

Lean construction – nuläget

Lean construction – the current situation

Slutrapport
Final report

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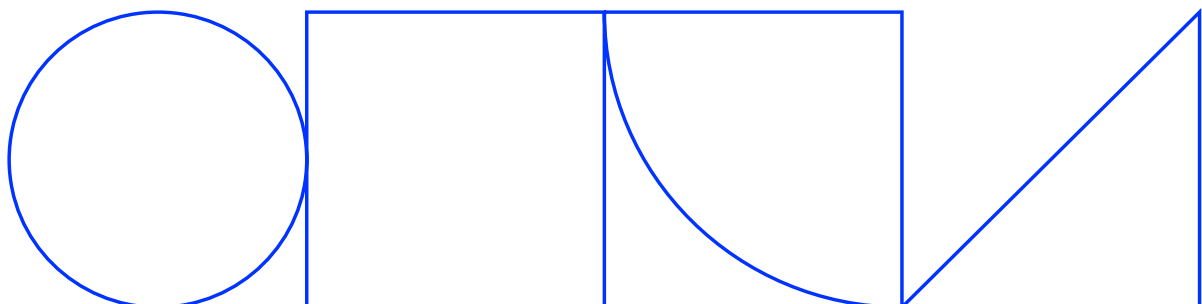


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FOREWORD

This is the first Swedish research study that has investigated the state-of-art-of lean construction for the entire Swedish construction sector. Lean construction can help in tackling prevailing issues in Swedish construction, such as ones connected to productivity, efficiency, value creation, quality, and work environment – this has been the long-standing position of both practitioners and researchers working with these issues.

However, relatively little is known about lean construction (LC) application in Swedish practice. Where is LC found within the Swedish construction sector? To answer this question, this project sets out to clarify the current Swedish LC state-of-art through a nation- and sector-wide questionnaire survey targeting all construction-related companies (1340+ firms, excl. industrialized housebuilders). Out of the 470+ respondents, almost 2/3 claimed to not even know about LC, while the rest recounted implementing LC in variants – i.e., picking parts of LC, and shaping them to their needs. The study provides empirical evidence of a state-of-art that is quite different from the one ascertained by previous, narrower studies, and shows that when LC *is* implemented in Sweden, it is done in a diversified way involving several variants.

A lot of effort went into this study, and we gratefully thank SBUF and CMB for funding it. The project was mainly undertaken by the authors of this report; however, we were enormously helped by Bogdan Bahnariu, PhD candidate, and student assistant Safaa Aqel (both in Halmstad University), who undertook crucial parts of the survey's preparation and development. As such, we cordially thank them for their large effort and collaboration. Moreover, we warmly thank F.O. Peterson & Söner Byggnads AB – especially Henric Wahlström and Jonas Steen – for being the project managers from SBUF. We also extend our thanks to FoU Väst, Byggföretagen, and Installatörsföretagen, for keeping our project to their sites, as well as the audience attending our CMB presentation. Last but not least, we are immensely thankful to the hundreds of our survey respondents, who took the time to help us understand what is actually happening with LC in Swedish practice. Their responses and feedback are the cornerstones of our project. Tusen tack!

Gothenburg, 12 May 2023

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SAMMANFATTNING

Lean construction (LC) har implementerats av svenska entreprenörer sedan ca. 2007. De 16 åren fram till 2022–2023 såg ett ökande svenskt forskningsintresse för LC. Hundratals relevanta publikationer och dussintals kandidat-, magister-, licentiat- och doktorsavhandlingar har producerats under åren. Detta tycks visa att diskussionen om huruvida LC kan hjälpa till att ta itu med frågor inom svenskt byggande har varit levande – både vad gäller långvariga utmaningar (t.ex. produktivitet, effektivitet, värdeskapande), såväl som framväxande (t.ex. klimatmål, instabila marknader, inflation).

Dock har få undersökningar om LC-praxis på sektornivå erbjudits hittills. Studier med empiriska fall finns men är få jämfört med det totala antalet relevanta publikationer, och själva empiriska materialet samlas mest kring några specifika företag som banar väg för LC i Sverige. Dessutom tenderar industrialiserat byggande att dominera i många forskningsbidrag och praktiska tillämpningar, till en grad oproportionerligt jämförd med dess marknadsandel. Svenskt byggande domineras fortfarande av produktion på plats, även om det finns en väl inbyggd praxis att använda prefabricerade komponenter och andra specifika off-siteelement. Som sådant syftar detta projekt till att förtydliga den nuvarande svenska LC-state-of-art, genom att undersöka hur väl den relevanta forskningsresultaten speglar svensk praxis 2022–2023, och empiriskt kartlägga det faktiska tillståndet till vilket LC för närvarande befinner sig inom den svenska byggsektorn. Därmed identifieras också de varianter där LC är praktiskt implementerad i Sverige – eftersom identifiering av LC-praxisvarianter i ett nationellt sammanhang kan underlätta LC implementering på ett sätt som passar branschbehoven, förutsatt att nationella institutionella inflytanden på LC-praxis erkänns.

Metodologiskt omfattar studien en systematisk litteraturgenomgång av svensk LC-forskning med empiriskt innehåll (även om det är snävt), följt av en riks- och branschövergripande enkätundersökning riktad till alla byggrelaterade företag (exkl. industrialiserade husbyggare) över alla geografiska regioner i Sverige. Företagen tillfrågades om vad, när och hur mycket de tillämpar LC i sin praktik. Resultaten av analysen av litteraturen och enkätsvarsdata syntetiserades kvalitativt med hjälp av abduktion.

Den granskade litteraturen analyserades i termer av deras teman (industrialiserat byggande eller konventionellt byggande), processtäckning (design, produktion, partnering och intressentsamarbete, planering, strategi, försörjningskedja), paradigm (systemteori, företagsekonomi, organisatoriskt beteende, interpretivism), och innehåll. Genom denna analys härleddes de preliminära varianterna av LC: Industrialiserat byggande, produktionsprocesser, produktionsstrategi, design, planering samt logistik och försörjningskedja. Studierna med empiriskt innehåll var som nämnd få jämfört med det totala antalet svenska LC-relaterade publikationer, och innehållet i sig klustrade sig mest kring ett fåtal specifika företag som har banad väg för LC i Sverige – vilket tyder på en bristande förståelse på sektornivå av den faktiska LC state-of-art. Slutligen, som tidigare nämnts, monopoliserade industrialiserat byggande intresset för många forskningsinsatser – oproportionerligt till dess marknadsandel.

De problematiseringar som härrörde från litteraturgenomgången tjänade som bakgrund till den riks- och branschövergripande enkätundersökningen som genomfördes från augusti 2021 till januari 2022. Den riktade sig till 1342 företag och fick 471 giltiga svar, vilket hade en svarsfrekvens på 35 %. Undersökningen visade att det finns en stor skillnad i LC-kunskap och praxis över hela Sverige. I vissa fall angav undersökningsrespondenterna genom sina svar en väl anpassad implementering av LC. Men 286 av 471 svarande (dvs. 61% av de totala svaren!)

hävdade att de inte ens visste vad LC är. Icke desto mindre fortsatte en undergrupp av de undersökta företagen som påstod sig vara omedvetna om LC fortfarande med att svara på enkäten på ett sätt som indikerar att de faktiskt kände till LC. När det gäller kommunikation, utbildning och andra hjälpaktiviteter (t.ex. simulering), finns även här några djupa fall men de flesta svar uppvisar en inte särskilt detaljerad tillämpning. Tidigare och nuvarande LC-implementering är mestadels partiella – vissa LC-element, som eliminering av avfall och ökat kundvärde, har tillämpats jämförbart tidigare och nu, men andra, som Last Planner, har gått igenom faser av varierad tillämpning. Analysen av svaren från företag som har implementerat LC, uppvisar fyra praktiska LC-varianter: (1) en variant relaterad till IT-stödd design, (2) en produktionsvariant, (3) en planeringsvariant som betonar användning av Last Planner, och (4) en försörjningskedja och logistikvariant fokuserad på partnerskap med leverantörer. Jämfört med de preliminära varianterna som hittats i litteraturoversikten är varianterna som hittats i svensk LC-praxis genom undersökningen färre (fyra i stället för sex), mer snävt definierade och mer förenklade – vilket indikerar att i praktiken endast specifika LC-element har varit mer populärt (t.ex. Last Planner).

Undersökningen har visat att LC har genomförts av både stora entreprenörer och små och medelstora företag (t.ex. underleverantörer, installatörer) som säger sig vara LC-kompetenta. Dessutom visar de framväxande praktiska LC-varianterna att den svenska implementering av LC (när det sker i första hand) följer mönster som är uppenbara i implementeringen av många andra ledningskoncept – d.v.s. att välja delar av hela konceptet och forma det till lokala behov, vilket ger adoptionen olika omfattningar i byggprocesser och företag. Detta kan innebära att varje variant kan anpassas ytterligare för att passa ett specifikt företags affärsaktiviteter, affärsmodell, företagskultur, organisationsstruktur och till och med lokala särdrag. Som sådan, även om dessa varianter kan spridas till intresserade parter via kommunikations- och utbildningsaktiviteter, är det mycket troligt att varje part sedan kommer att ta den variant som gällde mest för dem, och ytterligare kontextualisera den för att helt passa deras fall.

Detta är den första svenska forskningsstudien som undersöker LC-state-of-art i en sådan skala. Den ger empiriskt underlag för en svensk state-of-art som inte kan hittas i tidigare, snävare studier. Den visar också att den diversifierade implementeringen av LC i Sverige avviker från en mer ”puristisk” förståelse av LC. Som sådan kan LC-forskning, utbildning, information och spridning behöva omdirigeras för att realistiskt möta industrins krav. Parallellt bör LC-praxis möjligen informeras genom en kombination av top-down och bottom-up tillvägagångssätt. Slutligen kan ett starkare branschövergripande samarbete behövas för att underlätta LC-kunskap och praktik i Sverige.

Framtida arbete kan innefatta en fortsättning av den föreliggande studien för att forma vägen framåt för praktisk LC-implementering i Sverige – eftersom problem som påstås ha lösts av LC (t.ex. höga produktionskostnader), fortfarande är uppenbara. Detta kan innebära att förutom processer bör effekten av LC på organisationsbehov, kultur, värdeströmmar, utveckling, tillväxt och mänsklig interaktion utredas ytterligare. Detta kan inkludera berikning av de identifierade varianterna med mer relevanta koncept, processer och verktyg som kan hjälpa till att uppnå industri- och företagskrav, införlivandet av dessa berikade varianter i portföljerna och strategin för organisationer som förespråkar användningen av LC, och, avgörande, överväger integrationen av hållbarhet och cirkularitet med LC, genom ett starkare fokus på processer som end-of-life demontering istället för rivning och produktionsinriktad återvinning och återanvändning.

SUMMARY

Lean construction (LC) has been discussed by Swedish contractors since ca. 2007. Those 16 years up to 2022-2023 also saw an increasing Swedish research interest on LC. Hundreds of relevant publications and dozens of BSc, MSc, Licentiate, and PhD theses have been produced over the years. This seems to show that the discussion on whether LC can help in tackling issues in Swedish construction, has remained vibrant – both regarding long-standing challenges (e.g., productivity, efficiency, value creation), as well as emergent ones (e.g., climate goals, unstable markets, inflation).

However, limited studies on the sector-level LC practice have been offered so far. Studies featuring empirical cases do exist but are few compared to the total number of relevant publications, and the empirical material itself mostly clusters around a few specific companies pioneering LC in Sweden. Moreover, industrialized construction tended to be very visible in many research and practical efforts, to a degree disproportionate to its market share. Swedish construction is still dominated by on-site production, even if there is a well-embedded practice of using prefabricated components and other specific off-site elements. As such, this project sets out to clarify the current Swedish LC state-of-art, by investigating how well the relevant research output reflects Swedish practice in 2022-2023, and empirically surveying the actual state to which LC is currently found within the Swedish construction sector. In doing so, it also identifies the variants in which LC is practically implemented in Sweden – as identifying LC practice variants in a national context can facilitate LC adoption in a way that fits actual industry needs, provided that national institutional influences on LC practices are acknowledged.

Methodologically, the study comprises a systematic literature review of Swedish LC research featuring empirical content (even if narrow), followed by a nation- and sector-wide questionnaire survey targeting all construction-related firms (excl. industrialized house builders) across all geographical regions in Sweden. The companies were asked about what, when, and how much they are doing with LC in their practice. The results following the analysis of the literature review and the survey response data, were qualitatively synthesized using abduction.

The reviewed studies were analyzed in terms of their themes (industrialized construction or conventional construction), process coverage (design, production, partnering and stakeholder collaboration, planning, strategy, supply chain), paradigms (systems theory, business economics, organizational behavior, interpretivism), and content. Through this analysis, the preliminary variants of LC: Industrialized construction, production processes, production strategy, design, planning, and logistics and supply chain, were derived – indicating that Swedish LC practices primarily focus on improving technical process parameters. Moreover, the studies featuring empirical content were few compared to the total number of Swedish LC-related publications, and that content itself mostly clustered around a few specific companies pioneering LC in Sweden – indicating a lack of a sector-level understanding of the actual LC state-of-art. Finally, as mentioned before, industrialized construction monopolized the interest of many research efforts – disproportionately to its market share.

Those problematizations deriving from the literature review served as the background of the nation- and sector-wide questionnaire survey conducted from August 2021 to January 2022. Targeting 1342 companies, it received 471 valid responses, thus having a 35% response rate. The survey showed that there is a large discrepancy of LC knowledge and practices across Sweden. In certain cases, the survey respondents indicated through their answers a well-adapted

implementation of LC. However, 286 out of 471 respondents (i.e., 61% of the total responses!) claimed to not even know what LC is. Nonetheless, a sub-group of the surveyed companies claiming to be unaware of LC, still went on to answer to the survey in a way indicating that, in fact, they did know about LC. In other results, while there have been some precise cases of undertaking communication, training, and other auxiliary activities (e.g., simulation), most responses exhibited a not particularly detailed application. Furthermore, previous and present states of LC implementation were mostly piecemeal – certain LC elements, like waste elimination and customer value increase, have been comparably applied in the past and now, but others, like Last Planner, have gone through phases of varied application. The analysis of the responses of companies that *have* been implementing LC, shows four practical LC variants: (1) a variant related to IT-supported design, (2) a production variant, (3) a planning variant using Last Planner, and (4) a supply chain and logistics variant focused on partnerships with suppliers. Compared to the preliminary variants found in the literature review, the variants found in Swedish LC practice through the survey are fewer (four instead of six), more narrowly defined, and more simplified – indicating that, in practice, only specific LC elements have been more popular (e.g., Last Planner).

The survey has shown that lean construction has been implemented by both large contractors and SMEs (e.g., subcontractors, HVAC installers) which claim to be LC-competent. Moreover, the emergent practical LC variants show that the Swedish adoption of LC (when it happens in the first place) follows patterns apparent in the adoption 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. This might mean that each variant could be further customized to fit the business activities, business model, corporate culture, organizational structure, and even local peculiarities of a specific company. As such, while those variants can be disseminated to interested parties via communication and training activities, it is highly probable that each party will then take the variant that applies most to them, and further contextualize it to completely fit their case.

This is the first Swedish research study investigating the LC state-of-art on such a scale. It provides empirical evidence of a Swedish state-of-art that cannot be found in previous, narrower studies. It also shows that the diversified implementation of LC in Sweden departs from a more “purist” understanding of LC. As such, LC research, training, information, and dissemination, might need redirection to realistically meet industry demands. In parallel, LC practice should possibly be informed by a combination of top-down and bottom-up strategizing. Finally, a stronger cross-industry collaboration may be needed for facilitating LC knowledge and practice in Sweden.

Future work can include the continuation of the present study into shaping the way forward for practical LC implementation in Sweden – as issues claimed to have been solved by LC (e.g., high production costs), are still apparent. This could mean that besides processes, the effect of LC on organizational needs, culture, value streams, development, growth, and human interaction, should be further investigated. This can include the enrichment of the identified variants with more relevant concepts, processes and tools able to help attaining industry and company demands, the incorporation of those enriched variants in the portfolios and strategy of organizations advocating for the use of LC, and, crucially, considering the integration of sustainability and circularity with LC, through a stronger focus on processes like end-of-life disassembly instead of demolition, and production oriented to recycling and reusing.

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INTRODUCTION – BACKGROUND

Lean construction (LC) was initially introduced as the appropriation of lean manufacturing (LM) and the Toyota production system (developed by Toyota between 1948 and 1975) in the construction context (Koskela 1992). Ever since, the international interest in LC has prevailed (Li et al. 2019) – and was revitalized after the introduction of the Toyota way model as a management system (Liker 2004), along with its subsequent customization for construction (Gao and Low 2014). LC is considered by some authors to have caused a paradigm shift in the industry (Tommelein 2015) and has been in the focus of research and development (R&D) projects and dedicated organizations for a handful of engaged scholars – e.g., in Sweden LC is being advocated for by, among others, Lean Forum Bygg, which features several industrial partners (Lidelöw et al. 2019).

Evidence for LC practical implementation by Swedish contractors has appeared since ca. 2007 (Kifokeris and Koch 2020). Nonetheless, there has since been a growing LC-related research interest connected to the Swedish context, which has culminated in more than 350 publications by 2022-2023 – including many PhD theses. Among them, a limited number of studies went beyond theoretical conceptualizations, and investigated LC practices by featuring related empirical content.

The total number of relevant publications seems to show that the discussion on whether LC can help in tackling issues in Swedish construction, has remained vibrant – both regarding long-standing challenges (e.g., productivity, efficiency, value creation), as well as emergent ones (e.g., climate goals, unstable markets, inflation) (Kifokeris et al. 2022). However, little evidence on the sector-level Swedish LC practice has been offered so far. As mentioned above, the published studies featuring empirical content are only a fraction compared to the total amount of related publications, and that content itself is mostly clustered around a few specific companies pioneering LC in Sweden (Kifokeris 2021) – indicating a lack of a sector-level understanding of the actual LC state-of-art. Finally, industrialized construction monopolized the interest of many research efforts. Swedish construction is still dominated by on-site production, even if there is a well-embedded practice of using prefabricated components and other specific off-site elements (Kifokeris 2021).

Moreover, the Sweden-specific research on LC has so far been lacking a focus on the variants in which LC is implemented in practice. Nonetheless, the growing body of knowledge on LC (on the international or other national contexts) can be interpreted to point to variations in LC practices. This is shown in, e.g., Johansen’s and Walter’s (2007) survey of 61 construction companies in Germany, Bernstein and Jones (2013) report on 193 contractors in the United States of America, Neve’s and Wandahl’s (2018) study of four building renovation projects in Denmark, Meng’s (2019) research on building types in the United Kingdom, and a review on construction small-medium enterprises (SMEs) by Tezel et al. (2019). Such variations can be understood as:

1. The partial and/or project/company-specific implementation of LC processes and tools (e.g., Johansen and Walter 2007, Bernstein and Jones 2013, Sainath et al. 2018, Comelli et al. 2019), like Kanban (Sacks et al. 2012), the Last Planner system (Neve and Wandahl 2018, Ballard 2020b), and target value delivery (Ballard 2020a).
2. Different levels of integration between LC and other frameworks, tools, and methodologies, like, e.g., total quality management (Oakland and Marosszeky 2006), 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), sustainability (Carvajal-

Arango et al. 2019), integrated project delivery (Alves and Lichtig 2020), and building information modeling (BIM) (Dave and Sacks 2020).

Given such an understanding, identifying LC practice variants can be considered to facilitate LC research and application, because it could clarify the LC state-of-art, inform LC adoption, initiate a practical benchmarking, and update LC principles and tools. However, such an identification should acknowledge the impact of national institutional forces on modes of understanding and the practical diffusion of concepts (like LC itself)—as shown in studies on distinct aspects of the construction industry within different contexts (e.g., product diversification in Malaysia (Azman et al. 2021), and strategic partnerships in Denmark (Gottlieb et al. 2020)). Thus, identifying LC practice variants in Sweden should be embedded in the study and mapping of the Swedish sectoral practice.

Therefore, given the aforementioned motivations and understanding on the Swedish construction sector, the (so far) limited documentation of the sector-level Swedish LC practices in the relevant research, and the potential practice of implementing LC in variants, this project sets out to clarify and benchmark the current Swedish LC state-of-art by:

- 1. Investigating how well the relevant research output reflects Swedish practice in 2022-2023, by reviewing it accordingly.**
- 2. Empirically surveying the actual state to which LC is currently found within the Swedish construction sector.**
- 3. Identifying the variants in which LC is practically implemented in Sweden.**

The study's research method follows a previous systematic literature review of published Swedish research studies on LC which feature empirical content (even if narrow) (Kifokeris 2021), followed by a nation- and sector-wide questionnaire survey targeting all construction-related firms (excl. industrialized house builders) in Sweden. The companies were asked about what, when, and how much they are doing with LC in their practice. The results following the analysis of the literature review and the survey response data, were qualitatively synthesized using abduction.

Following this introduction, the study's theoretical basis (including fundamentals of lean construction, and an exposition of research paradigms mostly used in the literature review analysis) will be offered. Then, its methodological approach on the conduct of the literature review, the questionnaire survey, and the synthesis of its results, will be thoroughly described. Afterwards, the full description and analysis of the literature review and the questionnaire survey, and the abductive synthesis of their results to reach the study's final outcome, will be recounted in detail. This will then be followed by critical discussion points. Finally, the study will conclude with its final remarks and recommendations for future work.

THEORETICAL FRAMEWORK

Basics of lean construction

There is not a universally referable LC definition, but rather an assemblage of relevant interrelated aspects (Koskela 2020). Therefore, a non-exhaustive but overarching understanding of LC through the synthesis of fundamentals found in core publications, is offered below.

As mentioned earlier, LM was initially introduced in the automotive industry to streamline and improve production processes and product quality (Gao and Low 2014). A central element in LM is the elimination of waste, i.e., activities not creating customer value (Koskela 2020). This can be facilitated through continuous production flow, with just-in-time (JIT) product manufacturing (Liker 2004). On these bases, LC emerged as an appropriation of LM to construction (Koskela 1992). Specifically, LC aims at waste elimination, efficient resource usage, workflow optimization, on-time information and material delivery to construction sites, cost minimization, and customer value maximization (Tzortzopoulos et al. 2020). The process of waste reduction through production planning and control, end-customer focus, continuous improvement (kaizen), and cooperative relationships, are considered by researchers to be core LC foci (Eriksson 2010), although they are not always visible in practice.

Considering the above, five LC areas have been highlighted: lean project management (London 2008; Santorella 2017), lean supply, lean design, lean partnering (London 2008), and cooperative supply chain management (London 2008; Meng 2019). Koskela (1992) formulated 11 LC principles of flow process design and improvement, and Koskela (2000) proposed the transformation-flow-value (TFV) framework of production, which allowed those principles to be applied to construction management. According to TFV, inputs are transformed into outputs, whereas materials (and information) flow through value- and nonvalue adding activities, with end-customer value generation as the goal (Koskela 2000).

As within LM, JIT is applied to eliminate lead time and waste in LC, making products to-order and not to-stock (Tzortzopoulos et al. 2020). In this light, the manufacturing system of “Kanban” has been adapted to manage on-site material supply with the least physical and immaterial waste (Sacks et al. 2012). On-site management has also been claimed to have potential for optimization by reducing on-site complexities through component prefabrication, standardization, modularization, and configuration (Tzortzopoulos et al. 2020). Regarding LC implementation, Green and May (2005) have -in a UK context- identified three increasingly mature levels:

1. Lean Model 1: Waste elimination from a technical and operational perspective; responsibilities are tied to managers rather than workers (i.e., top-down). It encompasses elimination of needless movements, cutting of unnecessary costs, workflow optimization, Last Planner, and assuring the benefit of all stakeholders from improved performance,
2. Lean Model 2: Elimination of adversarial relationships; enhancing cooperation and teamwork. It encompasses long-term agreements and partnering workshops, and
3. Lean Model 3: Fundamentally changing project delivery. It encompasses information technology (IT), increased prefabrication, Last Planner, value stream mapping (VSM), strong emphasis on individuals and bottom-up activities, deep rethinking of the design and construction processes, sheltering from competitive forces, long-term contracts, training at all staff levels, and a systems perspective of both processes and products.

However, as it will be shown in the rest of this study, those progressively more evolved models cannot be found in practice in the Swedish construction industry. It will be described, the way LC

is implemented in Sweden shows the emergence of variants, which indicates that companies are picking the parts, tools, and methods of the main concept that are most relevant to them, and then they are shaping those according to their needs.

Last Planner should be noted, due to its central significance that led to its equation with LC itself over a span of many years (Koskela 2020). Last Planner has originally been a planning and scheduling system to improve collaboration on site on short-term basis (Ballard 2000).

RESEARCH METHOD

Following the theoretical preparation of the previous section, this study unfolds methodologically through: (1) a systematic literature review, (2) a questionnaire survey, (3) an analysis of the researched material and the synthesis of the outcomes of this analysis for the derivation of the results.

Literature review

For the systematic literature review, the concept-centric framework augmented by units of analysis (Webster and Watson 2002) was used. With 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 “lean construction practices in Sweden.” The units of analysis emerged during the review itself, facilitating its revision. This process followed the abductive reasoning of qualitative research, where observations and explanations of phenomena are developed by working iteratively between theory and data (Bell et al. 2019). Through abduction, the emerged units of analysis served as the basis of understanding the construction themes and processes covered in the relative publications (e.g., on-site production, factory physics, logistics). This framework was further strengthened by using the references-of-references and snowballing techniques (Greenhalgh and Peacock 2005) and conducting a comprehensive search to avoid a narrow sample (MacLure 2005). The latter techniques were also used to assemble the initial references in the “Introduction” and “Theory.”

