

SWEDISH LEAN CONSTRUCTION PRACTICES IDENTIFIED IN THE LAST DECADE OF RESEARCH

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Studies on lean construction (LC) can possibly point to differences in its practical realization (i.e. different coverage of construction processes), in order to fit certain purposes. Different LC practices may entail the implementation of parts of the bundle of concepts that constitute LC (e.g. Last Planner), or the integration of LC with other frameworks and tools (like BIM). The identification of such practices may lead to the emergence of certain positive outcomes, like initiating a discussion on suggesting new and/or updated LC tenets. Here, the contextual characteristics of different construction sectors are appreciated by focusing on the Swedish national context. We explore the last decade of research output documenting cases of LC practices in Sweden, and then we critically analyse this output to categorise these practices according to the construction processes they cover. Methodologically, a systematic literature review utilising the augmented concept-centric framework was conducted, and the abductive method was utilised to analyse the review outcomes. The main LC practices in Sweden are found to pertain heavily to production and strategy, while covering partnering, stakeholder collaboration, design, planning, and supply chains to a lesser extent. However, the knowledge of these practices is scattered, which precludes a more advanced adoption of LC in Sweden and prevents it from fully countering issues it is supposed to tackle - as shown in a recent report on the productivity in the Swedish construction sector. Moreover, through the years, there has been a heavy focus on industrialised, rather than “conventional”, construction. However, while the study of the former - which has a well-defined, but also modest market share in Sweden - has been precise and extensive, the needs of the latter have yet to be adequately addressed. These findings may entail that more work is needed for a stronger requirements-driven adoption of LC in Sweden.

Keywords: Lean Construction, industrialised construction, practice, Sweden

INTRODUCTION

Over the years, there has been increasing research and practical interest in lean construction (LC). LC is considered to have caused a paradigm shift in the industry (Tommelein 2015) and has been the focus of several contexts - e.g., Lean Forum Bygg in Sweden, which features several industrial partners (Lidelöw *et al.*, 2019). This growing body of knowledge can possibly point to variations in the way LC is practically implemented to address different practical purposes, as in e.g., Meng’s (2019) research on different building types in the UK. Different LC practices - understood as different ways in which LC tenets are used to cover various building

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processes - may entail, among other things: (a) the implementation of only certain LC processes and tools, like Last Planner (Neve and Wandahl 2018) and target value delivery (Ballard 2020), and/or (b) different levels of integration between aspects of LC and other frameworks and tools, like e.g., Building Information Models (BIM) (Dave and Sacks 2020) and integrated project delivery (Alves and Lichtig 2020).

Despite such attention on the differences in the practical adoption of LC, there have scarcely been studies on actually identifying the respective practices. The benefits of such identification, as can be envisioned through the insights of such efforts as Tzortzopoulos *et al.* (2020), may include: (a) providing a clearer image of the state-of-art, (b) facilitating the adoption of LC, (c) initiating a practical benchmarking, and (d) leading into the suggestion of new and/or updated LC principles and tools, specifically tailored to fit certain needs. Here we focus on a national context, Sweden, in order to appreciate that the diffusion of concepts (like LC) might be impacted by national institutional forces, and because it constitutes a researchable body of knowledge. In Sweden, there has been a growing research interest on LC, which in the middle of 2020 has culminated into more than 330 publications. Among them, a number of studies investigated actual examples of practical LC implementation. However, this number is relatively small, and the respective studies lack a specific direction on identifying distinct LC practices according to the construction processes they cover.

Given the aforementioned motivations, the aim of the current effort is twofold: (a) explore the research output regarding practical LC implementation in Sweden; and (b) attempt a construction process-driven identification of LC practices in the Swedish context, by critically analysing the aforementioned output. For the first aim, a systematic literature review covering the last decade (2011-2020), was performed. For the second aim, the studies found during the review were qualitatively discretised.

Following this introduction, the paper's theoretical basis and research method will be described. Afterwards, the content, analysis and results of the literature review, will be elaborated on and followed by a critical discussion. Finally, the current study will conclude with its final remarks and recommendations for future work.

THEORY

To identify LC practices in Sweden, it might be beneficial to first define LC itself. However, there is not a single and universally referable definition, but rather a bundle of relevant interrelated themes (Koskela 2020). Therefore, a systems theory approach (Arbner and Bjerke 2009) was adopted to synthesise a collection of fundamental LC aspects, in order to offer an overarching understanding (without claiming that it is exhaustive) and prepare for the analysis of the literature review.

