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A MAPPING OF SWEDISH LEAN CONSTRUCTION VARIANTS IN PRACTICE: REVIEW AND SURVEY

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Swedish Lean Construction (LC) practices focus mainly on improving technical process parameters – however, issues claimed to have been solved by LC (e.g., high production costs), are still apparent. This study reports on a survey about Swedish companies' LC practices. A literature review on Swedish LC variants served as the background. The questionnaire survey itself was answered by around 490 construction-related companies across all Swedish regions. Survey results indicate a cross-sectoral discrepancy of LC knowledge and practices, with almost 65% of respondents claiming not to know about LC – while those doing so, are applying it in variants (e.g., integrated with location-based planning). Such an implementation can either pertain to project portfolios or be required by clients – and is more visible in large contractors and some SMEs claiming to be LC-competent. A stronger cross-industry collaboration may be needed for facilitating LC knowledge in Sweden, as well as underpinning LC practice variants befitting each company's specific business model.

Keywords: lean construction; practical variants; Sweden

INTRODUCTION

Lean construction (LC) was initially suggested for implementation in Sweden close to 15 years ago, where innovations in construction processes were sought in lessons-learned from the automobile industry - especially regarding contractual, supplier, and customer relations. In academia, this has evolved into a growing research interest featured in more than 350 Swedish publications over 2007-2022. Moreover, elements of a practical LC implementation by some contractors commenced in 2007. However, only a fraction of the academic studies tried to go beyond LC theorisations by empirically investigating such LC practices. Kifokeris and Koch (2020) and Kifokeris (2021) sought to map those empirical studies, which resulted in the identification of six academically conceptualized (but also possibly practically implemented) LC variants in Sweden (see "Literature review"). Such variants can reflect the dedicated use of specific LC elements (e.g., the Last Planner system (LPS) (Ballard 2020a)), and/or the integration of LC with other frameworks, tools, and methodologies, (e.g., Building Information Modelling (BIM) (Dave and Sacks 2020)) (Kifokeris 2021).

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Identifying such LC practice variants can clarify the state-of-art, inform LC adoption, and initiate a practical benchmarking of LC in Sweden (Kifokeris 2021).

On this background, and going beyond the literature, our research question would be: How can Swedish LC practices be empirically documented, in order to grasp the current state-of-art, identify contemporary practical shortcomings, and start considering what a Swedish requirements-driven adoption of LC could be? This study's objective is to tackle such a research question by adopting an operations management approach and reporting a mapping of the Swedish companies' LC practices, as investigated in large-scale questionnaire survey (including basic LC concepts to more advanced themes, e.g., integrating LC with IT) conducted in the end of 2021. It targeted 1,200 companies of all sizes across all three construction-related industry groups and all geographical regions in Sweden. Close to 490 companies provided valid answers. Among others, preliminary survey results indicate a large discrepancy of LC-related knowledge and practices across the Swedish sector.

Following this introduction, the paper's literature review and research method will be described. Afterwards, the analysis of the survey's preliminary results will comprise the empirical focus of the study, followed by critical discussion points. The current study then concludes with its final remarks and recommendations for future work.

LITERATURE REVIEW

LC can be described as a bundle of interconnected themes and concepts (Koskela 2020). Central among those are eliminating waste (i.e., non-value-creating activities) (Koskela 2020), streamlining and internally improving production processes and quality with the Toyota system (Gao and Low 2014), and just-in-time construction production flow (Liker 2004). Complementarily, LC aims at efficiently using resources, optimising workflow, delivering information and material on-time, building relations and cooperation, continuous improvement, minimising cost, and maximising customer value (Tzortzopoulos *et al.,* 2020). Moreover, on-site logistics and supply chains can be optimised by using prefabrication (Vrijhoef 2020). Green and May (2005) have identified three levels of LC implementation maturity: (1) technical and operational waste elimination, (2) cooperation and teamwork enhancement, and (3) fundamental change in project delivery. Finally, London (2008) identified five LC foci (possibly understood as precursors of LC variants): lean project management, lean supply, lean design, lean partnering, and cooperative supply chain management.