In the literature review, the main search string was “Lean AND construction AND (Sweden OR Swedish).” This subsequently spawned the units of analysis; indicatively, the ones yielding most results were “Lean AND thinking AND (Sweden OR Swedish),” “(Industrialized OR Industrialized) AND house AND (building OR builders OR manufacturing OR manufacturers) AND (Sweden OR Swedish),” “(Prefabrication OR Modularization OR Standardization) AND (Sweden OR Swedish),” “Last Planner AND (Sweden OR Swedish),” “Continuous AND improvement AND (Sweden OR Swedish),” and “Construction AND production AND flow AND (Sweden OR Swedish).” The search was repeated in Swedish [e.g., “Lean AND byggande AND (Sverige OR Svensk)”; in this context, the word lean is used as it is].

The review was conducted in iterations, and the period was set from 1992 [when Koskela’s (1992) technical report was published] to the middle of 2023 (when this report was finished). Thirty-seven search engines featuring engineering and/or managerial content were initially tested using the search strings. After omitting 26 engines that returned results entirely included elsewhere or no results at all, the remaining 11 were utilized: Chalmers Library, Chalmers Open Digital Repository, Taylor & Francis Online, Google Scholar, BASE, Semantic Scholar, Baidu Scholar, Mendeley, WorldWideScience, Scopus, and the International Group for Lean Construction (IGLC) database. Filters and Boolean operators were applied to seek the search terms in all parts of each publication: title, abstract, keywords, main text, author affiliations, and references.

The process resulted in 356 unique publications. Applying exclusion criteria (Dundar and Fleeman 2017), all B.Sc. and M.Sc. dissertations (107 studies) were excluded, as they were lower-level academic output. The remaining 249 studies were scrutinized in terms of whether they featured empirical material on Swedish LC practices. This filtering returned 84 studies. Then, it was investigated whether entire individual papers were featured in collective works by the respective authors (e.g., PhD theses); in such cases, only the collective works were kept. This reduced the

selected studies to 67. Finally, conference papers featuring limited material that was investigated in more detail in subsequent studies, were omitted. This led to the final selection of 42 publications, sorted alphabetically and discretized per type in Table 1.

Table 1. Discretization of the finally included publications per type

	Type of publication					
	Journal articles	Lic. theses	PhD theses	Research reports	Conference papers	Book chapters
Bergsten (2005)		X				
Bergström and Stehn (2005)	X					
Bildsten et al. (2011)	X					
Björnfot (2006)			X			
Brege et al. (2014)	X					
Eriksson (2010)	X					
Gerth (2008)		X				
Gerth et al. (2013)	X					
Haller (2012)		X				
Holmlund et al. (2008)				X		
Höök (2008)			X			
Ivina and Olsson (2020)					X	
Jansson (2013)			X			
Jansson et al. (2016)	X					
Jimenez (2021)		X				
Jonsson and Rudberg (2014)	X					
Karlsson and Josephson (2014)						X
Lennartsson (2009)		X				
Lennartsson and Björnfot (2010)	X					
Lennartsson and Björnfot (2012)	X					
Lessing (2006)		X				
Lessing and Brege (2018)	X					
Lessing et al. (2015)	X					
Löwstedt and Sandberg (2020)	X					
Malmgren (2014)			X			
Meiling (2010)			X			
Modig (2006)				X		
Olofsson et al. (2006)				X		
Polesie (2012)	X					
Popovic (2020)			X			
Psilander (2012)	X					
Simonsson (2008)		X				
Simu and Lidelöw (2019)	X					
Stehn et al. (2021)	X					
Söderholm (2010)		X				
Tjell (2016)		X				
Tykkä et al. (2010)	X					
Unger (2006)			X			
Uusitalo and Lavikka (2020)	X					
Uusitalo and Lavikka (2021)	X		X			
Viklund Tallgren (2021)						
Wernicke et al. (2021)	X					
SUMS						
42	20	9	8	3	1	1

To aid in the comprehension of the systematic literature review process, the flowchart in Fig. 1 is presented (see next page).

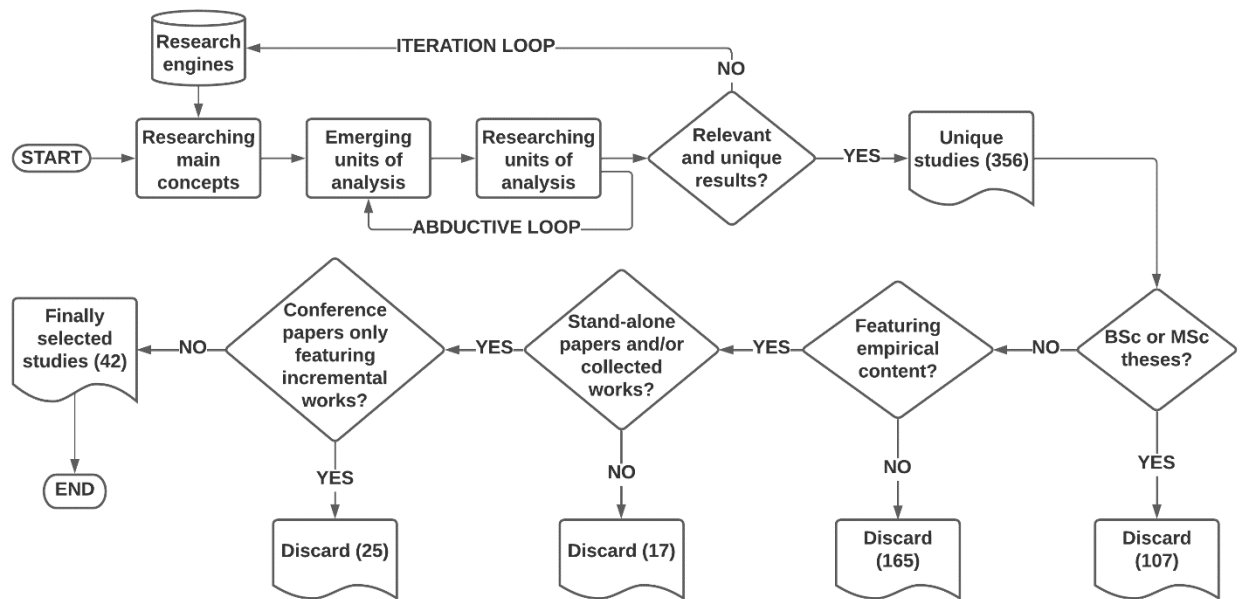


Fig. 1. Flowchart: Process flow of the systematic literature review

The construction themes and processes covered in the selected studies are shown in Table 3 and Fig. 2 (featured in “Analysis and Results”); they were derived from the units of analysis inductively, because generalizable inferences were drawn out of scrutinizing the acquired material (Bell et al. 2019).

When it comes to the paradigmatic approaches of the selected studies, certain problematizations let the researchers of the current project to strive for the identification of more than one paradigm in most of the reviewed studies (including systems theory, business economics, organizational behavior, and interpretivism), along with a consideration on the way these paradigms are integrated in the respective studies. These problematizations stem mainly from Dainty (2008) arguing that construction management research either focuses on discovering something factual (objectivist view), or on understanding “how different realities are constituted” (Dainty 2008, p. 4) (subjectivist view) – indicating different strands of thought on how research on construction management can be conducted and understood. Moreover, Fellows (2010) pointed that positivism had dominated construction research up to a point, but constructivism (e.g., employing interpretivism) has been increasingly utilized as well – and as such, positivism should not be considered as the sole suitable paradigm for construction management. Given those problematizations, the paradigmatic approaches of the selected studies were identified deductively, as hypotheses emanated from existing knowledge frameworks and theoretical considerations scrutinized against the content of the investigated material (Bell et al. 2019). A combination of the investigative frameworks in Lessing (2006) and Koch (2012) was used, where the reviewed literature (pertaining, among other things, to LC), was scrutinized against its deployment of systems theory (Lessing 2006; Koch 2012), business economics, organizational behavior, and interpretivism (Koch 2012). The identified paradigmatic approaches of the selected studies are shown in Table 4 and Fig. 4, featured in “Analysis and Results.”

The description of the selected studies’ empirical content on LC practices in Sweden, follows the scrutinization of their coverage of construction themes and processes and their paradigmatic approaches, and is summarily described in “Analysis and Results,” along with Fig. 6 and Table 4.

The identification of LC practice variants in the Swedish construction sector, as the outcome of the combined understanding of the studies' covered construction themes and processes, paradigmatic approaches, and empirical content, is found in "Analysis and Results."

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).

Questionnaire survey

The empirical part of the study addressed the research question stated in the Introduction, through the conduct of a questionnaire survey encompassing 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 managing construction production processes and business operations for efficiently and effectively meeting the client's requirements. The survey was designed and went live using the online tool Survey Monkey.

An industry-wide response pool was sought. As such, a database of all companies active in the Swedish construction sector was created – including 1,342 firms across all geographical regions in Sweden and all entries in the construction-related NACE groups 41, 42, and 43 (corresponding to F 41, 42 and 43 in SNI (SCB 2017)). The construction activities connected to each group, as well as the subgroups included, are described below:

- NACE group 41: Construction of buildings and construction of residential and non-residential projects. Subgroups: 41100 (Design of construction projects), 41200 (Construction of residential, and other, buildings).
- NACE group 42: Construction of infrastructural and civil engineering projects. Subgroups: 42110 (Construction of roads and motorways), 42120 (Construction of railways and subways), 42130 (Construction of bridges and tunnels), 42210 (Public construction works for heating, water and sewage), 42220 (Construction works for electricity and telecommunications), 42910 (Water-related construction works), 42990 (Other construction works).
- NACE group 43: Installations, facilities and crafts. Subgroups: 43110 (Demolition of houses and buildings), 43120 (Land and foundation work), 43130 (Geotechnical survey), 43210 (Electrical installations), 43220 (HVAC works), 43221 (Heating and sanitation works), 43222 (Ventilation works), 43223 (Refrigeration and freezer installation work), 43229 (Other plumbing), 43290 (Other building installations), 43310 (Plastering, facade and stucco work), 43320 (Building carpentry work), 43330 (Floor and wall covering works), 43341 (Painting works), 43342 (Glazier works), 43390 (Other building finishings), 43911 (Erection of sheet metal roof covering), 43912 (Erection of other roof covering and frames), 43991 (Renting of construction or demolition equipment with operator), 43999 (Various other specialized construction and civil engineering activities).

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. It should be noted that

industrialized construction companies were not part of the survey, as they represented a well-defined niche of the sector that is dissimilar to the vast majority of (still, mostly on-site) construction activity in Sweden. Table 2 offers statistical information about the database's content.

Table 2. Overall statistics of the supportive database

County	Industry groups			County sum & (%)
	41	42	43	
Blekinge	9	2	23	34 (2,53%)
Dalarna	10	9	17	36 (2,68%)
Gävleborg	10	5	19	34 (2,53%)
Gotland	6	3	19	28 (2,09%)
Halland	17	5	16	38 (2,83%)
Jämtland	7	2	20	29 (2,16%)
Jönköping	10	4	22	36 (2,68%)
Kalmar	9	2	13	24 (1,79%)
Kronoberg	7	1	18	26 (1,94%)
Norrbottn	9	5	21	35 (2,61%)
Örebro	9	0	24	33 (2,46%)
Östergötland	22	1	26	49 (3,65%)
Skåne	69	9	77	155 (11,55%)
Södermanland	18	5	9	32 (2,38%)
Stockholm	152	32	178	362 (26,97%)
Uppsala	10	3	22	35 (2,61%)
Värmland	11	1	18	30 (2,24%)
Västerbotten	12	4	15	31 (2,31%)
Västernorrland	11	2	13	26 (1,94%)
Västmanland	11	3	15	29 (2,16%)
Västra Götaland	99	14	127	240 (17,88%)
NACE group sum & (%)	518 (38,6%)	112 (8,35%)	712 (53,05%)	
Overall sum				1342

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).

Synthesis

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. In the case of this study, the knowledge derived from the theoretical bedrock of this study and the results following the analysis of the literature review, were abductively synthesized with the empirical results of the questionnaire survey. In other words, the understanding of the theory and literature, as well as the survey's response data, were analyzed in iterations and in a combinatory way, thus forming the study's results – i.e., the mapping of the Swedish LC state-of-art, and the identification of practical LC variants in Sweden.

In particular, the respondents were asked 23 questions in the survey: Information about their role and company affiliation (*two questions*), knowledge and understanding of basic LC concepts (*two questions*), LC elements (e.g., overarching philosophies, waste elimination, Last Planner) implemented by the company currently (*five questions*) and in the past (*five questions*), other applied approaches to facilitate LC (e.g., BIM 360, VDC, six sigma) (*one question*), factors of LC implementation (e.g., training, communication) (*seven questions*), and an optional contact confirmation for receiving the final project report (*one question*). Each question featured one, or a combination, of the following: multiple choice inquiry, free-form textbox, tickbox list, and 5-point Likert scales. In the Likert scales, 1 denoted a completely negative or disagreeing response, and 5 a completely positive or agreeing response – while in most inquiries there was also a “not applicable” option. Then, with the knowledge gained from the literature review and the six

preliminary research-found variants, answers strongly pertaining to a specific LC theme (emanating from a combination of fitting elements, e.g., BIM with IT-supported design) were grouped for the practical variants to gradually emerge. For example, the responses pointing to the planning variant using Last Planner (see later in the report) included, among others, the summing up of the companies answering with a Likert value of 4 and/or 5 to inquiries regarding Last Planner – while answers with a value of 1, 2, and/or 3, were not considered.

As an emergent result along the two (main) ones mentioned above, discrepancies between LC research and actual sector-level LC practice in Sweden were also identified and pointed out in the analysis and discussion.

ANALYSIS

Literature review

Coverage of Construction Themes and Processes

Table 3 shows the induced construction themes and processes covered in the selected studies.

Table 3. Identified themes and processes in the selected publications

	Themes		Processes					
	IND	CONV	PROD	STRAT	DES	PLAN	SUPCH	PRT/ST COL
Bergsten (2005)	X		X		X			
Bergström and Stehn (2005)	X			X				
Bildsten et al. (2011)	X			X			X	
Björnfort (2006)	X		X	X	X		X	
Brege et al. (2014)	X		X	X				
Eriksson (2010)		X					X	X
Gerth (2008)	X		X	X	X			
Gerth et al. (2013)	X		X	X	X			
Haller (2012)	X				X	X		
Holmlund et al. (2008)	X		X				X	
Höök (2008)	X		X	X	X	X		
Ivina and Olsson (2020)		X				X		
Jansson (2013)	X		X		X		X	
Jansson et al. (2016)	X		X		X	X		
Jimenez (2021)		X	X					
Jonsson and Rudberg (2014)	X		X	X				
Karlsson and Josephson (2014)		X					X	
Lennartsson (2009)	X		X	X				
Lennartsson and Björnfort (2010)	X		X		X			
Lennartsson and Björnfort (2012)	X		X			X	X	
Lessing (2006)	X		X	X	X			
Lessing and Brege (2018)	X			X				
Lessing et al. (2015)	X		X	X				
Löwstedt and Sandberg (2020)		X	X					
Malmgren (2014)	X		X					X
Meiling (2010)	X		X	X	X	X		
Modig (2006)	X		X		X			
Olofsson et al. (2006)		X	X		X			X
Polesie (2012)		X	X				X	
Popovic (2020)	X		X					
Psilander (2012)	X	X	X	X				
Simonsson (2008)	X		X		X	X		
Simu and Lidelöv (2019)	X	X	X	X				
Stehn et al. (2021)	X			X				
Söderholm (2010)	X				X			
Tjell (2016)		X		X	X	X		X
Tykkä et al. (2010)	X			X				
Unger (2006)	X	X	X	X				
Uusitalo and Lavikka (2020)	X		X	X				
Uusitalo and Lavikka (2021)	X			X				
Viklund Tallgren (2021)		X			X	X		X
Wernicke et al. (2021)		X	X					
SUMS								
42	32	13	29	21	17	9	8	5

Note: IND = Industrialized construction; CONV = Conventional construction; PROD = Production; STRAT = Strategy; DES = Design; PLAN = Planning; SUPCH = Supply chain; PRT/ST COL = Partnering / stakeholder collaboration

Evidently, some studies cover more than one theme, and almost all cover more than one process. Notably, there is an almost unanimous focus on buildings, except for Simonsson (2008) focusing on bridges, and Ivina and Olsson (2020) focusing on railways. To aid in the comprehension of Table 3, the bar chart in Fig. 2 is presented below.

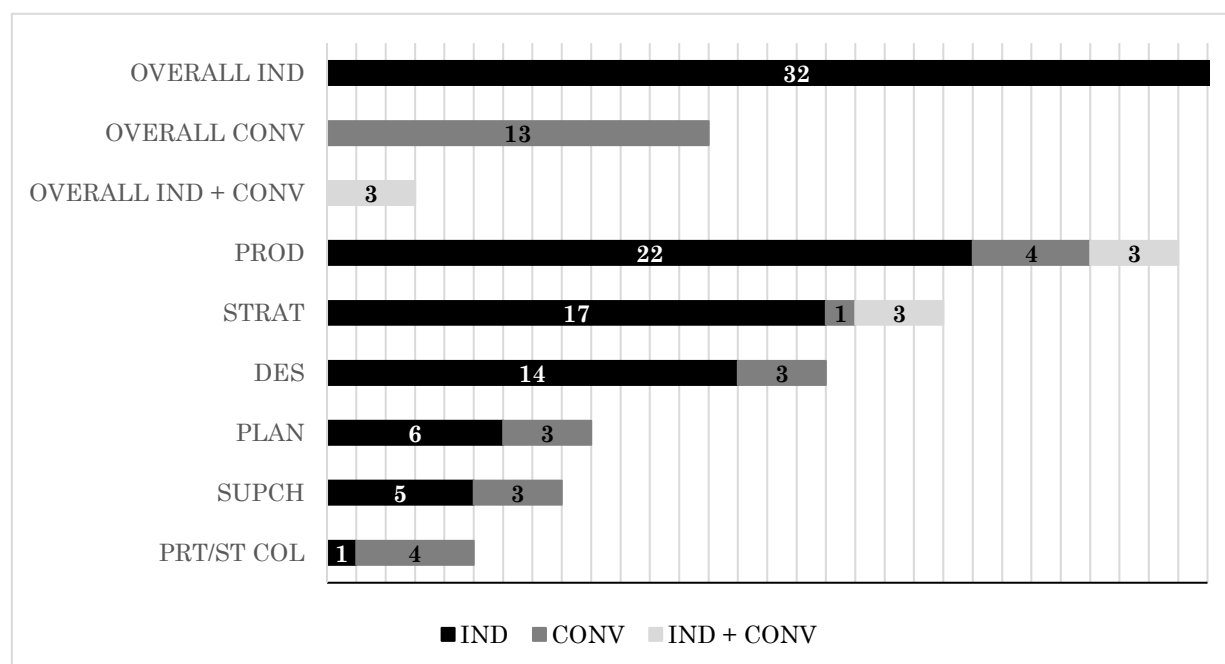


Fig. 2. Bar chart: Coverage of construction themes and processes in the reviewed studies

The large thematic focus on industrialized construction (IND) rather than conventional construction (CONV) can be considered imbalanced in terms of the modest IND market share in Sweden – which, according to Brege et al. (2014), has been at most 15% in the central case of multistorey house apartments. Moreover, when it comes to implementation, IND is more closely related to LM rather than LC, because its development areas are closer to factory physics managed with manufacturing principles (Höök 2008; Meiling 2010). Malmgren (2014) problematizes that IND lies somewhat ambivalently between manufacturing and CONV, whereas Simu and Lidelöw (2019) note that in flow-oriented operation strategy companies (such as IND firms), it is empirically shown that LM, rather than LC, is adopted. These considerations, coupled with Lessing’s and Brege’s (2018) observation that research on IND has been historically centered more on production and technical aspects rather than organizational strategy and business models, informed the process coverage results in Table 2 and Fig. 3. These are described below.

Production (PROD) is the process pertaining to most IND and CONV studies. It is primarily expressed through practical LC approaches to prefabrication and module and component manufacturing (e.g., Bergsten 2005; Meiling 2010); technical analyses on performed production processes utilizing LC (e.g., Björnfot 2006; Malmgren 2014); documentation on practical modularization, standardization, and/or mass customization (e.g., Gerth 2008; Lennartsson and Björnfot 2010); and the effect of practically implemented LC principles on production performance indicators (PIs), e.g., successful experience feedback (Meiling 2010), quality, delivery speed and dependability, cost level and dependability, production flexibility (Jonsson and Rudberg 2014), resource efficiency (Simu and Lidelöw 2019), and productivity (Jimenez 2021). A unique study by Löwstedt and Sandberg (2020) views the standardization of construction

production processes informed by, among others, LC, as a social challenge to the site managers' proclivity for free and independent work emanating from their identity as professional experts.

Strategy (STRAT) is studied in relation to business models featuring practical lean thinking [e.g., Björnfort 2006; Brege et al. 2014; Popovic 2020; see also Uusitalo and Lavikka (2020) for the connection of LC-informed business models to path dependency, namely past events and actions influencing current decisions and future ways of working]. Moreover, STRAT pertains to practically integrating LC with market, project management, agenda setting, technology transfer, and human resources management (HRM) strategies [e.g., regarding enterprise resource planning (ERP) (Bergström and Stehn 2005), and alignment with policies (Tykkä et al. 2010)]. STRAT is mostly featured in IND studies – the only CONV ones being Unger (2006), Tjell (2016), and Simu and Lidelöw (2019).

The respective studies on design (DES) show the practical interconnection of LC and lean design (Brookfield et al. 2004) 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 LC with tools such as 4D CAD (Bergsten 2005), design structure matrix (Björnfort 2006), virtual reality (VR) (Olofsson et al. 2006), digraphs for design process modeling (Haller 2012), visual management (Tjell 2016), and design breakdown structures (Jansson et al. 2016), is also featured prominently. This scope is explored primarily in IND studies, except Olofsson et al. (2006), Tjell (2016), and Viklund Tallgren (2021), although the latter's focus is on planning.

Planning (PLAN) overlaps heavily with DES and/or PROD, and is featured almost exclusively in IND studies, apart from Tjell (2016) and Viklund Tallgren (2021). The practical implementation of Last Planner is exemplified, and the practical integration of lean planning with other frameworks, such as knowledge innovation/visual planning (KI/VP) and Obeya (Jansson et al. 2016). Moreover, the visual project planner (VPP) application in Viklund Tallgren (2021), shows the utilization of BIM to enhance interdisciplinary knowledge sharing and collaborative scheduling and planning during the preconstruction phase.

Supply chain (SUPCH) is exclusively elaborated on only in Karlsson and Josephson (2014) and overlaps with other processes in the rest of the studies covering it. Different efforts focus on practical LC implementation at different points across the supply chain, like ordering [e.g., reducing the suppliers through component standardization and prefabrication (Björnfort 2006), transforming engineering-to-order into making-to-order (MTO) (Jansson 2013)], early supplier involvement in the material and economic flows (Eriksson 2010), value-driven purchasing (Bildsten et al. 2011), and waste minimization in site logistics (Karlsson and Josephson 2014).

Finally, partnering and stakeholder collaboration (PRT/ST COL) is the only process covered in more CONV rather than IND studies. It is always coupled with other processes (predominantly PROD) and is generally given diminished attention. However, Eriksson (2010) identifies the increased cooperation across the supply chain as a LC facilitator, whereas competitive bidding is criticized as not efficient for procuring customized products; rather, limited bidding should be coupled with bid evaluation based on soft parameters, and long-term contracts should be selected as a catalyst for kaizen.

Identified Paradigmatic Approaches

The deduced paradigmatic approaches of the selected studies are shown in Table 4. As evident in Table 3, 32 out of 42 studies were multiparadigmatic and followed a mixed method approach, and

only 10 were monoparadigmatic. Fig. 3 (see next page) offers a visual depiction of the paradigm combinations in the reviewed studies.

Table 4. Discretization of selected publications per paradigmatic approach

	Paradigmatic approach			
	ST	INT	BEH	BUEC
Bergsten (2005)	X			
Bergström and Stehn (2005)	X			X
Bildsten et al. (2011)	X			X
Björnfot (2006)	X	X		
Brege et al. (2014)	X	X	X	X
Eriksson (2010)	X			
Gerth (2008)	X	X		X
Gerth et al. (2013)	X		X	
Haller (2012)	X			
Holmlund et al. (2008)	X			
Höök (2008)	X	X	X	X
Ivina and Olsson (2020)	X		X	
Jansson (2013)	X	X	X	
Jansson et al. (2016)	X			
Jimenez (2021)	X	X		
Jonsson and Rudberg (2014)	X	X		
Karlsson and Josephson (2014)	X			X
Lennartsson (2009)	X			X
Lennartsson and Björnfot (2010)	X			
Lennartsson and Björnfot (2012)	X			
Lessing (2006)	X	X	X	
Lessing and Brege (2018)	X	X		
Lessing et al. (2015)	X	X		
Löwstedt and Sandberg (2020)		X	X	
Malmgren (2014)	X		X	
Meiling (2010)	X	X	X	
Modig (2006)	X			
Olofsson et al. (2006)	X		X	X
Polesie (2012)	X		X	
Popovic (2020)	X			X
Psilander (2012)	X	X		
Simonsson (2008)	X		X	
Simu and Lidelöw (2019)		X	X	
Stehn et al. (2021)	X	X		
Söderholm (2010)	X	X	X	
Tjell (2016)	X	X		
Tykkä et al. (2010)	X		X	
Unger (2006)	X	X		
Uusitalo and Lavikka (2020)	X	X		
Uusitalo and Lavikka (2021)	X	X		
Viklund Tallgren (2021)	X			
Wernicke et al. (2021)	X			
SUMS				
42	40	20	15	9

Note: ST = Systems theory; INT = Interpretivist; BEH = Organizational behavior; BUEC = Business economics

Systems theory was featured in all monoparadigmatic studies and was the most prominent constituent in all multiparadigmatic studies – except Simu and Lidelöw (2019) and Löwstedt and Sandberg (2020). The covered themes and processes, approached through systems theory, were thus elaborated on their constituent parts, interrelations, and systemic role; this understanding can practically allude to Lean Model 1 (Green and May 2005). However, such a technical and

operational perspective, especially in monoparadigmatic studies, also meant that in processes with a social reflection (e.g., STRAT, PRT/ST COL), certain nuances may not have been explored.