Initially, lean manufacturing (LM) was utilised within the Toyota production system to streamline and internally improve production processes and product quality (Gao and Low 2014). LM focuses mainly on eliminating waste, i.e., activities not creating value for the customer (Koskela 2020). This can be critically facilitated through continuous production flow, with just-in-time product manufacturing (Liker 2004).

LC emerged as a particularisation of LM for construction (Koskela 1992). LC aims at waste elimination, efficient resource use, optimisation of workflow, on-time delivery of information and materials to project sites, minimisation of cost, and maximisation of customer value (Tzortzopoulos *et al.*, 2020). Koskela (1992) proposed 11 LC principles of flow process design and improvement: (1) reducing the share of non-value-adding activities, (2) increasing output value through systematic consideration

of customer requirements, (3) reducing variability, (4) reducing cycle times, (5) minimising the number of steps, parts, and linkages, (6) increasing output flexibility, (7) increasing process transparency, (8) focusing control on the complete process, (9) building continuous improvement into the process, (10) balancing flow improvement, and (11) benchmarking. Moreover, Koskela (2000) defined the transformation-flow-value (TFV) framework of production, which allowed these principles to be applied to construction management. According to TFV, inputs are transformed into outputs while materials (and information) flow through value-adding activities and waste, with end-customer value as the goal (Koskela 2000). As in LM, just-in-time can eliminate lead time and waste in LC, making products to-order (Koskela 2020). Moreover, on-site logistics and construction supply chains can be optimised by using prefabrication (Vrijhoef 2020).

In terms of LC foci, five areas have been highlighted: lean project management, lean supply, lean design, lean partnering, and cooperative supply chain management (London 2008). Regarding LC implementation, Green and May (2005) have identified three increasingly mature levels: (1) waste elimination from a technical and operational perspective, (2) elimination of adversarial relationships and enhancing cooperation and teamwork, and (3) fundamentally changing the project delivery.

METHOD

In order to identify the core literature central to the research question, a systematic review was conducted, for which the concept-centric framework augmented by units of analysis (Webster and Watson 2002) was used. By using this framework, the review could be gauged to approach completion when no new relevant concepts could be found (Webster and Watson 2002). The main concept was “LC practices in Sweden”. The emerged units of analysis included, indicatively, “lean thinking”, and “prefabrication”. This framework was enhanced by using the “snowballing” and references-of-references techniques (Greenhalgh and Peacock 2005), while conducting a targeted but comprehensive search (MacLure 2005). A relatively complete body of literature was initially accumulated (n=237).

In order to be more relevant to the current Swedish construction context, we focused on publications within the last decade. Hence, the start for the literature search was set to 2011, and the end to June 2020 (i.e. the submission date of this paper). 37 search engines featuring engineering and/or managerial content were initially tested. After omitting 27 engines that returned no results or results already included in other engines, the remaining 10 (each returning at least one unique result) were utilised: Chalmers Library, Chalmers Open Digital Repository, Taylor and Francis Online, Google Scholar, BASE, Semantic Scholar, WorldWideScience, Baidu Scholar, Mendeley, and Scopus. Operators were applied to seek the searched terms in the title, abstract, keywords, text, author affiliations, and references of each publication.

The review was conducted in iterations and resulted in a large number of aggregated hits per research engine and per year. Refining the initial results led to finding the unique studies pertaining to the aforementioned criteria. In case entire papers were featured in collective works by the respective authors (e.g. “umbrella” theses), only the collective works were included here. Moreover, due to space constraints, no conference papers were considered, which reduced n to 27. Exploring these unique studies to find the ones featuring empirical material on Swedish LC practices, resulted in the final selection of the 16 publications featured in the following section. A simple visualisation of the systematic review process is shown in Fig. 1 (next page).

The review iterations followed the abductive reasoning of qualitative research, where observations and explanations are developed by working iteratively between concepts and data (Bell *et al.*, 2019) - in this case, data as research content. The themes of conventional and industrialised construction became the prevalent distinguisher, and the differentiated coverage of construction process became the second distinguisher.

