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Green Building and Lean Management: Synergies and Conflicts

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Abstract: The construction industry is one of the largest, most important and resource-intensive economic sectors, and at the same time one of the largest environmental polluters. About 30% of greenhouse gas emissions, approx. 40% of primary energy consumption and approx. 50% of waste is attributable to the building stock (DGNB 2013). In the future, the implementation of sustainable building concepts will gain more importance. The construction industry needs to improve resource efficiency, productivity, waste production and customer value.

The aim of this thesis is to present approaches considering the contribution of Lean methods in the context of Real Estate sustainability.

Keywords: Lean Management, Green Buildings, sustainability, synergies, conflicts, implementation strategies.

1 BACKGROUND

1.1 Fundamental ideas of Green Building (Real Estate Sustainability)

Bourdeau et al. (1998) identify the following sustainability criteria: energy efficiency, recyclability, non-toxic materials, value retention, flexibility, long useful lives, use of local resources, information dissemination, use of by-products, intangible services, mobility considerations and support for the local economy. In addition to new and more efficient technologies, the emphasis is on minimizing emissions, waste generation, energy and resource consumption, without compromising comfort and living standards.

1.2 Fundamental ideas of Lean Management

Lean production contains five core principles (Womack/Jones 1996): specification of value from the customer's point of view, analyzation of production processes (value stream), ensuring an effective process flow, pull production: produce what is demanded by the customer when it's demanded and continuous improvement of all processes. For the implementation of the principles Lean offers a number of tools. However, Lean is a philosophy and cannot be reduced to a set of tools (Herrala et al., 2012). Lean also requires that products and processes are designed at the same time. For that matter, it is not only determined what has to be achieved, but also its successful realization (Arroyo et al. 2012).

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2 SYNERGIES BETWEEN LEAN AND SUSTAINABILITY

1. **Economical advantages:** Improved productivity can save construction costs. These savings can compensate for the increased number and greater complexity of sustainable components and technical systems (Saggin et al., 2015).
2. **Competitive Advantages:** The implementation of Lean and sustainability principles leads to competitive advantages (Womack and Jones 1996) as companies analyse their production processes and optimize the use of resources, improve quality and reduce costs. This results in a high level of customer service and increases the company's profitability.
3. **Waste disposal:** Both philosophies regard the elimination and handling of waste as a great potential to achieve their goals.
4. **Improving quality:** Sustainability demands top quality. Lean also strives for perfection via continuous improvement so production is halted as soon as an error occurs and the problem is solved immediately. In this way, waste can be eliminated from the process as resources are treated with greater care, resulting in less rejects and less material consumption.
5. **Focus on people:** Involvement and support of employees through responsibility and decision-making skills lead to motivation, identification with work and operation, implementation of own ideas, interest in constant improvement, motivation, fun at work, acquiring new skills, further education, interest in quality and productivity. This investment in people also promotes social sustainability.
6. **Continuous improvement:** The culture of systematic, continuous improvement is focused on the elimination of waste in any form (time, process, material, people, etc.). Continuous improvement is not a goal, but perpetual steps towards perfection. Sustainable development in particular offers great potential and sources of innovation that can be analysed and realized through continuous improvement.
7. **Positive correlation between indicators:** Lean and sustainability targets have their own indicators. In some cases, a direct positive correlation can be observed. For example, production time shortening and avoidance of unnecessary transports are positively linked to the sustainability indicators of energy consumption and carbon emissions (Johnsen et al., 2016).
8. **Transparency:** According to Womack (2003), transparency is the ability of all actors in a system to discover the potential for value creation. Both Lean and Green Building projects promote transparency through visualization and documentation.
9. **Long-term and holistic implementation:** One-off and isolated applications of Lean methods as well as sustainability measures do not lead to success.

3 CONFLICTS BETWEEN LEAN AND SUSTAINABILITY

1. **Focussing on different dimensions of sustainability:** Lean aims at adding value at the lowest possible costs. The emphasis is on improvements in cost-intensive areas such as processes and people. Sustainability costs, on the other hand, are defined as value-adding investments in a better quality of components. Higher costs for ecological building materials, plants and processes have priority over short-term economic aspects as these investments subsequently lead to operational savings over the lifecycle and an increased market price. The limitation of financial resources, however, pushes for low construction costs, which hinders a growing market share of Green Buildings.

2. **Life Cycle Consideration:** Lean focuses primarily on the production process. Sustainability is considered as part of the entire lifecycle. The LCA takes into account all processes along the lifecycle of the building and its components. Green Buildings are geared up to the longest possible service life in order to be used not only by the customer, but also by future generations without restricting their needs.
3. **Value definition:** Centralized constraints are the lack of a superior value-understanding and the predominance of a customer-oriented perspective of value (subjectivity) (Salvatierra-Garrido et al., 2011). According to Koskela (2000), Lean is a systematic approach to meet customer values regardless of the degree of sustainability. Consequently, the effect of Lean depends on the customer, his sustainability aims and his requirements in value. Sustainable values can be generated considering a minimal building structure, maximum building efficiency, efficient energy use, reduced waste and a healthy and productive environment for the inhabitants (Horman et al. 2004). Intangible properties such as brand and image also contribute to customer values.
4. **Just-in-Time:** JIT is crucial for Lean's goals. Establishing a precisely coordinated production and material flow, throughput times and capital binding can be reduced, stock can be superfluous and thus the production costs can be reduced. The demand-oriented orders according to JIT result in reduced batch sizes causing more frequent transports and therefore higher energy consumption and emissions (Rothenberg et al., 2001, Bae and Kim, 2008).
5. **Different definitions of waste:** Lean defines waste as any action that consumes resources (labour, surfaces, machines) in some form, but does not generate value (Koskela 1992) and focuses on the elimination of production waste. These include in particular waiting times that result from the delay of an earlier activity, inefficient space division, low productivity of the crew, inadequate equipment, delay in information flow, non-availability of material, and external situations such as heavy rain. Waste also contains the production of non-ordered goods, error corrections, excess processing, movement, transport and storage.

   Sustainability, on the other hand, tries to avoid environmental waste (air emissions, solid waste, waste water, noise, over-lighting, excessive use of resources and excessive consumption). Environmental waste can also have social implications. These include suboptimal working conditions, a lack of education and training, undermining social acceptance and lack of social dialogue.

   Additionally, environmental, social and production waste is not always proportional. There are also production processes in which time and costs can be reduced, but no significant improvements or even worsening of environmental waste (energy consumption and emissions) can be generated.
6. **The success of Lean practices depends on the technology and the area:** Lean's success in sustainability is dependent on the methods and tools used as well as the intended areas of environmental improvement. For example, the value-stream model (VSM) can identify environmental impacts of production processes, but does not bring environmental advantages in itself. The same applies to 5S. On the other hand, cell production leads directly to the reduction of the electricity consumption and TPM can directly reduce the oil discharge. The use of SMED does not bring about any significant environmental improvement.
7. **Requirements of Lean to Employees:** Lean tools are in fact no more than a structured framework for the development of people to improve their problem-solving ability. A key role is played by employees. This role is seen by some as

exploiting, as the high process pressure and labor flexibility overtaxing the workers (Hines et al., 2004). Considering that certain practices are specific to the culture transferring the concept is very difficult. (Williams et al., 1992).

8. **Stationary production versus on-site construction:** Due to the fundamental differences between factory and on-site construction, there are different frameworks and requirements for the process organization:
   - **Process structure:** As production is moving through the product under construction, the workplace, conditions and the executives constantly change.
   - **Procurement by call for tenders:** In the project-based construction industry, the contract is concluded with the most cost-effective provider. This creates a temporary organization and a fragmented value chain due to many different actors.
   - **Responsibilities:** Construction project managers have a wide range of responsibilities. They focus on the customer, the construction, design problems, change orders, costs (payment of the suppliers) and the income side of the project.
   - **Uniqueness:** Changing framework conditions and uniqueness of the projects make it difficult to implement stable and standardized processes.
9. **Losing the pursuit of growth:** In direct contrast to environmental management, there is a growth-oriented management, which cannot be sacrificed for ecological reasons, as it is the basis of our social system.
10. **Lack of performance indicators:** Lean focuses on brilliant processes and non-performance indicators, as the hypothesis is that results are correct when the process is right.

4 IMPLEMENTATION STRATEGIES OF LEAN TO GENERATE BENEFITS FOR SUSTAINABILITY

1. **Implementation at all company levels:** The transformation into a Lean company requires a lot of commitment and everyone's participation in the introduction of the new principles in company culture and organizational structure. The bottom-up implementation approach has been useful for Lean actions. A top-down implementation is not sustainable because the actions (if any) are performed by hierarchical pressure and not by a true continuous improvement culture. Fragmented tooling, no person-centered approach, and inadequate lead indicators do not correspond to Lean principles (Berroir et al.).
2. **Broadening the definition of waste:** Lean's greatest potential for Real Estate sustainability is to avoid the common goal of waste. In Lean theory, environmental and social waste is scarcely taken into account. Sustainability, on the other hand, uses a narrow approach, which leaves many opportunities unused since many intangible aspects are not regarded as waste.
3. **Prefabrication:** Prefabrication can be a promising procurement method for sustainable construction. It can be optimized by the use of numerous Lean principles (Parrish 2012).
4. **Modularization:** This is an extended form of prefabrication. Serial prefabricated modules, i.e. individual rooms are delivered to the building site including windows, tiles, sockets and tables. The advantages are savings in construction costs (up to 40%), a sharp reduction in construction time, efficient production processes, less noise and high flexibility through any extensibility. In the future, buildings could be created at the customer's request and churned out without compromising. Lean

principles could then be transferred to the construction industry without major changes in order to achieve similar successes as in the automobile sector contributing to a higher sustainability of buildings (Müller 2016).

5. **Innovative types of contracts and methods for project definition:** Actually, the chosen type of contract and methods for the project definition of a construction project have no direct effects on sustainable construction. Nonetheless, they can promote innovation and sustainability by the elimination of contractual barriers and improved communication between stakeholders. The following Lean methods can be implemented in this case: multi-party contracts, integrated project teams, performance-based contracting and design build operation maintainers (Horman et al., 2004, Dahl et al., 2005, Bae et al. 2007).
6. **Design methods:** The design phase is crucial for a project's success, affecting the entire service life. The design of Green Building projects is particularly critical as raw materials, resources and construction technologies are relatively innovative and require comprehensive coordination for the best application. In order to minimize environmental impacts and energy consumption in the construction of sustainable buildings, several Lean design methods can be implemented. These include i.e. Integrated Design, Design for Maintainability (DFM), Set-Based Design, Target Costing and 3D Modeling (Bae et al., 2007).
7. **Using more efficient project tools:** Many workplace conditions or methods, such as the critical path, are not able to deliver high-quality projects on time and within the budget (Abdelhamid 2004). In order to improve project performance and increase efficiency new, more targeted instruments must be developed. Lean offers a conceptual basis and the potential for novel methods and tools for sustainable building. In recent years, the following methods have been developed: Construction Site Management, Big Room, Daily Huddle Meeting, Integrated Project Delivery, Lean Project Delivery System, Target Value Design, Time-of-Time Planning, Location-based Management System and Choosing by Advantages.
8. **LastPlanner® System:** The LastPlanner® system can contribute some essential core points of Lean Management to construction, i.e. process consistency, increasing the reliability of all work and information flows, applying the pull principle, transparency, recognition of obstacles in time and working in an integrated project team.
9. **Building Information Modelling:** BIM is an effective process to achieve leanness and sustainability. BIM acts as a catalyst to build up synergies between Lean principles and sustainability. It helps optimizing design and construction using visualization, information, exploration of alternatives and identification of errors and conflicts (Ahuja et al., 2004).
10. **Value Stream Mapping:** Value Stream Mapping is very practice-oriented and fundamental for evaluating where and how other Lean tools and techniques can be applied in production. It illustrates various different processes and information flows in the design and construction process and therefore allows a better understanding of the generation of the value stream. Traditionally, VSM evaluates process time and stock levels to define value and waste, as these factors are critical for economic purposes. However, this Lean method can not only be used for economic purposes, but also for social and environmental purposes by inserting downstream data into the map. Not only time and stock, but also a waste of resources, pollutions, resource use, security and interaction can be depicted (Bae et al., 2007). The most efficient and sustainable way to use VSM is when the card is created together with the

employees. This increases the awareness of action plans, improves communication and information exchange, reduces errors and rework and clarifies responsibilities and interdependencies.

