

STRATEGIC ISSUES IN LEAN CONSTRUCTION IMPLEMENTATION

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ABSTRACT

The paper discusses topics on production strategy and the need for proper definition of strategic goals before the implementation of Lean Production/Construction in construction companies. This research was motivated by two main reasons. The first reason is that few papers in the construction management literature tackle the relationship between strategic issues and Lean, even at IGLC conferences. The second is that construction companies seem to have implemented Lean in operational levels starting from tools and principles with low level of complexity without actually linking these to the companies' strategic goals. Without proper strategic orientation Lean implementation may fail like other initiatives to improve companies' performance. The research method used in this investigation comprised three phases: literature review, field research, and interviews with specialists and managers in construction companies. The authors carried out a research on a group of construction companies that have been implementing Lean in their construction sites and looked for evidences that link operational action to strategic planning. The paper concludes with the results of the cross analysis between the cases and the interviews as well as recommendations to assure proper engagement between Lean and strategic issues in construction companies.

KEY WORDS

Strategy, production strategy, lean construction implementation.

INTRODUCTION

In the early years of the 21st century, a construction company in Fortaleza (Ceará State, Brazil) decided to innovate by adopting concepts and tools based on the work of the Lean Institute Brazil. The initial phase of the implementation of Lean practices was supported by the work of academics and experienced consultants. The experience was successful as the company experienced fast and large productivity gains. Based on this experience, a group of academics, engineers, and consultants organized two international events about Lean Construction (International Seminar on Lean Construction – CONENX 2004 and 2006) and a set of classes on the topic as part of a larger program on innovative practices in construction (INOVACON). These events and the classes raised the interest of local and national construction companies for Lean Construction.

As time passed, it became clear that companies that had adopted Lean stopped moving forward in terms of sustaining the practices that had been implemented and

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implementing new ones. Some companies even moved backwards, and returned to the traditional production management practices. This phenomenon called some academics attention, and raised a discussion on the role of strategy definition and deployment when new practices are implemented to improve construction processes. We believe that some companies implement lean tools and practices, from an operational stand point, but are not able to sustain their use because the implementation was not grounded on a solid basis, i.e., company business strategy. Some companies lack a vision of future to define which goals they want to achieve by implementing Lean, and which path they should take to achieve them.

Motivated by the discussion presented, this paper aims to point important factors that should be taken into account during the implementation of Lean, especially strategic ones. Other papers have tackled the implementation of Lean Construction by discussing different approaches to do so (e.g., Alarcón et al. 2002, Arbulu and Zabelle 2006) but very few have actually discussed how the Lean implementation is liked or should be linked to a company's business strategy (e.g., Garnett et al. 1998; Featherston 1999; Barros Neto 2002).

LITERATURE REVIEW

The literature review is composed by three parts. From Cole's (1999) analysis of the quality movement in American companies, we search for links between the quality programs and organizations' business strategies. Next, we review the literature on implementation of Lean in manufacturing settings. Finally, we discuss the implementation of Lean in construction companies.

LESSONS LEARNT FROM THE QUALITY MOVEMENT

The discussion on how companies have historically implemented Lean and their lack of strategic orientation (Barros Neto 2002) repeats what happened during the Quality movement. Cole (1999) points out that the implementation of Quality in American companies initially went through the superficial use of its tools, principles, and concepts, before Quality effectively became part of these companies businesses. The same author stresses that the Japanese considered Quality in a strategic way, while for the Americans Quality was one more obstacle to be overcome to be competitive in the market.

Cole (1999) highlights that in the old Quality model, Quality was seen as another specialty inside companies' organizational structures, and was promoted by a specific department not by the whole company, e.g., each department worked towards their own goals independently. Companies were oriented by their own wishes and not by their client's and promoted local optimums and inspections.

As the Quality movement evolved, American companies faced the problems that hampered the effective implementation of Quality and the risk that it could become another unsuccessful initiative to improve their businesses. According to Cole (1999), in the new Quality model, companies are more client-oriented. Quality is deemed strategic and its goals, plans, and actions are deployed throughout the company so that all specialties work together to achieve global objectives. All workers are invited to participate in Quality initiatives and Quality permeates all processes to deliver a product of service.