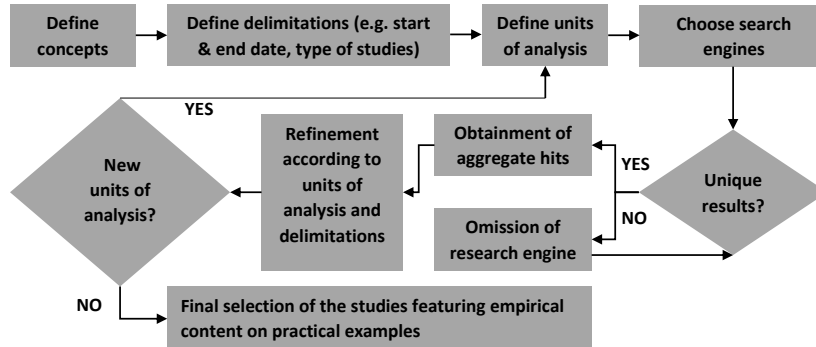


Figure 1: Flowchart depicting the systematic literature review process

RESULTS

Table 1 summarises the analysis of the 16 studies featuring empirical data on the practical implementation of LC in Sweden.

Table 1: Identified themes and LC-covered construction processes in the selected publications

References	Themes		Construction processes covered by LC practices					
	IND	CON	PROD	STRAT	DES	PLAN	SUP	PR/ST
Bildsten <i>et al.</i> , (2011)	x			x				x
Brege <i>et al.</i> , (2014)	x		x	x				
Gerth <i>et al.</i> , (2013)	x		x	x	x			
Haller (2012)	x				x x			
Jansson (2013)	x		x		x		x	
Jansson <i>et al.</i> , (2016)	x		x		x x			
Jonsson and Rudberg (2014)	x		x	x				
Lennartsson and Björnfot	x		x			x		x
Lessing and Brege (2018)	x			x				
Lessing <i>et al.</i> , (2015)	x		x	x				
Malmgren (2014)	x		x					x
Meiling <i>et al.</i> , (2012)	x		x					
Polesie (2012)		x	x					x
Psilander (2012)	x	x	x					
Simu and Lidelöw (2019)	x	x	x	x				
Tjell (2016)		x		x	x x			x
SUMS	16	15	4	12	8	5	4	2

Firstly, Table 1 features the themes of studies, by discretising them into the ones focusing on industrialised construction (IND), and the ones focusing on conventional construction (CON). It is shown that 13 studies focus exclusively on IND, two exclusively on CON, and two on both. Secondly, Table 1 features the construction processes that were reported in the respective studies as covered (sometimes overlappingly) by LC practices. These are described in more detail below.

Production (PROD) is the construction process covered in most studies, both IND- and CON-related (exclusively or overlappingly). It is mainly expressed through practical LC approaches to prefabrication and module and component construction (e.g. in Meiling *et al.*, 2012), technical analyses on performed production processes utilising LC (e.g. in Malmgren 2014), and the effect of practically implemented LC principles on production performance indicators, e.g., quality, delivery speed and

dependability, cost level and dependability, production flexibility (Johnsson and Rudberg 2014), and resource efficiency (Simu and Lidelöw 2019).

Strategy (STRAT) is mainly covered with regard to: (a) organisational practices and changes to accommodate LC principles, processes, tools, and product platforming (e.g. Lessing *et al.*, 2015), and (b) business models featuring practical LC (e.g. Brege *et al.*, 2014, Lessing and Brege 2018). While not being on the foremost concern of the respective studies, thus confirming Lessing's and Brege's (2018) observation mentioned earlier, STRAT is indeed the second most present process after PROD. It is applied exclusively for CON only in Tjell (2016).

The studies featuring the process of design (DES), express the practical interconnection of LC with frameworks like constructability (Gerth *et al.*, 2013), design-for-manufacturing-and-assembly (DFMA) (Gerth *et al.*, 2013), and product platform development (Jansson 2013). The practical integration of lean with tools such as digraphs for design process modelling (Haller 2012), visual management (Tjell 2016), and design breakdown structures (Jansson *et al.*, 2016), is also featured prominently. DES is explored mainly in IND studies, except Tjell (2016).

Planning (PLAN) often overlaps heavily with DES and PROD, and is featured almost exclusively in IND studies, apart from Tjell (2016). The practical implementation of Last Planner is exemplified (e.g. Haller 2012). Moreover, practically integrating other frameworks with lean planning, such as BIM (Jansson 2013), Knowledge Innovation/Visual Planning (KI/VP), and Obeya (Jansson *et al.*, 2016), is discussed.

Supply chains processes (SUP) are featured almost exclusively in IND studies. Different studies focus on practical LC implementation at different points across the supply chain; for example, Jansson (2013) investigated the transformation of the engineer-to-order approach to the make-to-order one, and Bildsten *et al.* (2011) argued for value-driven purchasing.

Partnering and stakeholder collaboration (PR/ST) is featured in one IND (Malmgren 2014) and one CON (Tjell 2016) study. In both studies, LC is identified as a facilitator for increased stakeholder collaboration. Malmgren *et al.* (2014) indicates that such a LC-facilitated collaboration can promote long-term commitments between clients and other stakeholders, rather than short-term relationships and opportunistic thinking. Tjell (2016) argues that LC-facilitated collaboration between the professionals in the design phase is crucial for increasing customer value.

The combination of the identified themes and the construction processes covered in the selected studies, indicates that within the last decade in Sweden, research has mostly reported on the LC practices pertaining to the production and strategy processes within industrialised construction. The focus on design, planning, supply chain management, and partnering and stakeholder collaboration has been smaller and scattered; whenever there was such a focus, it mostly regarded, again, industrialised construction. LC practices for conventional construction were investigated in only a few studies, where production was once more the main process covered. Figure 2 summarises the results of the analysis.

In Figure 1, the numbers in the bars indicate the amount of the selected papers that elaborate on the respective practice. There is an agreement between the results of our analysis and Lessing's and Brege's (2018) observation that research on industrialised construction has, historically, focused more on production and technical aspects, rather than organisational strategy and business models.

The focus on industrialised construction can be considered imbalanced in terms of its relatively modest market share in Sweden, which according to Brege *et al.* (2014), has recently been at 15% in the central case of multi-storey house apartments.

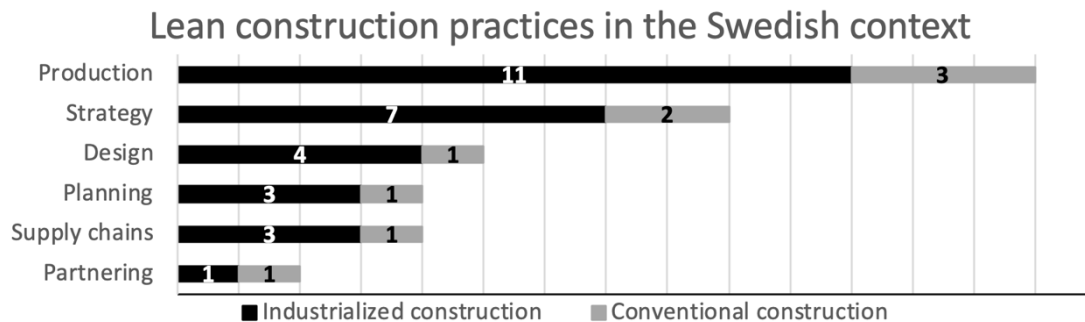


Figure 2: Summary of the results of the literature review

Moreover, apart from the end product itself (i.e. buildings and building modules), industrialised construction embodies a business approach that has been considered to diverge from conventional construction, and instead approach manufacturing (Malmgren 2014). This can mean that the practices explored in the respective studies, although designated as LC, might actually align better with LM. Indeed, Simu and Lidelöw (2019) note that in flow-oriented operation strategy companies (such as industrialised building firms), an ongoing empirical result is that they adopt LM rather than LC.

DISCUSSION

The material investigated in the present study clearly shows differences in the coverage of construction processes, but also large overlaps. Within the reviewed studies, an incomplete understanding of value from a LC lens, and a partial implementation of LC across the value stream, are prevalent. There is also a tendency to exemplify certain LC practices, but not elaborate on their actual positive or negative outcomes. Moreover, regarding the organisational context in most reviewed practical cases, there is largely an effort to tailor the organisation within lean, rather than the opposite. This has been posing, and continues to pose, a challenge in the adoption of LC tenets within construction management in Sweden, as there can be a dissonance between what is implemented and what is actually needed. This situation is accentuated due to the overt focus on technical aspects of production, which corresponds to the lowest level of LC implementation maturity in Green and May (2005). Indeed, the following two maturity levels, which could be considered as high-end goals for successful construction management, can potentially fall out when focusing only on waste elimination from a technical and operational perspective.

The present multiplicity of practices and their performance is sharply showcased in a recent industry-wide research report on the state of productivity in Swedish construction (Koch *et al.*, 2020), where, according to site managers, only around a third of projects actually feature LC - and there, the production costs are evaluated as higher (!) in all price ranges compared to the average of the other projects in the study. However, according to the respondents using LC, process parameters such as disturbance mitigation and schedule punctuality are improved. This indicates that there is a need for more LC competence in the industry, and a push towards requirements-driven LC adoption by focusing on its practical implementation and

understanding the way it affects not only project processes, but also organisational needs, culture, value streams, development, growth, and human interaction.

