

**Lean, produktivitet, kvalitet og samarbejde i byggeriet:
Et litteraturstudie**

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1. Introduktion

Dette notat præsenterer resultater fra internationale et litteraturstudie af videnskabelige artikler om sammenhængen mellem lean, produktivitet, kvalitet og samarbejde i byggeriet. Det bør ikke ses som en udtømmende gennemgang, og det vil ikke forsøge at korrelere fund fra forskellige undersøgelser ved at kvantificere konkrete effekter på tværs af studier.

Formålet er alene at synliggøre de relationer andre studier har identificeret mellem anvendelse af lean og effekten på produktivitet, kvalitet og samarbejde i byggeriet. Litteraturstudiet er foretaget som led i en undersøgelse om ”Lean i renoveringsprojekter” som Lean Construction DK gennemfører med støtte fra Grundejernes Investeringsfond og Realdania.

Rapporten er struktureret i fire hovedkapitler. I kapitel 2 redegøres kort for projektets grundlag, hvorefter kapitel 3 indeholder en gennemgang af det metodiske og empiriske grundlag for studiet. Kapitel 4 analyseres på tværs af de forskellige kilder og at udlede forhold, der ifølge den anvendte litteratur påvirker produktivitet, samarbejde og kvalitet i byggeriet. Dette består af en sammenfatning af faktorer, der har indflydelse på produktiviteten på tværs af de forskellige undersøgelser. Bilaget indeholder en skematisk oversigt over undersøgelserne og resultaterne.

Det skal bemærkes at litteraturstudiet er gennemført under væsentlige begrænsninger grundet de ressourcer, der er afsat i projektet. Litteraturstudiet, analyserne og notatet er udarbejdet på tre dage i juni og juli 2020. Dette betyder i sagens natur, at den omfattende kodning af materialet er baseret på tentative individuelle vurderinger, og er ikke blevet kvalitetssikret eksternt. Resultaterne skal derfor tages med et vist forbehold, selvom det vurderes, at de overordnede resultater og konklusioner der drages er retvisende.

2. Lean i renoveringsprojekter

Lean i renoveringsprojekter er et projekt, der gennemføres i samarbejde mellem Lean Construction-DK og LivingLean, med bistand fra BUILD, Aalborg Universitet til at validere metoder og resultater.

Projektet har til formål at undersøge, hvorvidt anvendelsen af lean i renoveringsprocessen øger produktiviteten, kvaliteten og styrker samarbejdet i renoveringsprojekter. Projektet gennemføres som et interventions- og følgestudie på to renoveringssager, hvor LivingLean afholder workshops og sparrer med projektdeltagere med henblik på at fremme dialog og samarbejde.

Som et led i dette arbejde, gennemfører BUILD et litteraturstudium med henblik at afdække mulige relationer mellem anvendelse af lean og øget effektivitet, styrket samarbejde og bedre kvalitet. Dette skal bruges som grundlag for dataindsamling og en kommende vurdering af, hvorvidt anvendelsen af lean, dialog og inddragelse øger alle aktørers indsigt og forståelse for processen, og resulterer i bedre samarbejde og højere produktivitet.

3. Metode og tilgang

Denne undersøgelse er blevet udført som et systematisk litteraturstudie. Målet har været at indsamle information om sammenhænge mellem leanindsatser, produktionsfaktorer og effekter/resultater, som de er rapporteret i videnskabelige studier og rapporter. Vores interesse har været i specifikke undersøgelser, der har produceret eller rapporteret primære data om disse forhold.

Litteraturstudiet - Søgning

For at identificere undersøgelser, der rapporterer om forholdet mellem anvendelse af lean og effekten på produktivitet, samarbejde og kvalitet, foretog vi en gennemgang af den akademiske litteratur. Vi søgte efter dokumenter i flere databaser, herunder Scopus og Google Scholar som de primære databaser. Google Scholar blev brugt i den første runde af relativt ustruktureret søgning, der fokuserede på at identificere artikler, der rapporterede data på undersøgelsens område. Dette førte til identifikationen af nogle få udvalgte artikler hvis emne og nøgleord blev brugt i den efterfølgende strukturerede Scopus-søgning. Et eksempel på anvendte søgetermer og metodik ses nedenfor:

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Søgestreng scholar:
- "lean construction" productivity factors (9.570 hits i google scholar)

Søgestreng Scopus:
- ALL ( "lean construction" AND productivity AND factors ) AND (
  LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( EXACTKEYWORD ,
  "Productivity" ) ) AND ( LIMIT-TO ( EXACTKEYWORD , "Lean Construction"
  ) ) 12 hits
- KEY ( "lean construction" AND productivity AND factors ) 5 hits
- KEY ( "lean construction" AND productivity AND factors ) 106 hits
- KEY ( "lean construction" AND productivity ) AND ( LIMIT-TO ( SRCTYPE
  , "j" ) ) 31 hits

KEY ( "lean construction" ) AND refurbishment AND productivity - 13 hits
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Figur 1. Søgestreng

Datagrundlaget

Scopus-søgningen resulterede i identificeringen af samlet 43 artikler, der indgår i analysen. Det er værd at bemærke, at søgningen blev afgrænset til at omfatte alene videnskabelige artikler og dermed ikke rapporter eller anden litteratur. Årsagen hertil er, at artikler er underkastet en (relativ omfattende) fagfællebedømmelse, som burde sikre et minimum af kvalitet.