In the early days of the Quality movement in the United States companies were adopting the concepts and tools in isolated areas and in a shallow fashion, i.e., use of tools and concepts without a link to the company's business strategy and the view of the whole. As time passed, Quality was considered an essential part of processes to deliver products and services oriented by the clients' wishes in an integrated fashion, i.e., all departments and suppliers working in an integrated fashion with goals oriented towards satisfying the client's needs.

IMPLEMENTING LEAN IN ORGANIZATIONS

Womack e Jones (1998, p. 290) suggest that companies should define a strategy to orient their growth while implementing Lean, and to assure a sustainable path of improvements through the years. According to them, companies that worry about immediate gains and fast growing profits achieved through the reduction of staff cannot sustain a supposedly Lean company for several years. They stress that Lean should be considered as a way to help companies to redefine their businesses and not as a short path to achieve competitiveness. The implementation of Lean in organizations has been described in the literature (e.g., Liker 2004) but several texts describe cases of Lean implementation at Toyota (Lewis, 2000). Lewis (2000, p.963) stresses that *"this encouraged observers to deconstruct the system as described (focusing in on apparently key attributes such as kanban cards or andon boards etc.) and inevitably de-emphasised the impact of 30 years of trial and error"*.

Womack and Jones (1998, p.284) suggest that Lean should be first implemented in activities that are "important and visible", e.g., production, so that all people in an organization can see the benefits achieved with Lean. The use of tools and displays is a way these changes take place in the work environment, at the same time, they serve as a way to disseminate information that wasn't shared before Lean practices were implemented. A problem happens when the simple implementation of these devices are understood as the implementation of Lean.

Lewis' (2000) comments about how Lean is implemented in some organizations partially reflects the way construction companies have embraced the Lean ideal. Papers have shown the implementation of tools and principles in construction sites in specific areas of production (e.g., Alarcón et al. 2002). The principles and tools implemented have a low level of complexity and can be easily implemented with minor adaptations to construction settings. Besides, discussions on Lean implementation often refer to actions implemented at construction sites, and to a lesser extent on other areas such as design, supply chain management, contracts etc. An analysis of 14 years of IGLC conferences (www.iglc.net) supports this assertion and reveals that there are few studies regarding the consideration of Lean as part of companies' business strategies and strategic planning. The words 'strategy' and 'strategic' are often found in IGLC papers as a synonym of the words 'approach' and 'relevant' respectively (e.g., 'implementation strategy' and 'strategic partnership'). Exceptions include the papers of Garnett et al. (1998), Featherston (1999), and Barros Neto (2002) in which the authors clearly discuss the link between the implementation of Lean Construction and the companies' business strategies.

Garnett et al. (1998) describes the initiative of the Construction Industry Task Force in UK to apply the principles of Lean thinking to construction at strategic levels. Featherston (1999) stresses that the implementation of Lean has to be

preceded by a desire to change, which may be imposed by external forces that may jeopardize the organization survival or by the possibility of being rewarded with the change. Barros Neto (2002) discusses the importance of linking the implementation of Lean to an organization's strategy and its market.

The implementation of Lean and its component parts requires a careful analysis of the contextual settings where practices were first implemented (Lewis 2000). For instance, Passos Júnior et al. (2005) stress the importance of conducting an analysis of the technical-economical logic in different settings before implementing automation, which is one of the core parts of the Toyota Production System often implemented by organizations pursuing the Lean ideal. These authors stress that different local economic characteristics, i.e., availability and costs of human work and equipment, lead to different ways to implement automation. Therefore, we can infer that there should be a close relationship between an organization's business strategy and the production philosophies it adopts.

Overall, the implementation of tools and principles of Lean and carrying out *kaizens* can guarantee temporary gains in processes but cannot assure long term competitiveness to organizations. Recently, a book on strategy deployment for implementing Lean has been published by the Lean Enterprise Institute, e.g., Dennis (2006), to help companies to implement Lean while bearing in mind their business strategy.

Dennis (2006) stresses the importance of strategy deployment to guide actions necessary to achieve an organization's goals. The author suggests that organizations should define a true north to guide their actions and align these actions to achieve the organization's strategic goals in defined period of time. After that, the organization can use the PDCA cycle (Plan-Do-Check-Act) as the basis for strategy deployment. Organizations that do not deploy their strategy adequately, risk optimizing isolated areas which are not coordinated with their overall businesses and strategic goals (Dennis 2006).