Considering industrialised construction specifically, current observations on the Swedish construction sector show that there is a concentration tendency; while the market share has not altered significantly in size over the years, there are presently fewer firms sharing it (Steinhardt *et al.*, 2020). Thus, a persistent research focus on the same, already significantly investigated companies, having a more or less solidified business model leaning heavily on manufacturing, may develop into giving somewhat less interesting and utilisable observations. Indeed, further research on the LC practices in the so-called conventional construction sector, may yield richer results.

Attention should also be drawn to the connection of the practices identified in research, compared to what is actually happening in the construction praxis itself. While some of the latest studies succeed in capturing facets of the current state-of-art (e.g. Simu and Lidelöw 2019), it is recurrent that research may lag behind practical LC developments, in subject areas like professional education and standardisation, digitalisation, project planning, logistics, stakeholder cooperation, and leadership (Lidelöw *et al.*, 2019). Resolving this tension would be beneficial for the Swedish construction sector and could simultaneously serve as a benchmark for other contexts facing similar issues. The kick-off for such a resolution could be the conduct of extensive empirical studies to update and deepen the knowledge on current LC practices, which could mark the boundaries of the state-of-art.

Questions about the generalisability of the present study beyond the national context can be raised. Construction sectors in different national contexts vary significantly (there can even be remarkable variations even within the same country or region), which would impede attempts of generalisation. Such variations obviously extend to the relevant praxis, including LC practices. Acknowledging these variations and trying to capture the specificities of a certain context can be considered a methodological strength, since research delimitations are more specifically defined and thin claims of universality are avoided. As such, the results of the current study, emanating from only Swedish context, are not considered generalisable. However, the reasoning behind the identification and reporting of LC practices, as well as the envisioned benefits from such an identification, have been recently noted in more generalised studies, e.g., Tzortzopoulos *et al.* (2020), as mentioned in the Introduction.

A last point in this discussion is the journey of the particular Swedish adoption of LC, something which is outside the direct focus of the current study, yet surfaces as an interesting set of reflections. The Swedish construction industry was not among the early adopters of LC, and when diffusion began, central LC elements were developed internationally. Nevertheless, the challenges Swedish construction management faced in adopting LC tenets over the last 10 years appear to be broadly the same as elsewhere - such as the lack of support to site managers' LC implementation, and/or the resistance to top down initiated change (Koch *et al.*, 2015). Training offers and other institutional support was established around 2009, shortly after the dominance of the interpretation of LC as factory production was established. It is likely that this even drew on and borrowed legitimation from the Swedish manufacturing industry, which had been actively adopting lean, drawing on the Toyota production system (Liker 2004). Apart from this characteristic early dominance of factory production and its split between with conventional production, it is likely that the adoption of the

LC concept follows patterns of many other management concepts - i.e., picking parts of the full concept and shaping it to local needs, thus giving the adoption different scopes in the building processes and firms (Kamp *et al.*, 2005). A particular example of this is the presence of a design variant, which largely can be ascribed to one large Swedish contractor with a practice of doing design-build contracts.

CONCLUSION

The research of the last decade which features empirical material on the practical implementation of lean construction (LC) tenets in the Swedish construction sector, can facilitate the possible understanding of relevant specific practices. Current research on such practices is far more focused on industrialised rather than conventional construction. Moreover, it primarily focuses on production and then strategy, with other processes (such as design, planning, supply chains, partnering and stakeholder collaboration) receiving much less attention. In short, the main identified LC practice in the Swedish context pertains to production within industrialised construction.

Identifying LC practices can be the first step in tackling certain issues within LC research and praxis in Sweden, e.g., properly understanding value within the value stream, accounting for the organisational context, balancing the foci on conventional and industrialised construction, resolving productivity-related issues, and capturing the state-of-art. As future work to corroborate the results of the present study and further facilitate the tackling of the aforementioned issues, in-depth empirical studies (interviews, surveys, visits to construction sites and production plants) across a wide spectrum of the Swedish construction sector, are recommended. A longer-term aim is to suggest new and/or updated LC principles and tools, mainly focusing on context-specific social and cultural aspects, and also support decision-making via advanced technologies.

The identified practices, problematisations and recommended future work of the current study, may focus on the Swedish context, but can be used as blueprints for studies in other specific construction contexts sharing tangential characteristics.

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