Int. Journal for Housing Science, Vol.40, No.3 pp. 171-180, 2016
Published in the United States

LEAN CONSTRUCTION OF PUBLIC HOUSING PRODUCTION IN HONG KONG: A PROCESS-BASED APPROACH

S. T. Ng, W. Zou, K. Wong
Department of Civil Engineering
The University of Hong Kong, Pokfulam
Hong Kong

G. Q. Huang
Department of Industrial and Manufacturing Systems Engineering
The University of Hong Kong, Pokfulam
Hong Kong

ABSTRACT

As a way to minimize the waste of materials, time and effort to generate the maximum value, the lean construction concept has been introduced successfully into the construction industry. This paper first examines the implementation of the lean construction principles, which is primarily focusing on waste reduction. The paper then suggests the adoption of a process-based approach to integrate the lean principles into the off-site prefabricated housing production. A case study on Hong Kong public housing production is presented in this paper. The study analyses the detailed business process along the supply chain of public housing production, which typically includes the design, manufacturing of prefabricated components, cross-border logistics, as well as on-site assembly and operation. Observations are made on the existing procedural deficiencies from the perspective of the client. In order to further improve the efficiency and increase the cooperation among various supply chain actors, information communication technologies are implemented by the client based on the process-based approach.

Key words: Prefabrication, Lean Construction, Information Communication Technologies

0146-6518/03/171-180, 2016

Introduction

Housing construction poses a grave concern for cities with high population density, such as Hong Kong. Currently, housing in Hong Kong is mainly supplied through three channels: private housing, public rental housing (PRH), and subsidized housing under the Home Ownership Schemes (HOS). The upsurge price of private housing has made it only affordable to a small portion of the people while nearly half of the population is now residing in some form of public housing [4]. There were over 100,000 applicants on the waiting list for PRH [4]. To produce more public housing is a long-term strategy for the local government. Table 1 shows the forecast public housing production from 2014/15 to 2016/17.

Table 1 : Forecast public housing production from 2014/15 to 2016/17 [Source: 10]

Year	*Public Rental Housing*	*Subsidized Sale Flats*	*Total*
2014/2015	12700	0	12700
2015/2016	20400	0	20400
2016/2017	15300	2200	17500
Grand Total			77800

Housing production in Hong Kong mainly adopted conventional construction technologies which is characterized by fixed jobsites, labor intensive, formwork and false work, cast-in- situ, wet trades, and bamboo scaffolding, as shown in Figure 1.

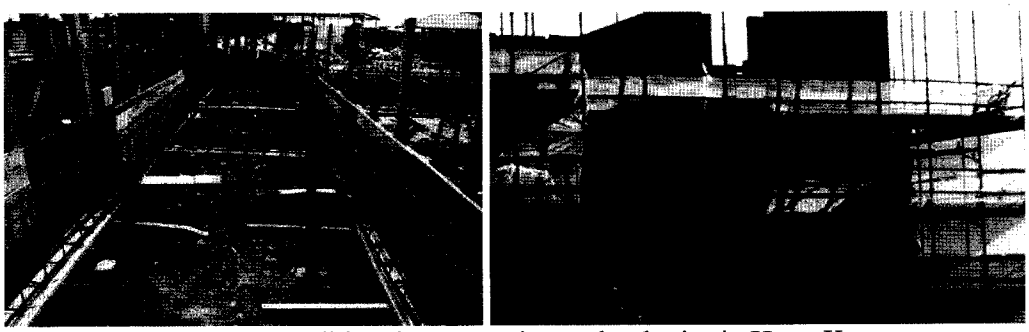

Figure 1 : Traditional construction technologies in Hong Kong

While cast in-situ construction technology has its own strengths (e.g. highly flexible to design changes), it has received widespread criticisms. A local industry report published by the Construction Industry Review Committee [6] in 2001 entitled "Construct for Excellence" has critically pointed out the problems, including:

- Poor site safety record.
- Inadequately trained workforce.
- Unsatisfactory environmental performance. The construction activities essentially disturb the environment, generating nuisance such as dust, noise, muddy site run-off, and considerable amount of waste. In particular,

conventional construction methods involve the use of significant amounts of timber formworks and wet trades which produce large amount of wastes [13].