As far as the Lean implementation in Construction goes, Picchi (2001) suggests that there are three levels for implementing Lean in construction: company-, project-, and sector-level. The implementation at the company level has limited results because at some point the company's actions will reach a ceiling defined by the flow of inputs provided by suppliers, designers, and other stakeholders. Picchi stresses that construction companies should unite and develop agreements with their main suppliers given that alone they cannot bear the power of some large and powerful suppliers (e.g., elevators, large mechanical systems, steel and rebar).

Regarding the different approaches for implementing Lean in construction, Arbulu and Zabelle (2006) suggest that there are two approaches discussed as follows:

- Shallow and wide – in this case companies want to implement Lean quickly and through imposition of the top-level management (top-down). Actions are implemented in several projects at once what puts high levels of pressure in all workers.
- Narrow and deep – initially, Lean is implemented in projects, which are temporary organizations; later, the initial changes are extended company-wide.

The first approach results in a loss of time and money as people may impose barriers and resist the change. The second approach requires less effort in terms of tutoring and coordination as the change is carried out in a project-basis (Arbulu and Zabelle 2006). The second approach is aligned to what Womack and Jones (1998) suggest in terms of providing fast feedback and visible results because changes are implemented at the project level and results can be perceived almost immediately. In addition to choosing the right approach to implement Lean, collaboration is seen as an important factor to be considered, as suggested by Alarcón et al. (2002): “*Working in a collaborative approach, with different training actions, sharing experiences and information among the companies produces a number of benefits: development of skills for implementation, development of a healthy competition among companies that are working together, fast learning from successes and failures.*” (Alarcón et al. 2002, p.10)

RESEARCH METHOD

The research method comprised three phases: literature review, field research and semi-structured interviews. The literature reviewed included papers and books on implementation of Total Quality Management and Lean Thinking, and strategy in organizations. The questions used in the interviews aimed at identifying relationships between the companies’ strategies and the implementation of the Lean philosophy. The authors tried to identify the competitive criteria used by the companies, why they had chosen to implement the Lean philosophy, the difficulties they faced in the implementation and the contributions brought by the philosophy to these companies. The questions used in the semi-structured interviews are listed in table 1.

Table 1 – Interview questions

Questions
What’s the target market of the company? What’s its market niche?
Why did the company choose to implement the Lean philosophy?
How did the implementation take place? What’s the path for implementation (what’s been implemented)?
What were the main difficulties faced by the company during the implementation?
What’s the company’s business strategy?
Which are going to be the next steps in the process of implementing Lean at the company?
How does the company relate the Lean philosophy with the company’s business strategy?
What are the contributions of the Lean philosophy to the company? (Collect evidence based on data and facts)
Where does the company want to get to with the implementation of the Lean philosophy?
Why has the company stopped the implementation of the Lean philosophy? (This question was asked to one of the companies interviewed)

Three companies were investigated based on a sample of companies that had participated in a Program for Innovation in Construction (INOVAÇON) in the state of Ceará, Brazil. These three companies have distinguished themselves from the others in the sense that they have sustained a successful implementation of Lean practices throughout time (in operational levels) and have been able to demonstrate the benefits of Lean to its workforce and clients. They have also been invited to share their experiences in local and national seminars on Lean implementation in construction and manufacturing settings.

RESULTS AND ANALYSIS

During the field visits, the authors observed that the companies started the Lean implementation through the use of production planning and control tools aiming at stabilizing production and controlling milestones. One of the tools widely used in the sites visited was the line of balance. Elements of the Last Planner System (Ballard 2000) can also be found in these sites, e.g., weekly work plans, percent plan complete and causes of problems analysis, lookahead planning.

In addition to the implementation of the planning and control tools, companies worked to stabilize production by using the “pull” concept. Companies used *kanban* manager boxes to balance demand and supply for mortar and concrete mixed at the site and *andon* boards, which indicate the status of production tasks in different areas of the building (these boards are located at the construction manager’s office). Each of the companies visited had implemented these tools according to their needs.

During the implementation of Lean, the companies investigated used to exchange information, and all of them had (and still have) a flow manager to take care of the inflow of resources needed to keep production running smoothly. The companies also use the value stream mapping to analyze physical and information flows at site.