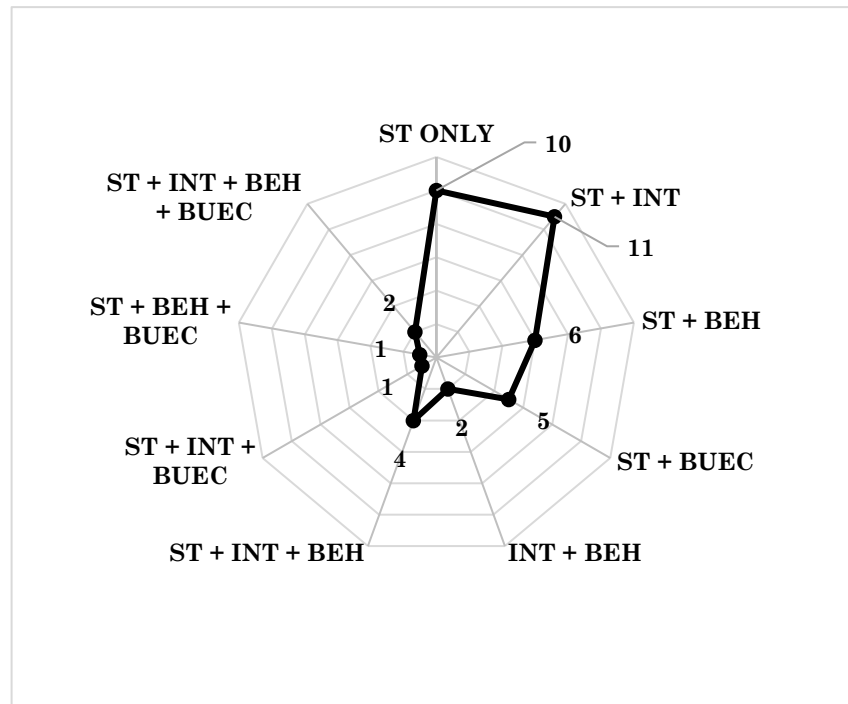


Fig. 3. Radar chart: Combinations of paradigmatic approaches. ST = Systems theory; INT = Interpretivist; BEH = Organizational behavior; BUEC = Business economics

The two sociological approaches (i.e., organizational behavior and interpretivism), were largely blended and/or in support of systems theory. In most cases, they were used to process qualitative data already studied through systems theory. This included, among others, the attribution of the actors' perspectives either on behavioral reactions, or on interpreting reality through social constructions (e.g., organizational structures and contexts like site or production line environments). Interestingly, behavioral approaches were mostly utilized to illustrate actors' (positive or negative) reactions to implementing LC (or aspects thereof) as an imposed framework [e.g., Gerth et al. (2013) and Löwstedt and Sandberg (2020)]. On the other hand, some studies relying primarily on interpretivism [e.g., Unger (2006), Höök (2008), and Simu and Lidelöw (2019)] also elaborated on reshaping organizational culture for a deeper implementation of LC; as such, almost all studies with an interpretivist approach on culture had also focused on strategy. This understanding can practically allude to Lean Models 2 and 3 (Green and May 2005).

The business economics approach was utilized to support either studies featuring systems theory (e.g., Karlsson and Josephson 2014), or the latter enriched to some level by the sociological approaches (e.g., Brege et al. 2014). Notably, this approach refrained from just focusing on simplified models, such as transaction economics—although, the use of statistics to depict economic aspects was indeed included in, e.g., Bergström and Stehn (2005), and Karlsson and Josephson (2014). Rather, there was a focus on LC impacting the diversity of organizational structures, and the relationships of firms with the market; as such, ERPs (Bergström and Stehn 2005), delivery control (Karlsson and Josephson 2014), economic-based visualizations of LC aspects (Höök 2008), purchasing characteristics (Bildsten et al. 2011), contractual relationships, and business models (Brege et al. 2014), were noted.

It is generally understood that the research method and theory building in most multiparadigmatic studies (especially those combining systems theory with sociological approaches) featured a pragmatic integration of the paradigms. Those were approached as separate blocks underlying the needs of different parts in the respective publications (i.e., the analysis of past knowledge or the design of case studies), and any paradigmatic conflicts were largely not accounted for. However, this may have meant that whether theories and paradigms can actually be combined within the same study—for which Lewis and Grimes (1999) argue toward a systematic and not a pragmatic integration—was scarcely considered in the reviewed studies. Thus, a discussion of a systematic integration of paradigms leading to a deeper analysis of LC practices, could not be found.

Reviewed studies' empirical content

In terms of their empirical content, the reviewed studies are categorized into the ones describing eponymous cases of practical LC implementation, and the ones describing anonymous cases. First, the eponymous examples are shown in Fig. 4 in connection to the number of featuring studies and discretized over the type of the investigated organizations: industrialized house builders, conventional construction contractors, designers, engineering services companies, and clients.

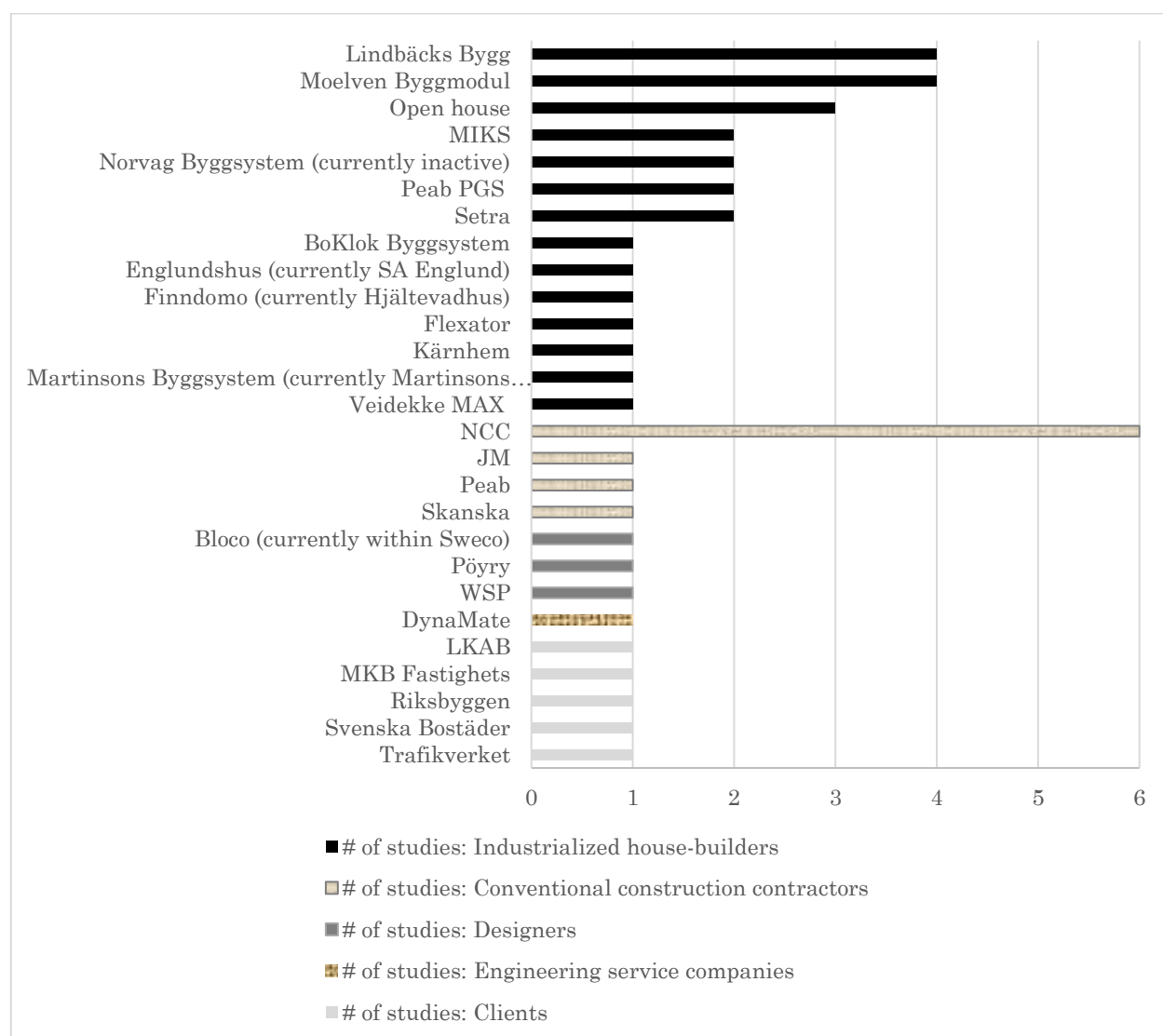


Fig. 4. Bar chart: Eponymous examples discretized per study type

The corresponding examples are described below chronologically, to mark the temporal evolution of eponymous practices recorded by research. All mentioned firms are still active, unless otherwise noted.

Regarding research on industrialized house builders in connection to LC, an early start can be ascribed to the open house system, developed as a joint venture and tested in three pilot projects in the 1990s (Modig 2006). The system gradually encompassed LC through, e.g., prefabrication and kaizen (Bergsten 2005; Lessing 2006), and approximately 1,200 apartments were built in 2003–2008; however, the project was discontinued afterwards. Later, Lindbäcks Bygg, Flexator, Finndomo (currently Hjaltevadhus), Moelven Byggmodul, and Norvag Byggsystem (currently inactive), implemented lean project delivery systems, although there were discrepancies between their practices and a perceived ideal state in a lean process culture (Höök 2008). Lindbäcks Bygg, Moelven Byggmodul, and Norvag Byggsystem were again investigated, together with Setra and Martinsons Byggsystem (currently within Martinsons Group), on their cooperation toward using prefabrication and product modularization to facilitate JIT and schedule flexibility (Lennartsson 2009). Lindbäcks Bygg, Moelven Byggmodul, and Setra, were “... gradually implementing lean production techniques and tools” (Brege et al. 2014, p. 216). Jansson (2013) noted that Lindbäcks Bygg used visual planning in 2013. Moelven Byggmodul, BoKlok Byggsystem, Kärnhem, Veidekke MAX (a development project of Veidekke Sweden), and Peab PGS (a subsidiary of Peab), developed lean product platforms to meet customers’ needs (Lessing and Brege 2018); see also Unger (2006) on Peab PGS. Englundshus (currently SA Englund), utilized 5S in its production processes (Holmlund et al. 2008). Moreover, within the MIKS (MFB Industriell Konstruktiv Sameverkan) project, the MFB (Masonite Flexible Building) system (developed by Masonite Beams) was implemented to increase planning efficiency using “... lean production techniques and tools” (Brege et al. 2014, p. 219) such as process mapping, off-site prefabrication, standardized technical solutions, and partnering (Haller 2012).

Regarding major construction contractors, NCC developed the “Komplett” building system in 2006, utilizing industrial processes for kaizen, JIT, productivity growth (Lessing 2006), and variation flexibility (Gerth 2008). With Komplett, NCC tried to integrate conventional construction and manufacturing (Gerth 2008). However, the project and the associated industrial production plant were discontinued in 2008, due to poor return on investment (Jensen et al. 2012). Elsewhere, NCC, LKAB, WSP, Pöyry and Bloco (currently within Sweco), jointly implemented lean processes in the construction of a large pelletizing plant project—such as the critical path method (CPM) during design, and collaborative VR tools to optimize the client’s required communication, decision-making, and design review (Olofsson et al. 2006). Further studies at projects by NCC revealed the implementation of design collaboration (Jansson 2013) and lean visual management concepts, such as Project Studio (which included pull-planning and collocation) (Tjell 2016). Moreover, JM developed lean guidelines to decrease the variation of technical solutions in apartment house design; Skanska ran an industrialization program focusing on building component modularization, global purchase and logistical patterns, IT tools, knowledge management, and off-site apartment production platforms for specialized suppliers; and Peab used visual planning toward leaner building processes (Lessing 2006).

Regarding the companies offering engineering services, about 2009 DynaMate started implementing on-site housekeeping, selfcontrol, milestone specification, concurrent engineering, limited bid invitation, team-building workshops, and broadening of the partnering team, to improve partnering and supply chain collaboration (Eriksson 2010).

Regarding professional clients, Svenska Bostäder had been working with industrialized house builders, by preferring prefabricated and standardized modules, and early design collaboration (Lessing 2006). Riksbyggen had been developing a knowledge feedback process for kaizen (Lessing 2006). MKB Fastighets had been exploring contractors' LC implementation (Malmgren 2014). Finally, Trafikverket tried to establish LC-inspired changes in the work routines of its contractors (regarding railway maintenance planning) (Ivina and Olsson 2020).

After the eponymous cases, the anonymous examples of LC practices are summarized in Table 5. They are categorized into industrialized timber house builders, industrialized house builders not explicitly utilizing timber, conventional construction contractors, and a single example of stakeholder constellation in an industrial pilot of a concrete bridge. As before, the corresponding examples are noted chronologically. It is noted that because the examples in Table 5 are anonymous, there is no way to confirm which of those organizations are still active in 2022-2023.

Table 5. Anonymous examples discretized per company type and study featuring them

Industrialized timber house-builders	
Bergström and Stehn (2005)	Six out of 74 companies used LC-inspired ERPs, including planning of material requirements and manufacturing resources
Björnfot (2006)	A firm pursued utilized modularity and prefabrication; however, there still were flow bottlenecks and waste generation, due to delays, complaints, slow workers' learning cycle, and complementary site work
Björnfot (2006)	A prefabricated components supplier, a multi-storey house producer, and an architectural firm, collaborated with a focus on customer value generation
Björnfot (2006)	Three component producers and one architectural firm jointly developed a product offer marketing strategy applying the LC principles of value, value stream, flow, pull, and perfection
Meiling (2010)	Two companies implemented lean tools, like 5S, in off-site production
Malmgren (2014)	Six firms utilized IT to make design and production platforming "leaner"
Jansson et al. (2016)	A company utilized KI/VP and Obeya to optimize cross-functional understanding of activity relationships, synchronized workflow, design standardization, and look-ahead planning
Stehn et al. (2021)	Through a dynamic capabilities lens, a company's corporate assets were traced over time, and lean practices were explored in relation to the corporate culture.
Tykkä et al. (2010)	A Swedish SME "... has incrementally developed a lean production design and building system based on standardised prefabricated volume elements..."
Uusitalo and Lavikka (2021)	Two construction companies participating in technology transfer implemented a platform strategy inspired by lean thinking to overcome uncertainties associated with the transferring process, as well as support the transferability to different markets.
Industrialized house-builders not explicitly specializing in timber	
Meiling (2010)	SMEs have been using experience feedback for kaizen
Söderholm (2010)	Two companies applied LC principles in design processes and production flow
Lennartsson and Björnfot (2010)	Five SMEs cooperatively developed building service modules and utilized modularity in product and process development
Bildsten et al. (2011)	In a company comprising a housing factory, "lean principles are part of everything they do, including supplier relations"
Lennartsson and Björnfot (2012)	A first-tier supplier to an industrial producer of detached housing, utilized Systematic Production Analysis (SPA) in a pilot project to streamline production by facilitating resource characterization and predictability
Jonsson and Rudberg (2014)	Three companies displayed various degrees of industrialized production, off-site manufacturing, and product standardization
Lessing et al. (2015)	Three firms implemented waste elimination, kaizen, close organizational and supply chain collaboration, increased customer focus, and process standardization
Jimenez (2021)	Five companies used LC principles and the Last Planner system to inform planning and production control.
Popovic (2020)	Two companies used LC-informed product platforms and product lifecycle management systems for industrialized house-building
Uusitalo and Lavikka (2020)	A company gradually implemented practical LC principles such as continuous improvement, standardised work, maintenance of equipment and tools, responses to defects, standardised components and standardised processes, daily huddles, scheduling, work floor layout, and visual information
Conventional construction contractors	
Polesie (2012)	Construction SMEs hired suppliers to transport materials to the installation spots outside of working hours
Psilander (2012)	A property developer was found to operate sequentially on a predefined planning and production routine

Gerth et al. (2013)	A major Scandinavian contractor developed a passive house multi-building project utilizing the design-for-construction (DFC) framework (a constructability-related take on LC inspired by DFMA) which consisted of: (a) specifying customer values and identifying on-site waste and cost drivers in previous projects, (b) developing constructability evaluation criteria, and (c) evaluating design constructability
Karlsson and Josephson (2014)	A construction SME, a construction logistics consultant, and a material supplier, developed tools (e.g. process mapping, delivery plans, responsibility allocation during material handling, location-based scheduling) to minimize waste in the supply chain material flow for a residential building project
Simu and Lidelöv (2019)	Three firms had "... an outspoken lean operations strategy"
Löwstedt and Sandberg (2020)	One construction company implemented standardized production processes grounded on regularity and repetition, informed by, among others, LC
Viklund Tallgren (2021)	A company utilized BIM to enhance interdisciplinary knowledge sharing, as well as collaborative scheduling and planning during the pre-construction phase, through an application called Visual Project Planner
Wernicke et al. (2021)	(Mainly) contractor representatives, along with some other actors (e.g., subcontractors) participated in a questionnaire survey and a workshop in order to evaluate a digital maturity assessment framework with a heavy focus on LC, including areas of potential improvements, maturity levels that indicate progression, criteria that define organizational aspects of the assessment, and an assessment procedure to guide assessors.
Key stakeholders (owner, contractor, material supplier, and designer) in infrastructural project	
Simonsson (2008)	Establishment of a lean design team (streamlining prefabrication and concurrent engineering) and a cross-functional LC planning team (utilizing standard operating procedure documents)

Final literature review outcome: Variants of lean construction practices in the Swedish context, as identified in the research so far

Combining the analysis results regarding the covered themes and construction processes, paradigms, and empirical content of the reviewed studies, six LC practice variants have been identified in the Swedish context:

1. The industrialized construction variant. It entails advanced prefabrication, modularization, standardization, off-site module and component manufacturing, and, optionally, mass customization. Its main LC tenets are kaizen, 5S, JIT, value stream mapping (VSM), and Last Planner. It requires technical analyses and documentation on performed production processes, and the appraisal of production PIs (e.g., productivity, successful experience feedback, return of investment, quality, delivery speed, cost level and dependability, decrease in the variation of technical solutions, and resource efficiency). It can encompass practical integration with 4D CAD, BIM, and systematic production analysis (SPA). It primarily reflects Lean Model 1, and to a lesser extent Lean Model 3 (when VSM is centrally implemented).
2. The production processes variant. It can include some or all of the following: prefabrication, modularization, standardization, off-site module and component manufacturing, and mass customization; however, it is not industrialized construction per se, because production still unfolds largely on-site. Its main LC tenets are vertical integration, MTO, pull systems, kaizen, kanban, 5S, JIT, VSM, Last Planner, increased stakeholder cooperation, and broadening of partnering teams. It requires process mapping, technical analyses and standard operating documents on performed production processes, and the appraisal of production PIs. It can encompass practical integration with 4D CAD, BIM, VR, VDC, and lean communication platforms. It primarily reflects Lean Model 1, and to a lesser extent Lean Model 2 (when facilitating stakeholder collaboration) and Lean Model 3 (when VSM is centrally implemented).
3. The production strategy variant. It entails production strategy optimization, value-driven purchasing, a product-offering marketing strategy, e-commerce, and bottom-up organizational changes (e.g., in project management, agenda setting, ERP, and HRM) to accommodate product platforming and lean business models. Its main lean tenets are vertical integration, kaizen, JIT, VSM, increased stakeholder cooperation, and broad

- partnering teams. Appointing specialized lean managers can facilitate a deeper integration of this variant within organizational culture. It primarily reflects Lean Models 2 and 3.
4. The design variant. It entails constructability, DFC, product platform development, and functional requirement analysis. Its main lean tenets are kaizen, JIT, and early client and supplier involvement in design. It can encompass practical integration with 4D CAD, BIM, VR, VDC, design structure matrices, digraphs, visual management, and design breakdown structures. It is usually apparent in companies working with design-build contracts. It primarily reflects Lean Model 1, and to a lesser extent Lean Model 2 (regarding the facilitation of stakeholder collaboration).
 5. The planning variant, which is sometimes integrated, to an extent, with the design-oriented variant. It entails process mapping, product platform development, material requirements and resource planning, and location-based planning. Its main lean tenets are Last Planner, vertical integration, kaizen, JIT, and increase stakeholder cooperation through collocation. It can encompass practical integration with BIM, VR, VDC, visual management, KI/VP, Obeya, and CPM. As with the design-oriented variant, it primarily reflects Lean Model 1, and to an extent Lean Model 2.
 6. The logistics and supply chain variant. It entails process mapping, material requirements and resource planning, value-driven purchasing, repositioning of the customer order decoupling point, location-based planning, and e-commerce. Its main lean tenets are pull systems, kaizen, kanban, JIT, Last Planner, early supplier involvement in the material and economic flows, and broadening of partnering teams across the supply chain. It can encompass practical integration with logistics analysis, demands profiles, delivery plans, bills of quantities, controlled deliveries, and lean communication platforms. It primarily reflects Lean Model 1, and to an extent Lean Model 2 (regarding the facilitation of stakeholder collaboration).

All these literature research-identified variants are noted to be **preliminary**. The **found** variants in Swedish LC practice in 2022-2023 will be described later, after the analysis of the questionnaire survey results and their synthesis with the understanding gained from the literature review.

Nonetheless, it is observed in the preliminary variants that except the first explicitly industrialized one, the rest can be attributed to conventional construction. This may strike as imbalanced in terms of the very strong research focus on industrialized construction; however, it is aligned with most of the studies sharing similarities in their coverage of construction themes and processes, paradigmatic approaches, and empirical content. Thus, whereas it was possible to induce a single industrialized construction variant – also informed by Lessing’s (2006) problematization on and conceptualization of industrialized construction as a LC variant in itself – the variants within conventional construction had also distinct orientations that allowed them to be considered separately, despite their occasional overlaps.

In more detail, the two production-oriented variants, while focusing on largely the same project lifecycle phase, differ due to their emphasis. The production processes variant primarily features a more mechanistic understanding of LC, which is shared in the majority of the reviewed studies; the focus seems to be on the optimization of parameters that can be quantitatively appraised in the short-term. The production strategy variant goes beyond production as a process, with the focus being on more fundamental changes in project delivery and, sometimes, organizational culture. However, this variant should not be outright considered as a subset of the production strategy variant; whereas the latter can include the former, there have been a few investigated cases where LC tenets were implemented on a higher level of strategy-making (e.g., connected to marketing) and did not focus too much on the hands-on optimization of process parameters.

The design variant features a logic similar to the production processes variant, but with a focus on design parameters. Interestingly, whereas it mostly appears in design-build contractors, the design variant is not necessarily implemented in conjunction with the production-oriented ones—maybe because design-build contractors can have separate business units specializing explicitly in design or production and approaching those with a different business logic.

The planning variant, while reportedly integrated with the design variant in some cases, can also be understood as not only pertaining to design-related aspects. Whereas in some studies LC-informed planning was pragmatically equated with Last Planner, nuances considering organizational structures and cooperation (e.g., vertical integration) allow this variant to encompass – rather than just be – Last Planner.

Finally, the logistics and supply chain variant has emerged in the relative empirical research. While mechanistically emphasizing processes to an extent, it also considers the implementation of LC in the facilitation of social collaborative aspects, due to the social peculiarities of the network-like, project-specific supply chains in conventional construction projects – which differ significantly from the more linear supply chains in manufacturing lines within a factory setting.

These variants appear to hint to an advanced LC implementation in Swedish practice. However, Kifokeris (2021) pointed out that this may not actually be the case in 2021. Specifically, Kifokeris (2021) noted that most reviewed studies had a disproportionately large focus on industrialized construction – while its market segment, although sizeable, is small compared to the rest of a sector dominated by not fully industrialized construction practices (Steinhardt et al. 2020). Moreover, Kifokeris (2021) showed that the reviewed studies mostly focused on the LC practices of few case companies – leading to narrow and not sector-reflecting results. Furthermore, Koch et al. (2020) empirically showed that LC practice 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. In the analysis of the survey results below, it will be empirically shown that the points above are reoccurring in the 2022-2023 state-of-art.

Questionnaire survey

General survey response statistics

As mentioned in “RESEARCH METHOD”, the survey was live mainly between 23/08/2021 and 31/10/2021 (with a few stray responses until 31/01/2022). During this period, 471 companies offered valid (i.e., not blank or severely partial) responses – resulting in a **35% response rate**. Table 6 (see next page) offers a detailed categorization of the valid responses per industry group and county. There were 203 companies in group 41, 57 in group 42, and 211 in group 43, providing 203 (43,1%), 57 (12,1%), and 211 (44,8%) of the responses, respectively. The largest representation of group 43 may be due to this group including installations, craftwork, many subcontractors (e.g., for HVAC), and specialized construction activities. Installations is a growing subsector and craftwork is carried out by numerous subcontractor SMEs, which evidently take up a large part of construction. This probably shows that an extended part of the various processes (e.g., in production) are subcontracted and not necessarily carried out by the personnel employed in the main contractor companies – which in turn might furtherly show that process are getting more fragmented, as they are performed by more diverse actors. Moreover, the counties from which most responses were recorded were Stockholm with 122 (25,9%), Västra Götaland with 99 (21,02%), and Skåne with 43 (9,13%) – respectively including Stockholm, Gothenburg, and Malmö.