Practical LC variants themselves can point to dedicatedly implementing specific LC concepts, processes, and tools - e.g., the LPS (Ballard 2020a), target value delivery (Ballard 2020b), and prefabrication (Yuan *et al.,* 2022). Moreover, they can reflect an integration of LC and other tools, frameworks, and methods - like, indicatively, location-based planning (Kenley and Seppänen 2010), virtual design and construction (VDC) (Kunz and Fischer 2012), visual management (Tjell 2016), six sigma (Plenert and Plenert 2018), integrated project delivery (Alves and Lichtig 2020), BIM (Dave and Sacks 2020), and robotic systems (Brissi *et al.,* 2021).

For LC variants within the Swedish context, Kifokeris and Koch (2020) and Kifokeris (2021) reviewed the relevant publications featuring empirical content, leading to the identification of six LC variants in Swedish practice, as communicated in research:

1. The industrialized construction variant: Prefabrication, modularisation, standardisation, just-in-time, product platforming, mass customisation (optionally), and usually integrated with CAD and BIM

2. The production processes variant: Prefabrication (but not on a fully industrialized level like in the previous variant), vertical integration, pull systems, just-in-time, LPS, stakeholder cooperation, broadening of partnering teams, and usually integrated with CAD, BIM, and VDC
3. The production strategy variant: production strategy optimisation, product platforming, bottom-up feedback, stakeholder cooperation, broadening of partnering teams, and even appointing specialised LC managers
4. The design variant: constructability, product platform development, early supplier, and client involvement in design, and usually integrated with 4D CAD, BIM, VDC, and visual management
5. The planning variant: process mapping, location-based planning, stakeholder collocation, LPS, just-in-time, usually integrated with BIM, VDC, and visual management, and sometimes combined with the design variant
6. The logistics and supply chain variant: process mapping, value-driven purchasing, location-based planning, just-in-time, LPS, and early supplier involvement in the material and economic flows

While these variants appear precise and hint to an advanced LC implementation in Swedish practice, Kifokeris (2021) points out that this may not actually be the case in the 2021-2022 state-of-art. Specifically, Kifokeris (2021) notes that most reviewed studies had a disproportionately large focus on industrialized construction - while the relevant market segment, although well-defined, is small compared to the rest of a sector dominated by more conventional construction practices (Steinhardt *et al.,* 2020). Moreover, Kifokeris (2021) shows that the reviewed studies mostly focused on the LC practices of few specific case companies - leading to well-contextualized, but not easily generalisable results. Furthermore, Koch *et al.,* (2020) empirically showed that practical LC implementation in Sweden focused mainly on improving technical process parameters, and issues claimed to have been solved by LC (such as impaired productivity and high production costs), were still apparent.

METHOD

To identify the literature for the background of this study, a concept-centric systematic review augmented by units of analysis was conducted in iterations - so that the review could be gauged to conclude when no new relevant concepts could be found (Webster and Watson 2002). The main concepts were “Swedish LC practices” and “LC variants”. The emerged units of analysis included, indicatively, “production platforms”, and “prefabrication”. This framework was supported by the “snowballing” and references-of-references techniques (Greenhalgh and Peacock 2005).

The empirical part of the study tackled the research question stated in the Introduction, through the conduct of a questionnaire survey addressing a wide sample in a well-structured manner with standardized questions (Boynton and Greenhalgh 2004). An operations management approach (Slack and Brandon-Jones 2019) was used in conjunction to our LC knowledge to inform the survey’s design - as we investigated lenses of designing and controlling production processes and business operations for efficiently and effectively meeting the client’s requirements. This resulted in a total of 23 questions categorized thus: information about the respondent’s role and company affiliation (two questions), knowledge and understanding of basic LC concepts (two questions), LC elements (incl. overarching philosophies, waste elimination, pull planning and kanban, LPS, and lean supply chain and logistics) implemented by the

company currently (five questions) and in the past (five questions), other applied approaches to facilitate LC (incl. e.g., BIM 360, VDC, and six sigma) (one question), factors of LC implementation (incl. e.g., competence development and training, communication, rate of implementation, and effects) (seven questions), and an optional contact confirmation for requesting to receive the project report when the survey is completed (one question). Each question had one of the following forms: multiple choice inquiry, free-from textbox, tick box list, Likert scale, or a combination thereof. The survey was designed and went live using the online tool Survey Monkey.