De 43 artikler, som er udvalgt er en begrænset delmængde af de mere end 100 artikler, som litteratursøgningen producerede. Alle artikler blev således hurtigt læst med henblik at screene dem

for resultater, der kunne bruges i denne undersøgelse. Adskillige artikler, der indeholdt de for undersøgelsen relevante nøgleord, viste sig således at behandle disse forhold overfladisk eller på anekdotisk niveau – eller blot gengive data fra andre studier. De 43 artikler i denne undersøgelse indeholder alle primære data om sammenhængen mellem lean, produktivitet, samarbejde og/eller kvalitet. Blandt de 43 artikler, er endvidere udvalgte artikler, som forfatteren af dette notat havde førstehåndskendskab til, men som ikke dukkede op i litteratursøgningen.

Det er videre relevant at notere sig, at nylige studier af lean og produktivitet, som er gennemført en dansk kontekst (se fx Neve og Wandahl, 2018a) ikke er medtaget af disse årsager. Denne type af litteratur, som vi er bekendt med, indgår på anden vis i øvrige dele af projektet. Alle artikler fremgår af litteraturlisten.

Dataanalyse og kodning

Efter at have identificeret de forskellige artikler blev hele de enkelte dokumenter gennemlæst med fokus på resultater og anvendte metoder. Alle artikler blev kodet. For at spare tid blev kodningen gennemført på en kombination af engelsk og dansk. Oplysninger om de enkelte artikler blev struktureret i følgende kategorier (hvor relevant):

- Name of paper
- Country of origin
- Productivity definition employed
- Level of analysis
- Type of study
- Methodologies employed
- Input data
- Output measure for productivity
- Main findings
- Factor influencing productivity
- Additional data presented
- Miscellaneous notes about the study

Figur 2. Oplysninger om artikler anvendt i kodningen

Kodningen på dette niveau er ufuldstændig, da ressourcerne blev anvendt på at kode resultaterne fra artiklerne fuldstændigt. I relation til de faktorer, som influerer på produktiviteten, blev artiklerne kodet efter følgende kategorier:

- Resultat
- Metadeskriptor (resultat)
- Fokusområde for indsats

- Metadeskriptor (indsats)
- Påvirkningsfaktor
- Metadeskriptor (faktorer)
- Korrelation (faktor til resultat)
- Projekttype
- Potentialemålingsfaktor
- Potentialemålingskategori
-

Figur 3. Kategorier i kodningen af indholdet artiklerne i litteraturstudiet

Data er struktureret således, at der er identificeret fokusområder for en indsats, faktorer der påvirker indsatsen og stipulerede resultater heraf samt korrelationer mellem påvirkningsfaktorer og resultater. De forskellige indsats, resultater og påvirkningsfaktorer er identificeret empirisk og er meget heterogene. Der er derfor foretaget en gruppering på forhold et en overordnet kategorisering (benævnt metadeskriptor) for indsats, påvirkningsfaktorer og resultater for at operere med et mere overskueligt antal relationer.

Hver artikel kan indeholde flere af disse elementer. En artikel kan fx omtale 20 forskellige faktorer (fx batch size eller standardisering), som påvirker et resultat hhv. negativt eller positivt. Fx er batch størrelse (påvirkningsfaktor) negativt korreleret med gennemløbstid (fokusområde for indsats) hvilket giver mere waste (resultat).

For at illustrere dette, identificeredes i alt 246 forskellige (lean-relaterede) faktorer, som ifølge artiklerne har en mulig indflydelse på produktivitet, samarbejde eller kvalitet. Disse blev reduceret til 21 overordnede faktorer som eksemplificeret nedenfor.

Metadeskriptor	Påvirkningsfaktor
Lokation	<ul style="list-style-type: none"> - Continuity of space (sequential progression) - Factory layout - Good weather - Optimizing the site conditions - Multi-functional layout on jobsite - Keeping needed items in the right places - Weather
Materiel	<ul style="list-style-type: none"> - Amount of equipment - Equipment breakdown - Improper equipment capacity - Poor quality of power tools - Equipment availability

Tabel 1. Eksempel på kodning af identificerede påvirkningsfaktorer

Tabellen skal læses på den måde, at vi identificerede 7 faktorer omhandlede "Lokation" der ifølge artiklerne har en indflydelse (positiv eller negativ) på opnåelse af et givent resultat. Den fulde tabel ses i bilaget (Tabel 9). Flere de 21 kategorier består af ganske få faktorer, og vil blive lagt sammen med andre faktorer i en kommende revision af kodningen.

Alle artikler blev kodet i et Excel regneark med henblik på efterfølgende krydstabuleringer i forbindelse med analysen. Bilaget indeholder en oversigt over udvalgte parametre, som er anvendt og identificeret i kodningen. Her vises fx de faktorer, der er identificeret, og som de forskellige artikler argumenterer for har en positiv eller negativ resultatindflydelse. Samme sted er også en liste over identificerede indsatsområder, som kan forfølges for at fremme resultatskabelse, og en oversigt over gevinster præsenteret. En kommende revision af kodningen med henblik på at samle og kvalitetssikre litteraturstudie vil blive gennemført. Dette vil ikke lede til en revision af dette notat. I stedet henvises til Excel regnearket som dokumentation.

4. Tværgående analyse

Den korte gennemgang af den internationale litteratur har vist, at der er mange forskellige lean relaterede indsats og faktorer, der på den ene eller anden måde giver anledning til et givent resultat. Her præsenterer udvalgte resultater af analysen. Bilag 2 indeholder flere resultater og oversigter.

Indsats/faktorer og resultater

I kodningen af de forskellige artikler var der fokus på de resultater, som en anvendelse af lean blev kædet sammen med. I den indledende kodning identificeres først de konkrete resultater (fx bedre samarbejde, reduceret ventetid, m.m.) som de enkelte studier pegede på. Herefter blev de faktorer (fx incitamentssystem, anvendelse af LPS, m.m.), der ifølge samme studier var årsag til resultaterne identificeret. Dette resulterede i samlet 246 forskellige faktorer, der gav anledning til 74 forskellige konkrete resultater. De identificerede faktorer og resultater blev dernæst grupperet i hovedkategorier med henblik på at reducere mængden af disse og gøre analyserne overskuelige. Tabel 2 nedenfor illustrerer de forskellige faktorer, der er identificeret. Dette er uafhængige variable i de forskellige undersøgelser. **I Fejl! Henvisningskilde ikke fundet.** i bilag 2 er alle 246 faktorer oplyst.