11. **Kaizen:** Kaizen provides the basis for an overall process approach for sustainable project development and thus plays a key role in improving the current state of sustainable methods. As a result of constant improvements, ever higher standards are set and made a rule. All sustainable indicators can be improved further.
12. **Processes for measuring sustainability and Lean:** In the construction industry, there are few performance measurement instruments that can link Lean efforts and sustainable results directly, since it is difficult to measure all sustainable effects of Lean implementation.

    The following instruments are used to measure and quantify the sustainability advantages of Lean: Value Analysis, Overall Equipment Effectiveness and Carbon Value Efficiency. A model for quantifying the degree of Lean implementation in construction is the Lean Construction Quality Rating Model (LCR). The evaluation is based on a questionnaire that evaluates the five principles of Lean Thinking according to Womack and Jones as well as the eleven principles of Lean Construction according to Koskela (Hofackeret et al., 2008). With the help of the Sustainability Construction Index (SCI), the sustainable performance of the work on construction sites can be monitored. This is measured by the indicators environmental performance, management system, working conditions as well as profitability and the value added (Vieira et al. 2011). In order to promote the degree of implementation of Lean and sustainability, research should be intensified and new methods of measurement should be developed. Only by verifiable facts companies can be convinced of the many advantages of the two philosophies.
13. **Expansion of the magic triangle in project management:** Traditional planning and construction focuses on the mutually influencing factors cost, time and quality as well as the all-encompassing factor of customer satisfaction. Sustainable planning and construction also pursues the following objectives: minimizing the scarcity of resources, minimizing the environmental impact and creating a healthy building fabric (Kibert 1994).
14. **Politics:** In order to promote the realization of sustainability stronger incentives and legal requirements are useful. Legislation must create clarity by bringing together various regulations, strategic plans and sustainability initiatives. Especially in the public sector, law restricts the companies in compiling the project team.
15. **Expansion of the production function:** The traditional production function limits the chances for the improvement of sustainability (Koskela et al. 2009). It is a functional description of the correlation between production factors used and the maximum quantity achieved using a given technology.
16. **New professions:** The Architectural Technologist is the creative partner in the value chain linking planning and construction. He considers the technical side of the design and ensures the desired functions. He also monitors quality assurance, costs and deadlines. (Emmitt, 2001).
17. **Value stream analysis:** Considering the value stream analysis, it is not sufficient to optimize individual processes. However, a correct investment in a part of the system (the longest value stream) can bring several advantages to the whole system.

5 CONCLUSION AND DISCUSSION

The analysis of core ideas shows that the philosophies Lean and sustainability are two separate mature initiatives in the construction sector with seemingly significant overlaps. Through a common integration framework, the potential weaknesses of one philosophy can be balanced with the potential strengths of others. Many researchers have identified the use of Lean Management Principles to increase environmental performance (Huovila and Koskela 1998, Horman et al., 2004). An application is possible both in the case of new construction, restoration as well as in the case of upstream and downstream areas. Lean has a positive impact on sustainability indicators, such as less stress, less health problems, increased productivity, more efficient use of resources and improved quality. The emphasis is on the disposal of waste, avoiding pollution and maximizing value for the customer.

Lean and sustainability are relatively new and complex philosophies. Due to the uncertainty regarding costs and actual benefits, there is some resistance to the introduction. Many companies have failed to implement, because it is difficult to spread the new organizational culture and mindset across the enterprise. The most common error is a tool-focused implementation that neglects the human aspect. The prerequisite for the successful implementation of Lean processes is the understanding of how the existing system works. In addition, an integrated design process and an early participation of the most important project participants are indispensable for the early integration of sustainable concepts as well as the commitment of the owners to sustainability.

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