From an operational standpoint, the companies investigated have adequately implemented Lean tools and have innovated in ways to adapt and implement these tools. The shift from traditional to Lean tools has brought benefits to the companies investigated, e.g., one of the companies had a 50% decrease in the consumption of cement when executing flooring; another company had a 30% increase on its productivity for concrete structures.

In order to complement the data collected in the field, semi-structured interviews were carried out with the three companies investigated. Table 2 summarizes the results obtained from the interviews.

Company A is part of a larger conglomerate of companies and they usually have several projects underway at any time. It started the Lean implementation with the support of its Technical Director and a group of the company’s engineers. In the beginning of the implementation process, the company hired a civil engineer who was pursuing a Master’s degree in Construction Management to act as their Lean Coordinator (to the implementation efforts running). For the authors, this seems to be the most motivated company with the Lean implementation. There are a few members in Company A’s staff who were currently pursuing Master’s degrees during the time the paper was written.

Company B builds upscale buildings in the most valued areas of the city; it usually develops several projects simultaneously. Its implementation process was led by its Technical Director and supported by a group of young engineers and interns. The company’s interns have broad responsibilities on site (e.g., operational planning and control) and are well-rewarded in terms of pay for their dedication to improving the company’s Lean system. They are also required to read literature related to Lean implementation and to look for ways to implement what they read on site activities.

Table 2 – Summary of the interviews

Construction Companies		
A	B	C
What's the target market of the company? What's its market niche?		
Industrial and commercial projects; upscale high-rise residential buildings.	Upscale high-rise residential buildings; hotels.	High-rise residential buildings.
Why did the company choose to implement the Lean philosophy?		
To industrialize construction processes; use Lean concepts to banish waste and improve quality.	To make the project development more dynamic and to stabilize production.	Because of the influence of ideas brought by academics and because of its low cost of implementation.
How did the implementation take place? What's the path for implementation (what's been implemented)?		
Through ideas presented at the CONENX event and the help of INOVACON Program's team. Implementation started at one construction site and has spread to all of the company's sites.	Through the ideas brought by academics (SIBRAGEC event and INOVACON Program) and the reading of books, e.g., The Goal, Critical Chain, which have contributed to establish a theoretical background that unites employees at the company.	After the success of the implementation at the first construction site, there was a backward movement because there was not a person in charge of the implementation efforts. The supervisor was not following the implementation closely and the chief-engineer of the project changed during that time.
What were the main difficulties faced by the company during the implementation?		
Making employees understand Lean concepts, and convincing suppliers to adopt the Lean philosophy.	Motivating the efforts to assimilate concepts through readings and courses about Lean. Changing the employees' mindset.	Making the top level management to participate. It's important to reduce the hierarchical levels so that top management gets involved with the changes. Involving workers in the change process.
Which are going to be the next steps in the process of implementing Lean at the company?		
Progressing with the Lean implementation in production emphasizing its implementation in industrial projects. Implementing Lean in administrative and finance sectors, and in the design process.	Stabilizing the Lean concepts and tools already implemented. Implementing Lean in the administrative and finance sectors.	Implementing Lean in the design process.
What's the company's business strategy?		
Innovation, technology and quality.	Client satisfaction, flexibility, reliability, cost.	Time (dependability), target cost, quality.
How does the company relate the Lean philosophy with the company's business strategy?		
Aggregating value; banishing waste; shortening production time.	Organizing production through Lean helps building trust-based relationship with the client. Making easy the implementation of flexibility in different project plants.	Reducing cost through banishing waste. Reducing production lead times and the time to finish projects.
What are the contributions of the Lean philosophy to the company? (Evidence based on data and facts)		
Decrease of 1/3 of the workforce needed in a project. Reduction of waste levels in different areas of a project. Better site organization. Improved planning and control.	Productivity gains. Better site organization. High levels of employee and clients' satisfaction. Cost reduction.	Shortening projects lead times in 50%. Productivity gains.
Where does the company want to get to with the implementation of the Lean philosophy?		
Keep on avoiding waste. Disseminate the Lean philosophy to suppliers. Implement the Lean philosophy in other areas of the company, beyond production.	Make the Lean philosophy part of the company's culture so that it stands strong for future generations.	Deliver projects on time, with the quality desired by the clients and achieving the planned costs.

Company C, was the first one to implement Lean techniques in its sites, and started the implementation with the support of a local consultant. The owner of Company C got motivated by the results achieved with the consultant's work and decided to invest further on Lean. Company C works as a contractor for a large industrial group and, in addition to that it usually deals with one residential project at a time.

By comparing the results shown in table 2 with the Quality movement in American organizations (e.g., Cole 1999), the companies investigated seem to be in the initial stages (or the old model) of the road to Lean implementation. The interviews have revealed that there is a tacit understanding that the Lean implementation has improved performance indicators traditionally used in the construction industry, i.e., time, cost, and productivity. The stability reached after implementing Lean was mentioned and confirmed by the fact that managers are not frequently called "to put off fires" at construction sites anymore.

RELATING LEAN IMPLEMENTATION TO COMPANY'S BUSINESS STRATEGY

What follows is a discussion of strategic factors related to implementing Lean in construction to help companies to bridge the gap between the implementation of Lean and their business strategy.

- *Analyzing the context* – in the literature (e.g., Lewis 2000, Passos Júnior et al. 2005) and in the IGLC group's list, researchers and practitioners alike have called people's attention to the importance of contextual characteristics during the implementation of Lean. Companies tend to implement Lean following different trajectories (Lewis 2000, Womack and Jones 1998). For the companies investigated, academy- and industry-promoted events have initiated a wave of actions that encouraged the implementation of Lean. Local consultants have helped these companies to disseminate Lean; however, each company adopted Lean concepts, principles, and tools according to their needs and contexts.
- *Strategically analyzing resources with the implementation of Lean* – according to Lewis (2000), some resources may be deemed strategic given certain market situations (e.g., geographical positioning of plants, suppliers proximity to production plants) and the organization's characteristics regarding its relationships with clients (e.g., market proximity). For the companies analyzed, the implementation of Lean has become part of their marketing campaign as clients perceive more organized construction sites and can exchange information with companies using more transparent communication channels.
- *Benefiting from the implementation of the Lean philosophy* – companies can become more competitive if they are capable of reaping the benefits that result from the Lean implementation (Lewis 2000). The companies investigated are not in a good bargaining position to persuade their service suppliers to change towards Lean but companies should be encouraged to work on that as they can reap the benefits that result from achieving stability in their production systems and in the demand for resources. The use of Lean from a strategic standpoint should include the definition of agreements among different sectors in the construction industry, as suggested by Picchi (2001), so that companies can reap benefits achieved in their supply chains.

- *Defining and deploying production strategies* – when questioned about their competitive business strategies, companies cited different criteria such as quality, reliability, cost, and flexibility. In one of the companies analyzed, the flexibility criteria was put into practice through delayed differentiation of the housing units, e.g., walls and finishings were added only after housing units had been sold. Another company cited the benefits achieved through the Lean implementation to shorten projects lead times and (dependability). The companies investigated do not formally develop their business strategies, however, their operational actions are aligned with the competitive criteria they adopt, as cited in the interviews. Companies should know how the use of Lean contributes to the achievement of companies' long term goals and define the best sequence for achieving these goals (Featherston 1999). Finally, it is also important to know what the consequences are of implementing Lean in terms of market share.
- *Implementing Lean from bottom-up* – Arbulu e Zabelle (2006) suggest that the implementation of Lean should follow a bottom-up strategy (implement Lean in projects and then extend it to business units). We observed that the companies investigated first implemented Lean in their projects. The implementation was extended to other projects once lessons had been learned and adjustments had been made. Currently, the companies aim to implement Lean in administrative and financial sectors, and to extend the implementation to their strategic suppliers.
- *Involving white and blue collar workers* – the interviewees mentioned the importance of involving workers and managers while implementing Lean. Company B has relied heavily on the work of interns during the implementation because they tend to be more open to new ideas and are not used to the traditional systems for production management. “[interns and managers] even fight over the ownership of how things are interpreted and implemented on the field”, said the Company B's interviewee. Collaboration and information sharing are essential during the implementation (Alarcón et al. 2002).
- *Internalizing the knowledge* – in Company C, the implementation of Lean was so dependant of a single person that when he left the company the process came to a halt, and some old practices even returned their daily routine. This tends to happen when organizations do not disseminate the knowledge among all of its employees and tend to transfer all the responsibilities for the implementation process to a single person or department. In Company B, one of its key employees was hired by an out-of-state company during the Lean implementation. This happened after the company had presented several seminars on Lean during academic and industry events. Company B followed the Lean implementation without problems as the knowledge had been disseminated throughout the company's employees. It is a challenge for organizations to maintain highly qualified personnel after they have become proficient in Lean concepts and have been exposed to other companies (Lewis 2000).
- *Improving process continuously* – Companies A and B have demonstrated a strong commitment to improving their processes through learning and internalizing Lean concepts and principles. According to Dennis, “action without theory is aimless; theory without action is lifeless” (2006, p.21).