Påvirkningsfaktorer (hovedkategorier)	Antal af faktorer
Arbejde	22
Design	5
Kompetencer	26
Koordinering	22
Ledelse	52
Leverancer	2
Logistik	26
Lokation	7
Materiel	8
Planlægning	33
Proces	1
Produkt	1
Produktionsstørrelse	1
Sikkerhed	1
Standardisering	7
Værktøj	12
Økonomi	8
Materialer	2
Organisation	6
Projekt type	1
Koordination	3
Hovedtotal	246

Tabel 2. Antal faktorer identificeret

Ikke overraskende ses der at være mange ledelses- og planlægningsmæssige faktorer, der er identificeret i undersøgelserne. Hertil kommer også adskillige faktorer, der omhandler koordinering og logistik.

Tabel 3 viser de hovedkategorier af resultater som er identificeret. Tabel 12 i bilag 2 indeholder alle 74 resultater oplyst.

Resultat (hovedkategorier)	Antal
Barrier	1
Flow	19
Implementation	1
Productivity	23
Project performance	1
Value	13
Waste	15
Organizational performance	4

Tabel 3. Kategorier af resultater ved brug af lean jf. litteraturen.

Her er der fokus på projektets performance generelt, men også på et mere snævert fokus på spild og flow. To kategorier indeholde kun en identificeret faktor.

Faktorerers indflydelse på kvalitet, effektivitet og samarbejde

Næste skridt var at kode artiklerne med henblik på at identificere relationer mellem indsatser/faktorer og resultater. Dette blev gjort ved for hver faktor at angive, hvorvidt denne var positivt eller negativt korreleret til et givent resultat. Dette giver følgende billede.

Kategori af faktorer	Indflydelse på samarbejde, kvalitet og effektivitet		
	Negativ	Positiv	Hovedtotal
Arbejde	7	15	22
Design	4	1	5
Kompetencer	15	11	26
Koordinering	1	21	22
Ledelse	17	35	52
Leverancer		2	2
Logistik	19	7	26
Lokation	1	6	7
Materiel	7	1	8
Planlægning	12	21	33
Proces	1		1
Produkt		1	1

Produktionsstørrelse	1		1
Sikkerhed		1	1
Standardisering		7	7
Værktøj	2	10	12
Økonomi	5	3	8
Materialer		2	2
Organisation	3	3	6
Projekt type	1		1
Koordination	3		3
Hovedtotal	99	147	246

Tabel 4. Korrelation mellem faktorer og resultater.

Denne oversigt skal læses på den måde, at vi har identificeret 99 faktorer, som er negativt korreleret med et givent resultat og 147 faktorer som er positivt korreleret. Dette skal dog ikke forstå således, at der er 99 faktorer, der leder til fx lav effektivitet. Årsagen hertil er, at korrelationerne tager udgangspunkt i de konkrete formuleringer af faktorer og resultater i de forskellige tekster.

Faktoren ”produktionsstørrelse” (i Tabel 4) er således negativt korreleret til en gevinst forstået således, at jo større ”batch size” jo sværere er det at reducere gennemløbstiden, hvilket resulterer i mere ventetid, og dermed mere spild. Var faktoren formuleret som ”smaller batch size” i den oprindelige kilde, ville korrelationen til resultat være positiv. De identificerede korrelationer afhænger dermed af en forståelse af de bagvedliggende data i artiklerne. Nedenstående oversigt fokuserer på en enkelt af de ovenstående faktorer (omhandlende produktionsforhold), som er foldet ud for at vise systematikken.

Påvirkningsfaktor	Negativ	Positiv	Hovedtotal
Clear and transparent work process		1	1
Collaboration of each part in the project		1	1
Continuity of work		1	1
Continuity of space (sequential progression)		1	1
Contractor handles too many projects at the same time	1		1
Contractor involvement in design process		3	3
Cooperating with different departments		1	1
Debris impeding material access/movement	1		1
Delivery material out-of-specification	1		1
Design changes, errors and omissions	1		1
Design error	1		1

Tabel 5. Uddrag af produktionsmæssige faktorer som påvirker resultatet.

Her ses det eksempelvis, at ”Debris impeding material access/movement” har en negativ indflydelse på resultatet, medens fx ”Contractor involvement in design process” i tre studier er positivt korreleret med resultatet. Disse resultater kan enten være bedre samarbejde, højere kvalitet eller øget effektivitet. Dette kan identificeres ved opslag i Excel regnearkets pågældende pivottabel, hvor følgende information dernæst fremkommer:

Kodningskategori	Contractor involvement in design process	Contractor involvement in design process	Contractor involvement in design process
Resultat	Reduced need for in-situ work	Defects rectification	Reduced redesign
Metadeskriptor (resultat)	Productivity	Productivity	Productivity
Fokusområde for indsats	Mimize steps and part	Variability	Variability
Metadeskriptor (indsats)	Produktion	Produktion	Produktion
Metadeskriptor (faktorer)	Koordinering	Koordinering	Koordinering
Korrelation (faktor til resultat)	Positiv	Positiv	Positiv
Studie ID	Pheng et al. (2015)	Pheng et al. (2015)	Pheng et al. (2015)
Potentialemålingsfaktor	Kommunikation og roller	Kommunikation og roller	Kommunikation og roller
Potentialemålingskategori	Tiilid	Tiilid	Tiilid

Tabel 6. Uddrag af data vedr. betydningen af ” Contractor involvement in design process”

Heraf fremgår det, at ”Contractor involvement in design process” ifølge litteraturen (Pheng et al., 2015) er positivt korreleret med “reduced need for in-situ work”, “defects rectification” og “reduced redesign”, hvilket er alle her ses som produktivitetsfremmende faktorer, der vedrører forhold vedr. koordinering.

