Empirical Assessment of the Impact of VDC and Lean on Environment and Waste in Masonry Operations

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Introduction

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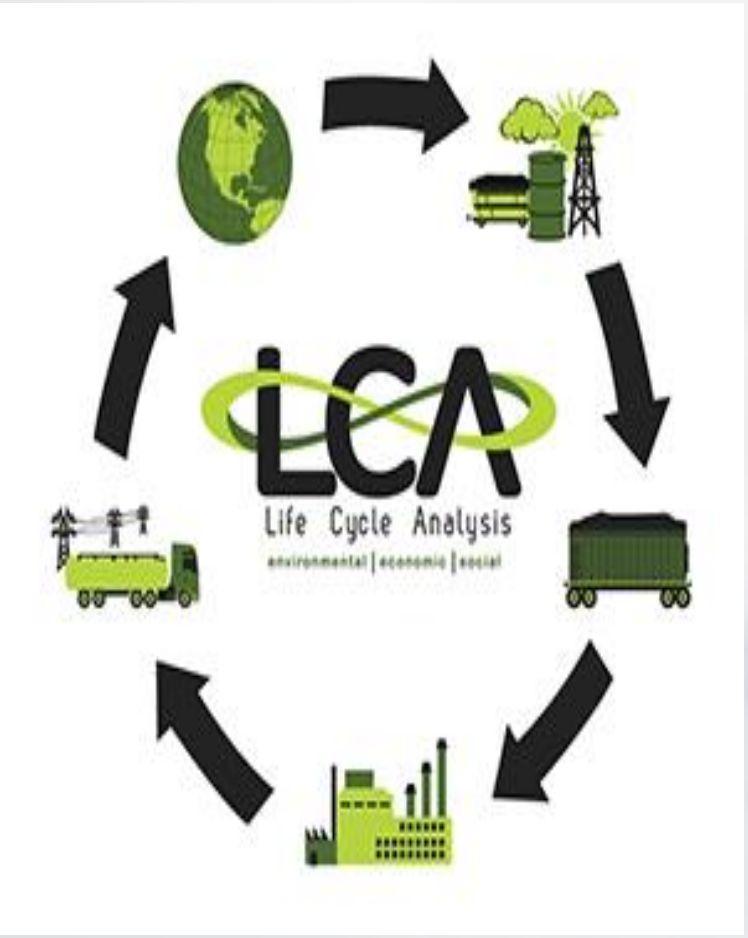
Impact of Lean and VDC on masonry operations through LCA



Literature Review

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- Lean production has had a transformative impact on building construction projects in which it has been applied (Koskela,2000; Sacks et al., 2018).
- Waste, which includes the exhaustion of time, money and energy that returns no value to the end customer, is the most important variable that lean aims to minimize (Womack and Jones, 2003).
- Virtual Design and Construction (VDC) is a practice in which both construction products and related construction processes are modelled collaboratively and in detail using Building Information Modeling (BIM) tools (Kunz and Fischer, 2012; sacks et al.,2018).
- VDC approaches are being combined with life cycle thinking to reduce rework, waste, energy and environmental impact and to recover materials from construction and demolition activities (Aknabi et al., 2018; Honic et al., 2019).
- Life cycle assessment (LCA) is a valuable tool that can guide the sustainable design of products, processes, and activities. In recent years, LCA has been used to evaluate a variety of decisions in building material production (Stadel et al., 2011).

Research Questions/Goals

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- To what extent can Lean and VDC improve masonry block partition operations? Can they reduce the non-value adding activities?
- How can they reduce the wastes?
- What are the environmental impacts ?

Main Method: Case study

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Two construction companies

- Company A
- Company B

Company B

Company A

Quantitative Research Sources

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Project	Lean and VDC implemintations	Year
Project A1	Traditional	2007
Project A2	Lean	2014
Project A3	Lean and VDC	2019
Project B1	Traditional	2019

Waste examples

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Waste

5S…..X

Moving Pallets

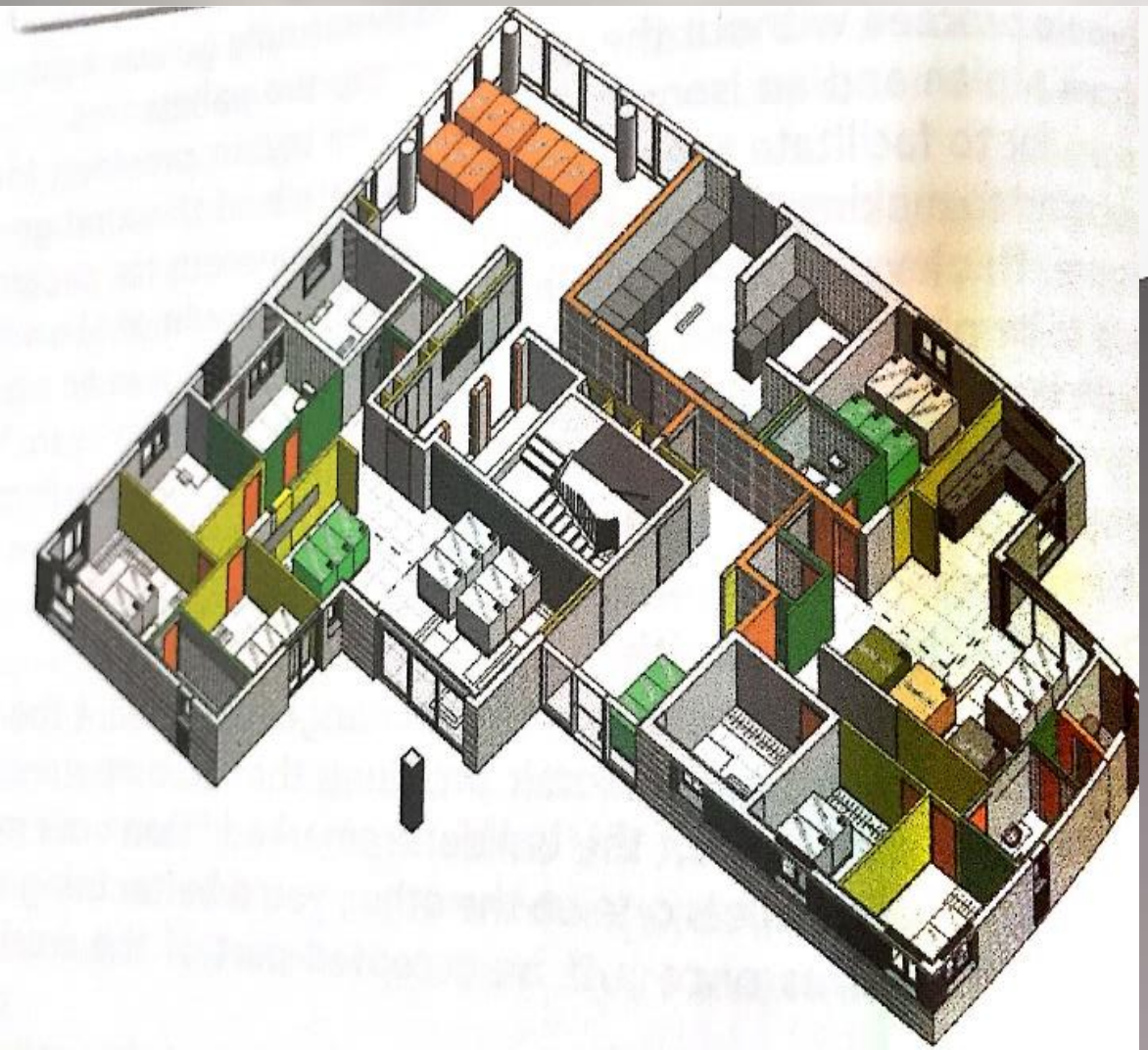
Waste

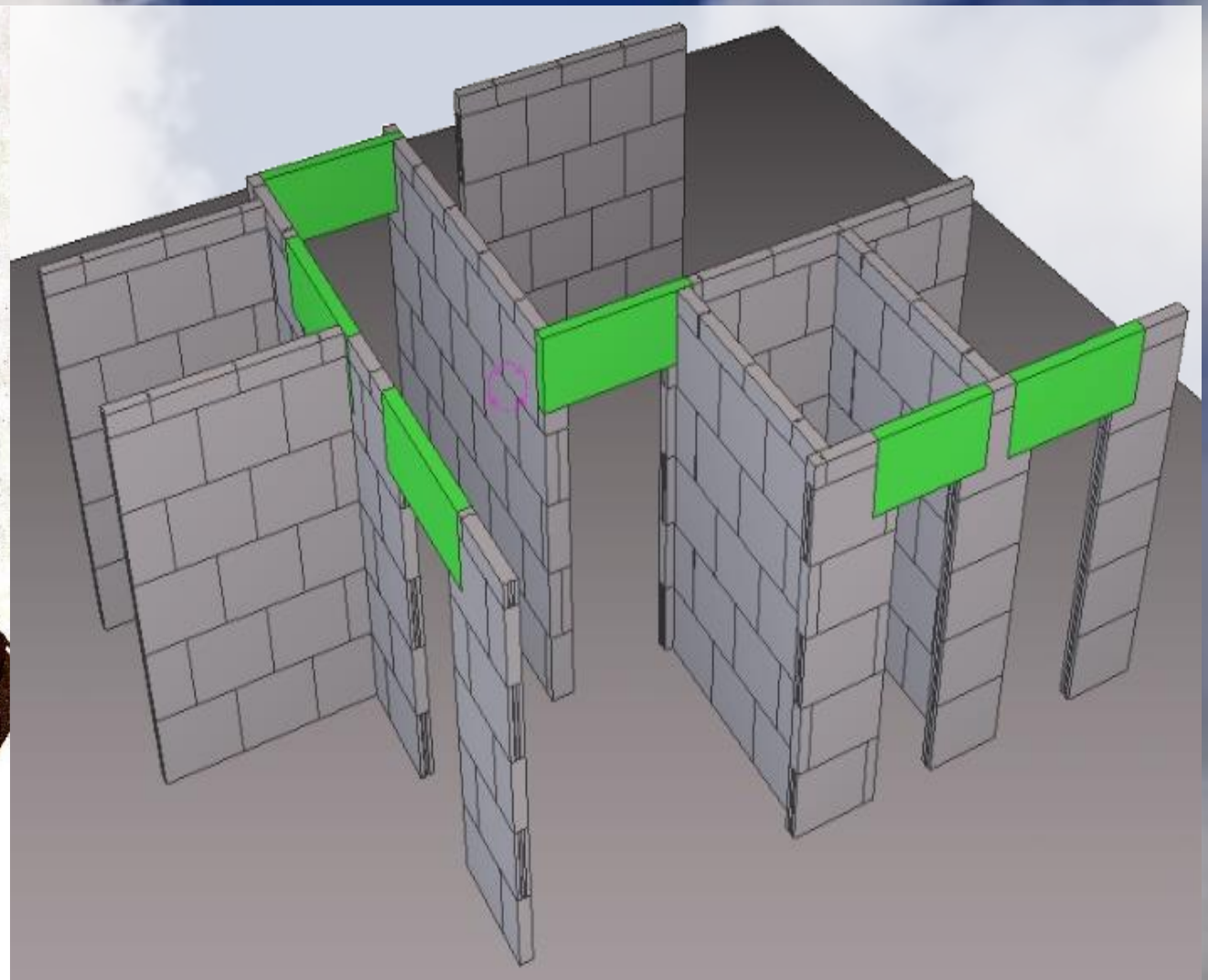
5S…..X

Rework

Wastes

BIM and Lean





Findings

To what extent can Lean and VDC improve masonry block partition operations?

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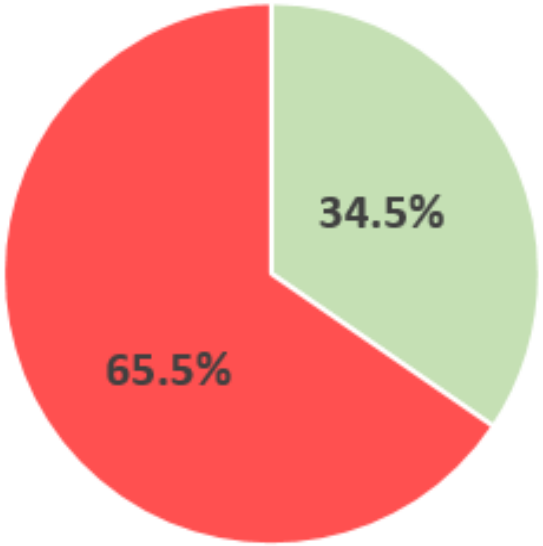
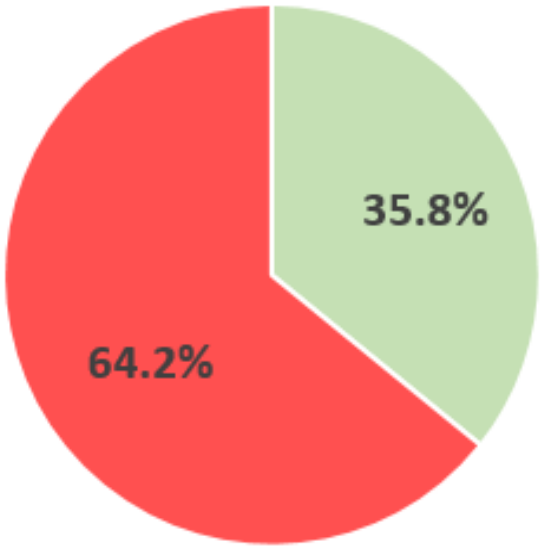
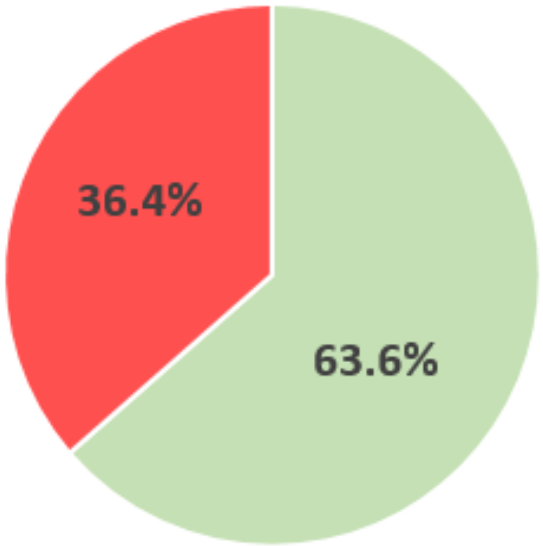


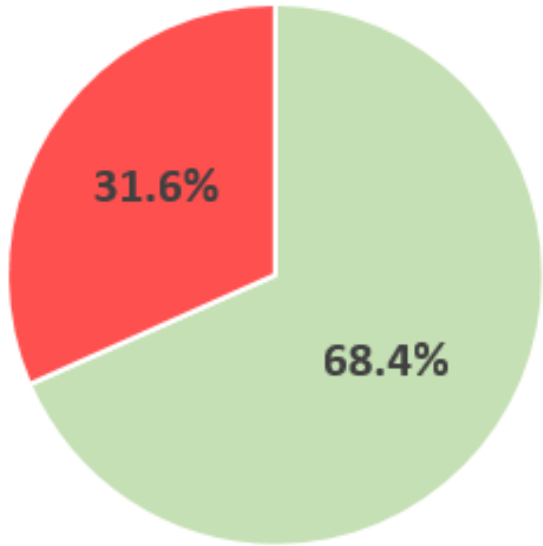
Project A1
2007 (Traditional)



Project B1
2019 (Traditional)



Project A2
2014 (Lean)



Project A3
2019 (Lean & VDC)

Findings

To what extent can Lean and VDC improve masonry block partition operations?

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Work activity	Project A1 2007 (Traditional)	Project A2 2014 (Lean)	Project A3 2019 (Lean & VDC)	Project B1 2019 (Traditional)
Building, gluing and levelling	34.5	63.6	68.4	35.8
Cutting	24.1	7.8	1.3	12.6
Moving pallets	4.4	1.3	4.8	19.0
Move between storeys	0.4	1.3	1.9	3.7
Cleaning	9.9	5.2	4.9	5.7
Marking out	7.3	11.7	3.5	5.6
Scaffold	2.0	0.0	0.3	1.2
Waiting and rework	10.5	3.9	6.1	6.6
Design changes and others	7.0	5.2	8.8	10.0
Total	100.0	100.0	100.0	100.0

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Waste and GWP from traditional and lean/VDC management

Inventoried Data and Performance Metrics	Traditional management	Lean and VDC management		
	Ytong block	Ytong block	Gypsum block	Total
Delivered quantities (m^3)	2,225	344	1,969	2,313
Block volume built (m^3)	1,762	334	1,759	2,093
Waste volume (m^3)	463	10	210	220
Delivered blocks (ton)	890	138	1,674	1,812
Blocks built (ton)	705	134	1,495	1,629
Block waste generated (ton)	185	4	179	183
No. of pallets	1,646	251	2,587	
No. of truckloads	55	9	86	
Distances travelled (km)	5,500	900	8,600	
Transportation of unused blocks to site (km)	1,000	0	900	
Transportation of waste from site (km)	500	0	450	
Block embodied GWP (t CO_2e)	291	44.9	176.2	221.1
Block transport to site (t CO_2e)	6	0.9	11.2	12.1
Embodied GWP in transport to landfill (t CO_2e)	0.6	0.00	0.6	0.6
Total embodied (t CO_2e)	297.6	45.8	188	233.8
Total embodied GWP in waste (t CO_2e)	62.4	1.2	20.6	21.8
GWP per block volume built (kg CO_2e /m^3)	169	137	107	112
GWP waste percentage (%)	27	3	12	10

Hypothetical case

Assuming gypsum block was used under both Traditional and Lean/VDC management approaches

Inventoried Data and Performance Metrics	Traditional management	Lean and VDC management
	Gypsum block	Gypsum block
Delivered quantities (m^3)	2,225	2,313
Block volume built (m^3)	1,762	2,093
Waste volume (m^3)	463	220
Delivered blocks (ton)	1,891	1,966
Blocks built (ton)	1,498	1,779
Block waste generated (ton)	393	187
No. of pallets	2,923	3,028
Distances traveled (km)	9,800	10,100
Block embodied GWP (t CO_2e)	199.1	207
Block transport to site (t CO_2e)	12.7	13.2
Embodied GWP in transport to landfill (t CO_2e)	2.6	0.63
Total embodied (t CO_2e)	214.4	221
Total embodied GWP in waste (t CO_2e)	46.7	21.6
GWP per block volume built (kg CO_2e /m^3)	122	106
GWP waste percentage (%)	28	11

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Hypothetical Instance

What if ...

Suppose that ...

Conclusions

➢ Operational Impact

- Lean and VDC play an important role in improving the masonry operations. They increase the value-adding activities from 35.8 to 68.4.
- Lean and VDC significantly reduce moving pallets from 19% to 4.8%.
- Lean and VDC significantly reduce cutting from 12.6% to 1.3%.
- Lean reduce moving between storeys to the third from 3.7% to 1.3%.
- Lean reduce design changes by half from 10% to 5.2%.

➢ Environmental impact

- Lean and VDC reduce the block wastes from 463 m^3 to 220 m^3.
- Lean and VDC reduce the total embodied GWP from 62.4 t CO2e to 21.8 t CO2e.
- Lean and VDC reduce the GWP waste percentage from 27% to 10%.

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