Table 6. Overall response statistics

County	Industry groups			County sum & (%)
	41	42	43	
Blekinge	1	2	9	9 (1,91%)
Dalarna	6	5	16	16 (3,40%)
Gävleborg	2	3	8	8 (1,70%)
Gotland	3	1	14	14 (2,97%)
Halland	13	0	22	22 (4,67%)
Jämtland	5	2	12	12 (2,55%)
Jönköping	5	1	13	13 (2,76%)
Kalmar	3	1	9	9 (1,91%)
Kronoberg	4	1	10	10 (2,12%)
Norrbottn	3	5	11	11 (2,34%)
Örebro	4	0	11	11 (2,34%)
Östergötland	10	1	17	17 (3,61%)
Skåne	20	2	43	43 (9,13%)
Södermanland	7	1	9	9 (1,91%)
Stockholm	61	13	122	122 (25,9%)
Uppsala	6	1	12	12 (2,55%)
Värmland	4	1	7	7 (1,49%)
Västerbotten	3	3	10	10 (2,12%)
Västernorrland	5	1	9	9 (1,91%)
Västmanland	2	1	8	8 (1,7%)
Västra Götaland	36	12	99	99 (21,02%)
NACE group sum & (%)	203 (43,1%)	57 (12,1%)	211 (44,8%)	
Overall sum				471

The respondents featured, among others, Skanska, NCC, Peab, JM, Veidekke Sweden, Serneke, and Svevia, which together share $\approx 65\%$ of the Swedish construction market in 2022-2023 (Largest Companies 2022).

Q1: Företagets namn (Company's name)

The respondent companies' names are not included in this report for data protection reasons.

Q2: Din roll i företaget (Your role in the company)

Table 7 offers an overview of the respondents' professional role and contribution to responses.

Table 7. Survey respondents' profiles and overall contribution to responses

Role in company	No. of responses
Top managers: CEOs, department managers, business unit managers	259
Middle and lower managers: project, site, and production managers	149
Officers and clerks	31
Engineers	5
Craft/site workers	2
Other roles	30

The responses pertaining to "Other roles" included the following:

- Administrator (x2)
- Architect and business developer (x2)
- Calculation manager
- Calculation, tender and purchase
- Construction manager (x2)
- District responsible salesperson (x2)
- Financial manager
- HR Director

- IR & communications manager
- KMA responsible (x2)
- Owner (x3)
- Production manager (x2)
- Project developer (x2)
- Project manager apprentice
- Quality, environment, and work environment coordinator
- Sales communication
- Self-employed
- Seller, organizer
- Supervisor (x2)
- Work manager

This strong representation of top management may indicate that most respondents are possibly responsible for important initiatives and strategic decisions.

Q3: Känner ni till vad lean construction är och vad detta kan användas till? (Do you know what lean construction is and what it can be used for?)

The strong representation of top management can hint to the practice of LC (or its lack thereof) being connected with strategic initiatives in Sweden, as when the respondents were asked about whether they knew what LC was and for what it could be used, 286 of them (ca. 60%) answered that they did not. A far lower percentage (ca. 31%, i.e., 149 companies) declared that they knew about it. 36 respondents noted that they knew about LC but implemented it under a different definition. In Fig. 5, the Y axis denoting the number of responses.

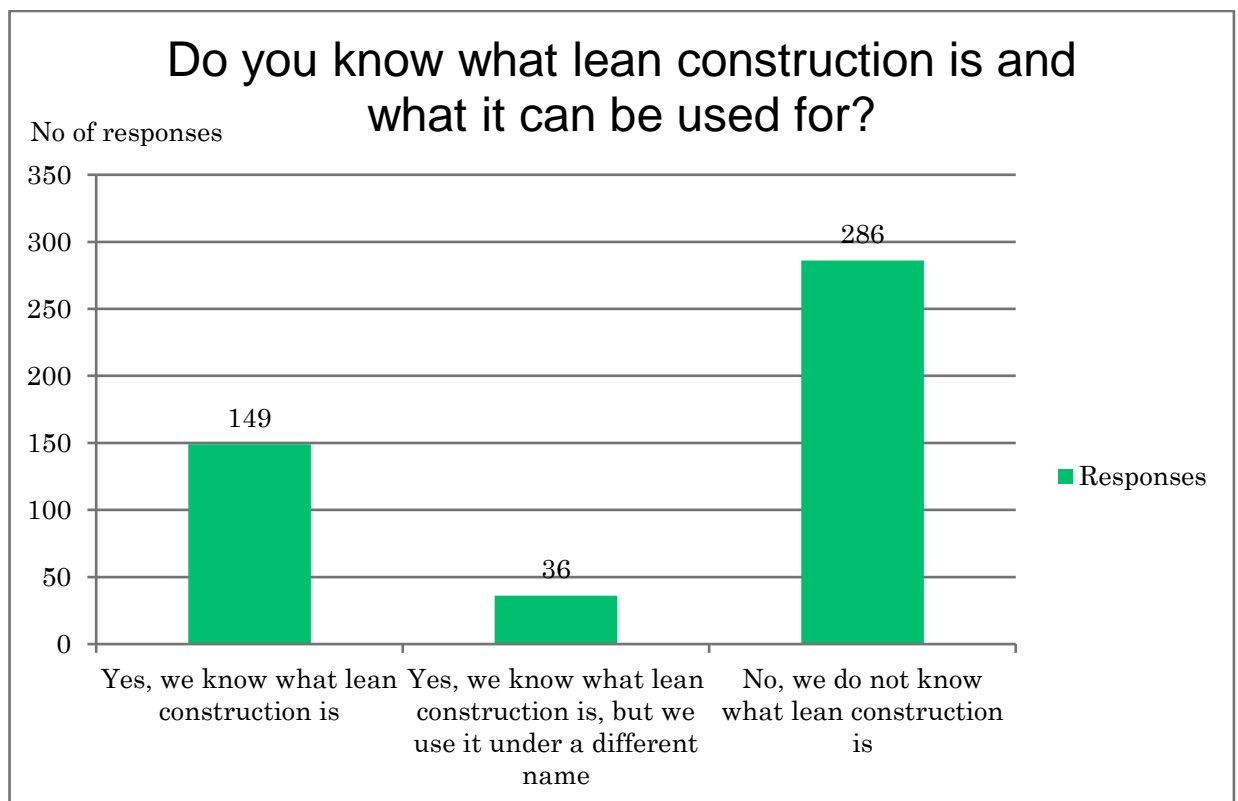


Fig. 5. Survey responses regarding the state of knowledge about what lean construction is

This image already supports the problematizations in Kifokeris and Koch (2020) and Kifokeris (2021), as it shows a rather different state-of-art than the one described by the reviewed academic studies in the Swedish context. It is reminded that previous literature had painted a far more advanced picture when it comes to practical LC implementation in Sweden. This can probably be attributed to both a disproportionate focus on industrialized construction, and a contextually narrow empirical material focusing almost exclusively to few very specific companies considered to be pioneers of LC implementation in Sweden.

Afterwards, 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.

Q4: Hur väl passar följande påståenden? Flera svar är möjliga. (How well do the following statements fit? Several answers are possible.)

The respondents were then asked about how strongly they agree with specific LC-related statements (see Fig. 6, with the Y axis denoting the number of responses). They could choose multiple answers on a 5-step Likert scale: 1 – Not at all, 2 – Little, 3 – Relatively little, 4 – Relatively well, and 5 – Very well, while also having the opportunity to choose “Don’t know” and/or offer another statement themselves.

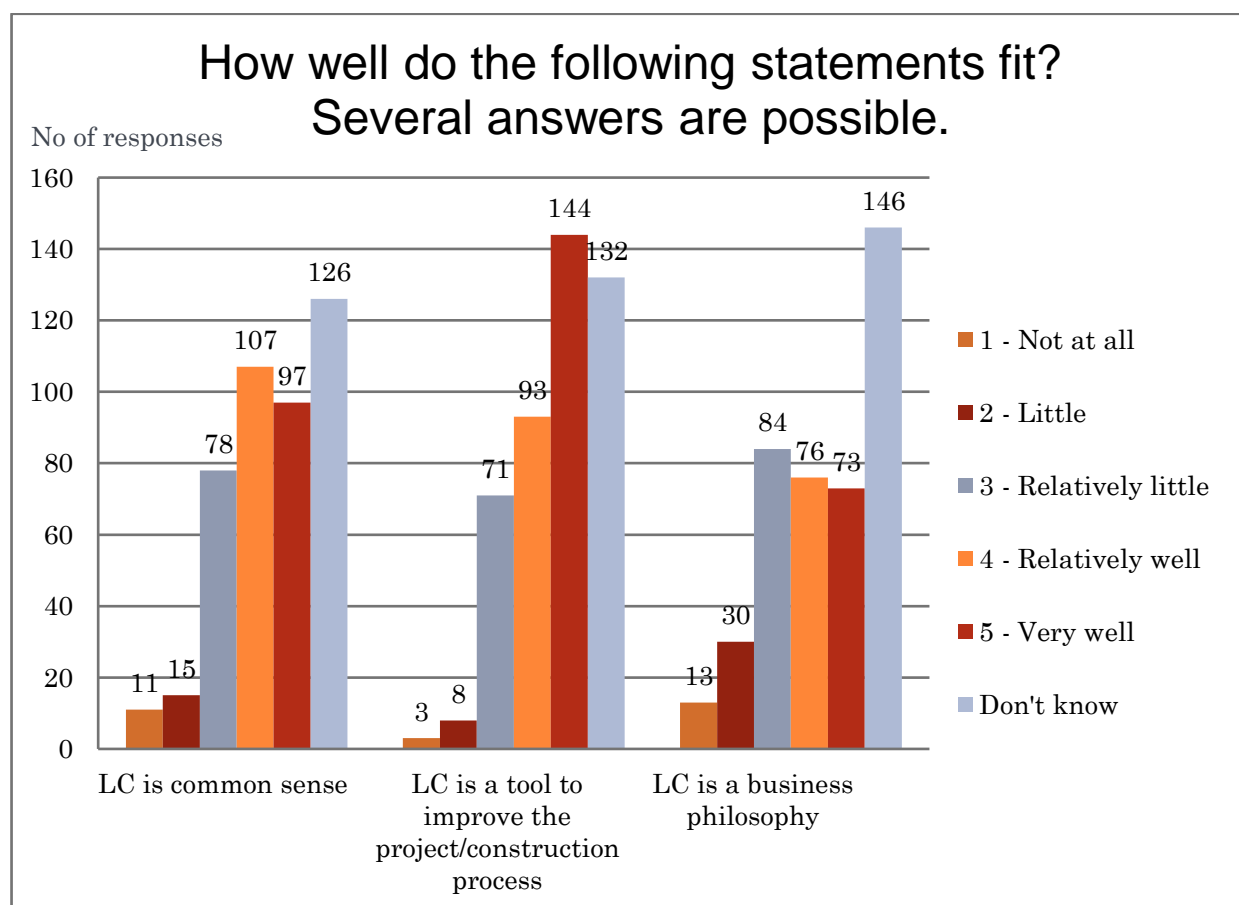


Fig. 6. Degree of agreement with specific lean construction-related statements

Other statements included the following (translated from Swedish):

- “We do not apply lean.”
- “Lean affects more than you think.”
- “Have looked at the questions. And because we have not used the term Lean Construction in our production. My answers become completely irrelevant. Glad you found me! At [company], we have 95% repeat customers. Our philosophy is to always strive for 100% customer satisfaction. The parameters include finances, time, and goal achievement.”
- “Don't use this.”
- “Haven't heard of it before.”
- “Knows lean methodology but not exactly lean construction.”

Succeeding the previous question, the respondents were asked to respond to a series of five inquiries regarding the degree with which LC factors or elements have been **currently** applied in their companies' contexts. The Likert rating included 1 – Not at all, 2 – Rarely, 3 – It happens, 4 – To some extent, and 5 – To a great extent, while also having the opportunity to choose “Not applicable”.

It should be noted that in the following shown responses, what is mainly reflected is not the vast majority of non-users of LC, but rather the companies that shared their experiences connected to the respective inquiries of the questionnaire.

Q5: Övergripande filosofier (Overarching philosophies)

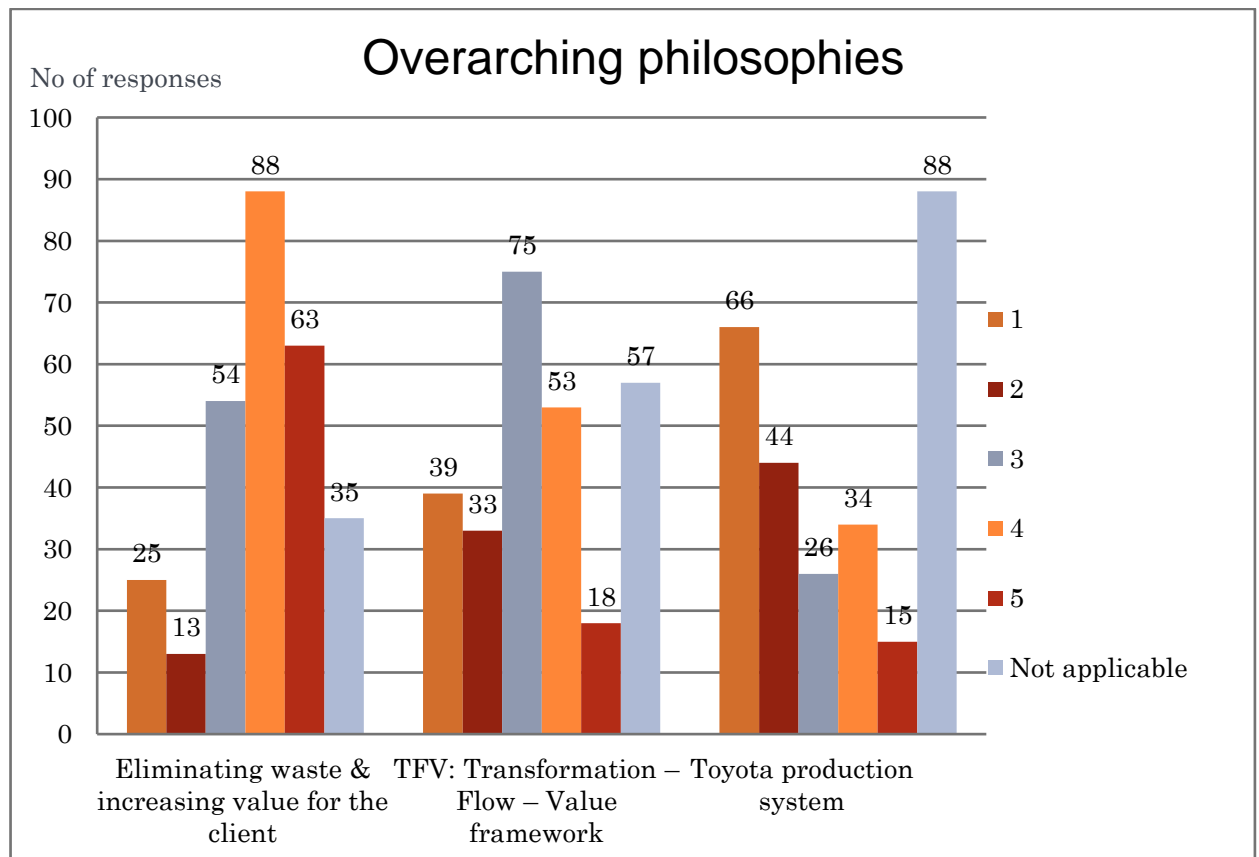


Fig. 7. Degree of agreement with overarching LC philosophies

In the inquiry about overarching LC philosophies, waste elimination and customer value increase mostly applied to some extent, the transformation-flow-value (TFV) framework was mostly perceived as sometimes happening, and the Toyota production system was mostly understood as not applicable (see Fig. 7 in the previous page, with the Y axis denoting the number of responses).

Q6: Verktøy – Eliminering av slöseri inom (...) (Tools – Eliminating waste in (...))

The respondents understood waste elimination to be associated to (in prioritized order): rework, value creation, transportation, delays, and errors. Waste elimination is less associated with non-utilization of personnel resources and inefficient resource handling. It is sometimes associated with overproduction and stock (see Fig. 8, with the Y axis denoting the number of responses). The relatively weaker recognition of “overproduction” could relate that the LC discourse may have transferred this dimension in a too “light” manner from lean manufacturing.

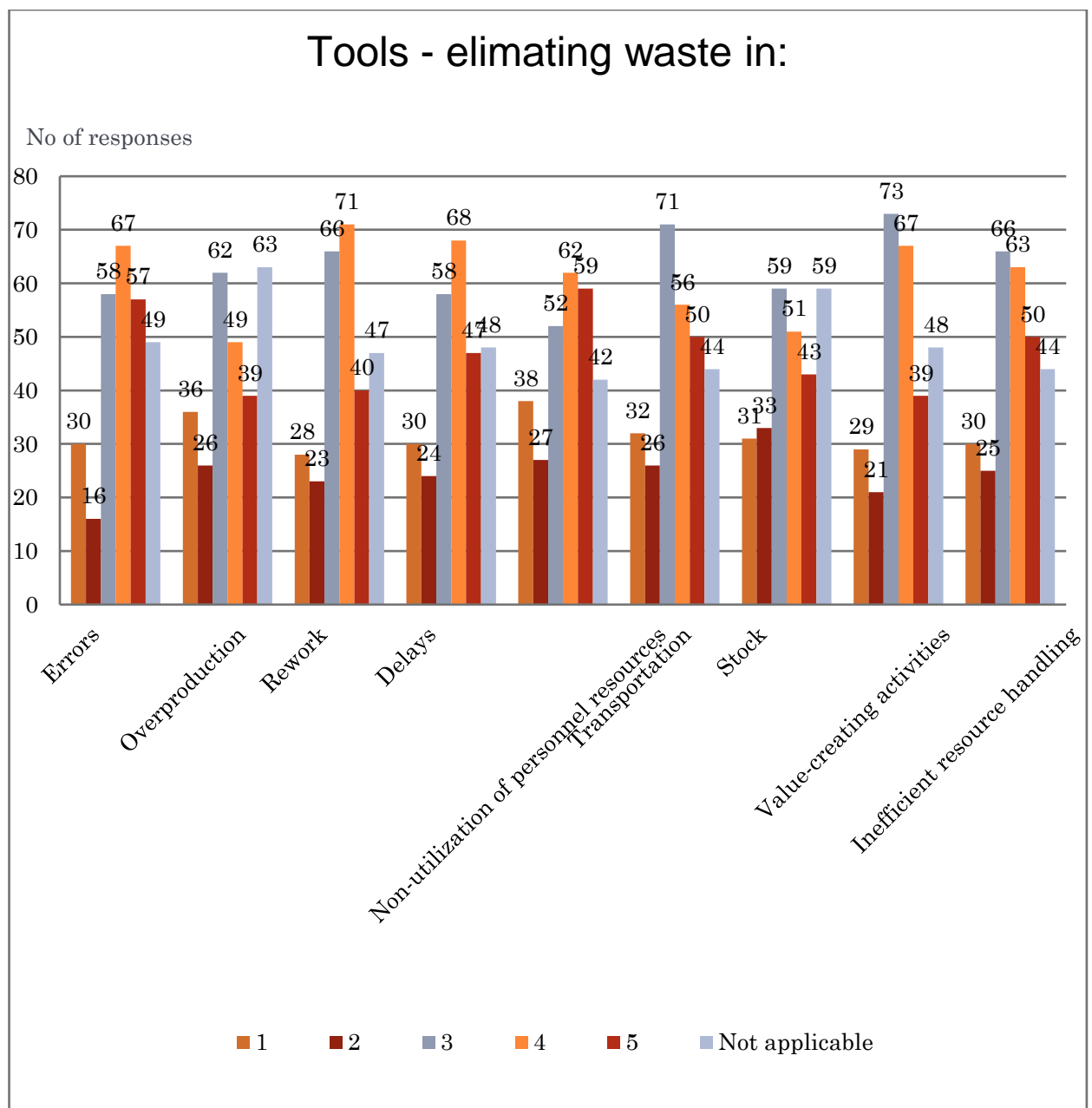


Fig. 8. Degree of association of waste elimination with various parameters

These results show that in the construction sector in Sweden, not all factors of waste that are approached as targets to be amended by the implementation of LC (as is commonly described in the LC discourse), are equally perceived to have an association with elimination efforts.

Q7: Verktyg – Dragplanering, kanban (Tools – Pull planning, kanban)

With pull planning, the intention of the concept is to perform a detailed constraints analysis at the lookahead and weekly planning level (Dave and Sacks 2020). Responsibilities are assigned to task/trade leaders/managers to ensure those constraints are removed before the tasks are considered production-ready; pull planning comprises evolving the management team, following the project milestones, setting the schedule, setting durations, creating weekly plans, setting daily and weekly meetings, and updating the plan (Dave and Sacks 2020). Pull planning can be used in tandem with Kanban, which is a lean method of managing work by balancing demands with available capacity and improving the handling of system-level bottlenecks; Kanban is often using marked boards and sticky notes (Rooke 2020). This imagined combined use is assumed to manifest in work items being visualized on a Kanban board to give participants a view of progress and process, from start to finish; work is then pulled as capacity permits, rather than work being pushed into the process when requested (Costa and de Burgos 2015). The survey showed that pull planning and Kanban were mostly “not used” closely followed by “it happens” (see Fig. 9, with the Y axis denoting the number of responses).

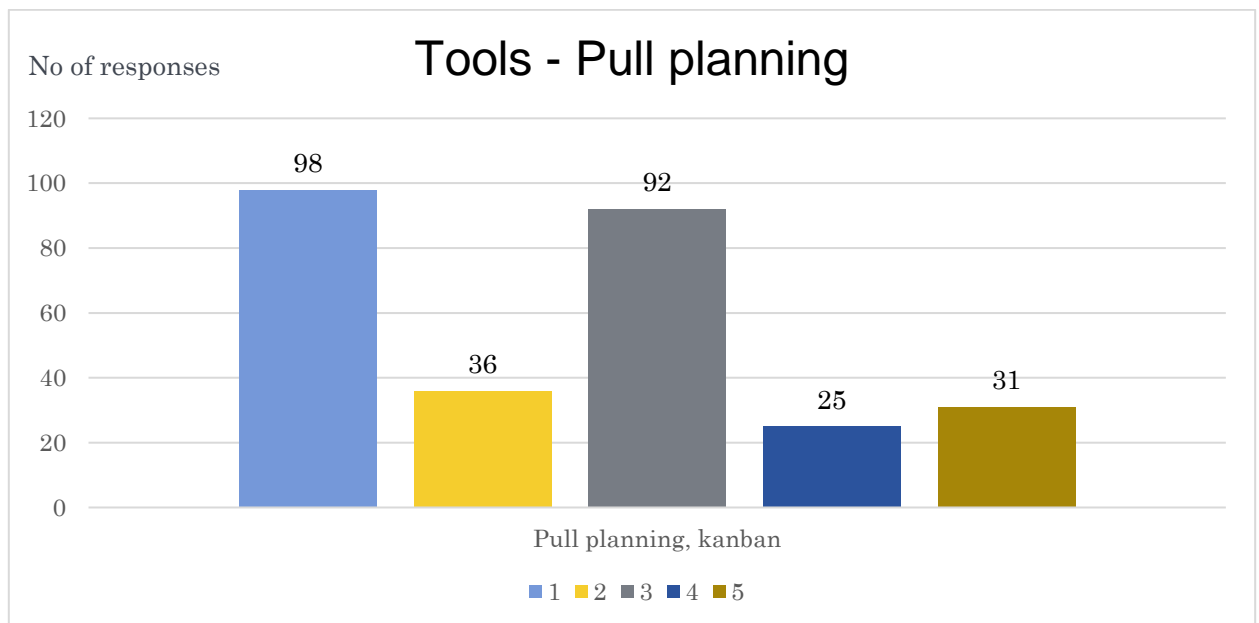


Fig. 9. Degree of utilization of pull planning and kanban

Q8: Verktyg – Last Planner (Tools – Last Planner)

Last Planner is a system created as a reaction to the critical path method (CPM) approach for planning (Ballard 2000), and as a concept comprises the following functions: specifying what tasks should be done when and by whom, from milestones to phases between milestones, to processes within phases, to operations within processes, to steps within operations; making scheduled tasks ready to be performed; replanning/planning to complete in order to achieve project objectives; selecting tasks for daily and weekly work plans – deciding what work to do next; making release of work between specialists reliable; making visible the current and future state of the project;

measuring planning system performance; and learning from plan failures (Ballard 2020b). Over the years, Last Planner has experienced some popularity – to the point that Koskela (2020) has expressed the opinion that in several contexts, Last Planner has been equated with LC itself. As a concept, it is associated with the following elements (Ballard 2020b):

- Adherence to the master plan.
- Degree to which planned activities are successfully completed (“percent planned completed”).
- The preparation of the “seven healthy flows”, which include:
 1. Documents completed.
 2. Workplace prepared.
 3. Machines, tools on site.
 4. Crew prepared.
 5. Construction materials available.
 6. Related work completed.
 7. External conditions (e.g., the weather) accounted for.

The responses show a dissimilar application of the different LP elements, indicating a variable and/or partial implementation of Last Planner. Fig. 10 offers an illustration of those results, with the Y axis denoting the number of responses.