- Extensive use of traditional and labor-intensive construction methods. While in-situ construction methods (i.e. construction work carried out on site) are well proven and may be more economical when labor supply is sufficient, the output quality hinges on the workmanship of construction workers. As the site environment is less conducive to the consistently good outputs possible in an established indoor production facility, close supervision is required.
- Declining productivity growth and high building cost. A number of factors may affect the efficiency and productivity of local construction. Prevalence of labor-intensive in-situ construction methods and relatively low investment in the use of new technologies, inter alia, are obviously the perceived culprits.

Overseas construction industry is also facing the similar issues. Research has been conducted to tackle and solve these problems [7], [12], [18], [23], [25]. Lean construction, such as the use of prefabrication, standardized and modular components, is considered as an effective way to enhance construction productivity and therefore the current practice [6], [7], [9], [12], [18]. This paper examines the implementation of lean construction and its implication on public housing in Hong Kong, through a case study.

From Lean Manufacturing to Lean Construction

Each organization strives to add value to their products via high returns on investment in the long run, regardless of which industry. Lean manufacturing combines the capabilities of the workforce with organizational techniques to achieve high outcomes with fewer resources [1], [14], [19], [24]. Lean principles determine the goals of lean manufacturing. Researchers have explored the following principles for lean manufacturing, e.g. value specification, value stream (waste elimination), flow, pull, and continuous pursuit of perfection [27].

However, due to the intrinsic characteristics of each industry, each organization employs different means to achieve their objectives. For example, supply in the manufacturing sector is an order-driven activity that is synchronized through the material handling systems, whereas supply in construction projects is schedule-driven because the process span is longer and the sequence of tasks can be affected by unforeseen exceptions [23]. More importantly, the complexity of construction projects is much greater due to its customization-oriented nature, as shown in Figure 2 below.
The lean concepts comprise a variety of production systems that share certain principles, including waste minimization, responsiveness to change, just-in-time, effective relationships within the value stream, continuous improvement, and quality from the beginning [11], [23]. However, the implementation of lean construction principles is in specific context of projects and rather fragmented [3], [20], [21]. Most

of research in lean construction is focusing on waste reduction despite much work needs to be done on project management principles to increase and maximize the value of the client [12], [15], [18], [23]. This study focuses on the lean construction principles being applied in public housing construction from the perspective of the client through a case study.

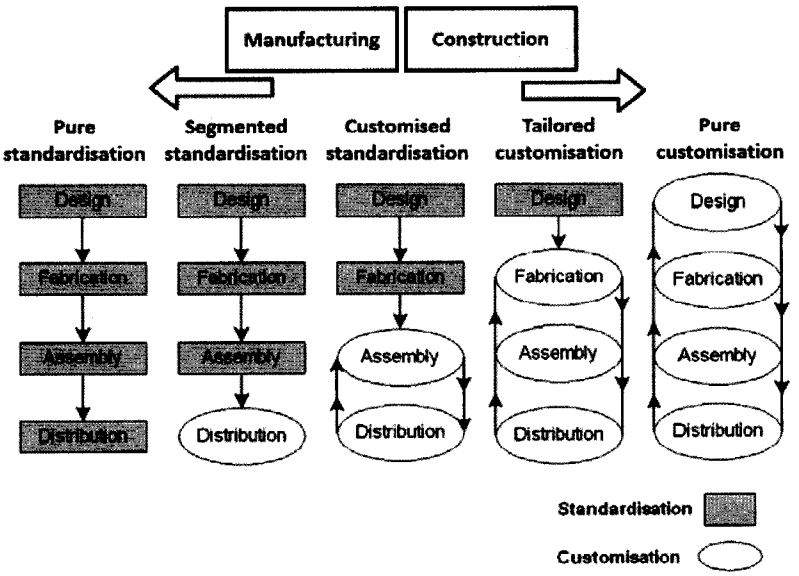

Figure 2 : Standardization and customization {adopted from [16]}

Prefabricated Public Housing Production in Hong Kong

Prefabrication technology has been widely adopted by the Hong Kong Housing Authority (HKHA) for its public housing projects, due to its higher efficiency, cleaner and safer working environment, and better quality. There is a total of 12 prevailing prefabrication construction components being used for public housing, namely precast water tank, precast façade, precast parapet, semi-precast slab, precast staircase, precast refuse chute, precast water meter cabinet, precast stair landing, partition wall for staircase, partition wall for kitchen, precast tie beam and precast bathroom. The prefabrication sector serving Hong Kong is primarily located in the Pearl River Delta (PRD) region due to lower costs of materials and labors.

The prefabrication housing development consists of several critical phases: (i) design; (ii) prefabrication production; (iii) cross-border logistics; (iv) on-site assembly; and (v) operation. As the project client, HKHA coordinates and monitors the project quality, cost and progress, from the project inception stage up until the substantial completion of the project. These entire phases are presented in Figure 3.

Lean Construction Through A RFID-Enabled BIM Platform

Applying lean principles in public housing construction is different from traditional construction and building projects for its wider use of cross-border prefabrication. With the distinctive project natures, construction adopting lean construction should use a project- based approach while industrialized housing should adopt a process-based approach for its mass off-site production of prefabricated components [12]. The process-based perspective goes compatibly with the initiatives and requirements of supply chain management [5]; it shapes an analytic approach to mapping the structures and relationships among the supply chain network, in order to apply the lean construction principles.

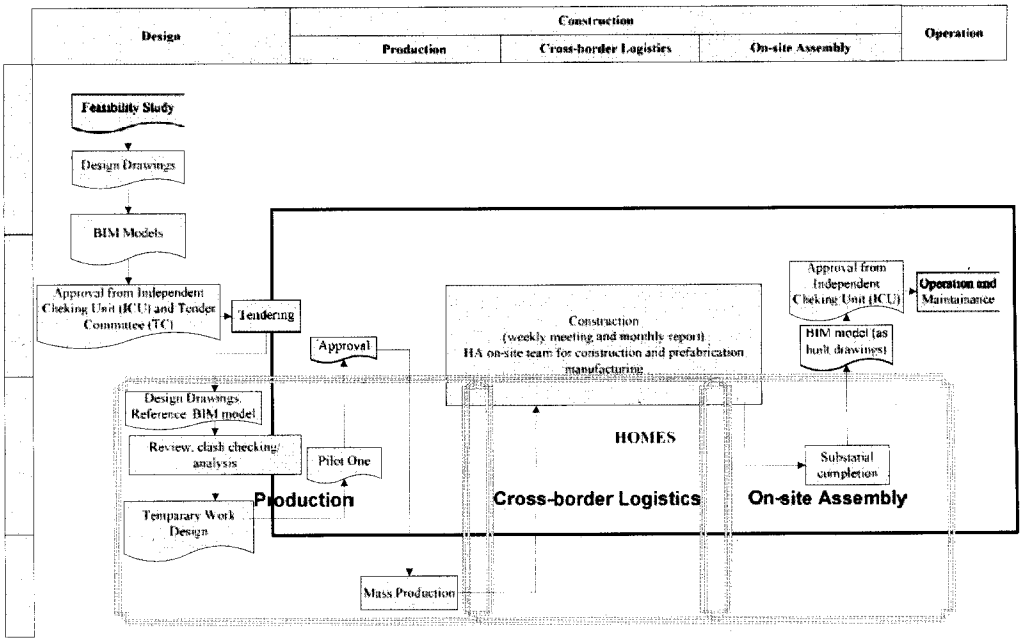

Figure 3 : Prefabrication housing production flow chart

Information communication technologies (ICT) including the geo-spatial database infrastructure, building information modelling (BIM) and internet of things (IoT), such as the radio frequency identification (RFID), have already been used to support prefabrication construction by HKHA, as shown in Figure 4. BIM plays an important role in supporting the prefabrication construction due to its powerful management of digital presentations of physical and functional aspects. Currently, BIM software is able to plan, design, construct, operate and maintain most physical infrastructures from apartments to bridges [2]. Due to the advantages of compressed project cycle, increased worker safety, and fewer environmental impacts, BIM supported prefabrication construction has been adopted widely in the US, UK, Japan, South Korean, and Singapore [2], [26], [8], [22].

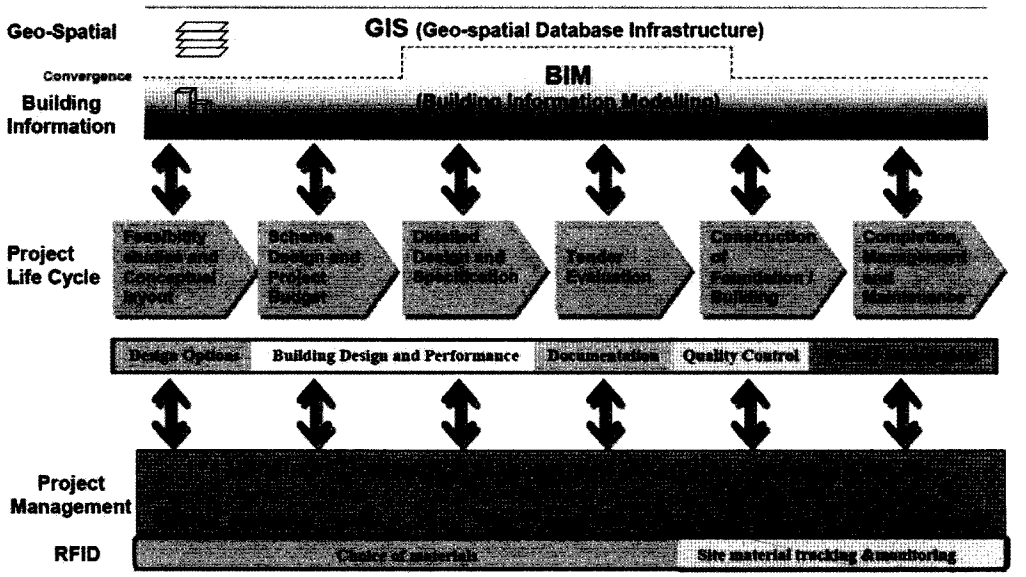

Figure 4 : The visionary roadmap of Hong Kong housing authority for ICT applications

ICT could not just improve the efficiency and increase the cooperation among supply chain actors, but it would also enhance lean construction for public housing production. For example, the contractors and prefabrication suppliers may use the BIM models to conduct clash-detection before project execution, which can save lots of time and cost suffered from rework. Nevertheless, technological challenges still exist. The challenges can be generally classified into three aspects: (i) the information gaps between stakeholders, technologies and processes, caused by 'a dummy BIM'; (ii) a lack of real-time information visibility and traceability, due to 'a blind BIM'; and (iii) the absence of information interoperability between different stakeholders and their heterogeneous enterprise information systems which create the 'new information islands' [17]. These issues can be resolved through the development of a RFID-enabled BIM platform, which follows the process-based approach. The envisaged RFID-enable BIM platform can be used to visualize and manage information and material flow through real-time visibility and traceability. The RFID tag embedded in the prefabricated components can link all different work processes together to achieve integration and synergy, as shown in Figure 5.

With the RFID-enabled BIM platform, the application of BIM technique can be henceforth extended to the construction and operation phases. Historical data of building and its components can now be kept for subsequent operation and maintenance, during which the BIM of the built works can also be utilized. It should be noticed that, instead of changing the current core business process, the envisaged RFID-enabled BIM platform would gather real- time data associated with different processes.

As a result, the RFID-enabled BIM platform shall improve the accuracy and reliability of the data acquired by the prefabrication yard and exchanged among stakeholders, as well as the ability of project parties in response to design changes. The RFID tag attached to the precast components can facilitate the tracking and tracing of the material flow whilst the BIM model can provide support to information flow. Their integration through the RFID-enabled BIM platform can enhance the management of flow and buffer. Due to the improved accuracy and reliability, reduction in construction recourses consumption and waste generation can also be achieved. On the other hand, the project client can be benefited from obtaining real-time information from the prefabrication production yard to the status of on-site assembly. Historical information pertinent to stakeholders' performance resided in the RFID-enabled BIM platform can even be used to support future decision making, such as contractor and sub- contractor selection.

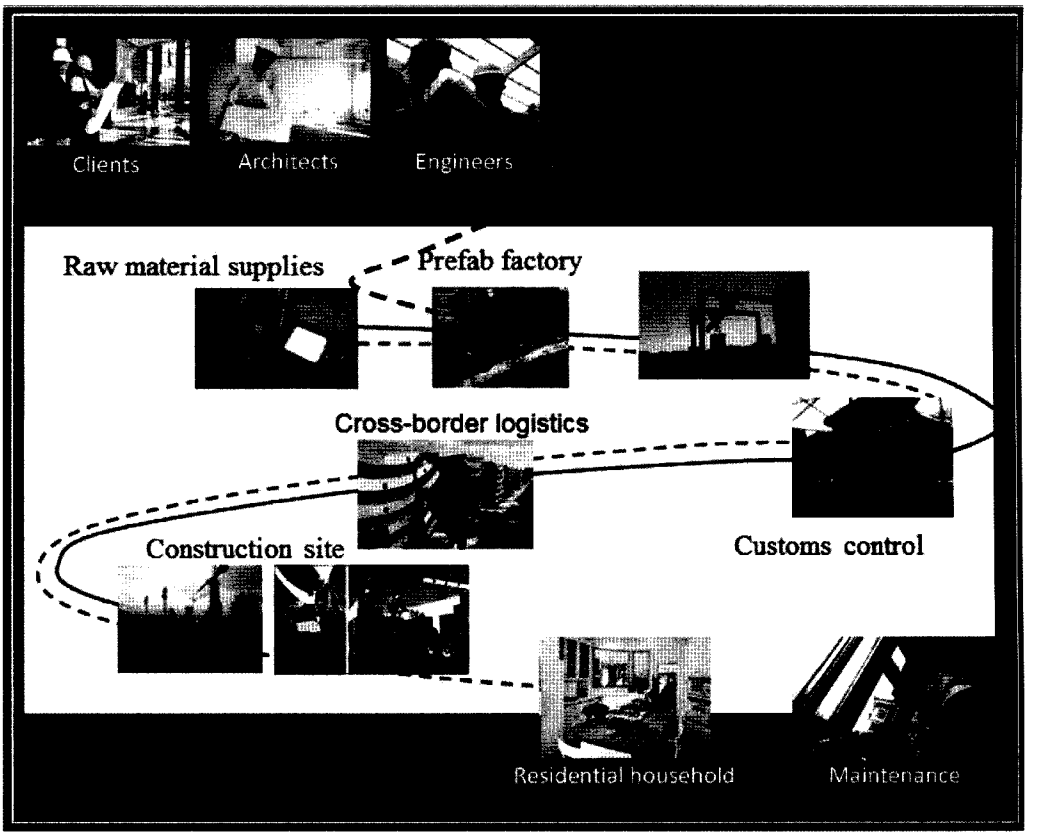

Figure 5 : Lean construction through RFID-enabled BIM platform for integration and synergy

Conclusion

Majority of the lean-related principles and aspects identified in the literature review have been focusing on minimizing wastes in the construction industry. This paper presents a process-based approach from the perspective of the project client. The applications of lean-related principals from the case study focuses on promoting BIM together with other ICTs, to improve the efficiency and increasing the cooperation among the supply chain actors. Technical problems in relation to prefabrication still exist in the construction industry of Hong Kong. In order to solve these problems, a RFID-enabled BIM platform is proposed in this study. This platform shall be able to provide various services, tools and mechanisms to different stakeholders in order to fulfil their daily operations and decision making. With that, the efficiency and effectiveness of construction projects involving a large number of prefabricated components can be improved thanks to the enhanced information sharing ability provided by the proposed RFID-enabled BIM platform.

For the purpose of continuous improvement, future work should be carried out. First of all, the industrial standards including but not limited to the Construction Standard CS2:2012 and ISA 95 (International Standard for the Integration of Enterprise and Control Systems) shall be integrated into the RFID-enabled BIM platform so that the operations, behaviors and data formats can be standardized to further enhance the efficiency and interoperability. Secondly, huge amount of activities data can be captured and collected from prefabrication yards, logistics companies, and construction sites where the precast components are finally assembled. Such data can be fed into various analytical models to generate another layer of data, such as the embodied carbon of construction components. All in all, the data captured and generated should carry rich implicit information and knowledge which is indeed an invaluable asset for advanced technologies in particular the 'big data' model development in future.

References

1. R. Arbulu, G. Ballard, N. Harper, Kanban in Construction, in Proceedings of IGLC 11, Blacksburg, VA, 2003
2. S. Azhar, "Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry" Leadership and Management in Engineering, vol. 11(3): pp. 241– 252, 2011.
3. S. Bertelsen, J. Nielsen, "Just-In-Time Logistics in the Supply of Building Materials", in Proceedings of 1st International Conference on Construction Industry Development, Singapore, 1997.
4. Census and Statistics Department, 2011 Population Census, website assessed on 15 October 2014: http://www.census2011.gov.hk/pdf/main-report-volume-I.pdf, HKSAR Government, 2014.

