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EVALUATION OF THE LITERATURE SYNTHESES ON LEAN CONSTRUCTION CONTRIBUTIONS TO SUSTAINABILITY

Müge Tetik[1], Lauri Koskela[2], Ergo Pikas[3] and Kädi-Riin Vendel[4]

ABSTRACT

In the last ten years, the interest in the question on how lean construction could contribute to sustainability has considerably increased. This is reflected in the rapidly growing number of publications addressing this question. Especially systematic literature reviews have been popular. In this explorative paper, such reviews are critically evaluated. A synthesis of findings about the conceptual framework of the relation between lean and sustainability is provided. Based on the findings, we determine the missing topics in the available literature reviews. For example, target value design and takt production have not been gaining attention on reviews focusing on lean and sustainability relationship compared to other lean methods. We present suggestions for future research as well as a conceptual framework for contributions of lean construction on sustainability.

KEYWORDS

Lean construction, sustainability, critical evaluation, target value design.

INTRODUCTION

Sustainable development initiatives have been significantly impacting the building lifecycle phases already for the last three decades (Kibert, 2022). In the same period, another initiative for improving construction, namely lean construction, has been evolving. In the community of sustainable construction, there has not been much interest in lean construction. For example, the thorough book by Kibert (2022) mentions lean construction only twice and does not go into much detail. In the community of lean construction, there has been more interest in sustainability, but still that topic has been somewhat in the periphery.

Sustainability is defined as a long-term strategy where economic growth, social coherence and environmental protection are closely associated and are jointly supporting (European Comission, 2024). Lean contributes to sustainability, for example, through reduced waste and resource consumption, and improved safety (Solaimani & Sedighi, 2020). The idea of a relation between lean construction and sustainability has been raised already in 1998 by Huovila and Koskela. After that, the interest into this topic has increased dramatically (Fig. 1). Examples of current studies exploring the connection between lean construction and sustainabilityare provided by Moradi & Sormunen (2023) and, Le & Nguyen (2024). Thus, the topic is

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contemporary and continues to attract attention. The wider topic of the relation between lean and sustainability has experienced a similar pattern of increased popularity (Fig. 1s).

What can we learn from this considerable literature about the possible contribution of lean construction to sustainability? Because this question triggered the publication of many literature reviews (many are systematic), we choose to critically evaluate them. A specific topic is to make a synthesis of findings regarding the conceptual framework of the relation between lean and sustainability. Our method to achieve this is the critical evaluation of systematic literature reviews.

The underlying research has been done in two stages. First, a number of the most cited papers looking at the contributions of lean construction to sustainability were analyzed. Based on findings, a few topics for critical evaluation were determined. In the critical evaluation, when relevant, more papers were taken to be scrutinized. After critically evaluating the available literature, missing topics in the reviews have been determined. Then we discuss the conceptual relationship between lean and sustainability, ways to scale up its sustainability benefits and the methodological limitations of literature reviews.

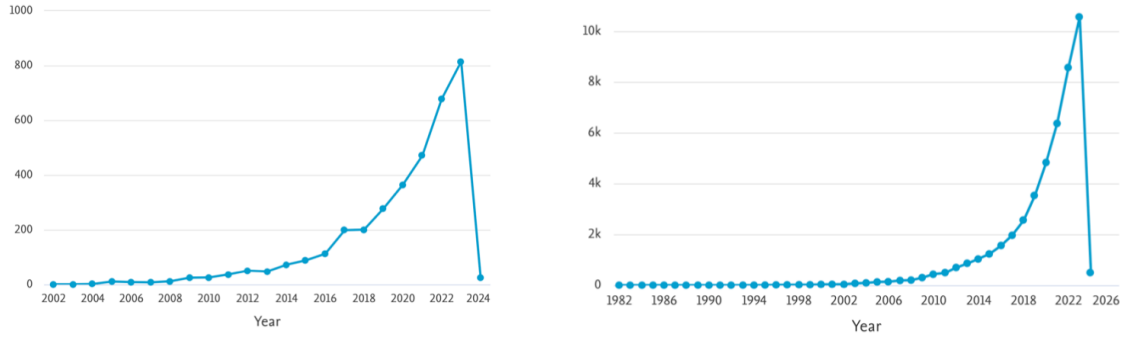

Figure 1. Number of documents found in Scopus database illustrated by year for “lean construction AND sustainability”, and the number of documents found in Scopus database illustrated by year for “lean AND sustainability” (taken from scopus.com).