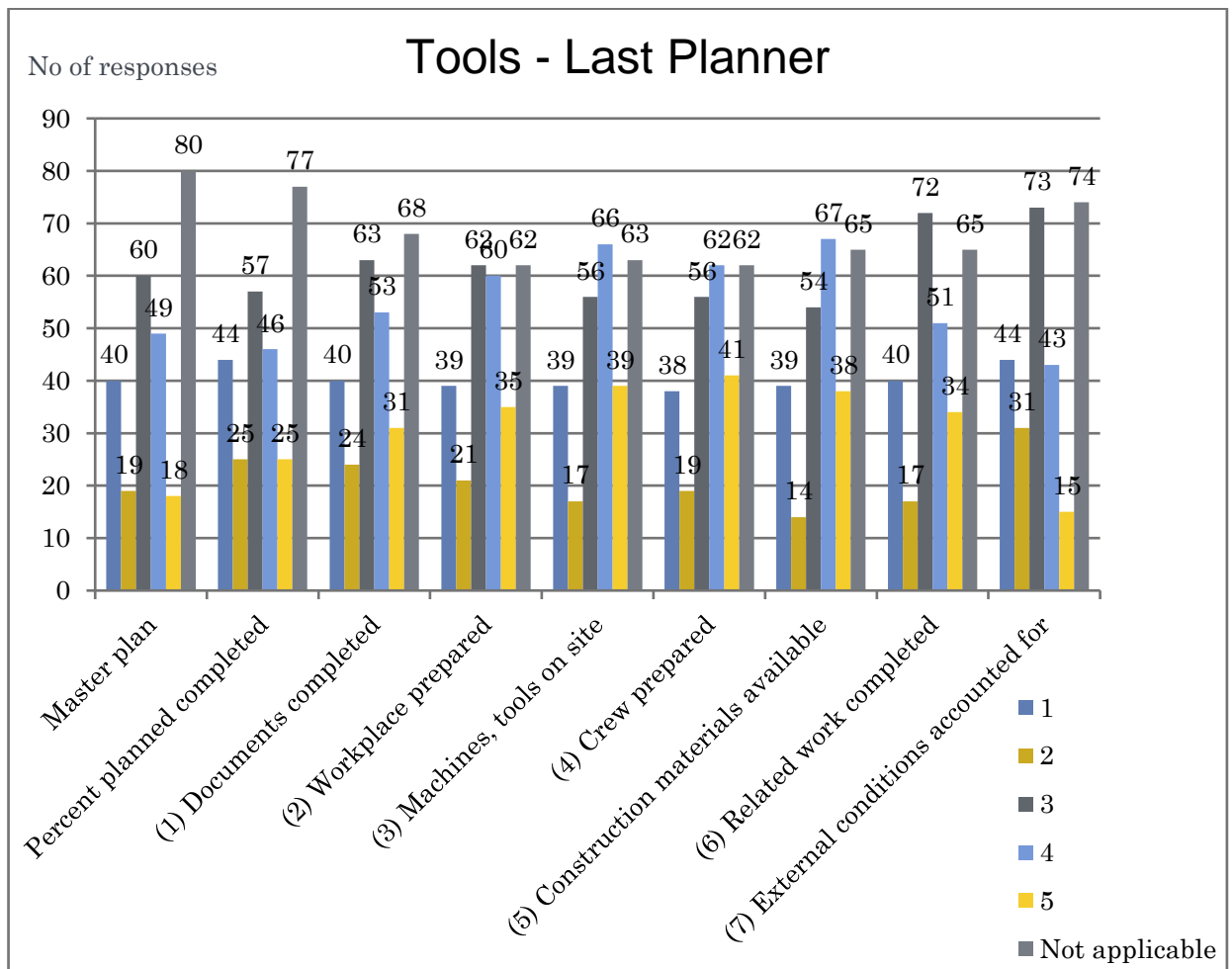


Fig. 10. Degree of implementation of different elements of Last Planner

It is evident that a few Last Planner elements were perceived as not applicable by most of the respondents. Specifically, this refers to the master plan, the percent planned completed, the completed documents, the prepared workplace, the prepared crew, and the accounted for external conditions. On the other hand, the machines and tools being on site, the availability of construction materials, and the crew prepared, were found to be mostly implemented to a large extent among the respondents replying to this question. Finally, the healthy flow pertaining to the completed related work was found to be implemented sometimes.

Q9: Verktyg – Lean försörjning, bygglogistik (Tools – Lean supply, construction logistics)

LC concepts like just-in-time deliveries can be used to make the construction supply chain and logistics “leaner” (Vrijhoef and Koskela 2000), by improving the interface between the site and supply chain, making supply chains and logistics more efficient, transferring activities from the site to the supply chain (e.g., production of offsite building modules instead of in situ), and integrating the site and the supply chain (e.g., provisionally planning of logistics already in the design phase) (Vrijhoef 2020). As such, Q9 asked whether any lean approaches to supply chain and construction logistics management have been applied. Most respondents found those elements not applicable – however, 70 companies also showed that a lean approach to supply chain and construction logistics management is being applied to some extent by their companies (see Fig. 11, with the Y axis denoting the number of responses).

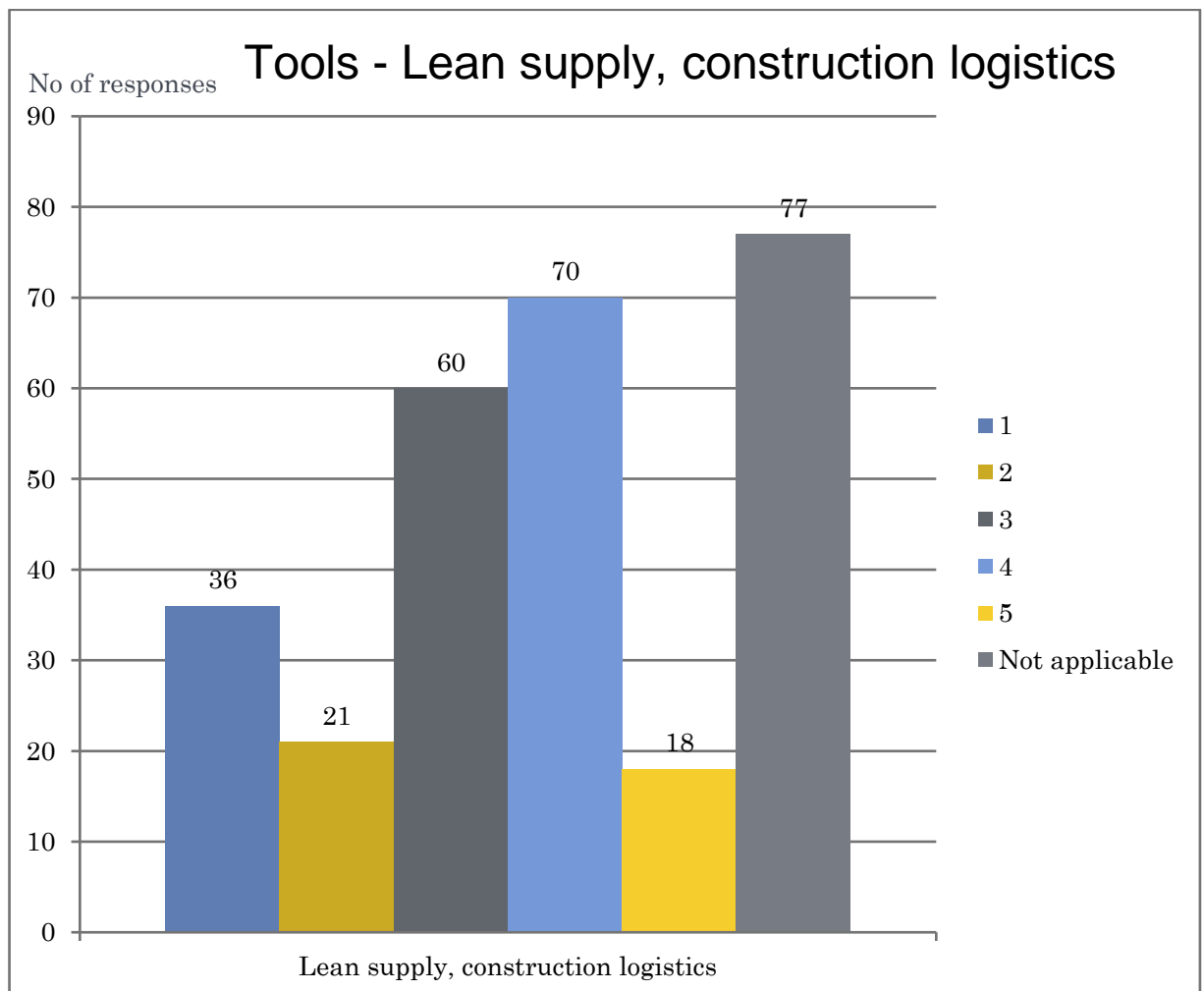


Fig. 11. Degree of implementation of lean supply chain and construction logistics

After this five-question set, **the respondents answered five more inquiries (Q10-Q14) regarding the degree to their companies had applied LC factors or elements in the past**. As with before, the Likert rating included 1 – Not at all, 2 – Rarely, 3 – It happens, 4 – To some extent, and 5 – To a great extent, while also having the opportunity to choose “Not applicable”.

Q10: Övergripande filosofier (Overarching philosophies) (in the past)

Waste elimination and customer value increase had mostly been applied in the past to some extent, while the transformation-flow-value (TFV) framework and the Toyota production system had mostly been understood as not applicable (see Fig. 12, with the Y axis denoting the number of responses). However, 50 respondents declared that TFV had been applied to some extent.

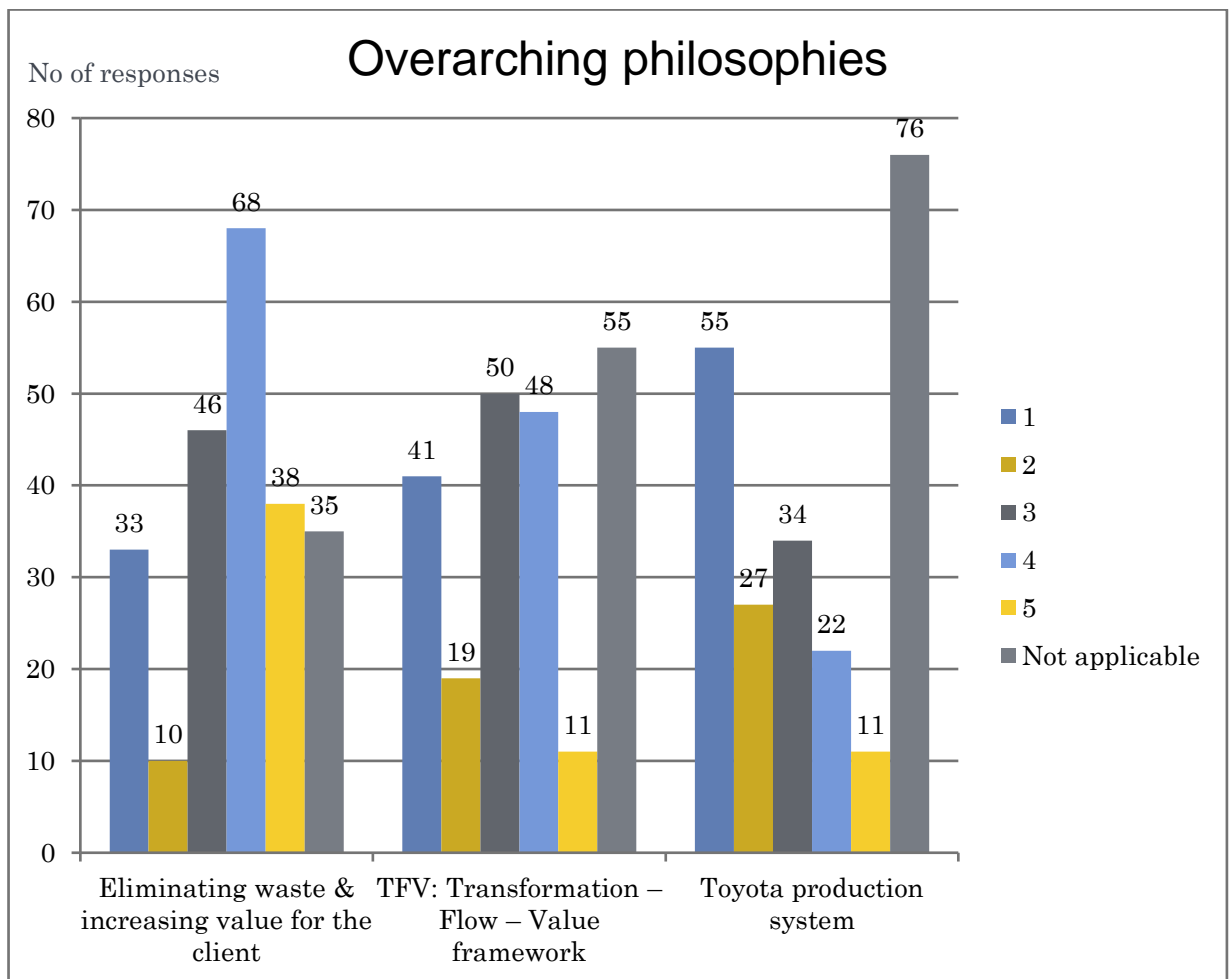


Fig. 12. Degree of past agreement with overarching LC philosophies

Q11: Verktøy – Eliminering av slöseri inom (...) (Tools – Eliminating waste in (...)) (in the past)

62 respondents associated waste elimination to some extent with errors, non-utilization of personnel resources, and transportation. It was also sometimes associated with overproduction, rework, delays, stock, value-creating activities, and inefficient resource handling. No majority of respondents found waste elements to have been inapplicable. For overproduction and stock, an applicability to some extent was noted (see Fig. 13 – the Y axis denoting the number of responses).

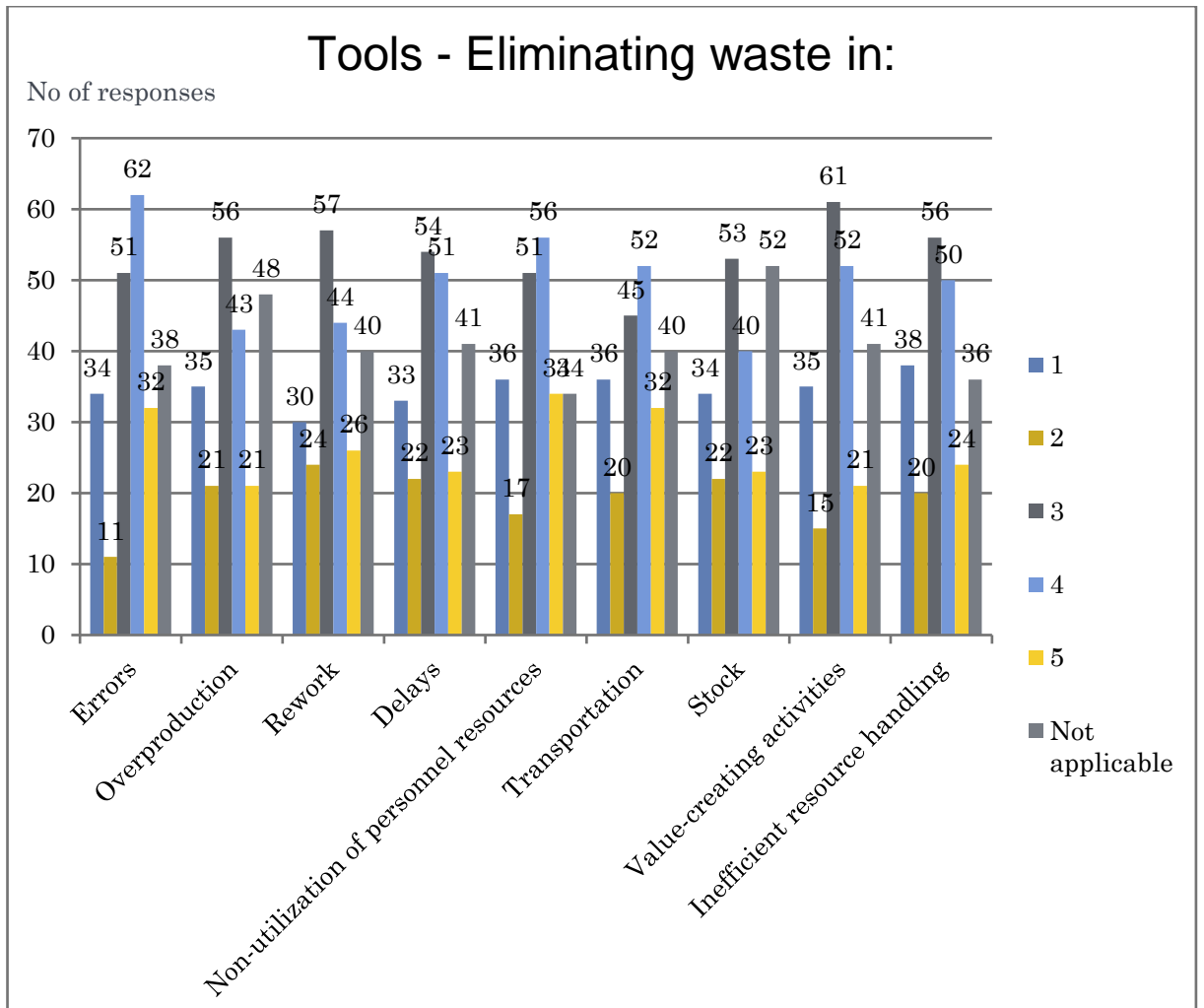


Fig. 13. Degree of past association of waste elimination with various parameters

Q12: Verktøy – Dragplanering, kanban (Tools – Pull planning, kanban) (in the past)

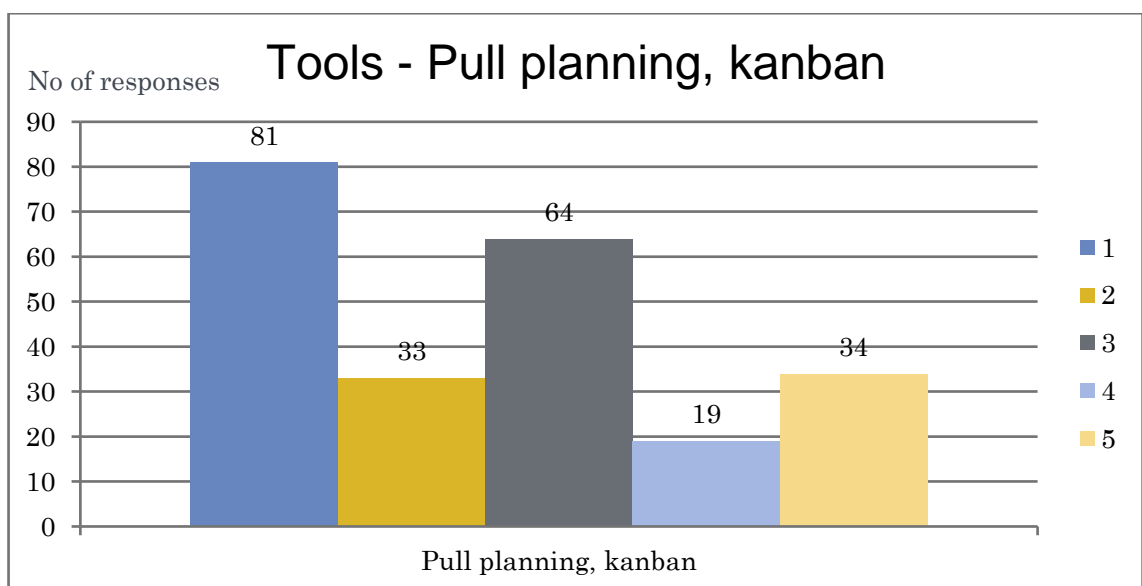


Fig. 14. Degree of past utilization of pull planning and Kanban

It was shown that, in most cases, pull planning and Kanban had not been used in the past (see Fig. 14 in the previous page, with the Y axis denoting the number of responses).

Q13: Verktys – Last Planner (Tools – Last Planner) (in the past)

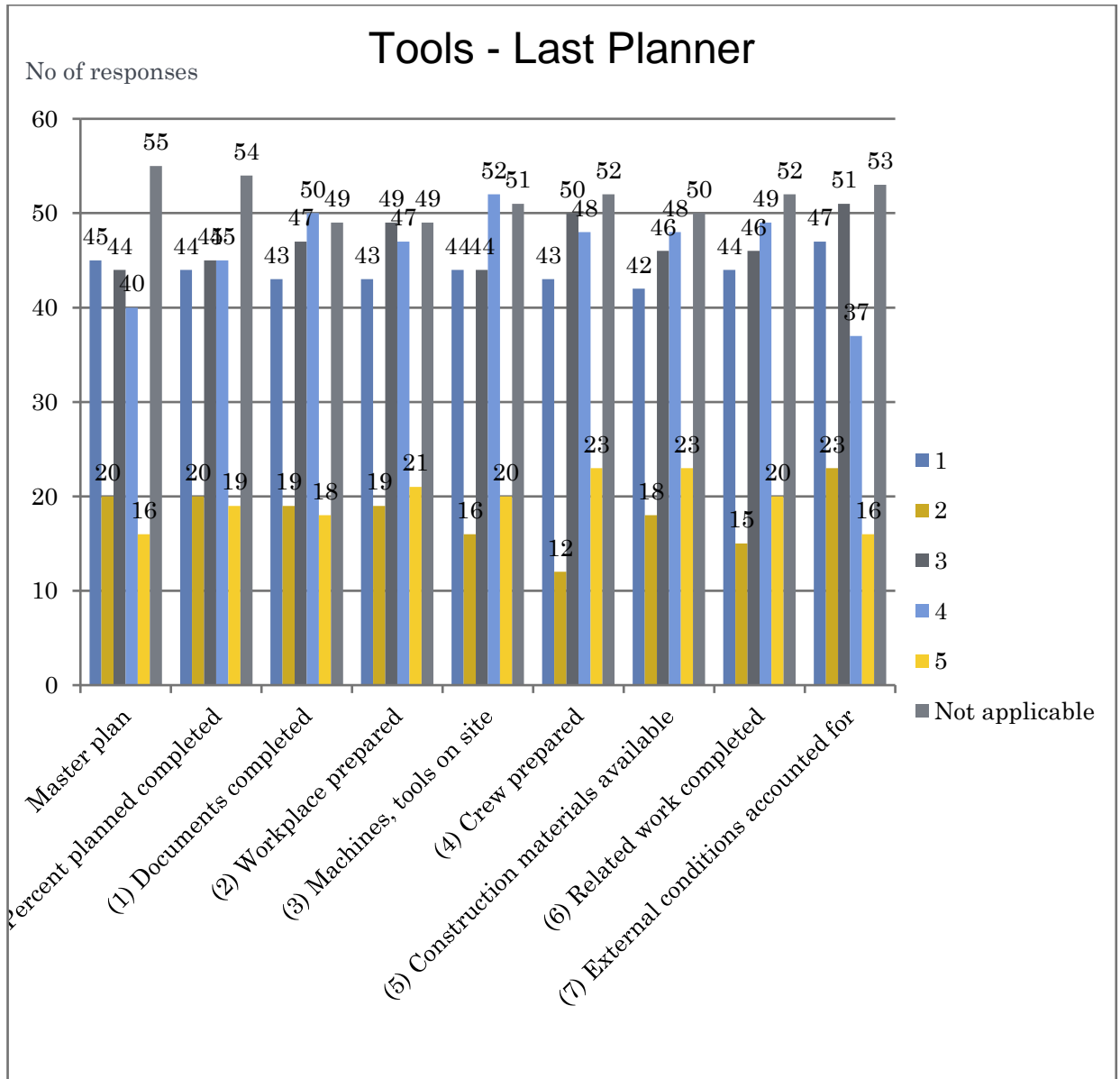


Fig. 15. Degree of past implementation of different elements of Last Planner

As it turned out, in the past there had been a dissimilar application of the different Last Planner elements, indicating a variable and/or partial implementation of Last Planner. Most of the respondents perceived the following tools not applicable: The adherence to the master plan, the percent planned completed, the prepared crew, the availability of construction materials, the completed related work, and the accounted for external conditions. Nonetheless, in all those cases, the responses indicating an application that happens up to an extent were close. Moreover, the prepared workspace had been found to be implemented sometimes in the past. Finally, the healthy flows pertaining to the completed documents, as well as the machines and tools on site, were found to have been mostly implemented to some extent. Fig. 15 offers an illustration of those results, with the Y axis denoting the number of responses.

Q14: Verktyg – Lean försörjning, bygglogistik (Tools – Lean supply, construction logistics) (in the past)

67 respondents found the elements of lean supply and logistics to have been applied to some extent in the past. However, 50 respondents showed that a lean approach to supply chain and construction logistics management had not been implemented at all or been generally not applicable. Those results are shown in Fig. 16, with the Y axis denoting the number of responses (see next page).