5. T. S. Felix, H. J. Q. Chan, "Feasibility of Performance Measurement System for Supply Chain: A Process Based Approach and Measures" Integrated Manufacturing Systems, vol. 14(3), pp. 179–190, 2003.

6. Construction Industry Review Committee (CIRC), Construct for Excellence, Construction Industry Review Committee Report, Hong Kong, 2001.

7. P. E. Eriksson, "Improving Construction Supply Chain Collaboration and Performance: A Lean Construction Pilot Project" Supply Chain Management: An International Journal, vol. 15(5), pp. 394 – 403, 2010

8. A. Gruen, M. Behnisch, N. Kohler, "Perspectives in the Reality-based Generation, n D Modelling, and Operation of Buildings and Building Stocks" Building Research & Information, vol. 37(5-6), pp. 503–519, 2009.

9. Hong Kong Housing Authority, 2012-2013 Sustainability Report: Quest for Excellence in Low Carbon Housing, HKSAR Government, 2013.

10. Hong Kong Housing Authority, Housing in Figures, website assessed on 25 October 2014: http://www.housingauthority.gov.hk/en/common/pdf/about-us/publications- and-statistics/HIF.pdf, HKSAR Government, 2014.

11. W. J. Hopp, M. L. Spearman, Factory Physics, MacGraw-Hill International Editions, 2000.

12. M. Höök, L. Stehn, "Applicability of Lean Principles and Practices in Industrialized Housing Production" Construction Management and Economics, vol. 26(10), pp. 1091–1100, 2008.

13. L. Jaillon, C. S. Poon, "The Evolution of Prefabricated Residential Building Systems in Hong Kong: A Review of the Public and the Private Sector" Automation in Construction, vol. 18, pp. 239–248, 2009.

14. H. Katayama, "Lean Production in a Changing Competitive World: A Japanese Perspective" International Journal of Operation Production Management, vol. 162, pp. 823, 1996.

15. L. Koskela, An Exploration towards a Production Theory and its Application to Construction, VVT Technical Research Centre of Finland, Finland, 2000.

16. J. Lampel, H. Mintzberg, "Customizing Customization" Sloan Management Review, Fall, pp. 21–30, 1996.

17. W. S. Lu, G. Q. Huang, H. Li, "Scenarios for Applying RFID Technology in Construction Project Management" Automation in Construction, vol. 20, pp. 101-106, 2011.

18. I. Nahmens, L. Ikuma, "Effects of Lean Construction on Sustainability of Modular Homebuilding" Journal of Architectural Engineering, vol. 18(2), pp. 155–163, 2012.

19. T. Ohno, Toyota Production System, Beyond Large-Scale Production, Productivity Press, Cambridge Massachusetts, 1998.

20. I. Pavez, L. F. Alarco´n, "Lean construction professional's profile (LCPP): understanding the competences of a lean construction professional", in Proceedings of 15th IGLC Conference, Michigan, July, pp. 453–464, 2007.

21. F. A. Picchi, A. D. Granja, "Construction sites: using lean principles to seek broader implementations", in Proceedings of 12th IGLC Conference, Elsinore, August, pp. 833–844, 2004

22. A. Porwal, K. N. Hewage, "Building Information Modeling (BIM) Partnering Framework for Public Construction Projects" Automation in Construction, vol. 31, pp. 204–214, 2013.

23. O. Salem, J. Solomon, A. Genaidy, I. Minkarah, "Lean Construction: From Theory to Implementation" Journal of Management in Engineering, vol. 22(4), pp. 168–175, 2006.

24. S. Shinggo, Non-stock Production, Production Press, Cambridge, 1998.

25. L. Song, D. Liang, "Lean Construction Implementation and its Implication on Sustainability: A Contractor's Case Study" Canadian Journal of Civil Engineering, vol. 38(3), pp. 350-359, 2011.

26. V. W. C. Tam, S. Zeng, W. C. Ng, "Towards Adoption of Prefabrication in Construction" Building and environment, vol. 42(10), pp. 3642–3654, 2007.

27. J. Womack, D. Jones, "Lean thinking", Simon & Schuster, New York, 1996.