RESULTS OF THE PRELIMINARY STUDY

Among the 20 most cited papers which match the “lean construction AND sustainability” query in Scopus database, a classification of the nature of papers was done. The existing literature mostly consists of literature reviews, and conceptual frameworks to integrate sustainability and lean construction. Examining and trying to use the proposed frameworks, especially with utilizing case studies, as well as implementing more real-life cases would crystallize the findings obtained from the current studies. Among the most-cited 20 papers, the systematic literature reviews (SLR) were selected and more SLRs were added when found relevant. Table 1 summarizes the contents of the selected articles.

Table 1. Synthesis table of the selected articles

Paper	Scope, sample	Key findings
Rosenbaum et al., (2014)	Structural concrete work phase, medical center project in Chile	Reports a value stream mapping (VSM) application case study as a lean approach in a hospital project to improve its environmental and production performance
de Carvalho et al., (2017)	Building sector, 46 papers	The literature review determines synergies between lean thinking and sustainability and provides a conceptual framework depicting their integration
Erdil et al., (2018)	4 cases from healthcare, manufacturing, construction	Proposes a framework to integrate sustainability into improvement initiatives with a DMAIC process
Khodeir & Othman (2018)	Design and construction management, 16 company reports in 11 countries	Provides guidelines for firms through a correlation matrix for applying integrated lean and sustainability principles on design and construction management
Carvajal-Arango et al., (2019)	Construction phase, 117 papers	Reveals that prefabrication, VSM and Kaizen lead to the most sustainability benefits. The social aspect of sustainability is the least addressed by researchers
Solaimani & Sedighi, (2020)	Different construction phases, 118 papers	The current literature focuses more on the economic values than social and environmental aspects, provides a holistic, multi-dimensional framework toward sustainability
Mellado & Lou (2020)	Building lifecycle, 215 papers	Suggests an integrated framework based on theoretical elements. The analysis reveals that the focus is on waste reduction regarding the interactions between BIM and lean
Li et al., (2020)	Structural construction, MEP installation in 6 high-rise projects in China	A conceptual framework of the on-site industrialization method developed; it is suggested to be a cleaner and more sustainable industrial construction method
Dehdasht et al., (2020)	Survey of 23 construction professionals, case study in Malaysia	The empirical study determines the key drivers for successful and sustainable lean construction implementations

A few preliminary observations can be made based on the analysis conducted on the selected 9 papers. The case studies focus only on a specific phase of construction projects such as Rosenbaum et al., (2014) and Li et al., (2020), lacking the whole lifecycle perspective while literature reviews try to have a more comprehensive and holistic perspective such as in De Carvalho et al., (2017), Soleimani and Sedighi (2020), Mellado and Lou (2020) and Khodeir

and Othman (2018). While most papers try to focus on all three aspects of sustainability, the social side was found to be under emphasized such as in Erdil et al., (2018) and Carvajal-Arango et al., (2019) and limited to only intra-company interactions in especially case studies such as in Mellado and Lou (2020).

However, when engaging with this small sample of papers, a number of such observations were made which indicate that another tack than systematic literature review as such had to be taken in our research. One such observation was that the share of systematic literature reviews was surprisingly high; what is the reason for this? Another finding was that it is difficult to compare the papers as the results were presented in different ways, i.e., some proposing theoretical frameworks and some listing mere findings. Furthermore, it was spotted that there are three times as many papers on lean and sustainability in comparison to lean construction and sustainability. Probably many conclusions from this more general literature are valid or interesting for construction, too. How to take this wider literature on board? Thus, it was decided to continue towards a critical evaluation of the literature syntheses on lean construction contributions to sustainability.

CRITICAL EVALUATION OF THE METHODOLOGY IN PRIOR REVIEWS

SYSTEMATIC LITERATURE REVIEWS: CRITIQUE

The problems of systematic literature reviews may be visible in many papers. First, a general term, such as lean, does not necessarily catch all activity which could be termed lean but is not. An important example is provided by value engineering/management/methodology (Musa, Pasquire & Hurst, 2016), which exists as an independent method but is also used, at least informally, in lean efforts (especially Target Value Design). Terminology problems exist also on the sustainability side, for example, the terms green and sustainability are used interchangeably. Thus, Garza-Reyes (2015) is using the term green as a synonym for sustainability, more or less.

Second, it might be also argued that SLRs have been partially misunderstood; having a well-documented and disciplined way of finding literature is not always that important; especially when the intention is to have as comprehensive a picture on the phenomenon as possible.

Third, the SLRs have been mostly conducted with a focus on the quantitative aspects such as lists of cited works, classification of papers based on the publisher, or number of hits in databases, rather than considering the qualitative aspects in depth.

Fourth, contextual and historical awareness would be needed. The method of Integrated Project Delivery, now a common lean method, was originally developed in Canada in the framework of sustainability efforts (Kibert, 2022). This is rarely mentioned in the literature reviews.

ABUNDANCE OF LITERATURE REVIEWS

The somewhat strange abundance of literature reviews on lean and sustainability deserves a comment. Taşdemir and Gazo (2018) are among the few authors (of literature reviews on lean/lean construction and sustainability) who have analysed past literature reviews on this topic.They found 35 of them. Consequently, the authors present thinly veiled criticism on this situation:

> *Researchers are expending substantial effort to discover the path to "true sustainability" by re-visiting findings and proposals of their colleagues who approached the situation from various perspectives.*

Aligned with this, these authors proposed that the research must focus on new actionable methods for promoting sustainability:

> *Researchers and professionals should channel their concentration on the development of new methodologies, frameworks, and tools that could help with the achievement of truly sustainable organizations and supply chains compliant with the proposed ultimate objective concept.*

One can ask what the reasons for this inflated interest towards literature reviews on lean and sustainability are. One basic reason of course is that there **is** an ample stock of recent papers to review. Another might be that both topics, lean and sustainability seem extensive and amorphous, and thus a literature review seems a good way to create some basic order and understanding and to start research in this area. Often, when reading a literature review, one gets the impression that the authors have scarce familiarity with either lean or sustainability.

CRITICAL EVALUATION OF SUBSTANTIAL FINDINGS IN PRIOR REVIEWS

SYNTHESES OF FINDINGS

Most review papers present a synthesis of the findings as a conceptual framework. In fact,

a considerable variety of conceptual frameworks are presented in the papers:

- Simple diagram showing that lean-green and sustainability tools are contributing to economic growth, environmental integrity and social accountability (Carvajal-Arango et al., 2019)
- Overlap of Lean and Green presented as a Venn diagram (Mellado & Lou, 2020)
- A pie chart for Lean principles and practices for sustainable construction (Solaimani & Sedighi, 2020)
- Conceptual map: Common features of lean and green, moderated by contingencies, lead to triple bottom line results (de Carvalho et al., 2017)
- Causal-loop diagram (Forrester-style) of Lean management in sustainable construction (Solaimani & Sedighi, 2020)
- Concept map of the lean and green literature review showing the different research streams identified (Garza-Reyes, 2015)
- Sustainability additions to DMAIC (Erdil et al., 2018)
- *Affects* and *Effects* between lean and sustainability from the environmental perspective (León & Calvo-Amodio, 2017)

It is evident that the conceptual frameworks presented are largely incommensurable, and this makes it difficult, but not impossible, to compare the results of different papers. Especially, in this case, this problem is alleviated by the fact that the findings are relatively straightforward (as discussed below).

Besides conceptual frameworks, review findings are usefully presented in the form of

- Types of related literature (Garza-Reyes, 2015)
- Questions for future research (Garza-Reyes, 2015)
- Propositions (León & Calvo-Amodio, 2017)

The distinctions between different types of papers will not necessarily surface in conventional systematic literature review, however, these may throw illuminating light on the research

activities. Questions for future studies reveal gaps in current knowledge. In turn, propositions contain broad, preliminary conclusions which attract validation in future research.

RELEVANCE OF LEAN AND ITS PRINCIPLES TO SUSTAINABILITY

Lean and lean construction are overwhelmingly found to produce benefits, rather than disbenefits, from the sustainability viewpoint. Thus, Solaimani and Sedighi (2020) write:

> *[…] that almost all the Lean principles and techniques seem to have a positive impact (or a 'reinforcing' effect) on triple bottom line across the construction process.*

Further:

> *…the Lean principles and practices are useful in largely all the facets of construction process, across various phases and stakeholders.*

Carvajal-Arango et al., (2017) similarly claim:

> *Implementation of lean construction practices during the construction project generates positive effects on the three dimensions of sustainability, namely, economic, social, and environmental, in the construction phase."*

It is noteworthy that if (almost) all the Lean principles and techniques contribute to sustainability, one of the central justifications for literature reviews drops out, namely responding to the question whether such a contribution exist. Koskela (2020) has claimed that lean construction is the best available (although constantly evolving), theory-based method to manage construction towards the goals set by the client. If we accept this, then, of course, lean construction should be used in sustainability efforts. Then, it is not an optional or niche approach, and the focus should be turned away from whether it can contribute, and which are the impacts, etc., to how it can best contribute.

ARE THE FINDINGS RELEVANT?

The typical result of a literature review has the following form: Lean method X, when applied in construction project phase Y, brings benefits to environmental (or social or economic) sustainability. The number of lean methods covered is typically large, 50 – 100. As stated above, most lean methods are found to contribute to sustainability. It can be asked whether these results are relevant?

Those results can be considered relevant in a situation where the relation between lean and sustainability is not well known. Such a situation indeed prevailed 5 – 10 years ago. However, today, such results lack academic novelty and industrial relevance.

What, then, would be industrially relevant knowledge? While determining industrial knowledge needs is a fertile research topic as such, we posit that there are two obvious directions for relevant research, both geared towards narrowing the gap between lean and sustainability. First, it is probably worthwhile to augment lean methods so that sustainability aspects are taken into consideration. There are already excellent examples on this, such as sus-VSM, and takt production. The purpose is to extend the lean construction toolbox to be fully able to promote sustainability targets. Second, the current methodologies for sustainable construction could be looked at and the opportunities for added efficiency through lean methods could be suggested.

MISSING TOPICS IN PRIOR REVIEWS

The literature mostly focuses on lean construction and sustainability integration (de Carvalho et al., 2017) as well as lean practices applications such as VSM (Carvajal-Arango et al., 2019; Rosenbaum et al., 2014). Takt production, TVD and value engineering have high potential for

sustainability aspects. Based on our review of the previous synthesis literature, the relation and interaction of TVD, value engineering and takt production with sustainability have not gained much attention. Thus, it is deserved to outline possible sustainability connections regarding these three approaches.

TARGET VALUE DESIGN/DELIVERY

Target Value Design (TVD) is an important lean methodology for sustainability because it is possible to achieve all three aspects of sustainability through TVD (Olender & Rosen, 2023; Russel-Smith et al., (2015). Decreasing the environmental impacts of buildings is possible by establishing sustainability targets in the design stage of the building projects. Sustainability values are required to be clearly communicated to obtain a shared view (Novak, 2014). Silveira and Alves (2018) mention that TVD inspired practices such as involving the users and owners in the process, pull design, transparency, and creating a clear vision leads to environmentally friendly buildings. Iteratively utilizing sustainable design targets during the design phase is proven to decrease the environmental impact of buildings throughout the life cycle, especially reducing the energy consumption during the use phase of the buildings (Russel-Smith et al., 2015). Thus, taking sustainability aspects earlier into account in building projects enhances sustainability performance.

TAKT PRODUCTION

Takt production in relation to sustainability aspects has gained limited attention. An exception is provided by Slosharek et al. (2021) who develop a conceptual framework to evaluate environmental performance using the takt production method. Both qualitative and quantitative environmental impacts were examined. Takt production has considerable potential for sustainability. It decreases process waste and shortens lead times (Frandson et al., 2013; Heinonen & Seppänen, 2016), improves control and flow of the construction processes (Lehtovaara, 2023), increases transparency (Kujansuu et al., 2020) and enforces the production schedule (Tetik et al., 2019). Increased transparency and control enable workers to focus on the tasks without losing time due to uncertainty over processes. Takt production also decreases material waste (Chauhan et al., 2021), thus contributing to the environmental performance of construction projects. Moreover, improving the flow of the production reduces the energy consumption on site (Maraqa et al., 2023). However, more case studies are needed to concretize the impacts of takt production in sustainability on construction industry.

VALUE ENGINEERING/MANAGEMENT/METHOD

Value engineering/management has the potential to benefit sustainability in construction by addressing environmental concerns in the early project stages. Yet, its focus has often been predominantly on cost reduction (Zainul Abidin & Pasquire, 2005). Integrating sustainability into the VE/VM job plan is significantly influenced by clients' priorities, often conflicting with sustainability objectives, especially in terms of first cost (Wao et al., 2016). To encourage the consideration of sustainability in proposals, VE/VM facilitators must establish connections between sustainability and other value drivers, align these goals with ongoing activities, and showcase potential monetary benefits to create real incentive (Abidin & Pasquire, 2007). A paradigm shift is necessary from the traditional approach of VE, which assesses cost-worth primarily in terms of initial expenses, towards a performance-worth VE that seeks optimal value for the lowest economic investment throughout the entire building life cycle (Wao et al., 2016). Still, further research is needed to validate proposed methods and explore additional approaches to adapt the VE/VM practice to sustainability.

DISCUSSION

HOW IS LEAN CONCEPTUALLY RELATED TO SUSTAINABILITY?

That lean can contribute to sustainability is thus widely agreed in the literature examined, however this conceptual linkage is variably presented. We contend that little new has been forwarded in comparison to the scheme presented already in 1998 by Huovila and Koskela. Basically:

- Lean and sustainability are aligned by their purpose; specifically, the lean purpose of waste reduction/elimination aligns with the general sustainability purpose of reduction of the use of material resources. In this angle, the contribution of lean to sustainability is broad and diffuse.
- Lean, through its methods for increasing value, is instrumental in achieving sustainability purposes and the contributions of lean to sustainability are related to specific sustainability purposes.

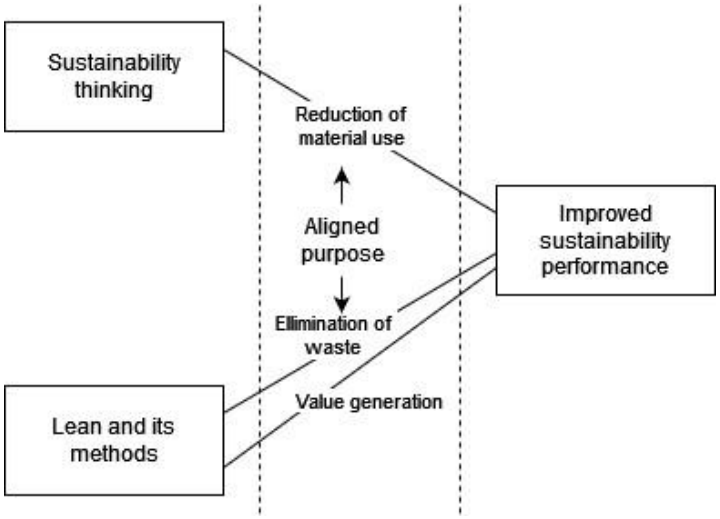

Figure 3. Conceptual relationship between lean and sustainability

SCALING LEAN UP

Lean construction has been thus far utilized in individual projects and mega-projects (Leth et al., 2019; Evans et al., 2021). Scaling lean application beyond single projects to neighbourhoods can scale up the sustainability contributions especially for the social and environmental aspect of sustainability. Moreover, since almost all lean practices seem to contribute to sustainability in construction industry, there is value in incorporating lean principles into policy making to reap more benefits for all sustainability aspects. For instance, it was suggested that efforts for trainings and spreading knowledge in collaboration with policy makers would improve the practical impact of using lean construction practices on regional level through the industry, specifically for small and medium sized enterprises (Tezel et al., 2019). Involving policy makers for adopting lean practices due to their contribution to sustainability would enhance the contribution to sustainability to a larger scale.

To determine the highest sustainability performance and low-cost solutions, algorithmic optimization methods have been developed for urban scale (Kämpf & Robinson, 2009). Several methods exist utilizing design automation, such as computational design for assessing sustainability of design solutions (Shahi et al., 2021). Simulations can be run to assess and determine the design options with higher sustainability performance (Østergård, Jensen & Maagaard, 2022). Utilization of these solutions are limited to specific instances and application in larger scale is needed.

METHODOLOGICAL PROBLEMS

The systematic literature reviews seem to suffer from two specific methodological problems: lack of criticality regarding systematic literature reviews and loose definition of the notion of conceptual framework. Both problems may have been inherited from the weaknesses of more general management literature.

Systematic literature review (SLR), as a methodology, originates in medicine and healthcare, representing settled disciplines with stable terminology. Later, SLR has started to be used in many other disciples, such as management and information technology. However, this methodology has also attracted critical views. For example, Boell and Cecez-Kecmanovic (2014) argue that SLR as a general approach to conducting literature reviews is highly questionable, concealing significant perils and caution that SLR could undermine critical engagement with literature. In the case of lean contributions to sustainability, the risk that seems to have been unnoticed or underestimated by authors is related to the still evolving terminology and scope of both areas, namely lean and sustainability.

Thus, when trying to create a literature overview on a selected topic, it is clearly advisable to critically approach the available methodological choices. Especially, an integrative literature review (Torraco, 2016) offers itself as a methodological alternative where active engagement of the researcher with the literature is supported. As discussed above, there is considerable looseness regarding the notion of conceptual frameworks. Van de Veldt (2020) states that there is evidently no clear-cut definition and application model for conceptual frameworks. This lack of unity has clearly created the impractical manifold of different understandings of conceptual frameworks in the SLR papers reviewed. It would be advisable to consult some of the few guidebooks covering how to define and prepare a conceptual framework (for instance, Ravitch & Riggany, 2016).

CONCLUSIONS

The interest into lean/sustainability topic has grown exponentially. The many literature reviews have been instrumental in showing that the general question whether lean can contribute to sustainability has already been solved: it definitely can. It must be concluded now that research efforts should be directed elsewhere. Now, it is time to focus on relevant topics and target actionable outcomes. We propose especially the following for further research:

- Critical case studies on implementation of lean/sustainability programmes in companies and projects.
- Augmenting existing lean methods with sustainability add-ons.
- Using value generation methods for sustainability purposes (especially Target value Design and Value engineering).
- Developing lean support for methods aligned with sustainability but usually not covered from the lean viewpoint, especially Circular design and production.
- Possible contributions of lean towards developing renovation policies at national and urban level must be explored.
- Identifying how lean can best contribute to sustainability.

The limitation of this study is that the analysis covered only some of the most cited "sustainability and lean construction" related papers.

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