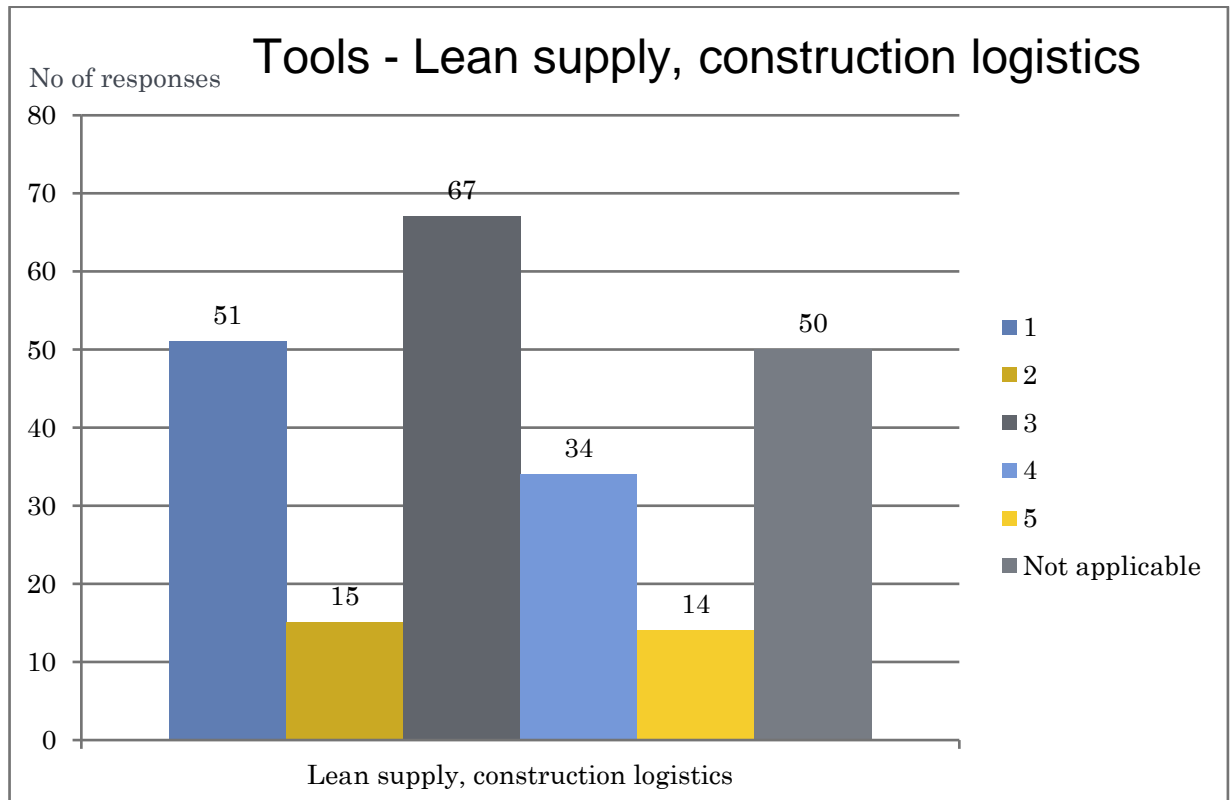


Fig. 16. Degree of past implementation of lean supply chain and construction logistics

When comparing the responses on applying LC factors now and in the past, certain application and implementation trends can be ascertained. Overarching LC philosophies, waste elimination and customer value increase applied relatively strongly now and in the past, the TFV framework applied relatively strongly in the past but weakly now, and the Toyota production system applied weakly both in the past and now. Moreover, both now and in the past, waste elimination was relatively strongly associated with errors, non-utilization of human resources, inefficient resource management, reworks, delays, transportation, and value-creating activities, and relatively weakly with overproduction and the inventory. Furthermore, pull planning and Kanban had not been used in the past, but are applied quite strongly now. In addition, there has been a varying past and present application of Last Planner elements – which however indicated that the Last Planner system has been present for quite some time, even if it has been in a partial sense. Finally, there is a relatively weak current application of lean supply chain and logistics, but that one was stronger in the past.

The survey results apparently show that, in general, experiences from the past do not always strongly correlate with whether the respondents are **currently** using LC or not.

Q15: Tillvägagångssätt (Approaches)

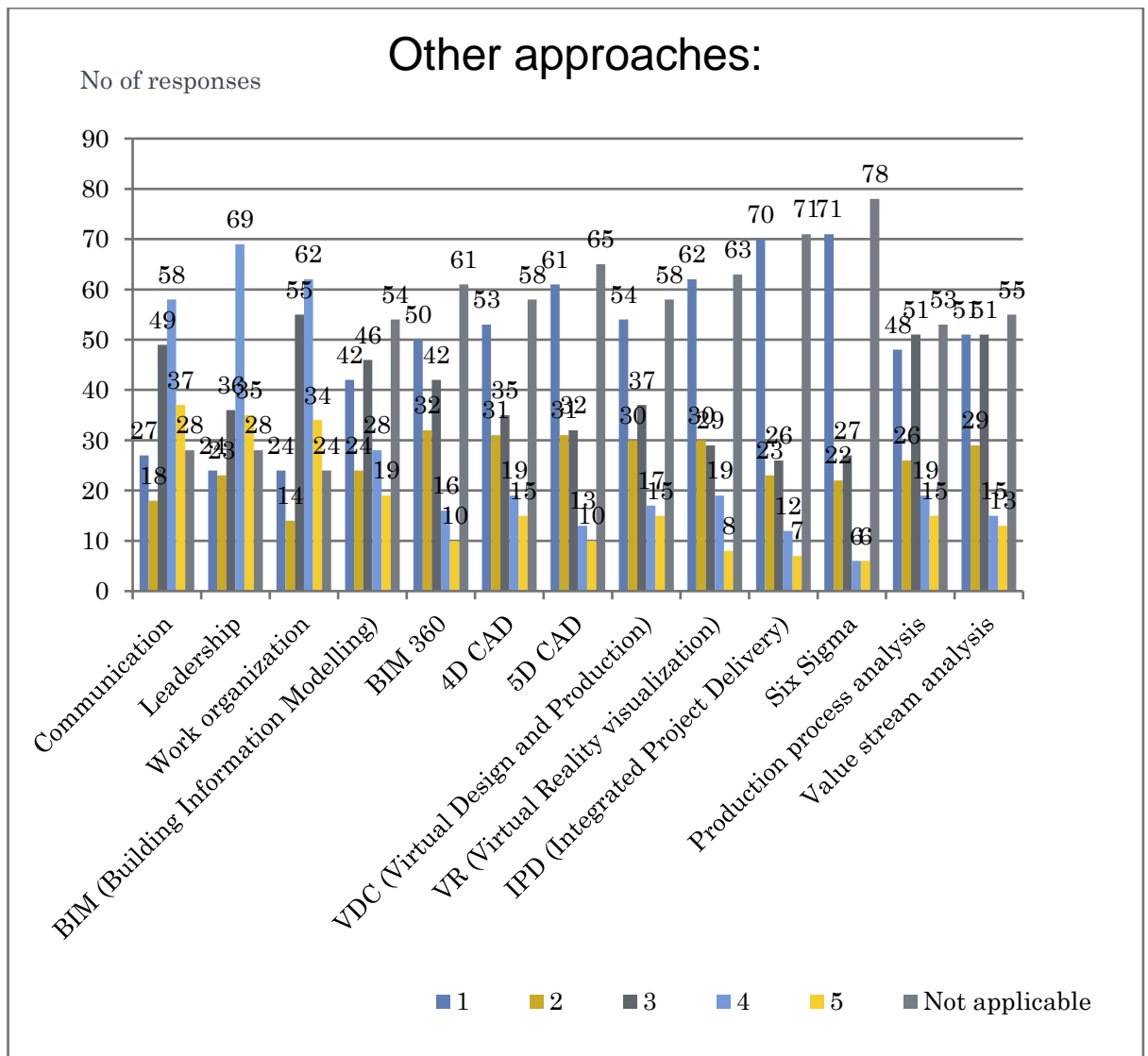


Fig. 17. Other approaches (e.g., initiatives, tools) for facilitating lean construction – the Y axis denotes the number of responses

Following the inquiries about present and past implementation of LC factors by the companies, the respondents were asked about what other approaches have been applied by the companies to be facilitated by lean construction. Those approaches had to do with initiatives connected to:

- Communication activities.
- Leadership activities.
- Work organization.
- Building Information Modelling (BIM) and BIM 360. BIM 360 is an Autodesk cloud-based solution that aims at facilitating a collaborative environment for project teams (Autodesk 2022).
- 4D and 5D computer-aided design (CAD).
- Virtual Design and Construction (VDC), namely the use of integrated multi-disciplinary performance models of design and construction projects in order to support explicit and

public business objectives (Kunz and Fischer 2012). These models emphasize the project that can be designed and managed, i.e., the product (e.g., a building), the organization that will conceive, design, construct and operate it, and the process that the corresponding organization teams will follow (Kunz and Fischer 2012). Such models are logically integrated in terms of accessing shared data and highlighting or changing interdependent aspects (Kunz and Fischer 2012).

- Visualization with virtual reality (VR). Such visualizations can potentially be used to facilitate the implementation of LC aspects in the design and early production phase, as shown in the case study by Olofsson et al. (2006).
- Integrated project delivery (IPD), namely the approach to project delivery approach where people, systems, business structures and practices are integrated into a collaborative process to optimize project results, increase owner value, reduce waste, and maximize efficiency through design and construction (Alves and Lichtig 2020).
- Lean Six Sigma (6S), namely the method relying on a collaborative team effort to improve performance by systematically removing waste, reducing variation and evaluating the capability of processes in construction (Plenert and Plenert 2018).
- Production process analysis.
- Value stream analysis (or mapping), namely assessing the share of non-value adding activities of a process and designing a future state of it (Formoso et al. 2020).

The responses shown in Fig. 17 (see previous page, with the Y axis denoting the number of responses) strong support for soft management tools like leadership and communication, but poor support to two integrated management and technology concepts (VDC and IPD), and poor support for six digital solutions: BIM, BIM 360, 4D CAD, 5D CAD, and virtual reality (VR). Nonetheless, three respondents offered more specific answers on using branded digital tools – two of them Dalux, and another one Bidcon. However, no more elaboration was offered on the specific utilization of these tools.

Q16: Utbildning och/eller träning av (flera kryss möjliga) (Education and/or training of (multiple answers possible))

The respondents were then asked about the organizational roles to which any LC-related education (competence development) and training activities have directed (multiple roles could be selected). The highest counts regarded 83 respondents directing such activities towards project and site managers, 72 towards upper managerial positions, and 58 specifying other options (see Fig. 18 in the next page, with the Y axis denoting the number of responses).

Among the 58 respondents choosing the “Other” option, 53 simply responded with a variation of “no activity”, while the five remaining answers comprised the following (translated from Swedish):

- “All attended the [Company] school”.
- “Dialogue with the client.”
- “No external training has been completed. We regularly discuss internally how we can improve. We use different terms, but the meaning is largely the same.”
- “We have not educated ourselves. We are not talking about lean construction. But we largely work in this way. We often build for public clients with strict requirements.”
- “Lean has been promoted at departmental meetings.”

It is thus remarkable that only around 50% of the respondents (213 out of 471) appeared to have carried out training for their organizational members.

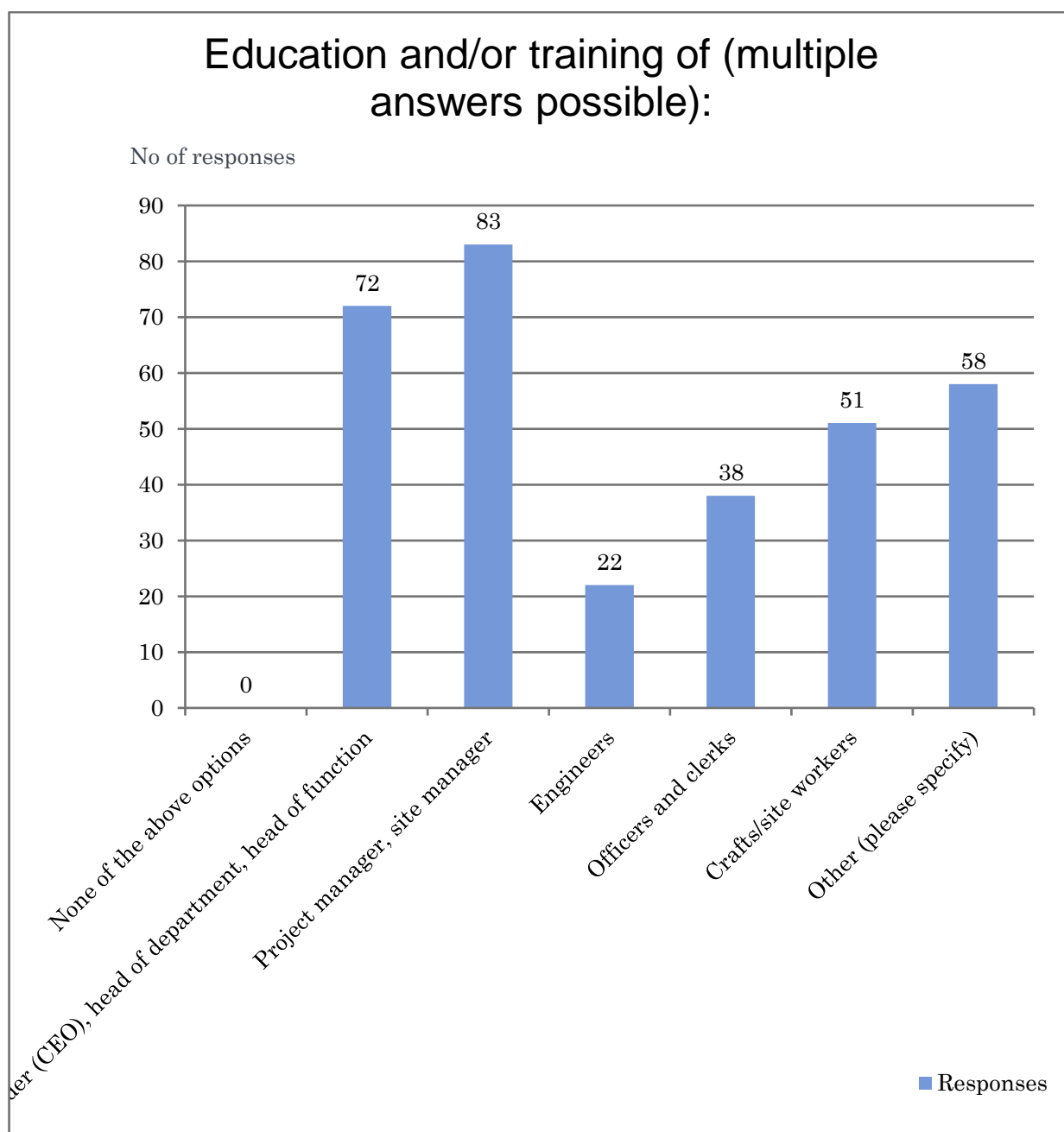


Fig. 18. Professional roles towards which education and training activities are directed

Q17: Beskriv utbildningsinsatserna ytterligare (Describe the training efforts further)

Following the previous inquiry, the respondents were asked to offer a further description of the training activities they implemented (if any). Out of the 89 answers, 42 were variations of “no activities implemented”. The rest are noted in the following (translated from Swedish):

- “Workshops as integral parts of training courses.”
- “Leadership.”
- “Development of own production system and internal training.”

- “Education/course 10 years ago.”
- “Quality training and quality audits.”
- “Leading fitters, work management, project management training.”
- “Industry training courses.”
- “All required education in the painting industry (e.g., ISO etc.).”
- “Increased understanding.”
- “Took a course in lean.”
- “Lean games and training days.”
- “Helped by consultants with good insight into BIM modeling and project managers.”
- “Law and technology.”
- “Internal training courses.” (x 9)
- “Various courses that make our work more efficient.”
- “Lean Construction 10p course in Chalmers.”
- “Improving understanding and value.”
- “Working groups to shape structure with both installers, partners, and project managers.”
- “Safe Water, Bas U and P, Hot Work, etc.”
- “Started: Leadership, flow optimization, communication, the common thread.”
- “Project manual produced.”
- “A short feature during a conference.”
- “Ongoing.”
- “Basic training in lean.”
- “Other courses that deal with efficiency improvement, etc.”
- “Internal training of the lead fitter (also the rest of the team), how we set up and plan our work considering the right material at the right time, wastage, and also the end result for the customer.”
- “Training on lean to be able to introduce it on a larger scale.”
- “Various applicable training courses in leadership, etc.”
- “Ongoing project follow-up.”
- “The production processes.”
- “Expertise.”
- “Various courses within the industry.”
- “Toyota's production philosophy.”
- “Various.”
- “Ongoing training.”
- “Work the right way with flows.”
- “One person within the company has studied quality management.”
- “Collaboration with Stanford for VDC, internal trainings and trainings in projects with all project participants.”
- “A lean expert is recruited” (the actual name of the recruited person was mentioned, but it was redacted in this report for reasons of anonymity).
- “External information and training.”

Q18: Kommunikation riktad mot (specifierade) aktörer (flera kryss möjliga) (Communication directed to (multiple answers possible))

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 responses

for Q16, just with relatively different response sums (see Fig. 19 in the next page, with the Y axis denoting the number of responses).

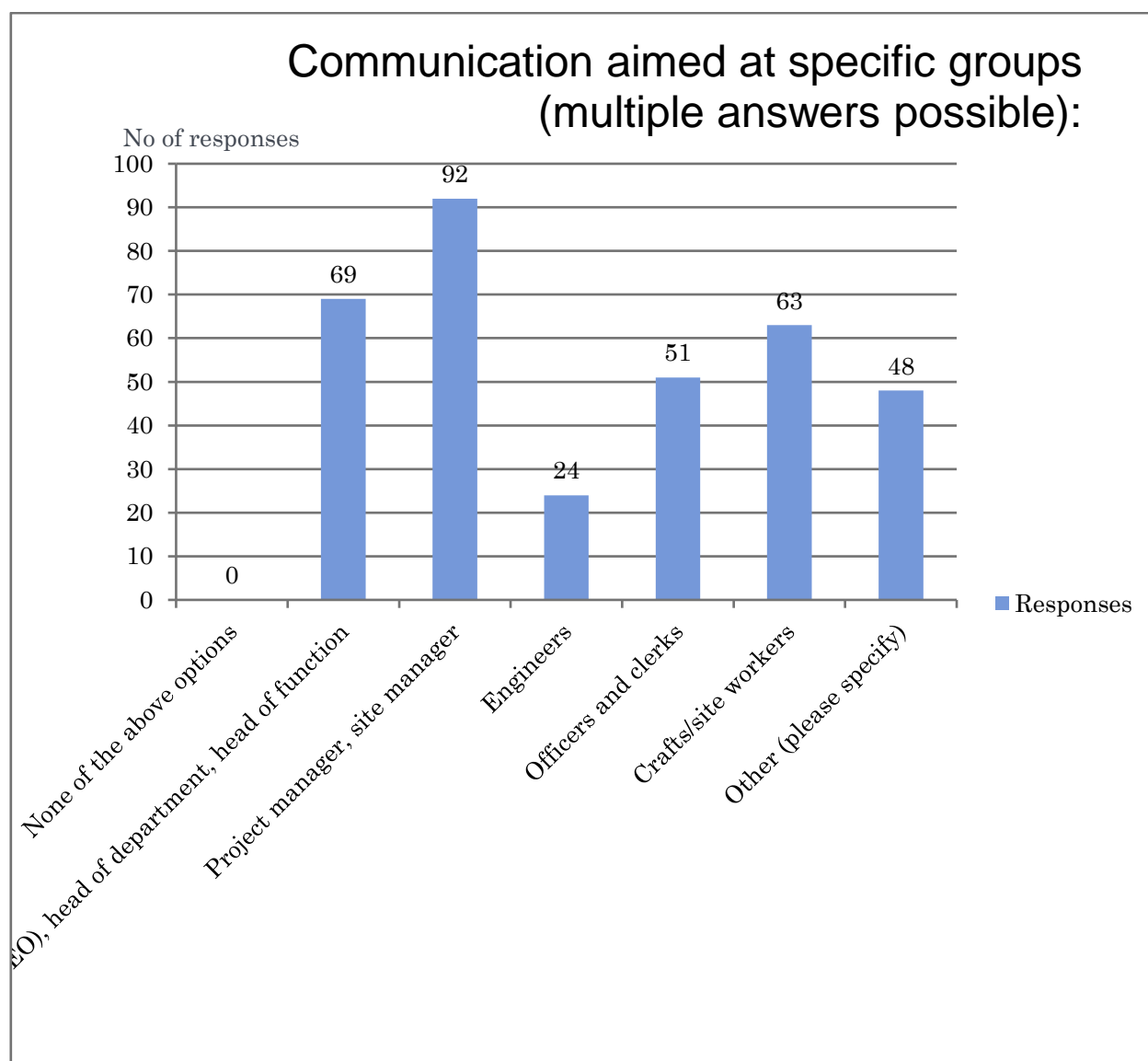


Fig. 19. Professional roles towards which communication activities are directed

Q19: Beskriv kommunikationsinsatserna ytterligare (Describe the communication efforts further)

Following the previous inquiry, the respondents were asked to offer a further description of the communication activities they implemented (if any). Out of the 92 answers, 52 were variations of “no activities implemented”. The rest are noted in the following (translated from Swedish):

- “Clarity.”
- “A large part of the autumn conference as well as a cultural issue.”
- “Courses in quality systems and follow-up of audits.”
- “Ensuring that everyone works according to the correct documents. Mostly oral communication.”
- “Discussion.”
- “Lifting this issue in every meeting.”

- “Staff meetings, meetings regarding ISO, development interviews, etc.”
- “Straight and clear communication.”
- “See previous answer.” (x 4)
- “Operations meetings, weekly planning.”
- “Business meetings.”
- “Internal courses.”
- “Extra ‘face2face’ meetings to create a better team spirit and team, as well as eliminate the ‘us and them’ syndrome.”
- “Digital communication.”
- “Meetings, information.”
- “Management group meetings, work preparation meetings, planning meetings, calculation reviews, etc.”
- “Optimization of meetings and their content as well as how the information is disseminated in the organization.”
- “Internal training courses.” (x 2)
- “Drawings from project management/customer/construction logistics.”
- “Ongoing.”
- “Dialogue with customers and information in the company.”
- “Monthly meetings with staff where we discuss production efficiency. Through discussions we learn from each other.”
- “Better communication.”
- “Talk to the employees about the project.”
- “Training.”
- “Seek improvement all the time.”
- “Toyota.”
- “Towards entrepreneurs and customers.”
- “Various.”
- “Daily briefings.”
- “Reconciliation meeting at workplaces.”
- “Only at internal meetings.”
- “Transparency and follow-up/information meetings.”
- “Another way of explaining and managing the work has been started to gain a greater understanding of how we can make continuous improvements and make better decisions at each stage.”
- “Morning meetings every day.”

Q20: Andra insatser (Other efforts)

In the final inquiry about implementation activities, the respondents were asked to describe other effort they may have undertaken to implement LC. The following options were initially offered:

- Sim Lean, which is a web-based game for showing how lean can be applied in construction. In a series of virtual building projects, the player is offered the opportunity to practice controlling the flow of material and personnel resources in an effective way (Sim Lean 2022).
- Any kind of other simulation activities.
- Long-term supplier relationships (Vrijhoef 2020).
- Other efforts.

Fig. 20 (with the Y axis denoting the number of responses) shows the response results for Q20.

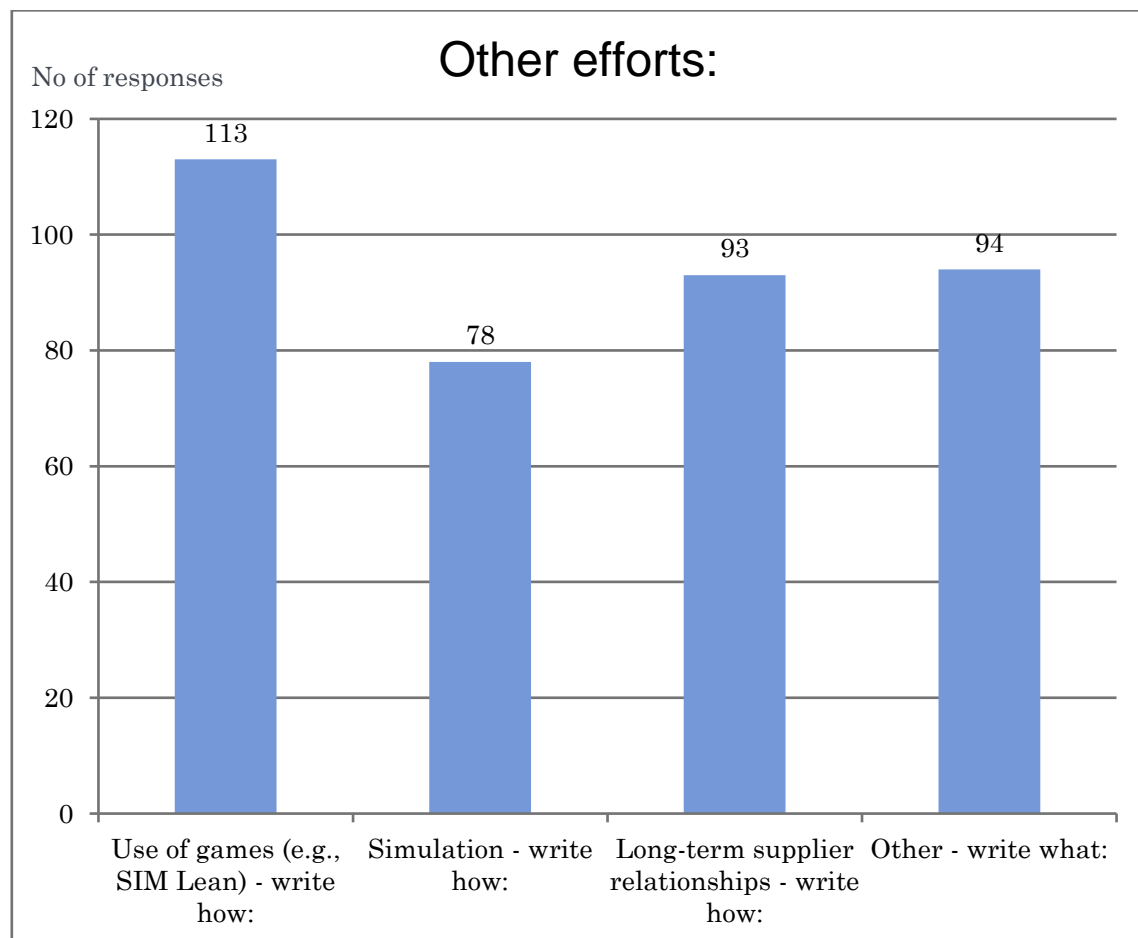


Fig. 20. Other implementation activities

For all four options, the respondents were asked to elaborate more on the way they undertook the implementation activities. However, there were only a few further elaborations:

- For Sim Lean:
 - “In the project.”
 - “Real-life lean game.” (x 2)
 - “Very limited scope.”
 - “Used only when necessary.”
 - “Sim Lean, kind of simulation, what happens now.”
 - “Increased training.”
 - “Experience feedback.”
 - “Among new employees/student events.”