Litteraturstudiets relation til potentialemålingen

Hovedprojektet, som dette litteraturstudie er en del af, gennemføres af Living Lean, der udfører såkaldte potentialemålinger på udvalgte byggesager. Disse potentialemålinger fokuserer på tre hovedområder: Tillid, Kvalitet og Effektivitet med henblik på at vurdere og udvikle samarbejdsprocesser. Disse tre hovedområder består af samlet 10 underområder:

Hovedområder	Underområder
Tillid	<ul style="list-style-type: none"> - Selvledelse - Relation - samarbejde - Kommunikation- roller - Forandringsmodenhed
Kvalitet	<ul style="list-style-type: none"> - Kvalitetsfokus - Indbygget kvalitet - Kvalitetsudvikling

Effektivitet	<ul style="list-style-type: none"> - Flow i arbejdet - Udvikling - problemløsning - Arbejdsvilkår
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Tabel 7. Hoved- og underområder i potentialemålingen

Kodning af data er derfor også foretaget med henblik på at etablere en sammenhæng mellem disse områder, og de i litteraturen identificerede faktorer og potentielle gevinstområder. Disse fremgår af Tabel 13 i bilaget.

Sammenfattes resultaterne af, hvor mange faktorer, der er positivt eller negativt korreleret med effektivitet, kvalitet eller tillid fås følgende oversigt. Denne gengives i sin helhed i bilaget i figur X.

Korrelation	Andet		Effektivitet		Kvalitet		Tillid	
	-	+	-	+	-	+	-	+
Arbejde			5	5	1	4	1	6
Design			4			1		
Kompetencer			5	2		2	10	7
Koordination			3					
Koordinering							1	21
Ledelse	1	1	8	13	3	12	5	9
Logistik			11	3	8	3		1
Lokation	1	1		3		2		
Materialer						2		
Materiel			6	1	1			
Planlægning			12	11		4		6
Værktøj		1		4	2	5		
Økonomi	4	2	1			1		
Hovedtotal	8	5	57	53	15	38	19	51

Tabel 8. Antal identificerede faktorer og korrelationer med effektivitet, kvalitet eller tillid

Disse relationer mellem faktorer og potentialemålingens kategorier vil blive anvendt i projektet til at vurdere, hvilke forhold der skal fokuseres på og spørges ind til i dataindsamlingen.

Begrænsninger og refleksioner

Mange af de rapporterede undersøgelser er 'mangelfulde' i den forstand, at det metodiske grundlag for undersøgelserne er meget usikre og tvivlsomme. Dette skyldes en mangel på beskrivelse af antagelser, variabler, dataindsamlingsmetoder samt beregninger / analytiske tilgange.

Derudover rapporterer de forskellige undersøgelser data forskelligt, hvilket gør det meget vanskeligt at foretage sammenligninger på tværs af datasættene. Selv når undersøgelser tilsyneladende

rapporterer de samme faktorer, er der forskelle på dataindsamling eller datakvalitet, hvilket gør sammenligninger tvivlsomme.

En anden faktor, der gør sammenligningen vanskelig, og som ikke er blevet behandlet eksplicit i dette notat er, at forskellige nationale sammenhænge sandsynligvis vil påvirke de faktorer, der har indflydelse på produktiviteten. Forskelle i markedsstruktur, reguleringer, bygningsteknologier osv. varierer og påvirker processer på forskellige måder. En stor del af den identificerede litteratur omhandler således udenlandske forhold, hvor der kan være stor forskel i forhold til danske forhold.

Slutteligt skal det bemærkes, at der ikke findes mange studier, der omhandler lean i renovering specifikt, hvorfor de resultater der fremdrages her, og som omhandler andre segmenter af byggeriet, skal tages med et vist forbehold.

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Bilag: Kodning af data og resultater fra analysen

Påvirkningsfaktorer

Meta-descriptor	Indsastområder
Arbejde	<ul style="list-style-type: none"> - Commitment - Daily work huddle - Establishing long-term employee relationships - Extensive multiple-handling of materials - Improper crew size/composition - Inadequate labor flexibility on-site - Labor loyalty - Labor resource stability - Lean training on project - Less rework - Low fabrication shop production rates - Participation - Self-management - Reduce overprocessesing - Reduce waiting - Eliminating non-value-adding tasks - Increase stability in the construction task - Decrease the time required for performing tasks
Design	<ul style="list-style-type: none"> - Design changes, errors and omissions - Design-strategi - Inappropriate construction method
Kompetencer	<ul style="list-style-type: none"> - Clear roles in lean - Fatigue, mental and physical worker stress - Learning - Low worker motivation - Physical worker limitations - Problem solving - Providing training activities - Relationship management/degree of harmony, trust, and cooperation - Skilled/experienced worker shortage - Using multi-skilled workforce - Worker absenteeism - Worker turnover frequency - Project team skills - Communication within teams - Knowledge and skills of workers - Group culture, shared vision and shared consensus - Continuous improvement - Continuously improve the processes - lack of organizational education. - Poor qualification/experience of management at different level

<p>Koordinering</p>	<ul style="list-style-type: none"> - Alignment of objectives - Appropriate information transfer - Collaboration of each part in the project - Communication - Contractor involvement in design process - Cooperating with different departments - Early coordination between designer and contractor - Initial collaboration between contractor and designer - Joint responsibility of design - Organizing regular meetings - Relationship management - Teamwork - Transparent information and rapid - Effective interaction between foremen and labourers - Capability of teams to maintain alignment with other teams - lack of contractual agreement
<p>Ledelse</p>	<ul style="list-style-type: none"> - Adequate prerequisite - Appropriate amount of work - Benchmark - Completed work valuation inaccuracy - Contractor handles too many projects at the same time - Customer focus - Encouraging the project participants for consensus-based decision making - Improper tool/equipment allocation - Improving the process transparency - Indifference to worker opinion - Inspection delays - Instruction time and supervision delay - Lack of overall quality culture - Lean as company strategy - Lean culture - Lean implementing - Lean leadership - Management commitment - Organizational needs - Owner's intervention - Poor supervision, performance monitoring, and control - Process inspection - Project management - Reasonable task - Reasonable work sequence - Reliable planning - Selection of appropriate subcontractors

	<ul style="list-style-type: none"> - Site management - Slow management decision process - Reward systems based on teams goals - Participative management style for workforce - Well-defined focus of teams - Client and supplier involvement - Understanding of needs of customers, i.e., internal and external - Organisational culture supporting teamwork - Ability to measure performance of the team to gauge the team's progress - Documenting agreements and procedures - Management leadership - Keep the focus of the control process on finished tasks - lack of encouragement from leadership, - Communication system - Poor qualification/experience of management at different level
Leverancer	<ul style="list-style-type: none"> - Push driven deliveries - Certainty in the supply chain
Logistik	<ul style="list-style-type: none"> - Debris impeding material access/movement - Delivery material out-of-specification - Establishing long-term supplier relationships - Late material delivery - Material damage from deficient stockpiling and handling - Material shortage at construction site - Materials improperly sorted/marked - Minimizing the material storage - Poor material quality - Supplying materials in time - Tools and equipment unavailability - Transportation and/or equipment installation delay - Unnecessary equipment movement - Reduce excess transportation of goods - Reduce excess movement of people - Certainty in the production process, i.e., workflow reliability - Enhance the flexibility of deliverables
Lokation	<ul style="list-style-type: none"> - Continuity of space (sequential progression) - Factory layout - Good weather - Optimizing the site conditions - Multi-functional layout on jobsite - Keeping needed items in the right places - Weather
Materiel	<ul style="list-style-type: none"> - Amount of equipment - Equipment breakdown

	<ul style="list-style-type: none"> - Improper equipment capacity - Poor quality of power tools - Equipment availability
Planlægning	<ul style="list-style-type: none"> - Access route planning and design - Buildability - Clear and transparent work process - Completed work valuation inaccuracy - Continuity of work - Contractor involvement in site layout - Design based on capabilities - Design changes, errors and omissions - Engineer's action - Engineer's specific knowledge - Faster start - Improper crew size/composition - Improper tool/equipment allocation - Inadequacy of planning and risk management process - Inappropriate construction method - Inspection delays - Lean methods and tools - More planning - Reduced variations - Schedule changes and acceleration - Using time buffers - just-in-time - Buildable designs - Parallel execution of development tasks in multidisciplinary teams - Accurate pre-planning - Defect prevention - Steady work engagement - Design error - TAKT planing
Proces	<ul style="list-style-type: none"> - Work-in-progress
Produkt	<ul style="list-style-type: none"> - Product fleksibilitet
Produktionsstørrelse	<ul style="list-style-type: none"> - Batch size
Sikkerhed	<ul style="list-style-type: none"> - Safe and tidy workplace
Standardisering	<ul style="list-style-type: none"> - Mechanization - Reduced variations - Standardisering - Use of standard components - Prefabrication - Reduce the number of components and connections
Værktøj	<ul style="list-style-type: none"> - Kanban

	<ul style="list-style-type: none"> - Last Planner System - Lean tools and methodologies - Poka-yoke - Quality at Source - Using 4-D scheduling and simulation - Using risk management techniques - Using the clean construction principles - Value stream mapping - Visual control - Lean practices
Økonomi	<ul style="list-style-type: none"> - Contractor's unstable financial background/insolvency - Delay in payment to sub-contractors - Investment in lean practices - Lack of regular cash flow forecasting - Owner's fund - Steady prices of commodities - Cost
Materialer	<ul style="list-style-type: none"> - Reduce defects - Quality materials
Organisation	<ul style="list-style-type: none"> - Provision of benchmarks - Systematically assess the requirements of customers - Improve transparency - reluctance of owners, - reluctance of subcontractors - reluctance of people within the company
Projekt type	<ul style="list-style-type: none"> - Refurbishment
Koordination	<ul style="list-style-type: none"> - Improper coordination between construction trades

Tabel 9. Påvirkningsfaktorer

Resultatfaktorer

Meta-descriptor	Indsastområder
Barrier	- Barrier
Flow	- Improved flow - Labour performance
Implementation	- Implementation
Productivity	- Better client understanding - Better constructability - Comprehensive design brief - Decrease unnecessary storage - Decrease waiting time - Defects rectification - Familiarity with product - Increased productivity - Increased productivity of schedules - Less conflicts - Productivity - Project performance - Reduced congestion - Reduced construction errors - Reduced duration - Reduced manhours - Reduced need for in-situ work - Reduced redesign - Reduced rework - Reduced time - Reduced variation - Reduced waiting times
Project performance	- Reduced variability
Value	- Continuous improvements - Enhance the delivered value
Waste	- Increased waste - Less wasted time retrieving tools and materials during the workday - Reduce waste - Reduced chance of damaging material - Reduced time and distance needed to retrieve materials and tools - Reduced time needed to position cement blocks and helped align frame to be square - Reduced waste - "Workers did not need to stop and ask for directions, thus less wasted time"

Tabel 10. Resultatfaktorer

Indsatsområder

Meta-descriptor	Indsatsområder
Activities	- Reduce the share of non-value-adding activities
Arbejde	- Manpower - Udnyttelsesgrad
Kontrakt	- Early contractor involvement
Kvalitet	- Yield rate
Ledelse	- Motivation - Projektindsats - Strategi - Virksomhed - Manpower flow - Workflow - Equipment and tools flow - Information flow - Material flow
Organisation	- Accomplishing customer requirements - Aiming to perfection - Applying lean principle - Employee involvement - Implementering - Incremented gains - Material management - Setting and measureing goals - Technical setup - Transparency - Transparency
Produktion	- Accomplishing customer requirements - Continuous improvement - Flow management - Flow variability - Implementering - Mimize steps and part - Pulling - Variability - Work flow - Work flow realibility - Reduced process variability - Production levelling - Manpower flow - Workflow - Equipment and tools flow - Material flow
Tid	- Cycle time

	- Implementering
Økonomi	- Implementering - Virksomhed
Barriers	- Barriers to lean - Overcoming lean production barriers
Samarbejde	- Manpower flow - Information flow - Material flow

Tabel 11. Indsatsområder

Resultater ved brug af lean

Resultat (hovedkategori)	Underkategorier af resultater
Barrier	<ul style="list-style-type: none"> - Barrier
Flow	<ul style="list-style-type: none"> - Improved flow - Labour performance - Progress - Reduced interferences - Time efficiency - W1 Improper sequencing of activities - W10 Ineffective work because of improper management decisions - W11 Ineffective work because of tool/equipment unsuitability - W12 Ineffective work because of poor maintenance - W13 Number of setup or changeover times - W14 Unnecessary inventories such as delays in processing information - W15 Unnecessary inventories such as resources - W2 Waiting due to poor workflow planning - W21 Change orders - W3 Waiting for information - W6 Ineffective work because of worker morale problems - W7 Ineffective work because of worker physical problems - W8 Ineffective work because of worker unavailability - W9 Ineffective work because of unqualified workers
Implementation	<ul style="list-style-type: none"> - Implementaion
Productivity	<ul style="list-style-type: none"> - Better client understanding - Better constructability - Comprehensive design brief - Decrease unnecessary storage - Decrease waiting time - Defects rectification - Familiarity with product - Increased productivity - Increased productivity of schedules - Less conflicts - Prodcutivity - Productivity - Project performance - Reduced congestion - Reduced construction errors - Reduced duration - Reduced manhours - Reduced need for in-situ work - Reduced redesign - Reduced rework

	<ul style="list-style-type: none"> - Reduced time - Reduced variation - Reduced waiting times
Project performance	<ul style="list-style-type: none"> - Reduced variability
Value	<ul style="list-style-type: none"> - Barrier - Continuous improvements - Enhance the delivered value - Inflexible management system - W17 Not taking advantage of worker involvement in a process - W18 Not taking advantage of collaboration with supplier - W19 Not taking advantage of collaboration among project parties - W20 Improper choice of method - W22 Design errors - W26 Lack of intended use - W28 Imperfect institutional processes
Waste	<ul style="list-style-type: none"> - Increased waste - Less wasted time retrieving tools and materials during the workday - Poor labour performance - Reduce waste - Reduced chance of damaging material - Reduced time and distance needed to retrieve materials and tools - Reduced time needed to position cement blocks and helped align frame to be square - Reduced waste - W16 Excessive consumption of materials - W23 Rework - W24 Excessive transportation - W25 Unnecessary work - W4 Unnecessary movement - W5 Defects - "Workers did not need to stop and ask for directions, thus less wasted time"
(tom)	<ul style="list-style-type: none"> - Continuous improvements - Reduce complexity
Organizational performance	<ul style="list-style-type: none"> - Organizational performance

Tabel 12. Resultater ved brug af lean

Påvirkningsfaktorer i forhold til potentialemåling

Hovedområder	Underområder
Selvledelse	<ul style="list-style-type: none"> - Commitment - Engineer's specific knowledge - Inadequate labor flexibility on-site - Indifference to worker opinion - Knowledge and skills of workers - Labor loyalty - Learning - Low worker motivation - Management commitment - Participation - Poor qualification/experience of management at different level - Poor supervision, performance monitoring, and control - Project team skills - reluctance of people within the company - reluctance of subcontractors - Self-management - Skilled/experienced worker shortage - Steady work engagement - Using multi-skilled workforce - Worker absenteeism
Relation - samarbejde	<ul style="list-style-type: none"> - Collaboration of each part in the project - Communication within teams - Cooperating with different departments - Daily work huddle - Early coordination between designer and contractor - Establishing long-term employee relationships - Establishing long-term supplier relationships - Group culture, shared vision and shared consensus - Indifference to worker opinion - Joint responsibility of design - Participative management style for workforce - Relationship management/degree of harmony, trust, and cooperation - Teamwork
Kommunikation- roller	<ul style="list-style-type: none"> - lack of encouragement from leadership, - Alignment of objectives - Appropriate information transfer - Capability of teams to maintain alignment with other teams - Certainty in the supply chain - Clear roles in lean - Client and supplier involvement - Communication - Communication system

	<ul style="list-style-type: none"> - Contractor involvement in design process - Contractor involvement in site layout - Effective interaction between foremen and labourers - Encouraging the project participants for consensus-based decision making - Engineer's action - Improving the process transparency - Initial collaboration between contractor and desinger - lack of contractual agreement - Management leadership - More planning - Organizing regular meetings - Relationship management - Selction of appropriate subcontractors - Transparent information and rapid - Well-defined focus of teams
Forandringsmodenhed	<ul style="list-style-type: none"> - Design based on capabilities
Kvalitetsfokus	<ul style="list-style-type: none"> - Daily work huddle - Defect prevention - Delivery material out-of-specification - Design-strategi - Eliminating non-value-adding tasks - Kanban - Lean practices - Material damage from deficient stockpiling and handling - Minimizing the material storage - Optimizing the site conditions - Poor material quality - Process inspection - Quality at Source - Quality materials - Reduce defects - Reduce overprocessesing - Systematically assess the requirements of customers - Visual control
Indbygget kvalitet	<ul style="list-style-type: none"> - Access route planning and design - Debris impeding material access/movement - Extensive multiple-handling of materials - Keeping needed items in the right places - Materials improperly sorted/marked - Poor quality of power tools - Product fleksibilitet - Reduce excess movement of people - Reduce excess transportation of goods

	<ul style="list-style-type: none"> - Reduce waiting
Kvalitetsudvikling	<ul style="list-style-type: none"> - Continuous improvement - Continuously improve the processes - Contractor handles too many projects at the same time - Customer focus - Investment in lean practices - Lack of overall quality culture - Lean as company strategy - Lean culture - Lean implementering - Lean leadership - Lean methods and tools - Lean tools and methodologies - Organisational culture supporting teamwork - Organizational needs - Parallel execution of different development tasks in multidisciplinary teams - Understanding of needs of customers, i.e., internal and external - Value stream mapping
Flow i arbejdet	<ul style="list-style-type: none"> - Appropriate amount of work - Batch size - Certainty in the production process, i.e., workflow reliability - Continuity of work - Continuity of space (sequential progression) - Decrease the time required for performing tasks - Enhance the flexibility of deliverables - Equipment breakdown - Factory layout - Improper coordination between different construction trade - Improper crew size/composition - Improper equipment capacity - Improper tool/equipment allocation - Inappropriate construction method - Increase stability in the construction task - just-in-time - Last Planner System - Late material delivery - Less rework - Low fabrication shop production rates - Material shortage at construction site - Poka-yoke - Poor quality of power tools - Push driven deliveries

	<ul style="list-style-type: none"> - Reasonable work sequence - Schedule changes and acceleration - Standardising - Supplying materials in time - TAKT planning - Tools and equipment unavailability - Transportation and/or equipment installation delay - Unnecessary equipment movement - Work-in-progress
Udvikling - problemløsning	<ul style="list-style-type: none"> - Ability to measure performance of the team to gauge the team's progress - Benchmark - Completed work valuation inaccuracy - Delay in payment to sub-contractors - Documenting agreements and procedures - Inspection delays - Instruction time and supervision delay - Keep the focus of the control process on finished tasks - Poor supervision, performance monitoring, and control - Problem solving - Provision of benchmarks - Using 4-D scheduling and simulation - Using risk management techniques
Arbejdsvilkår	<ul style="list-style-type: none"> - Access route planning and design - Accurate pre-planning - Adequate prerequisite - Amount of equipment - Buildability - Buildable designs - Clear and transparent work process - Design changes, errors and omissions - Design error - Equipment availability - Faster start - Fatigue, mental and physical worker stress - Improper crew size/composition - Improve transparency - Inadequacy of planning and risk management process - Inappropriate construction method - Inspection delays - Labor resource stability - lack of organizational education. - Late material delivery - Lean training on project

	<ul style="list-style-type: none"> - Low fabrication shop production rates - Mechanization - Multi-functional layout on jobsite - Physical worker limitations - Prefabrication - Project management - Providing training activities - Reasonable task - Reduce the number of components and connections - Reduced variations - Reliable planning - Reward systems based on teams goals - Safe and tidy workplace - Site management - Slow management decision process - Use of standard components - Using time buffers - Worker turnover frequency
Andet	<ul style="list-style-type: none"> - Contractor's/subcontractor's background/insolvency - Cost - Good weather - Lack of regular cash flow forecasting - Owner's fund - Owner's intervention - Refurbishment - reluctance of owners, - Steady prices of commodities - Using the clean construction principles - Weather

Tabel 13. Påvirkningsfaktorer i forhold til potentialemåling

Korrelationer mellem påvirkningsfaktorer og hovedkategorier i potentialemålingen.

Korrelation	Andet		Effektivitet		Kvalitet		Tiilid	
	-	+	-	+	-	+	-	+
Arbejde			5	5	1	4	1	6
Commitment								1
Daily work huddle						1		1
Decrease the time required for performing tasks				1				
Eliminating non-value-adding tasks						1		
Establishing long-term employee relationships								1
Extensive multiple-handling of materials					1			
Improper crew size/composition			1					
Inadequate labor flexibility on-site							1	
Increase stability in the construction task				1				
Labor loyalty								1
Labor resource stability				1				
Lean training on project				1				
Less rework				1				
Low fabrication shop production rates			4					
Participation								1
Reduce overprocessing						1		
Reduce waiting						1		
Self-management								1
Design			4			1		
Design changes, errors and omissions			2					
Design-strategi						1		
Inappropriate construction method			2					
Kompetencer			5	2		2	10	7
Clear roles in lean								1
Communication within teams								1
Continuous improvement						1		
Continuously improve the processes						1		
Fatigue, mental and physical worker stress			2					
Group culture, shared vision and shared consensus								1
Knowledge and skills of workers								1
lack of organizational education.			1					
Learning								1
Low worker motivation							1	
Physical worker limitations			1					
Poor qualification/experience of management at different level							2	
Problem solving				1				
Project team skills								1
Providing training activities				1				

Relationship management/degree of harmony, trust, and cooperation							3	
Skilled/experienced worker shortage							3	
Using multi-skilled workforce								1
Worker absenteeism							1	
Worker turnover frequency			1					
Koordinasion			3					
Improper coordination between different construction trade			3					
Koordinasion							1	21
Alignment of objectives								1
Appropriate information transfer								1
Capability of teams to maintain alignment with other teams								1
Collaboration of each part in the project								1
Communication								1
Contractor involvement in design process								7
Cooperating with different departments								1
Early coordination between designer and contractor								1
Effective interaction between foremen and labourers								1
Initial collaboration between contractor and designer								1
Joint responsibility of design								1
lack of contractual agreement							1	
Organizing regular meetings								1
Relationship management								1
Teamwork								1
Transparent information and rapid								1
Ledelse	1	1	8	13	3	12	5	9
lack of encouragement from leadership,							1	
Ability to measure performance of the team to gauge the team's progress				1				
Adequate prerequisite				1				
Appropriate amount of work				1				
Benchmark				2				
Client and supplier involvement								1
Communication system								1
Completed work valuation inaccuracy	1							
Contractor handles too many projects at the same time					2			
Customer focus						1		

Documenting agreements and procedures				1				
Encouraging the project participants for consensus-based decision making								1
Improper tool/equipment allocation			1					
Improving the process transparency								1
Indifference to worker opinion							2	
Inspection delays			1					
Instruction time and supervision delay			1					
Keep the focus of the control process on finished tasks				1				
Lack of overall quality culture					1			
Lean as company strategy						1		
Lean culture						1		
Lean implementering						4		
Lean leadership						1		
Management commitment								1
Management leadership								1
Organisational culture supporting teamwork						1		
Organizational needs						1		
Owner's intervention		1						
Participative management style for workforce								1
Poor qualification/experience of management at different level							1	
Poor supervision, performance monitoring, and control			2				1	
Process inspection						1		
Project management				1				
Reasonable task				1				
Reasonable work sequence				1				
Reliable planning				1				
Reward systems based on teams goals				1				
Selection of appropriate subcontractors								1
Site management				1				
Slow management decision process			3					
Understanding of needs of customers, i.e., internal and external						1		
Well-defined focus of teams								1
Leverancer				1				1
Certainty in the supply chain								1
Push driven deliveries				1				
Logistik			11	3	8	3		1
Certainty in the production process, i.e., workflow reliability				1				

Debris impeding material access/movement					1			
Delivery material out-of-specification					3			
Enhance the flexibility of deliverables				1				
Establishing long-term supplier relationships								1
Late material delivery			3					
Material damage from deficient stockpiling and handling					1			
Material shortage at construction site			2					
Materials improperly sorted/marked					1			
Minimizing the material storage						1		
Poor material quality					2			
Reduce excess movement of people						1		
Reduce excess transportation of goods						1		
Supplying materials in time					1			
Tools and equipment unavailability			2					
Transportation and/or equipment installation delay			2					
Unnecessary equipment movement			2					
Lokation	1	1		3		2		
Continuity of space (sequential progression)				1				
Factory layout				1				
Good weather		1						
Keeping needed items in the right places						1		
Multi-functional layout on jobsite				1				
Optimizing the site conditions						1		
Weather	1							
Materialer						2		
Quality materials						1		
Reduce defects						1		
Materiel			6	1	1			
Amount of equipment				1				
Equipment availability			1					
Equipment breakdown			3					
Improper equipment capacity			1					
Poor quality of power tools			1		1			
Organisation	1			2		1	2	
Improve transparency				1				
Provision of benchmarks				1				
reluctance of owners,	1							
reluctance of people within the company							1	
reluctance of subcontractors							1	
Systematically assess the requirements of customers						1		

Planlægning			12	11		4		6
Access route planning and design				1		1		
Accurate pre-planning				1				
Buildability				1				
Buildable designs				1				
Clear and transparent work process				1				
Completed work valuation inaccuracy			1					
Continuity of work				1				
Contractor involvement in site layout								1
Defect prevention						1		
Design based on capabilities								1
Design changes, errors and omissions			1					
Design error			1					
Engineer's action								1
Engineer's specific knowledge								1
Faster start				1				
Improper crew size/composition			1					
Improper tool/equipment allocation			1					
Inadequacy of planning and risk management process			3					
Inappropriate construction method			2					
Inspection delays			1					
just-in-time				1				
Lean methods and tools						1		
More planning								1
Parallel execution of different development tasks in multidisciplinary teams						1		
Reduced variations				1				
Schedule changes and acceleration			1					
Steady work engagement								1
TAKT planing				1				
Using time buffers				1				
Proces			1					
Work-in-progress			1					
Produkt						1		
Product fleksibilitet						1		
Produktionsstørrelse			1					
Batch size			1					
Projekt type	1							
Refurbishment	1							
Sikkerhed				1				
Safe and tidy workplace				1				
Standardisering				7				

Mechanization				1				
Prefabrication				2				
Reduce the number of components and connections				1				
Reduced variations				1				
Standardisering				1				
Use of standard components				1				
Værktøj		1		4	2	5		
Kanban					1	1		
Last Planner System				1				
Lean practices					1			
Lean tools and methodologies						1		
Poka-yoke				1				
Quality at Source						1		
Using 4-D scheduling and simulation				1				
Using risk management techniques				1				
Using the clean construction principles		1						
Value stream mapping						1		
Visual control						1		
Økonomi	4	2	1			1		
Contractor's/subcontractor's unstable financial background/insolvency	2							
Cost	1							
Delay in payment to sub-contractors			1					
Investment in lean practices						1		
Lack of regular cash flow forecasting	1							
Owner's fund		1						
Steady prices of commodities		1						
Hovedtotal	8	5	57	53	15	38	19	51

Tabel 14. Korrelationer mellem påvirkningsfaktorer og hovedkategorier i potentialemålingen.