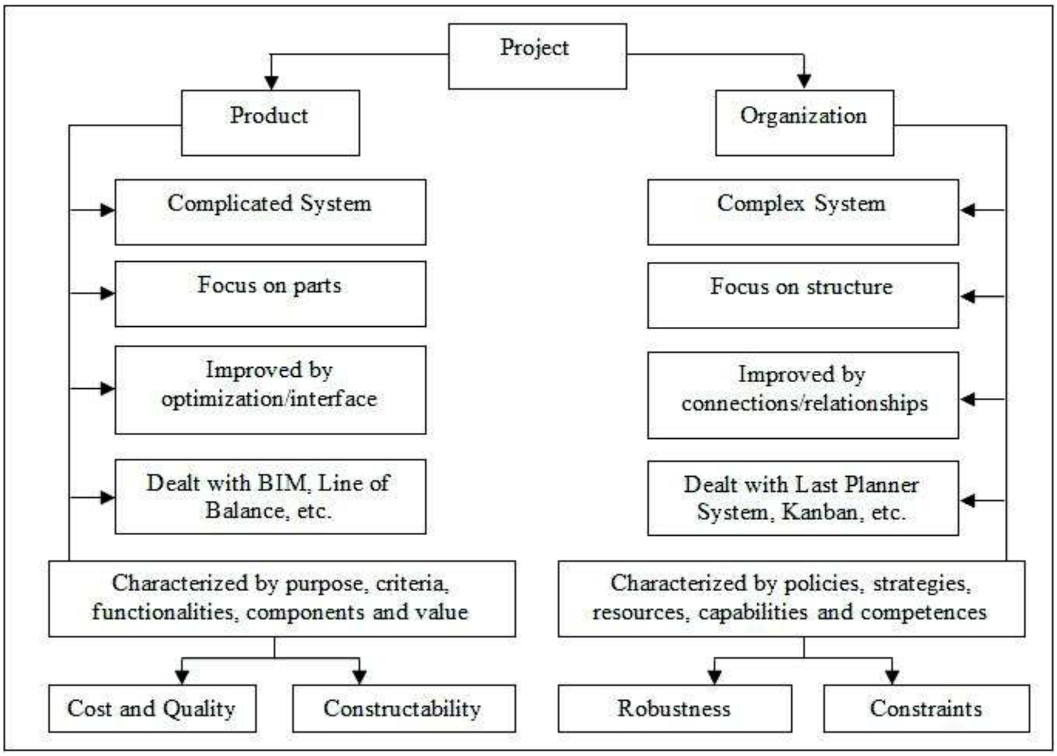

Figure 1: A Model for Project Realms, where Complexity is more Directly Derived from Organizational Characteristics and not Necessarily from Product Attributes

Distinguishing a complicated system from a complex system is an important step to guide improvements in project performance. As mentioned by Sargut and McGrath (2012), serious, expensive mistakes are made when a complex organization is managed as if it were just a complicated one. Ottosson and Björk (2004) observe that traditional management practices can deal well with complicated systems, i.e. systems consisting of many components that are stable over time. Complex systems, on the other hand, cannot be dealt with in the same way as stable systems, because the changes are greater in each chosen time interval. The nonlinear interactions in complex systems cannot be predicted by traditional budget and schedule tools, as they are the results of relationships inside and among the various subgroups in the structure. Thus, countering the harmful effects of nonlinear interactions requires paying close attention to the design of functional areas in the organization structure and managing work efforts in real time as much as possible.

UNDERSTANDING NONLINEARITIES AND VARIATIONS

Understanding nonlinear dynamics and how they are aggravated is a prerequisite to devising solutions for structuring and managing large project organizations. When facing a problem, managers tend to assume that some external event caused it. But not every problem is caused by an external event and secondly, the way external events evolve and are dealt with pretty much depends on the organization's internal capabilities. From the viewpoint of systems thinking, the internal structure is often more important than external events in generating problems that affect performance (e.g., Kirkwood 1998).

The problems faced over and over by the management team are, very often, symptoms of an underlying cause in the organizational structure. Focusing on a symptom leads to corrective interventions that may amplify the problem or even generate other deviations. For this reason, Toyota's strategy says "ask why 5 times", which is its way of pointing out the need to find the underlying cause. However, perceiving how nonlinear dynamics originate and propagate requires combining ideas from different systems thinking approaches like theory of constraints, system dynamics and complexity theory.

To begin with, Kirkwood (1998) states that many business processes are nonlinear, especially when pressed to extremes. For example, while it may be true that if an employee works ten percent longer hours he will accomplish ten percent more work, it is probably not true that if he works twice as many hours he will accomplish twice as much work. By trying to increase even further the amount of overtime the employee soon suffers from fatigue, which leads to a reduction in his working effectiveness. Similarly, despite the efforts of the sales team, if the degree of customer demand grows too rapidly the available production capacity of a manufacturing plant may limit the amount of a product that can be sold, making customer satisfaction give way to dissatisfaction. These are both practical examples of nonlinear responses encountered by business organizations. In both cases the final result is quite different from what was originally intended.

What stands out from these examples is that the nonlinear behaviour of the interactions is aggravated by constraints in the systems. Different constraints have in common the fact that they are related to the capacity of the resources involved. Indeed, resources are defined as things that have a limited capacity to bear strain; e.g., labor, tools, equipment, space, and time (e.g., Ballard et al. 2001; Ballard and Howell 2003). Although systems are sometimes constrained by policies (e.g., Goldratt 1990), it is a fact that rules can be stretched while resources are often physical entities that cannot. This shows the need to consider the impact of overloaded resources in cause-effect chains.

Regardless of having been started by an intended or unintended event, the dynamics originated after exceeding a resource's load capacity will always be harmful to business performance. As a matter of fact, if the desired state of a subsystem is characterized by specific values for a relevant set of variables, an event causing one of those variables to change beyond a tolerable limit alters the state and is, thereby, considered to be disturbing the course of the subsystem (e.g., Campagne et al. 1995). For this reason, Van der Merwer (2002) mentions that often the optimal operating point of a subsystem is near the limits of constraints in the operating window.

However, in construction projects the currently impeding constraint typically changes with time and situations. Therefore, there may be little time to identify and exploit internal constraints in complex adaptive systems that have a continuously changing structure (e.g., Meijer, 1998). To make matters worse, the hierarchic layers and different occupational specializations within the organizational structure added to the peculiarities of site production have a negative effect on the degree of operational interaction between project elements. This implies that there can be not one, but many unknown constraints that are being pushed to the limit as the dynamics propagate throughout the organization all the way to the frontline workers. Consequently, what may seem like a simple decision or request to a project stakeholder can turn into a major exercise for hundreds of other people. Connection problems between components of a large system and the lack of sufficient information regarding the existing constraints explain why a series of outputs may appear random to an outside observer.

The notion that dynamics of both intended and unintended events can cause positive and negative influences shows that it is paradoxical that a construction project is itself a process of continuous change, but within the project every change may be hazardous (e.g., Love et al. 2002). In construction, managerial interventions to cope with environmental dynamics or to initiate planned activities start dynamics that rapidly create intermediate states or move the production system from one project phase to another (e.g., Bertelsen 2003). Alterations in product specifications or scope, handoffs between specialists, increases in the workforce, and changes in the construction site layout are just a few examples of such events.

Knowing that dynamics causing positive and negative influences co-exist throughout a project's life cycle implies that appropriate solutions need to be devised to maximize the positive effects and minimize the negative ones. Although a source of managerial concern, this volatile systemic behavior can be prevented if addressed early in the process of production strategy formulation. The decisions made when designing the production system can not only create capabilities that reduce the negative influences of harmful dynamics, but also induce a project to undergo less intersecting phase transitions. Underlying the production system design and operation should be the philosophy that a system cannot achieve management goals nor be improved if it is not stable. Even though construction projects need to pass through a series of phase transitions, it is necessary to place emphasis in understanding how production systems can be designed and operated to deal with dynamics that cause a process to vary from the expected or desired state.

PROPOSING GUIDELINES FOR STABILIZATION

Field observations support the notion that overloaded resources in cause-effect chains aggravate the nonlinear behaviour of interactions. Another interesting notion is that nonlinearities between project stakeholders naturally arise from their distance in terms of communication, geography, work pattern, culture, and technology. Those two insights are particularly important to appreciate the difficulty of making decisions in a temporary organization characterized by high division of work and many hierarchic layers.

Even so, decision-making in construction management is mainly based on the reductionist thinking, where the focus is on a smaller number of decision areas and possible outcomes. This is especially true for time-stressed situations. Reductionist thinking causes managerial interventions to be more frequent and commonly taken from a macroscopic perspective. A large project observed macroscopically is characterized and evaluated based on few variables, which creates the illusion of a predictable behaviour. Hence, decisions are made considering a relatively small number of variables, such as the match between resources and tasks to accomplish a project schedule. However, as mentioned by Ottosson and Björk (2004), decision-making centralized in upper hierarchic levels will have serious problems in grasping the small things, which include interrelationships and constraints. Thus, in a particular project the different interventions are either done: optimistically, with unknown constraints being overloaded and starting harmful dynamics; or pessimistically, with unknown constraints being dealt with by buffers placed in project plans. This provides a partial explanation to why detailed long-term planning and budgeting are rather meaningless in practice.

The combination between reductionist thinking and macroscopic perspective illustrates the problem with strategies that allow the occurrence of many events and that foster centralized decision-making. The high probability of occurring uncontrollable dynamics that cause deviations indicates that managers should not try to manage complexity, but rather to organize their way around it (e.g., Meijer 1998). Therefore, two complementary guidelines for a better stabilization of large project production systems are proposed:

Reduce the number of intended and unintended events/changes to be handled by the production system. This first guideline is more related to organizational simplicity. Intense and overlapping managerial interventions to absorb environmental dynamics or to initiate planned activities are likely to overload resources and thereby start harmful dynamics. For this reason, over-intervention, which is quantified by the magnitude and the frequency of changes, is counter-productive.

Improve the production system's integration by increasing the quality and quantity of interactions between project stakeholders. This second guideline is more related to organizational integrality. Designing a production system in a way that enhances the degree of proximity between participants improves their interactions and allows them to help in keeping the subsystems operating optimally near the limits of the closest active constraints. This reduces nonlinearities in the system and consequently enhances project performance.

FOLLOWING THE GUIDELINES THROUGH LEAN

In order to follow the guidelines, it is important to perceive the drivers of organizational complexity that can be minimized. The first influence comes from external drivers of complexity. The business strategy establishes the external environmental complexity in which the firm will compete. As a result, the complexity of the organization's internal structure tends to match that of the external environment. Even firms that have outsourced many of their production tasks still need to take into account a number of aspects and to emphasize control on the interrelations with the outsourcees (e.g., Meijer, 2002). This is especially true for the lead firm in a large-scale product development characterized by site production and performed under a tight schedule.

Fortunately, business organizations are able to select to a certain degree the external environment they want to live in depending on its complexity (e.g. Gröbler et al. 2006). It is up to top managers to decide about a specific strategic orientation or particular geographic area in which the firm will compete. Therefore, complexity is considered lower for firms with a focus on certain customer segments or higher degree of geographical concentration. The choice to create value for a limited well-chosen set of customers helps to reduce the number of aspects that need to be taken into account simultaneously and to lower the bandwidth and randomness of interrelations (Meijer, 2002). In other words, focusing the business proposition can not only reduce the exposure to events and unplanned changes that cause dynamics but also improve the quality of interactions between stakeholders. This is well aligned with the abovementioned two guidelines for improving systemic stability.

Regarding the second influence to organizational complexity, it is important to recognize the internal drivers that largely contribute to the heterogeneity of participants, functions, and processes performed within the system. As mentioned before, the way an organization is structured strongly shapes its inner complexity. Therefore, despite the influence of contextual factors in the external environment, at least to a certain degree, organizations are able to reduce internal complexity (e.g. Gröbler et al. 2006).

The reduction of internal complexity is justified by the need to counter nonlinearities. The notion that both intended and unintended events can start harmful dynamics highlights the importance of organizational features that shield downstream activities from disturbances or that foster adaptive management schemes (e.g., Mawby and Stupples 2002; Ballard and Howell 2003). To do so, organizational structuring in civil construction should pay more attention to strategies and practices that enhance simplicity and integrality. Organizational simplicity based on low differentiation can reduce changes and events that cause dynamics. Complementarily, organizational integrality based on proximity in different dimensions can reduce nonlinearities within dynamics.

Initiatives aimed to strengthen linkages between participants in temporary organizations allow them to help in keeping the dynamics from over loading the currently active constraints. The lower degree of differentiation and the higher degree of proximity eliminate intermediate barriers to flows, including layers of authority relationships in the chain of command, and empower people at each level to make decisions and solve everyday problems. Hence, each work team becomes an attractor that ensures that a subsystem will move to the desired state during a phase transition or that it will remain stable when disturbances occur. A production system founded on lean principles and tools seeks to create the same systemic behaviour, but with the purpose of using it to increase the stability needed to achieve management goals. Table 1 provides examples of tools that are advocated by lean practitioners and that seem to be well aligned with the two guidelines for systemic stability.

Table 1: Examples of Tools that Follow the Guidelines

Lean Tool	**Reduce Intended and Unintended Events/Changes (more related to simplicity)**	**Improve the Quality and Quantity of Interactions (more related to integrality)**
Design-Build	Generates fewer handoffs and reduces problems during the construction phase	Enhances data management and exchange between specialists
Partnering	Reduces uncertainties like supply shortages and utilization of work capacity	Creates common work methods, knowledge and values
Relational Contracting	Avoids disputes by establishing the framework in which interactions will occur	Establishes common business mores, benefits and burdens
Last Planner System	Influences factors upstream through medium and short term planning	Improves commitment to goals and cooperation in finding solutions
Mobile Cells	Generate fewer handoffs and rework interventions	Connect workers and tasks in terms of time, space and information
Andon	Helps in preventing disturbances in ongoing operations	Improves communication of work status between teams
Kanban	Reduces inflow variations and avoids overloading the systems with work in process	Enhances lateral relations between specialist and support teams
5S	Avoids careless handling and storing of materials that can lead to supply shortages	Improves transparency and flows between workstations
Visual Control Methods	Clarify what is and what is not being done so as to avoid interruptions in the workflow	Connect teams with timely information for many forms of actions
First Run Study	Allows an early identification of constraints that could affect the work	Allows a better adjustment between product and work methods

CONCLUSIONS

Project management is commonly described as a mature topic. However, the layers of complexity that have been added to construction projects have placed project managers too far from where value is being created to the final customer. Thus, even though projects are temporary processes, construction managers should not be seen as process leaders because of their macroscopic perspective of what is going on. Their frequent interventions may exacerbate complexity or cause deviations. Instead, process leaders should be the people who are actually closer to the operations. This insight shows the need to change managerial schemes and habits, because organizational complexity is a cumulative by-product of decisions regarding business selection, structure and management. Therefore, complexity leads to revaluating traditional paradigms about system design and operation in construction projects.

In a large-scale product development, an effective effort to create stability during the project's short life cycle requires managerial actions by people at all levels of the temporary organization. However, the proactive behaviour of all participants is very much dependent on structural arrangements made by the general contractor. One necessary arrangement is simplicity in terms of less division of work and hierarchical levels. Another important arrangement is integrality in terms of geography, work pattern, culture, communication and technology. Despite influence coming from external drivers of complexity, internal arrangements that foster a lower vertical and horizontal differentiation and a higher proximity in different dimensions can reduce to a certain degree organizational complexity. As a result, different stakeholders, including frontline workers, become empowered to reduce the number of events handled by the production system and to help in keeping it operating optimally against production constraints. This reduces nonlinearities in the system and consequently enhances project performance.

Although the TFV model has been the major foundation for developments in lean construction, the systems thinking approach can also help in understanding what works and what does not in a construction environment. The strategic nature of lean implementation points to the importance of using systems thinking, since stability is affected by the design and operation of an organization and its functional areas. The discussions herein indicate that future studies in lean construction should address organizational simplicity and integrality because both concepts seem to be intuitively guiding the successful renewal solutions in project production. Further research is needed to expand the comprehension of their role in the issue of systemic stability.

REFERENCES

Ashkenas, R. (2007). "Simplicity-minded management." *Harvard Business Review* 85(12): 101-109.

Baccarini, D. (1996). "The concept of project complexity – a review." *International Journal of Project Management*, Vol. 14, No. 4, pp. 201-204.

Ballard, G.; Koskela, L.; Howell, G.; and Zabelle, T. (2001). "Production system design in construction". *The 9th International Group for Lean Construction Conference*, Singapore: National University of Singapore.

Ballard, G. and Howell, G.A. (2003). "Lean project management." *Building Research and Information*, 31(2): 119-133.

Bertelsen, S. (2003). “Complexity - construction in a new perspective.” *The 11th Annual Conference of the International Group for Lean Construction*, Blacksburg: Virginia Tech.

Bertelsen, S. and Koskela, L. (2003). “Avoiding and managing chaos in projects.” *The 11th Annual Conference of the International Group for Lean Construction*, Blacksburg: Virginia Tech.

Campagne, J.P.; Jacot, J.H.; Frein, Y. and Vitry, G. (1995). “A framework to specify a reactive and proactive management system.” *IEEE Symposium on Emerging Technologies & Factory Automation*.

Goldratt, E.M. (1990). *What Is This Thing Called Theory of Constraints and How Should It Be Implemented?* New York, North River Press.

Gröbler, A.; Grübner, A.; and Milling, P.M. (2006). “Organizational adaptation processes to external complexity.” *International Journal of Operations and Production Management* 26(3), 254-281.

Kirkwood, C.W. (1998). "System dynamics methods: a quick introduction." <http://www.public.asu.edu/~kirkwood/sysdyn/SDIntro/SDIntro.htm> (September 18, 2005).

Koskela, L. (2000). “An exploration towards a production theory and its application to construction.” Espoo, Technical Research Centre of Finland. *Doctoral Thesis*: 296.

Love, P.E.D.; Holt, G.D.; Shen, L.Y.; Li, H.; and Irani, Z. (2002). “Using system dynamics to better understand change and rework in construction project management systems.”*International Journal of Project Management* 20: 425-436.

Mawby, D. and Stupples, D. (2002). “Systems thinking for managing projects.” *IEEE International Engineering Management Conference*.

Meijer, B.B.R. (1998). “To manage or not to manage complexity.” *IEEE International Engineering Management Conference*.

Meijer, B.B.R. (2002). “From reducing complexity to adaptive organizations.” *IEEE International Engineering Management Conference.*

Mendes Jr., R. and Heineck, L.F.M. (1999). “Towards production control on multi-story building construction sites.” *The 7th International Group for Lean Construction Conference*, Berkeley: University of California.

Ottosson, S.S. and Björk, E. (2004). "Research on dynamic systems - some considerations." *Technovation* 24(11): 863-869.

Sargut, G. and McGrath, R. G. (2012). “Learning to live with complexity.” *Harvard Business Review*, Summer 2012: 44-50.

Snowden, D. (2003). "Uma nova forma de ser simples." *Revista HSM Management* 4(39): 98-106.

Van der Merwe, A.A.P. (2002). “Project management and business development: Integrating strategy, structure, processes and projects.” *International Journal of Project Management*, 20(5): 401-411.

Voordijk, H.; Meijboom, B.; and Haan, J. (2006). “Modularity in supply chains: a multiple case study in the construction industry.” *International Journal of Operations and Production Management*, Vol. 26 No. 6, pp. 600-618.

Williams, T. (2002). *Modelling complex projects*. New York: John Wiley & Sons.