- For simulation:
 - “Simulating orders.”
 - “Very limited scope.”
 - “Can occur with customer.”
 - “Visits to other buildings, good examples.”

- “Partly direct and partly long-term.”
 - “Testing.”
 - “Simulation of 2D and 3D models.”
 - “Pleasant activities together.”
 - “Working with independent architectural firms.”
- For long-term supplier relationships:
 - “Selected recurring suppliers on current account.”
 - “Good communication.”
 - “Long-term contracts.”
 - “Preferably working with long-term business relationships.”
 - “Collaboration meetings.”
 - “Partnering with suppliers.”
 - “Good follow-up and well-executed projects.”
 - “Follow-up and requirements state.”
 - “Worked together for a long time.”
 - “Logistics company for just-in-time material deliveries.”
 - “Clear terms.”
 - “Constant dialogue with suppliers.”
 - “Good customer contact.”
 - “A good way to create long-term sustainability.”
 - “Kick-off meetings.”
 - “Ongoing.”
 - “Personal and appealing.”
 - “Follow-ups.”
 - “Trained in our way of building standard drawings.”
 - “Through frequent meetings with the client, UE, staff, etc., we can minimize errors and streamline production as well as a better economy.”
 - “Communication email/call.”
 - “Framework agreement suppliers.” (x 2)
 - “We work efficiently. Ordering right from the start. Thinking about waste, the right amount, lengths of wood planks, etc.”
 - “Building trust, creating a win-win situation.”
 - “Processed contacts.”
 - “Close collaboration, experience feedback.”
 - “Partners with the same concern for quality.”
 - “Follow-up and experience meetings as a standing point in all our meetings.”
 - “We are careful to take good care of our customers and that the reception and information provision takes place in a good way that promotes the projects and our relationship with the customer both in the short and long term.”
 - “Collaboration in projects.”
- For other activities:
 - “The flow through certain larger projects/works.”
 - “Own production system. Project plan with Prio 100 activities etc.”
 - “Increased communication.”
 - “ISO-certified management system.”
 - “Common sense.”
 - “Adapted to needs.”

- “Dialogue with the client.”
- “Supplier evaluation.”
- “Communication and planning.”
- “Department meetings only.”

Those “other activities” are alike to previous responses on education or communication activities.

Q21: Implementeringsgrad: Lean construction tillämpats inom (flera kryss möjliga) (Degree of implementation: Lean construction applied within (several answers possible))

Most respondents declared that they have used LC in all company projects (see Fig. 21, with the Y axis denoting the number of responses). The second largest group comprised the ones implementing LC only when clients ask for it – indicating construction companies implementing LC due to external requirements and not internal strategic choices.

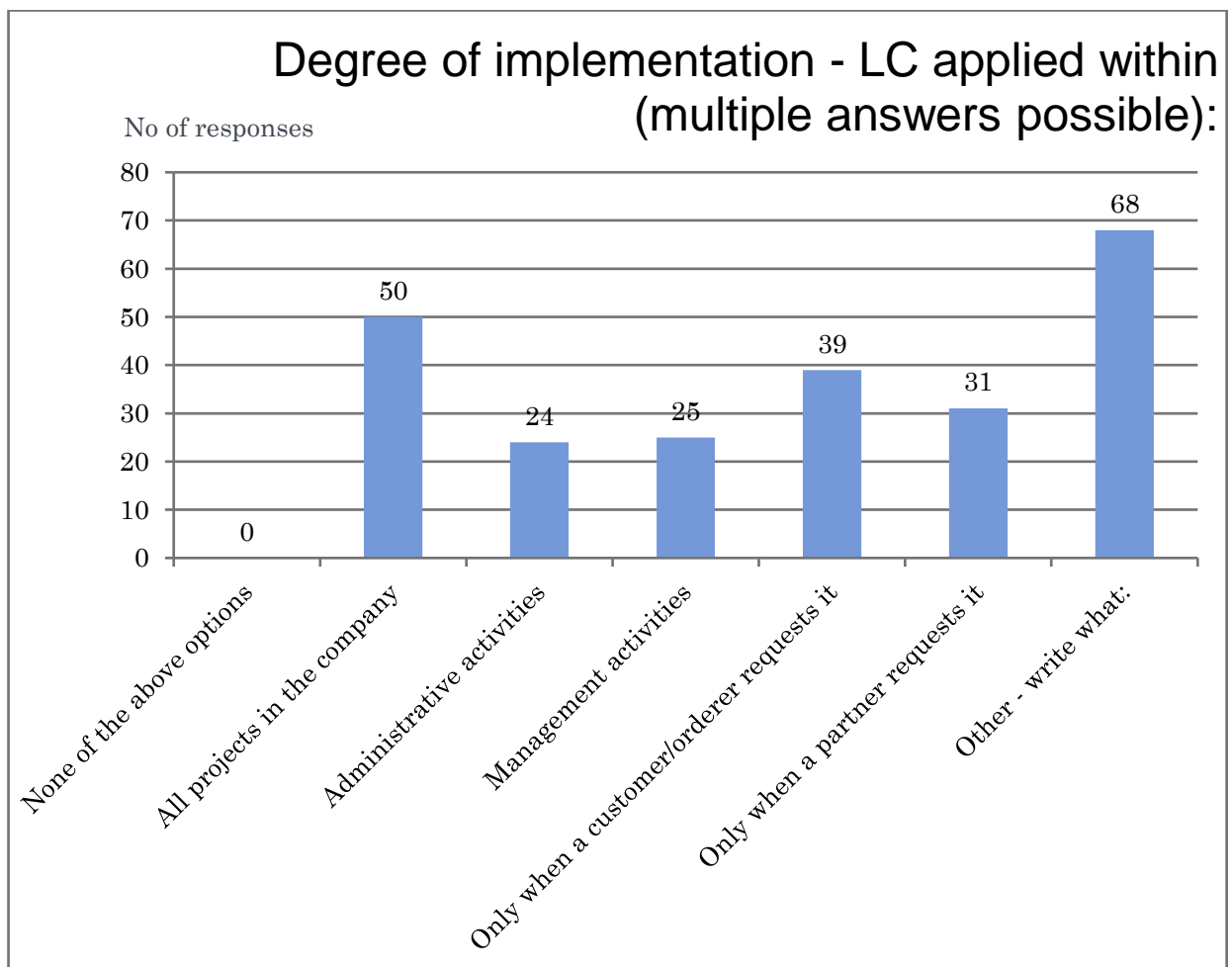


Fig. 21. Degree of implementation of lean construction within companies

When it comes to the “Other” option, 56 of 68 answers were variations of “nothing”. The rest are noted in the following (translated from Swedish):

- “We do a lot of lean but do not work with the concept.”
- “Above all in production in our factories.”

- “Partially in all projects.”
- “Where we find effects of it, in our production and planning of production.”
- “On selected projects to set the standard.”
- “More or less.”
- “In a few projects.”
- “We work with continuous improvements in production. Don't know if this can be described as lean construction.”
- “When it is meaningful.”
- “Installations.”
- “Varying application due to maturity.”
- “Previously in all projects. Now in selected projects in consultation with selected contractor.”

The last response potentially shows either a decreased or a more specific LC implementation.

Q22: Effekter: Vilka resultat har lean construction lett till i företaget? (Effects: What results has lean construction led to in the company?)

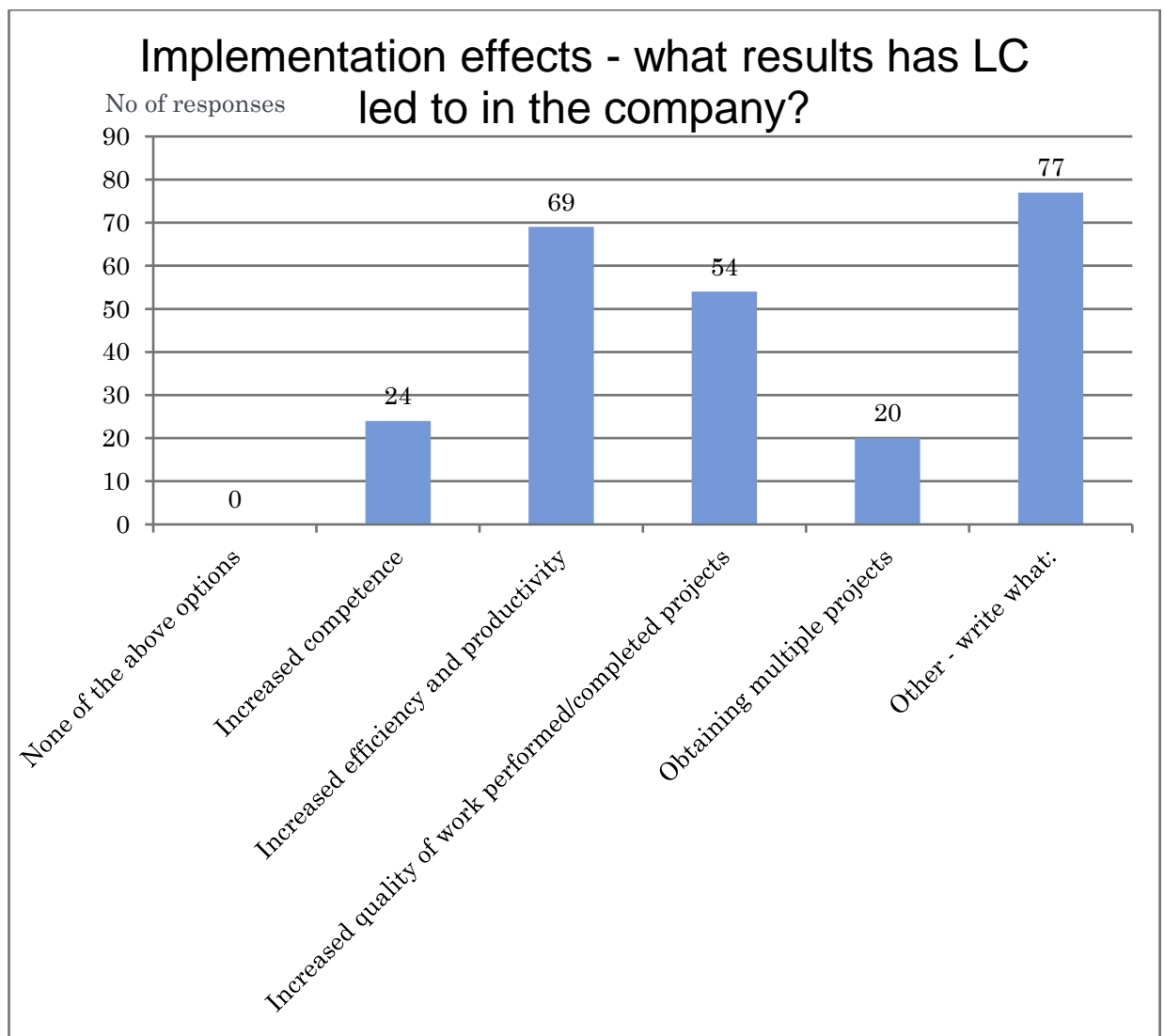


Fig. 22. Effect of lean construction implementation within companies

The last inquiry on implementation concerns results after applying LC. 77 respondents did not opt for already given choices and preferred to write their own (“Other”) responses (see Fig. 22 in the previous page, with the Y axis denoting the number of responses). 69 respondents chose the option of increased efficiency and productivity, 54 chose increased quality of performed work or completed projects.

From the 77 respondents choosing the “Other” option, 54 offered some form of a “No effect” answer, while eight answered in variations of “I don’t know”. The remaining 15 answers comprised the following (translated from Swedish):

- “Improved financial results, increased safety, more fun at work, increased sense of ‘togetherness’, cleaner buildings, etc., etc.”
- “Too few projects completed to see an effect.”
- “We get several assignments, so we deliver good projects. Regardless of whether it is due to lean or not.”
- “Nothing special yet, just started with it.”
- “Good cohesion in the project groups that work according to lean.”
- “We use lean too little to be able to assess any difference.”
- “Not measurable yet.”
- “Good self-service on the part of employees when they realize that they can be involved and influence.”
- “Still under adaptation.”
- “We have only recently started our development work, so far we have only scratched the surface.”
- “Has worked like that.”
- “We work with continuous improvements in production. Don't know if this can be described as lean construction.”
- “See above.”
- “Not fully used.”
- “Difficult to face this as it coincides with the Corona impact.”

It can be observed that most of the “Other” answers show that although LC has been implemented in the respective companies, its application has been understood as too little or at too early a stage for any noticeable results to emerge. Only three responses offered definite positive comments on LC implementation results, while two answers described good results but did not necessarily connect them to the implementation of LC.

Q23: Om du vill ta del av slutrapporten, ange din mailadress här (If you want to receive the final report, enter your email address here):

The last inquiry in the questionnaire was about providing the current report, after it is finished, to all interested participants in the survey. 48 respondents declared they would like to receive the report. Interestingly, all the interested participants belonged to private construction SMEs or medium-to-large enterprises, but none was working for the four largest construction companies in Sweden.

SYNTHESIS AND FINAL RESULTS – LEAN CONSTRUCTION VARIANTS IN PRACTICE

Through the survey, it can be shown that there is a large discrepancy of LC knowledge and practices across Sweden. In certain cases, there appears to have been a broad implementation of LC. However, most respondents declared that they did not even know what LC is, while others implemented in a piecemeal manner not allowing for postulating that LC is implemented in the same way across the whole Swedish construction sector. The implementation of LC seems to have mostly been either fragmented, or in variants.

Beside the large group of respondents answering that they do not know about lean construction, there is also a much smaller group (36 companies) claiming that they use it under another name. Moreover, even among the respondents declaring that they do not know about lean construction, there is a small group of companies that have indeed filled out the questionnaire with a set of answers to a series of LC inquiries, which indicates the opposite – i.e., that they do know about LC, yet have for various reasons not implemented it.

This result can also be expanded to communication, training, and other auxiliary activities (e.g., simulation); while there are some precise cases, most exhibited no particularly detailed application of such activities. Moreover, previous and present states of LC implementation were dissimilar in some respects – certain LC elements, like waste elimination and client value increase, have been applied in a similar way both in the past and now, but others, like Last Planner, have not.

Nonetheless, the analysis and combination of the survey results pertaining to the responses by the companies implementing LC, and the consideration of the preliminary variants emerged from the literature review, lead to the abductive identification of **four LC variants being implemented in the Swedish state-of-art in 2022-2023**. These are further explained below:

- 1. A variant related to IT-supported design.**
- 2. A production variant.**
- 3. A planning variant using Last Planner.**
- 4. A construction supply chain and logistics variant.**

As explained in the method, answers strongly pertaining to a specific LC theme (emanating from a combination of fitting elements, e.g., BIM with IT-supported design) were grouped in the analysis process to allow for identification of the practical variants. For example, this meant that for a particular variant, the summing up of the companies answering with a Likert value of 4 and/or 5 to relevant inquiries was retained, while the answers with a value of 1, 2, and/or 3 were not considered. In the variants' analysis below, the elements considered for each are described in detail.

Moreover, it should be noted that, depending on the case, there may be large overlaps among the variants. This might mean that some companies use more than one variant – and, conversely, elements that can be considered as elements of one variant, can just as well be considered as elements of another variant. It also shows that tools, processes, and methods that can be included within LC might have a wider scope than just one specific phase (e.g., design or production). Nonetheless, companies can also use, specifically, only one variant. The overlaps and juxtaposition between the variants are furtherly commented below.

The IT-supported design variant

The characteristics of the IT-supported design variant, initially informed by the literature review reflects the use of IT tools and methods supporting design in a way aligned with LC (e.g., for eliminating waste in design activities). In the survey, these include BIM, BIM 360, 4D and 5D CAD, VDC, VR, and IPD – which translates into companies choosing those responses with a Likert value of 4 or 5 in Q15: *Tillvägagångssätt (Approaches)*.

Eventually, we counted roughly 50 companies that respond that they use BIM and/or VDC to a high degree or to some extent. This variant is apparent across the three industry groups (41, 42, and 43) and in both large and smaller companies. It features juxtaposition between two or more of these digital concepts: 4D and 5D CAD, BIM, VDC, and to much lesser degree virtual reality. In other words, this means that the contractors operate a design and production setup where BIM is brought to support production as well – but it is not always implemented in conjunction with the production variant (see further below). This might may reflect that, in large contractors, there can be separate business units specializing explicitly in design or production and approaching those with a different business logic.

A point should be made that this variant does not reflect lean design per se, in the way the latter is understood in the literature in terms of elements like early client involvement, value maximization, identification of stakeholder needs, concurrent engineering, and just-in-time decision-making (e.g., see in Brookfield et al., 2004, London 2008, and Simonsson, 2008). As mentioned above, the IT-supported design variants mostly reflect an IT-powered design process that possibly can result in waste elimination in the relevant activities. Nonetheless, we should not overlook that the literature has shown some very specific Swedish cases where lean design is implemented in a more “formal” sense – like, e.g., the case of lean design realized through collocation with the Project Studio system, as the latter is implemented in NCC (Tjell 2016).

The production variant

The characteristics of the production variant include the following:

- A strong presence of the argument that “Lean construction is a tool for improving the project and construction processes”, which translates into companies choosing that response with a Likert value of 4 or 5 in Q4: *Hur väl passar följande påståenden? Flera svar är möjliga. (How well do the following statements fit? Several answers are possible.)*
- A strong consent to the philosophies “Eliminating waste and increasing value for the client”, “Transformation – Flow – Value (TFV) framework” and “Toyota production system”, which translates into companies choosing those responses with a Likert value of 4 or 5 in Q5: *Övergripande filosofier (Overarching philosophies)*.
- A strong presence of the following fields in which waste is sought to be eliminated through LC: errors, overproduction, rework, delays, non-utilization of personnel resources, value-creating activities, and inefficient resource handling. This translates into companies choosing those responses with a Likert value of 4 and/or 5 in Q6: *Verktyg – Eliminering av slöseri inom (...) (Tools – Eliminating waste in (...))*.
- A strong utilization of BIM 360, VDC, and production process analysis, which translates into companies choosing those responses with a Likert value of 4 or 5 in Q15: *Tillvägagångssätt (Approaches)*.
- A direction of the companies’ LC educational and training activities towards project managers, site managers, crafts/site workers, and officers and clerks. This translates into

companies choosing those responses in Q16: *Utbildning och/eller träning av (flera kryss möjliga)* (*Education and/or training of (multiple answers possible)*). In addition, companies elaborating more on production-related LC educational and training activities in Q17: *Beskriv utbildningsinsatserna ytterligare* (*Describe the training efforts further*) were considered. Among the responses in Q17 that were described in the survey analysis, the ones relevant to production were:

- “Development of own production system and internal training.”
 - “Quality training and quality audits.”
 - “Internal training of the lead fitter (also the rest of the team), how we set up and plan our work considering the right material at the right time, wastage, and also the end result for the customer.”
 - “The production processes.”
 - “Toyota’s production philosophy.”
- A direction of the companies’ LC communication activities towards project managers, site managers, crafts/site workers, and officers and clerks. This translates into companies choosing those responses in Q18: *Kommunikation riktad mot (specifierade) aktörer (flera kryss möjliga)* (*Communication directed to (multiple answers possible)*). In addition, companies elaborating more on production-related LC communication activities in Q19: *Beskriv kommunikationsinsatserna ytterligare* (*Describe the communication efforts further*) were considered. Among the responses in Q19 that were described in the survey analysis, the ones relevant to production were:
 - “Monthly meetings with staff where we discuss production efficiency. Through discussions we learn from each other.”
 - “Toyota.”
 - “Another way of explaining and managing the work has been started to gain a greater understanding of how we can make continuous improvements and make better decisions at each stage.”
 - A presence of other LC efforts related to production. This translates into companies giving production-related responses in Q20: *Andra insatser (Other efforts)*. This was the following:
 - “Own production system. Project plan with Prio 100 activities etc.”
 - A stated degree of LC implementation in production-related activities and processes. This translates into companies giving production-related responses in Q21: *Implementeringsgrad: Lean construction tillämpats inom (flera kryss möjliga)* (*Degree of implementation: Lean construction applied within (several answers possible)*). These were the following:
 - “Where we find effects of it, in our production and planning of production.”
 - “We work with continuous improvements in production. Don't know if this can be described as lean construction.”
 - “Installations.”

- Stated effects of LC implementation in production-related activities and processes. This translates into companies choosing “Increased efficiency and productivity” and/or “Increased quality of work performed/completed projects” in Q22: *Effekter: Vilka resultat har lean construction lett till i företaget? (Effects: What results has lean construction led to in the company?)*.

It was found that companies satisfying a combination of these production variant characteristics (as derived from their responses in the survey) were 292 in total – which reflects 62% of all 471 responses. This is a far larger number than the sum of 185 companies claiming that they know about LC (149) or know about it but use it under a different name (36) – meaning that a lot of the respondents using the production variant also belong to that subgroup of companies claiming that they don’t know about LC and yet have responded to the survey questions in a way that shows otherwise. Out of those 292 companies, 141 belonged to group 41, 37 to group 42, and 114 to group 43. This shows that most production variant users are either large or small-medium contractors that work with the construction of building projects. Nonetheless, other users also reflect specialized craft companies (e.g., painters) and other subcontractors that can be either SMEs, or larger firms. Such a result furtherly underpins our finding that most of the production seems to be taken over by various subcontractors. Interestingly, it also shows that the production variant is popular not only among companies taking up more than one segments of the production process (e.g., companies that work with various building processes), but also ones more specialized to dedicated crafts and activities (e.g., HVAC installation, or painting). What this may allude to could be that it is not only companies having a larger overview of the production process that are LC-competent, but even ones working with particular process segments. This could mean that even smaller companies and subcontractors with a narrower focus may be capable of understanding and using LC production tenets during their work and/or collaboration with the larger contractors.

Tools like BIM 360, VDC, production process analysis, and even (to a lesser degree) the TFV framework are shown to be part of this variant. However, while not explicitly found in the survey results above, an extrapolation to the literature findings allows us to assume that the production variant users working with buildings and/or infrastructural projects (which refers to most companies in groups 41 and 42, including the larger and more well-known contractors) might also be implementing many (partially) industrialized processes, including the off-site assembly of prefabricated components which are then put together along the in-situ ones on site. It is important to note that here, we do not refer to industrialized construction per se (which would be another variant that is beyond the scope of this study), but rather the use (up to a degree) of some prefabricated elements in production processes that still take place largely on site. Other extrapolations to the literature may show that in the cases of “own production systems”, “continuous improvement” and other relevant systems that some of the production variant users have claimed to implement, it means that they may implement LC tenets like product platforming, vertical integration, value flow analysis, appraisal of production PIs.

Given the discourse above, it can be argued that the production variant (and its use thereof) mainly reflects the elimination of waste and increase of value for the client during the production phase, with the focus mostly seeming to be on the optimization of production parameters that can be quantitatively appraised in the short-term. However, the survey results also show that there is a juxtaposition with the IT-supported design variant, especially considering the use of BIM 360 and VDC.

The planning variant using Last Planner

The characteristics of the planning variant using Last Planner mainly reflect a strong utilization of the elements of master plan, the percent planned completed concept, and the seven healthy flows. In the survey, this translates into companies choosing those responses with a Likert value of 4 or 5 in Q8: *Verktyg – Last Planner (Tools – Last Planner)*.

About 130 companies have indicated that they use Last Planner, including 40-60 companies which have shown in their responses that they use the different tools included in Last Planner (such as assuring having the personnel before initiating a process, or performing a master planning process). This variant has been apparent in a few large companies in groups 41, 42 and 43, as well as some craft companies in group 43 – but in general, the user companies are of all sizes. Smaller companies responding that they master Last Planner is an especially important result, because around 80% of the building process today is carried out by smaller companies being subcontracted by larger ones (including main contractors). Moreover, there is a remarkable variation in the adoption of the seven “healthy flows”. Having building material ready for a particular process scores highest and taking external conditions (such as weather) into consideration scores lowest. The Last Planner variant features a juxtaposition with BIM 360 and 5D CAD to a high degree (see below).

A far smaller number of companies (56) indicated that they use pull planning to a significant effect – and most of those did so in conjunction with Last Planner. This underpins that the planning variant is mainly reflected in the use of Last Planner. However, specific cases of companies documented in the literature to be using other planning tools in particular cases, do exist – as with, e.g., the case of Peab using visual planning (Lessing 2006).

The construction supply chain and logistics variant

The characteristics of the construction supply chain and logistics variant mainly reflect a strong utilization of LC thinking in building logistics. In the survey, this translates into companies responding with a Likert value of 4 or 5 in Q9: *Verktyg – Lean försörjning, bygglogistik (Tools – Lean supply, construction logistics)*. The use of lean on the supply chain and building logistics was also identified in the literature review.

All in all, there were 95 companies strongly using the construction supply chain and logistics variant. Remarkably, most of those used Last Planner as well. This large overlap might indicate that both variants can potentially function together in an integrated manner, and that the companies using both find value in doing so. The construction supply chain and logistics variant appeared in a few large companies in groups 41, 42 and 43, as well as some craft companies in group 43 – but in general, there were all sizes of user companies.

While not explicitly found in the survey results above, an extrapolation to the literature findings allows us to imply that the construction supply chain and logistics variant users may implement one or more of the LC tenets of vertical integration, just-in-time, increased cooperation with suppliers (by potentially including them in partnering teams and/or placing long-term agreements with them), and value-driven purchasing.

Juxtaposition of variants in single companies

Above, we identified four major variants among the Swedish companies that have responded to our survey – with the production variant being the broadest (in terms of included elements) and

strongest (in terms of the number of user companies) among them. However, the LC concepts, tools and approaches belonging to each of the variants are also used by companies in broader constellations, i.e., there are cases where more than one of the variants are used in the same company. The production variant, the planning variant using Last Planner, the use of BIM 360 and 5D CAD, and the construction supply chain and logistics variant, are shown to be the most important juxtaposed variants in one company. For example, as already mentioned, the planning variant using Last Planner is juxtaposed with the use of BIM 360 and 5D CAD. These variants cut across industry sectors 41, 42, and 43, as well as across company size.