CONCLUSIONS

This paper discussed factors deemed important by the authors, based on the literature reviewed, for the implementation of Lean Construction. Despite the fact that these companies do not have formally developed their production strategies and linked Lean to these, the actions implemented are aligned to the competitive criteria they indicated during the interviews. However, some questions remain to be answered: will these initiatives be sustained in the long run without a clear link to companies' business strategies? For how long will companies keep on implementing changes in the production helm before they reach for strategic agreements with their suppliers?

REFERENCES

- Alarcón, L.F.; Diethelm, S.; Rojo, O. (2002) "Collaborative Implementation of Lean Planning Systems in Chilean Construction Companies." *Proc., 10th Conf., Intl. Group for Lean Construction*, IGLC, Gramado, Brazil, 11pp.
- Arbulu, R.; Zabelle, T. (2006) "Implementing Lean in construction: How to succeed." *Proc., 14th Conf., Intl. Group for Lean Construction*, IGLC, Santiago, Chile. 553-565.
- Ballard, G. H. (2000) "The Last Planner System of Production Control." Ph.D. Dissertation. Faculty of Engineering. School of Civil Engineering. The University of Birmingham.
- Barros Neto, J.P. (2002) "The Relationship between Strategy and Lean Construction." *Proc. 10th Conf., Intl Group for Lean Construction*, IGLC, Gramado, Brazil, 12pp
- Cole, R.E. (1999) *Managing Quality Fads: How American Business Learned to Play the Quality Game*. ASQ, Oxford University Press: New York, 284pp.
- Dennis, P. (2006) *Getting the Right Things Done: A Leader's Guide to Planning and Execution*. Lean Enterprise Institute: Cambridge, Mass., 232pp.
- Featherston, S. (1999) "Study for Reasons for the Adoption of Lean Production in the Automobile Industry: Questions for the AEC Industries." *Proc. 7th Conf., Intl Group for Lean Construction*, IGLC, Berkeley, CA, USA, 11-19.
- Garnett, N.; Jones, D.T.; Murray, S. (1998) "Strategic Application of Lean Thinking." *Proc., 6th Conf., Intl Group for Lean Construction*, IGLC, Guarujá, Brazil, 12pp
- Koskela, L. (1992) "Application of the New Production Philosophy to Construction." Stanford University, CIFE, *Technical Report # 72*, 87 p.
- Lewis, M.A. (2000) "Lean production and sustainable competitive advantage." *Intl J. of Operations & Production Management*. V.20, No. 8, 959-978
- Liker, J.K. (2004) *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. McGraw-Hill: New York, NY, 330pp.
- Passos Júnior, A.A.; Antunes Júnior, J.A.V.; Klippel, M. (2005) "Circuitos da autonomia e os fatores de produção – implicações na gestão de empresas brasileiras." (in Portuguese) *Proc. XXV Enc. Nac. de Eng. de Produção*. ABEPRO, Porto Alegre, RS, 434-441
- Picchi, F.A. (2001) "Lean thinking (mentalidade enxuta): avaliação sistemática do potencial de aplicação no setor de construção." *Proc. Simp. Brasileiro de Gestão da Qualidade e Org. do Trab.o Ambiente Construído*, 2º, Fortaleza, CE, 19pp.
- Womack, J.P.; Jones, D.T. (1998) *A Mentalidade Enxuta nas Empresas: Elimine os Desperdícios e Crie Riquezas*. (in Portuguese, translation of Lean Thinking) Rio de Janeiro: Campus, 427pp.