The respondents were not sampled, but rather, an industry-wide response pool was sought. As such, a nationwide database of all companies active in the Swedish construction sector was created - including around 1,200 firms across all geographical regions in Sweden and all entries in the construction-related industry groups 41 (development of buildings and construction of residential and non-residential projects), 42 (infrastructure), and 43 (facilities and crafts). The database fields covered the companies' names, website, place of main activity, postcode, registration year, organisation number, 2019-2020 turnover and net profit, number of employees, contact person (name, e-mail, cell phone number), and business activities. The questionnaire was then sent via e-mail (through Survey Monkey) to all database entries. This process was iterated thrice; in between each iteration, the targeted respondents were also called on the phone, to ensure the highest possible response rate. The survey was live between 23/08/2021 and 31/10/2021 (with a few stray responses until 31/01/2022), and around 490 companies offered valid (i.e., not blank, or partial) responses - resulting in a ca. 41% response rate. Companies in groups 41, 42 and 43 provided ca. 43%, 12% and 45% of the responses respectively.

The synthesis of the literature review and survey results followed the abductive reasoning of qualitative research (Bell *et al.,* 2019), where observations and explanations were developed by working iteratively between theory and data.

Empirical Part - Survey, Results, and Analysis

The survey results will be presented and analysed here in more detail. Table 1 offers an overview of the respondents' profiles and contribution to the overall response rate.

Table 1: Survey respondents' profiles and overall contribution to the response rate

Role in company	% of responses
Top managers: CEOs, department managers, business unit managers	55
Middle and lower managers: project, site, and production managers	31
Officers and clerks	7
Technical personnel: engineers and craft/site workers	1
Other, e.g., environment and HR managers	6

This strong representation of top management may indicate that most respondents are possibly responsible for important initiatives and even top-down strategic decisions. This strikes however as particularly alarming, as when the respondents were asked in the following question about whether they knew what LC was and for what it could be used, close to 65% answered that they did not. A far lower percentage (ca. 34%) declared that they knew about it, and very few noted that they knew about LC, but implemented it under a different definition (without, however, offering a further explanation about what such a definition could be). This response already supports the problematisations in Kifokeris and Koch (2020) and Kifokeris (2021), as it shows a rather different picture than the one described by the reviewed academic studies in the Swedish context. Figure 1 offers a graph depicting the aforementioned responses.

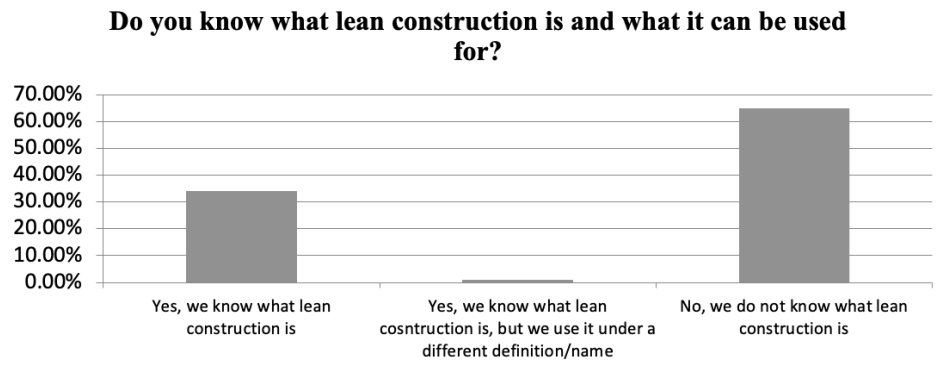

Figure 1: Survey responses regarding the state of knowledge about what lean construction is

Then, a basic definition of LC was offered to aid the respondents, as it was anticipated that some would not know about LC - although, not to such a large percentage. That definition was a simplified combination of concepts by Koskela (2020), Gao and Low (2014), and Liker (2004): "Although there are many concepts of lean construction, it is generally considered that it aims to eliminate waste and increase value for the client". The survey then continued under the premise that equipped with this definition, even less knowledgeable respondents could follow through.

The respondents were then asked about how strongly they agree with specific LC-related statements (see Figure 2). They could choose multiple answers on a 5-step Likert scale: 1 - Not at all, 2 - Weakly, 3 - Relatively weakly, 4 - Relatively strongly, and 5 - Strongly, while also having the opportunity to choose Don't know / N/A.

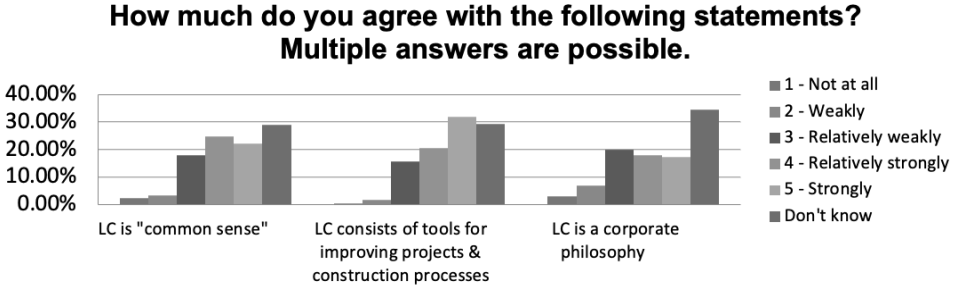

Figure 2: Degree of agreement with specific lean construction-related statements

Due to space limitations not permitting the inclusion of all survey graphs, below we will textually describe the rest of the survey's Likert-like questions and responses, while focusing on the most prevalent degree of agreement for each statement.

Succeeding the previous question, the respondents faced a series of inquiries regarding the degree with which LC factors or elements have been applied in their companies' contexts. In the inquiry about overarching LC philosophies, waste elimination and customer value increase applied relatively strongly, the transformation-flow-value (TFV) framework applied relatively weakly, and the Toyota production system was N/A. Waste elimination was then shown to be relatively strongly associated with errors, non-utilisation of human resources, inefficient resource management, reworks, delays, transportation, and value-creating activities; and relatively weakly associated with overproduction and the inventory. Finally, three following inquiries about specific tools showed that there was a relatively strong application of pull planning, a relatively strong and similar application of the different LPS elements (master plan, percent of completed plan, and preparing the seven healthy flows regarding completed documents, prepared workplace, machines and tool on site, ready crew, building

materials, completed related work, and external conditions like the weather), and a relatively weak application of lean supply chain and logistics.

The following set of inquiries was like the previous one but concerned the companies' application of LC tools and elements in the past. Regarding overarching LC philosophies, waste elimination and customer value increase applied strongly, the transformation-flow-value (TFV) framework applied relatively strongly, and the Toyota production system applied relatively weakly. Waste elimination was relatively strongly associated with errors, reworks, delays, non-utilisation of human resources, transportation, inefficient resource management, and value-creating activities, and relatively weakly associated with overproduction and the inventory. Finally, there was a relatively strong application of pull planning, a relatively weak and similar application of the different elements of LPS, and a relatively strong application of lean supply chain and logistics. It seems that while not fully aligned, past and current applications of LC elements by the Swedish companies are similar.

When asked about other approaches that have been applied by their companies to specifically facilitate LC, the respondents answered that there was a relatively strong application of initiatives connected to communication, leadership and work organisation, a relatively weak application of BIM, production process analysis, and value flow analysis, and a weak application of BIM 360, 4D CAD, 5D CAD, VDC, virtual reality (VR), integrated project delivery (IPD), and six sigma.

The last group of questions considered the efforts that had been made by the responding companies to apply LC. First, the companies were asked whether they've been involved in competence development and training activities (incl. workshops, academic or industrial courses, etc.) of the respondent roles stated in the beginning of the survey (multiple roles could be selected). Close to 46% focused on project and site managers, ca 40% on top management, and the percentages pertaining to engineers, officers and site workers were far lower. Interestingly, close to 34% elaborated on other training and development activities, the most notable of which being a relevant "unofficial" training by working with clients having strict requirements. Secondly, when asked about which of the respondent roles were aimed at by most of the relevant communication activities (incl. meetings, information flows, etc.), the trend was like the previous inquiry, just with relatively different percentages: 50% at project and site managers, ca 40% on top management, and less at engineers, officers, and site workers. Around 28% elaborated on other communication activities, including meetings with logistics specialists.

Considering other implementation activities, around 30% responded that they have used educational games (e.g., SIM Lean), ca 24% that they sought long-term relationships with the supplier, 20% that they implemented simulation activities (e.g., through lessons-learned from other projects), and close to 26% that they implemented something else - a notable case being what was claimed as a special production system developed in-house. The two final inquiries in this set concern the degree of LC implementation within the company activities (see Figure 3), and the results of such an implementation (see Figure 4). In both cases, the prevailing percentage reflected answers documenting no implementation and no effect, respectively. However, among the rest of the answers, LC was claimed to prevalently be implemented in all company's projects (28%), and the main result of such an implementation to be an increase of efficiency and productivity (39%), respectively.

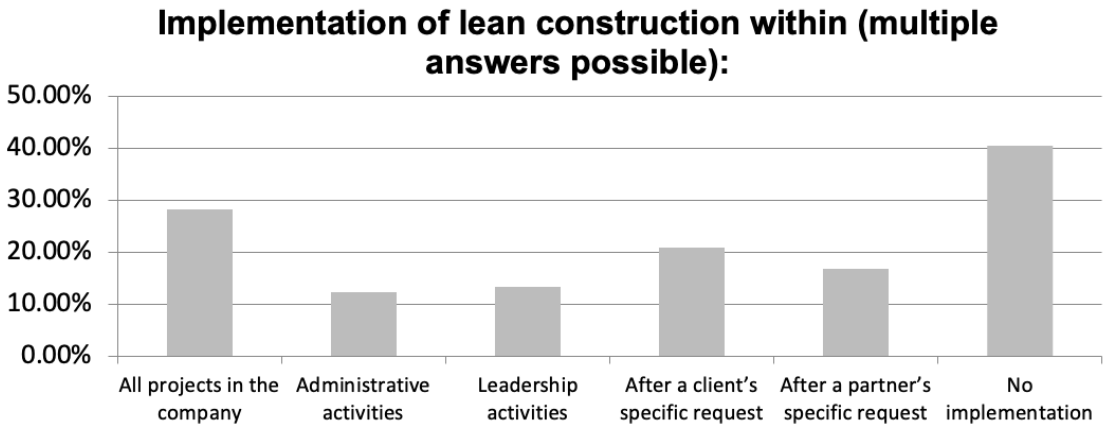

Figure 3: Degree of implementation of lean construction within companies

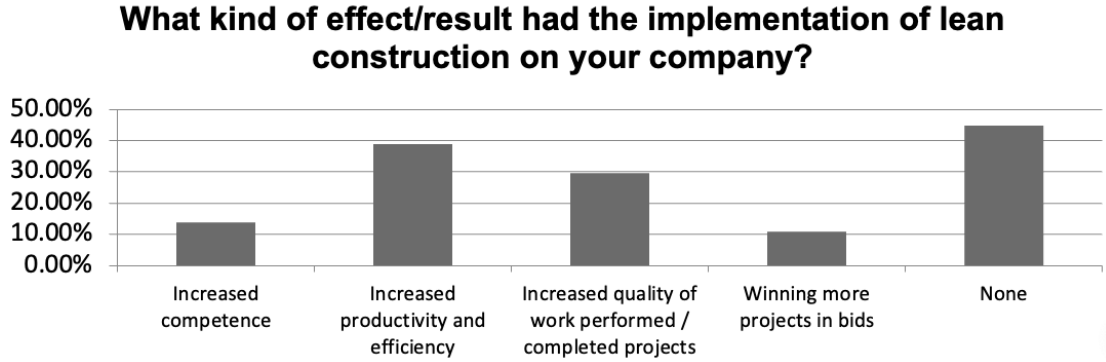

Figure 4: Effect of lean construction implementation within companies

The statistical analysis of the results discretized per geographical region and industry groups is still ongoing. However, it has preliminarily been shown that most LC-competent companies are found in the larger Swedish urban centres (Stockholm, Gothenburg, and Malmö), and that LC implementation appears to be more visible in companies within groups 41 and 42, rather than 43; within group 43, elements of LC are mostly found in HVAC companies.

FINDINGS

The overall survey results show that there is a large discrepancy of LC knowledge and practices across the industry, with almost 2/3 of the companies not being aware of LC. However, subsequent inquiries also showed that even among those respondents, some might have still implemented or are implementing elements of LC unwittingly.

While a detailed interpretation of the survey results is still ongoing, the relevant analysis can so far show that there are four discernible LC variants implemented in practice by those respondents working with LC:

1. A design variant integrated with IT systems (e.g., BIM, VDC).
2. A planning variant integrated with location-based planning and partly to LPS.
3. A management variant integrated with management systems.
4. A production variant integrated with production platforms.

These variants were deduced by drawing correlations among the survey results, as well as between each company and its responses. This correlation also shows that LC implementation appears to positively relate to the company's size and volume of projects - the larger, the better. However, there are also LC-competent SMEs, which

might mean that LC is part of their strategy in practice for rising above the competition.

When comparing to the relevant literature, the disproportionately large research focus on industrialized construction evidently does not reflect the reality of the rest of the sector - which, as shown by the survey, is dominated by more conventional construction practices and other LC variants. This "skewed" interest in the literature might reflect the researchers' particular interests in arguing in favor of a more industrialized sector in Sweden. However, it indicates that LC research, training, information, and dissemination, need to be redirected to also meet the demands of the rest of the industry. Moreover, most reviewed studies focus on the LC practices of a few specific Swedish case companies, which paint a far more advanced picture than what is shown in the current, industry-wide survey.

This mapping implies that a stronger cross-industry collaboration may be needed for establishing a common ground in LC knowledge in the Swedish context. In that vein, an improved facilitation of LC in Swedish companies should maybe pervade all organisational levels - possibly even a combination of top-down and bottom-up strategizing about practical LC implementation (Kifokeris and Löwstedt 2021). Furthermore, LC variants should be underpinned to fit each company's specific needs and business model - LC should not be approached as a dogma, but as a flexible bundle of concepts, tools, processes, and methodologies. The current empirical results confirm Kifokeris' and Koch's (2020) assumption that practical LC adoption in Sweden probably follows patterns of other management concepts - i.e., picking parts and shaping them to local needs (i.e., the LC variants), thus vesting the adoption with different scopes within construction processes and firms (Kamp *et al.,* 2005).

CONCLUSIONS

This study aimed to empirically document lean construction (LC) practices in Sweden, to grasp the current Swedish state-of-art, identify contemporary practical shortcomings, and facilitate a requirements-driven adoption of LC. A large-scale questionnaire survey was conducted at the end of 2021 to map Swedish companies' LC practices. Close to 490 construction sector companies of all sizes and across Sweden, provided valid answers. Survey results indicate a large discrepancy of LC-related knowledge and practices across the Swedish sector. Close to 2/3 of the respondents claimed to not know what LC is, and among those who did, they mainly implemented it in variants: a design-based variant integrated with IT systems (e.g., BIM, VDC), a planning-based variant integrated with location-based planning, a management-based variant integrated with management systems, and a production-based variant integrated with production platforms.

Given the above, this study's main contribution to the body of knowledge is the clarification of the Swedish state-of-art in practical LC implementation, informed by an industry-wide survey covering multiple concepts, themes, understandings, methodologies, activities, tools, and techniques associated with LC. The structure of this study may be used for the design of other relevant studies in different contexts.

However, generalising the content and results of the present study beyond Sweden can be debated. Construction sectors in different national contexts can vary significantly, possibly impeding attempts of generalisation. However, acknowledging such variations can be considered as a methodological strength, since research delimitations are more specifically defined and unfounded claims of universality are avoided. As

such, while this study's results may not be easily generalisable, the reasoning behind the mapping of LC practices and variants, as well as the envisioned benefits from it, have indeed been noted in international studies (e.g., Tzortzopoulos *et al.,* 2020).

Recommendations of future work include the further analysis of the survey's results, the possible discerning of other practical LC variants, and the communication of such results across the Swedish industry, through workshops and education activities - which can even include LC fundamentals, to help companies not recognising what LC is in understanding whether they could benefit from it in the first place.

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