Nonetheless, it should be noted that the opposite occurs as well, with companies implementing specific variants that differ significantly from each other. For example, 68 of the companies operating the building logistics variant, are distinct from those implementing Last Planner.

Insights related to all variants

The existence of these practical LC variants shows that the Swedish adoption of LC (when implemented in the first place) follows patterns apparent in the adoption 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). This might mean that each variant can potentially have been further customized and contextualized for the business activities, business model, corporate culture, organizational structure, and other particular demands or peculiarities of a specific company. As such, while those variants can be disseminated to interested parties via communication and training activities (e.g., workshops), it is highly probable that each party will then adapt a variant that applies most to them, and further contextualize it to make a LC variant that fits their case. This procedure of contextual customization can be considered to follow the process of conceptual translation from a framework of ideas to a specific practice, as described in Buser et al. (2021). While initiatives do exist (e.g., see Lean Forum Bygg in Sweden, and IGLC internationally), those mostly stem from professional associations supporting, investigating, and advocating for the implementation of LC, rather than creating policies or legally binding frameworks.

DISCUSSION

This section will problematize and offer some critical insights about the synthesized result of the questionnaire survey, as well as adding some points from the literature review.

While the major result of our investigation is the large number of companies not implementing any of LC variants, it is also very remarkable that some 150 companies do use LC tools, methods, and approaches. Those companies cover all sizes (in terms of turnover and/or employees), including the SMEs, as well as all three of the investigated industry sectors (41, 42, and 43). As 80% of the construction process is probably carried out by SMEs being subcontracted to larger companies, it is very important to note that some of the smaller companies acting as subcontracting -all other equal- *can* participate in, for example, Last Planner meetings on site, or other activities that require cooperation and coordination.

Although there is a large output of Swedish research literature on LC, not all research efforts have gone beyond theoretical conceptualizations, and have featured (generally narrow) empirical content on Swedish LC practices – and so far, those that have, did not point to the identification of LC practice variants. The investigated companies have selectively adopted LC processes and tools (especially in field operations) and respond that they evaluate their on-site productivity and deliverable quality has been improved. This had already been flagged as a practically unresolved issue since 2006 in Björnfot (2006), but conclusive proposals to overcome it have yet to be offered. Moreover, a few empirical studies exemplify certain LC practices, but do not elaborate on their actual positive or negative outcomes, nor to which LC variants they may point.

London (2008) argued that LC principles do not account for the organizational context. Indeed, the analysis of most reviewed empirical studies in the literature shows that, in some contexts, LC is initially approached with an effort to tailor the organization to lean, rather than the opposite. However, the emergence of LC variants in our survey does show that, eventually, the focus in the Swedish context has shifted on shaping LC into what is needed.

The pragmatic and not systematic combination of paradigms in many of the reviewed studies in the literature review, may raise inquiries on the achieved results of these contributions. There is a very strong focus on industrialized construction specifically, which may be misaligned with its actual market share in Sweden. Current observations on Swedish industrialized construction also show that there is a centralization tendency; whereas the relative market has not altered significantly in size over the past several years, there are presently fewer firms sharing it (Steinhardt et al. 2020). Indeed, research on the LC variants in the non-industrialized construction sector in Sweden (as is the case of the survey in the current report), may yield richer results in understanding practical LC implementation in Sweden.

A comparison could be drawn between the connection of the preliminary LC variants found in the research literature, and what has been happening in the construction praxis itself. Where some of the latest literature studies captured facets of the state-of-art at the time (e.g., Simu and Lidelöw 2019; Popovic 2020; Uusitalo and Lavikka 2020), it is not unlikely that research may lag practical LC developments, in subject areas like professional education and standardization, digitalization, project planning, logistics, stakeholder cooperation, and leadership (Lidelöw et al. 2019). At the same time, in some academic writings there is still a rhetoric that draws back to older perceptions about LC (especially regarding production-oriented variants), which has been criticized in other research (e.g., see already in Björnfot (2006), pp. 14–18). Resolving this tension would be beneficial for the Swedish context and could simultaneously serve as a benchmark for other

contexts facing similar issues. For this resolving, we could also reflect to the work by Gibbons et al. (1994), where they point to a co-production of knowledge between the industry and the academia and reject a linear impact of research on practice. In the case of the Swedish construction sector, we could even consider that this knowledge is mostly going from the industry to research.

The questionnaire survey's overall 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. Nonetheless, among the respondents that *are* working with LC, the analysis shows that there are four discernible LC variants implemented in practice:

- 1. A variant related to IT-supported design.**
- 2. A production variant.**
- 3. A planning variant using Last Planner.**
- 4. A construction supply chain and logistics variant.**

The production variant is the strongest (in terms of the number of user companies) and the broadest (in terms of the included parts) of those four major variants. Interestingly, there are instances where the LC principles, tools, and techniques of more than one of the variants are used in a single company or utilized by businesses in broader constellations. The most significant among these overlaps are demonstrated to be the production variant, the planning variant using Last Planner, the utilization of BIM 360 and 5D CAD, and the construction logistics and supply chain variant. This can pertain to companies of all sizes and belonging to all three of sectors 41, 42, and 43. Yet, it should be highlighted that the opposite also occurs, with companies using specific variants that are different from one another.

The existence of these practical LC variants shows that the Swedish adoption of LC follows patterns apparent in the adoption of many other management concepts – i.e., picking parts of the full concept and shaping it to company needs, thus giving the adoption different scopes in the building processes and firms (Kamp et al. 2005). This might mean that each variant will potentially be further customized and contextualized for the business activities, business model, corporate culture, organizational structure, and even local peculiarities of a specific company. As such, while those variants can be disseminated to interested parties via communication and training activities (e.g., workshops), it is highly probable that each party will develop variants that apply most to them, and further contextualize it to fit their case. This procedure of contextual customization can be considered to follow the process of conceptual translation from a framework of ideas to a specific practice, as described in Buser et al. (2021).

The survey is focused on – if you like – more conventional construction practices and other LC variants than the industrialized construction one. LC research, training, information, and dissemination may need to be redirected to also meet the demands of the rest of the industry better. Moreover, most reviewed studies (that had an empirical orientation) have focused 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 an improved basis of LC knowledge in the Swedish context. In that vein, an improved facilitation of LC in Swedish companies about practical LC implementation (Kifokeris and Löwstedt 2021). Furthermore, 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 company needs (i.e., the LC variants), thus vesting the adoption with different scopes within construction processes and firms (Kamp et al. 2005).

The large number of respondents not knowing what LC is, as well as the identified practical LC variants, are alluded in a recent industry-wide research report on the state of productivity in the Swedish construction sector (Koch et al. 2020)—where, according to interviewed site managers, only about a third of projects feature LC. In those cases, whereas process parameters (e.g., omission of disturbances, schedule punctuality) are reported to have been improved, the production costs are evaluated as higher in all price ranges compared with the average of the other studied projects (Koch et al 2020). This result may indicate that understanding which LC variant to implement and how, is a continuous issue – and that the Swedish industry needs an even deeper LC competence for a requirements-driven LC adoption by focusing on the scope of implementation.

This study’s results can relate to the journey of the Swedish adoption of LC – which, while being outside the direct focus of the current study, can be reflected upon. The Swedish construction sector was not among the early adopters of LC, and when the LC diffusion began, central LC elements had already been developed internationally. Nevertheless, when adopting LC, the institutional challenges faced by Swedish construction management still appear to be broadly the same as elsewhere—such as the resistance to top-down-initiated change, and the lack of support to site managers’ LC implementation (Koch et al. 2015). Moreover, training offers, and other institutional support were established approximately in 2009, when the interpretation of LC as mostly factory production was apparently more dominant. This was likely influenced by Swedish manufacturing including the automotive industry, which had been actively adopting LM, drawing on the trend reported in Womack et al. (1990), as well as on the Toyota production system (Liker 2004). Beside this early dominance however, the emergence of other LC practice variants indicates that, eventually, the Swedish adoption of LC follows the “picking parts” pattern described earlier. The evolution of practical LC adoption in Sweden is also reflected in the extrapolation of the preliminary LC practice variants emerged from the literature review. The design and planning variants, while sporadically reflected in earlier studies, generally emerged more prominently later. Finally, the production strategy and logistics and supply chain variants are more clearly reflected in some of the later studies. This could (speculatively) inform the understanding of the implemented LC variants in the 2022-2023 Swedish state-of-art – keeping in mind, however, that the survey results indicate five variants, namely fewer than the preliminary variants traced in the literature review.

All in all, this study has showed that there is a large discrepancy of LC knowledge and practices across Sweden. While there have been some precise cases of undertaking communication, training, and other auxiliary activities (e.g., simulation), we still know little about the majority. Moreover, previous and present states of LC implementation appear to be dissimilar – certain LC elements, like waste elimination and customer value increase, have been comparably applied in the past and now, but others, like pull planning and Last Planner, have gone through phases of varied application. As already mentioned, from this analysis of the responses of companies that *have* been implementing LC, five practical LC variants have emerged: (1) a variant related to IT-supported design, (2) a production variant, (3) a planning variant using Last Planner, and (4) a supply chain and logistics variant focused on partnerships with suppliers. Compared to the preliminary variants found in the literature review, the variants found in Swedish LC practice through the survey are fewer (four instead of six), more narrowly defined, and more simplified – indicating that, in practice, only specific LC elements have been more popular (e.g., Last Planner).

Such an implementation can either pertain to project portfolios or be required by clients – and is more visible in large contractors and some SMEs (mostly HVAC installers) claiming to be LC-competent. Moreover, the emergent practical LC variants show that the Swedish adoption of LC (when it happens in the first place) follows patterns apparent in the adoption 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. This might mean that each variant could be further customized to fit the business activities, business model, corporate culture, organizational structure, and even local peculiarities of a specific company. As such, while those variants can be disseminated to interested parties via communication and training activities, it is highly probable that each party will then take the variant that applied most to them, and further contextualize it to completely fit their case. This contextual customization can be considered to follow a process of conceptual translation from a framework of ideas to specific practice – albeit not on a very high level, as LC has not yet been the subject of wider-scale Swedish and/or international policies in the same way that concepts like sustainability have. While such initiatives do exist, they mostly stem from professional associations advocating for LC implementation, rather than creating policies or legally binding frameworks.

This is the first Swedish research study investigating the LC state-of-art of industrial practice on such a scale – and to the best of our knowledge, the first study doing so in any national context. As such, it could offer a research template to extrapolate in other construction sectors and thus aid in developing a versatile understanding of LC practices. More importantly, it provides empirical evidence of a Swedish state-of-art that differs from the one found in previous, narrower studies. It also shows that the diversified implementation of LC in Sweden departs from a more “purist” understanding of LC. As such, LC research, training, information, and dissemination, might need redirection to realistically meet industry demands. In parallel, LC practice should possibly be informed by a combination of top-down and bottom-up strategizing. Finally, a stronger cross-industry collaboration may be needed for facilitating LC knowledge and practice in Sweden.

CONCLUSIONS

Some Swedish contractors have been using lean construction (LC) since around 2007. The 16 years leading up to 2022–2023 showed an increase in Swedish interest in LC research. Numerous BSc, MSc, Licentiate, and PhD theses have also been written since 2007, in addition to hundreds of pertinent articles. This appears to demonstrate that the debate over whether LC can aid in solving problems in Swedish construction has remained active, both in terms of persistent difficulties (such as productivity, efficiency, and value creation) and newly emerging ones (e.g., climate goals, unstable markets, inflation). However, up until now, not much empirical evidence has been provided on the sector-level LC practice. By conducting a study of the current practice of LC in the Swedish construction sector, this project sought to clarify the current state-of-the-art for Swedish LC. In doing so, it also identified variations in which LC is practically applied in Sweden.

The study's methodology entails a thorough analysis of previous Swedish LC research with some (although limited) empirical material, followed by a sector- and country-wide questionnaire survey that targets all construction-related businesses in Sweden (apart from industrialized house builders). The companies were questioned regarding their use of LC in their practice, including what, when, and how much. Abduction was used to qualitatively synthesize the findings after the study of the literature review and the survey answer data.

The analysis of the research-based literature included themes of industrialized construction versus conventional construction, process coverage (design, production, partnering and stakeholder collaboration, planning, strategy, supply chain), and research paradigms (systems theory, business economics, organizational behavior, interpretivism). In the research-based literature industrialized construction received a disproportionate amount of scientific attention compared to its market share. Even if using prefabricated parts and other specific off-site aspects is a well-established practice, on-site production still accounts for the majority of building in Sweden.

The problematizations deriving from the literature review served as the background of the survey conducted from August 2021 to January 2022. Targeting 1342 companies, it received 471 valid responses, thus having a 35% response rate. The survey showed that there is a discrepancy of LC knowledge and practices across Sweden. In certain (few) cases, there has been a precise and well-adapted implementation of LC. However, 286 out of 471 respondents (i.e., 61% of the total responses!) claimed to not even know what LC is, a small group respond they apply LC under other names, while others applied it by accommodating elements of the LC concepts shaped to fit company processes. Moreover, there have been responses indicating precise cases of undertaking communication, training, and other auxiliary activities (e.g., simulation). Previous and present states of LC implementation showed changes in emphasis over time for the companies: certain LC elements, like waste elimination and customer value increase, have been comparably applied in the past and now, while for others, the degree with which they have been used has changed. An example in the latter category is Last Planner, which used more in the current practice than in the past.

From the analysis of the responses of companies that have been implementing LC, five practical LC variants have emerged: (1) a variant related to IT-supported design, (2) a production variant, (3) a planning variant using Last Planner, and (4) a supply chain and logistics variant focused on partnerships with suppliers. Compared to the preliminary variants found in the literature review, the variants found in Swedish LC practice through the survey are fewer (five instead of six), more narrowly defined, and more simplified – indicating that, in practice, only specific LC elements

have been more popular (e.g., last planner). It should be noted that as industrialized house builders were not in the focus of the survey, the industrialized construction variant is absent on purpose.

Identifying these LC practice variants, can be the first step in tackling LC issues within the Swedish sector – even extending to the role of the value stream, accounting for the organizational context, considering cultural and social aspects to expand or overcome the focus on technical process parameters, increasing the effort of improving mainstream construction, and better capturing the state-of-art. It is tempting to extrapolate these findings to other countries; however, construction sectors can vary significantly, and generalization attempts should therefore be avoided.

The practically implemented LC variants show that the Swedish adoption of LC follows patterns apparent in the adoption of many other management concepts – i.e., selecting parts of the full concept and shaping it to local needs, thus giving the adoption different scopes in the building processes and firms. This might mean that each variant could be further customized to fit the business activities, business model, corporate culture, organizational structure, and even local peculiarities of a specific company. As such, while those variants can be disseminated to interested parties via communication and training activities, it is highly probable that each party will then take the variant that applied most to them, and further contextualize it to better fit their case. For example, our survey has shown that the concept of overproduction and the pull planning method do not fit with the way LC is practically implemented in Sweden – while the concept of eliminating waste (i.e., non-value-adding activities) is strongly visible in Swedish LC implementation. This contextual customization can be imagined following a process of conceptual translation from a framework of ideas to specific practice. Promotional initiatives do exist, but they mostly stem from professional associations advocating for LC implementation, rather than creating policies or legally binding frameworks.

To the best of our knowledge, this is the first Swedish research project to look at the LC state-of-the-art on this scale. It offers empirical proof of a Swedish state-of-the-art that is distinct from the one discovered in earlier, more narrow investigations. Moreover, it demonstrates how different the Swedish approaches to LC are from a more "purist" interpretation of LC. Therefore, it may be necessary to refocus LC research, education, information, and distribution to effectively fulfill market expectations. Parallel to this, LC practice may benefit from a bottom-up and top-down strategic approach. The facilitation of LC knowledge and practice in Sweden might also require a deeper cross-industry collaboration.

Future work can include the continuation of the present study into shaping the way forward for practical LC implementation in Sweden. Problems that LC is said to have resolved (such as high production costs) are still present, which suggests that additional research should be done. This could also focus on how LC affects organizational demands, culture, value streams, development, and human interaction in addition to processes. This can include the enrichment of the identified variants with an increased focus on social and cultural aspects, factors that may act as driving forces of LC adoption (e.g., innovation, digitalization), and processes and tools able to help attaining industry and company demands. Finally, and crucially, the integration of sustainability and circularity with LC should be considered, as those constitute major challenges both for Sweden but also on a global scale. Such an integration could be facilitated by a stronger focus on processes like end-of-life disassembly instead of demolition, an understanding production oriented to recycling and reusing, and taking account of institutional forces facing the onset of sustainability.

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APPENDIX A

Publications connected to this research project

- Kifokeris, D. (2021). Variants of Swedish lean construction practices reported in research: a systematic literature review and critical analysis. *Journal of Construction Engineering and Management*, 147(7), 05021005.
- Kifokeris, D., Bahnariu, B., and Koch, C. (2022). A mapping of Swedish lean construction variants in practice: review and survey. In: *Proceedings 38th Annual ARCOM Conference* (461-470). Glasgow: ARCOM.
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- Kifokeris, D., and Löwstedt, M. (2021). Lost and found in translation: top-down decoupling and bottom-up recoupling of strategies and practices in construction production. In: Scott, L., and Neilson, C.J. (eds.). *Proceedings 37th Annual ARCOM Conference* (532-541). UK: ARCOM.
- Tezel, A., Kifokeris, D., Koskela, L., Formoso, C., and Koch, C. (2022). A conceptual framework for lean construction and blockchain synergy. In: *Proceedings IGLC-30* (576-587). Edmonton: IGLC.

APPENDIX B

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APPENDIX C

Questionnaire in Survey Monkey

Enkät: Läget för lean construction i Svensk byggbransch

Introduktion

Denna undersökning genomförs i samarbete med Byggföretagen och Installatörsföretagen. Högskolan i Halmstad och Chalmers Tekniska Högskola samarbetar kring genomförandet av enkäten.

Enkäten handlar om lean construction i Svensk byggbransch: Tillämpning, innehåll, implementering, och effekt. Enkäten besvaras av ansvariga för ca 600 bygg- och anläggningsföretag i ett representativt urval.

Syftet med denna undersökning är att stimulera och vägleda förbättringsinsatser. Om ni vill ta del av slutrapporten, skriv in er mailadress på enkätens sista sida.

Svaren behandlas anonymt och presenteras endast tillsammans med svar från flera projekt.

Enkät: Läget för lean construction i Svensk byggbransch

Bakgrundsinformation

*** 1. Företagets namn**

* 2. Din roll i företaget

- Ledare (VD), avdelningschef, funktionschef
- Projektledare, platschef
- Ingenjör
- Annan (var god ange)
- Tjänsteman
- Byggnadsarbetare, Hantverkare



Enkät: Läget för lean construction i Svensk byggbransch Kännedom om lean construction

* 3. Känner ni till vad lean construction är och vad detta kan användas till?

- Ja, vi känner till lean construction
- Ja, vi känner till lean construction, men vi använder det under ett annat namn
- Nej, vi känner inte till lean construction



Enkät: Läget för lean construction i Svensk byggbransch Kännedom om lean construction

Även om det finns många begrepp om lean construction, anses det generellt att syfta till att eliminera slöseri och öka värdet för kunden.

Nu kan du vänligen fortsätta med enkäten!

Enkät: Läget för lean construction i Svensk byggbransch

Egen uppfattning av lean construction (egen definition)

* 4. Hur väl passar följande påståenden? Flera svar är möjliga.

	Inte alls				Mycket väl		Vet ej
Lean construction är sunt förnuft	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lean construction är verktyg för att förbättra projekt/byggprocess	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lean construction är en företagsfilosofi	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Annat (skriv vad)

Enkät: Läget för lean construction i Svensk byggbransch

Faktorer av lean construction företaget tillämpar (faktorerna är inte ordnade nedan)

Enligt din värdering, vilka faktorer eller delar av lean construction har företaget tillämpat? Använd denna betygssättning.

- 5: I hög grad
- 4: I en viss omfattning
- 3: Det händer
- 2: Sällan
- 1: Inte alls

* 5. Övergripande filosofier

	1	2	3	4	5	Ej tillämplig
Eliminera slöseri, öka värdet för kunden	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
TFV: Transformation - Flöde - Värde (Transformation - Flow - Value)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Toyota produktionssystem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 6. Verktyg

Eliminering av slöseri inom:

	1	2	3	4	5	Ej tillämplig
Fel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Överproduktion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Omarbetning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Väntan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ej utnyttjande av sina personalresurser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Transporter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lager	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Värdeskapande aktivitet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Oeffektivt hanterande med resurser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 7. Verktyg**

	1	2	3	4	5
Dragplanering (pull planning, Kanban)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 8. Verktyg**

Last Planner

	1	2	3	4	5	Ej tillämplig
Master plan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Procent planerad färdiggjord (percent planned completed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (1) Handlingar färdiga	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (2) Arbetsplats förberedd	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (3) Maskiner, verktyg på plats	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (4) Manskap färdig	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	1	2	3	4	5	Ej tillämplig
Förbereda sju hälsosamma flöden: (5) Byggmaterial	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (6) Relaterat arbete klar	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (7) Externa förhållande (t.ex. vädret)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 9. Verktyg

	1	2	3	4	5	Ej tillämplig
Lean försörjning (lean supply), bygglogistik	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Annan (var god ange)



Enkät: Läget för lean construction i Svensk byggbransch

Faktorer av lean construction som företaget *tidigare* har tillämpat
(faktorer är inte ordnade nedan)

Enligt din värdering, vilka faktorer eller delar av lean construction har företaget tillämpat? Använd denna betygssättning.

5: I hög grad

4: I en viss omfattning

3: Det händer

2: Sällan

1: Inte alls

* 10. Övergripande filosofier

	1	2	3	4	5	Ej tillämplig
Eliminera slöseri, öka värdet för kunden	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
TFV: Transformation - Flöde - Värde (Transformation - Flow - Value)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Toyota produktionssystem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 11. Verktyg

Eliminering av slöseri inom:

	1	2	3	4	5	Ej tillämplig
Fel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Överproduktion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Omarbetning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Väntan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ej utnyttjande av sina personalresurser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Transporter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lager	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Värdeskapande aktivitet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Oeffektivt hanterande med resurser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 12. Verktyg**

	1	2	3	4	5
Dragplanering (pull planning, Kanban)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 13. Verktyg**

Last Planner

	1	2	3	4	5	Ej tillämplig
Master plan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Procent planerad färdiggjord (percent planned completed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (1) Handlingar färdiga	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (2) Arbetsplats förberedd	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (3) Maskiner, verktyg på plats	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (4) Manskap färdig	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	1	2	3	4	5	Ej tillämplig
Förbereda sju hälsosamma flöden: (5) Byggmaterial	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (6) Relaterat arbete klar	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Förbereda sju hälsosamma flöden: (7) Externa förhållande (t.ex. vädret)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 14. Verktyg

	1	2	3	4	5	Ej tillämplig
Lean försörjning (lean supply), bygglogistik	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Annan (var god ange)



Enkät: Läget för lean construction i Svensk byggbransch Andra tillvägagångssätt som tillämpats för att underlätta lean construction

Vilka andra tillvägagångssätt har företaget tillämpat för att underlätta lean construction?

- 5: I hög grad
- 4: I en viss omfattning
- 3: Det händer
- 2: Sällan
- 1: Aldrig

*** 15. Tillvägagångssätt:**

	1	2	3	4	5	Ej tillämplig
Kommunikation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ledarskap	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Organisation av arbete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM (Building Information Modelling)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM 360	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4D CAD: Fyra dimensionell datorstödd projektering (fjärde dimension är tidsplanering)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5D CAD: Fem dimensionell datorstödd projektering (femte dimension är kostnader)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
VDC (Virtuell Projektering och Produktion)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
VR (Virtual Reality visualisering)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
IPD (Integrated Project Delivery)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Six Sigma	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Produktionsprocessanalys	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Värdeflödesanalys	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Andra IT teknologier eller insatser, ange vilka:



Enkät: Läget för lean construction i Svensk byggbransch Implementering

Vilka insatser har genomförts för att tillämpa lean construction?

*** 16. Utbildning och/eller träning av (flera kryss möjliga):**

Ledare (VD), avdelningschef, funktionschef

Projektledare, platschef

Ingenjörer

Tjänstemän

Byggnadsarbetare, Hantverkare

Annan (var god ange)

17. Beskriv utbildningsinsatserna ytterligare:

*** 18. Kommunikation riktad mot (flera kryss möjliga):**

Ledare (VD), avdelningschef, funktionschef

Projektledare, platschef

Ingenjörer

Tjänstemän

Byggnadsarbetare, Hantverkare

Annan (var god ange)

19. Beskriv kommunikationsinsatserna ytterligare:

*** 20. Andra insatser:**

Användning av
spel (t.ex. SIM
LEAN) - skriv hur:

Simulering - skriv
hur:

Långsiktiga
leverantörsrelatio
ner - skriv hur:

Annat - skriv vad:

*** 21. Implementeringsgrad**

Lean construction tillämpats inom (flera kryss möjliga):

Alla projekt i företaget

Bara när en kund/beställare efterfrågar
det

Administrativa aktiviteter

Bara när en samarbetspartner
efterfrågar det

Ledningsaktiviteter

Annan (var god ange)

*** 22. Effekter**

Vilka resultat har lean construction lett till i företaget?

Ökad kompetens

Ökad effektivitet och produktivitet

Ökad kvalitet på utfört arbete/färdigställda projekt

Erhåller flera projekt

Annan (var god ange)



HÖGSKOLAN
INGÅNGSD

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CONCRETE FOR
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BYGGFÖRETAGEN

IN
Installatörföretagen

Enkät: Läget för lean construction i Svensk byggbransch

Anmälan åt slutrapport

23. Om du vill ta del av slutrapporten, ange din mailadress här: