"EVOLVING LEAN CONSTRUCTION TOWARDS MATURE PRODUCTION MANAGEMENT ACROSS CULTURES AND FRONTIERS"

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A3's

Make Ready Planning Using Flow Walks: A New Approach to Collaboratively Identifying Project Constraints

Paul John Ebbs, Research Fellow, Centre for Lean Projects, Nottingham Trent University, UK

Christine Pasquire, Professor of Lean Project Management, Centre for Lean Projects, NTU, UK

I. Background

Flow and pull are key lean production principles. In lean construction (LC) these principles are embodied within the "Last Planner® System" (LPS) to create more reliable workflow which is the heart of Lean Project Delivery. LPS has continued to evolve and develop over the last 25 years with pull planning – identifying what tasks SHOULD be done - the last major element added. However, "pull planning" is often misunderstood as the entirety of LPS and frequently referred to as "Last Planner". The remaining levels of the Last Planner "System" – CAN; WILL; DID and LEARN - are not being used as originally intended by LPS developers Ballard and Howell. This paper explores how work CAN be made ready using a structured collaborative approach to identify project constraints and risks called a Flow Walk.

II. Current conditions

There is a prevailing belief that optomising the individual pieces of a project creates resource efficiency, and that this optimisation is achieved through the elimination of waste. Some, such as Cooke and Williams (2009) even propose lean construction simply as the elimination of waste from the production cycle. However, this belief set is a flawed understanding of lean principles representing a reductionist view heavily criticised by Green (1999). Table 1 tests this belief:

Table 1: Understanding of Lean Construction through thematic analysis (n=84) (Ebbs et al., 2015)

Code	Total (84)	Arch (12)	Eng (5)	Con (18)	QS (10)	Ac (38)	Owner (1)
Reduce waste	**40**	4	2	9	6	19	-
Holistic process	**22**	4	2	5	4	7	-
Reduce material waste	**17**	-	-	2	3	11	1
Reduce time	**16**	-	-	4	1	11	-
Reduce labour/resources	**15**	1	-	-	5	9	-
Reduce cost	**14**	2	1	5	-	6	-
System	**7**	-	1	1	-	5	-
Sustainability	**7**	2	-	1	2	2	-
Philosophy/concept	**6**	1	-	-	-	5	-
Continuous Improvement	**5**	2	1	2	-	-	-
Quality	**4**	-	-	1	-	3	-
Value engineering	**4**	-	-	2	2	-	-
Flow	**2**	**-**	**1**	**-**	**-**	**1**	**-**
Culture	**2**	-	-	1	-	1	-
Safety	**1**	-	-	-	-	1	-

Key: Arch – architect; Eng – engineer; Con – contractor; QS – quantity surveyor; Ac - academic; Owner – owner/client

Neither Womack et al.'s 5 Lean principles or Liker's 14 Toyota Way Management Principles offer the elimination of waste as a method for efficiency but rather discuss waste reduction as an outcome of achieving flow. Eliminating waste to maximising resource efficiency is often a focus of lean literature, however many scholars argue that helping materials, information, people and product flow is the critical concept to grasp. Preparing for flow requires identifying & removing constraints.

III. Working hypotheses

Using the 8 Flows of Lean Project Delivery through a combination of divergent and convergent thinking in a structured collaborative workshop (a Flow Walk) is an effective approach to identify constraints and risks and also create a shared understanding of project scope within project teams.

IV. Research Method

The Flow Walk was designed, developed, and tested through six action research cycles – each one informing the next - within a 27 month, funded UK case study within an Organisation (X) and through external workshops at the NTU Centre for Lean Projects 2nd Annual Research Showcase Day and LCI UK's Annual Summit in 2017.

Figure 1: Flow Walk Participants at LCI UK Summit 2017

V. Research Findings

1) Information - Blue	2) Equipment - Pink	3) Materials - Light Blue	4) People - Yellow
5) Prior Work - Green	6) External Conditions - Red	7) Safe Space - Orange	8) Shared Understanding - Purple

Figure 2: Flow Walk Pre-Work Sheet

Individual pre-work is first required (Figure 2). This sheet captures divergent thinking from multiple stakeholder perspectives using the question: "what are the constraints relating to each flow that will stop project delivery?" The structured workshop is then focused on the following 5 rounds:

1. **Individual Flow Walk –** Validate existing categories identified through the pre-work and identify any constraints that impact other flow.
2. **Group Flow Walk –** Generate consensus for any ambiguous constraints, category names & content, and add any additional constraints.
3. **Individual Flow Walk –** Prioritise the constraints that are perceived to have the biggest LOI (Level of Impact) and total the number of references to each constraint category
4. **Group Flow Walk –** Using convergent thinking combine similar categories of constraints from the different flows and rank them by the number of references to each combined category
5. **Poll Time –** Individually rank each combined category between 0 and 10 regarding the team's LOC (Level of Confidence) in their ability to remove the constraints where 0 is outside the team's control and 10 is fully within the team's control

VI. Conclusions

The "Flow Walk" is an effective approach to identify project constraints and risks as well as creating a shared understanding of project scope, strategy and purpose.

Guidelines to develop a BIM model focused on construction planning and control

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I. Background

Information pulled from 4D simulations may be used to compare construction scenarios as well as to support decision-making in production planning and control. Different projects, software, tools and planning methods result in a diversity of inputs that should be considered while trying to fulfil 4D simulation needs. If those are not properly addressed, it may lead to inconsistencies and lack of suitable information. The existing literature on 4D BIM does not provide much advice on which information should be considered to develop a 4D simulation. The aim of this paper is to propose a set of guidelines to devise BIM models to support production planning and control with emphasis on Lean Construction principles and concepts.

IV. Research Method

Design Science Research (DSR) was the methodological approach adopted in this study. Even though this research adopted DSR, the empirical studies were carried out as Action Research (AR) studies: representatives of the companies were fully engaged in the implementation of changes, and there were several learning cycles during the research process. Data from three empirical studies were retrospectively analysed and are the background and source of information for the guidelines established. Some key information regarding these empirical studies are compiled in Figure 1.

	Research A		Research B
	CASE 1 (12 months)	**CASE 2 (5 months)**	**CASE 3 (11 months)**
Software	**3D model -** ArchiCAD 20 **4D simulation** - Vico Office R6.1	**3D model** - Revit 2018 **4D simulation** - Vico Office R6.5	**3D model** - Revit 2017 **4D simulation** - Synchro Pro
3D model	Researchers developed the 3D model based on 2D CAD drawings of the architectural design	Company provided the architectural 3D model developed	Researchers developed the 3D model based on 2D CAD structural design drawings
Company	Construction company focused in the residential buildings segment	Construction company focused in the residential buildings segment	Company delivers complete solution of prefabricated structures
Project	Residential condominium consisting of 99 houses with 5 different layouts located in Porto Alegre, Brazil	Residential condominium consisting of 5-storey towers with 30 apartments each located in Porto Alegre, Brazil	University campus located in Porto Alegre, Brazil
Source of evidence	**Document analysis (including 2D designs, 3D models, and planning and control data)**		
	Interviews carried out with project stakeholders		
	9 unstructured interviews carried out with external consultants to discuss the plans, the BIM model needs, its development and 4D simulation	4 semistructured interviews with project manager, project planning responsible and the architecture firm which developed the 3D model to identify if it would attend 4D simulation	6 unstructured interviews carried out with concrete prefabrication company and Company C
	Site visits	**Meetings with site manager with the support of 4D simulation**	
	7 site visits to compare the 3D model to the construction site	5 meetings to discuss the master plan using 4D simulation	26 meetings to discuss loading plans using 4D simulation
	Participant observations in short/medium-term planning meetings to discuss construction progress		
	11	5	5

Figure 1: Description of the empirical studies

V. Research Findings

By analysing the results of the empirical studies, it was possible to identify the origins of 3D modelling demands in order to address required information to support production planning and control, as shown in the Figure 2. Based on these 3D modelling inputs, researchers proposed a set of guidelines to be addressed in order to develop a BIM model to support production planning and control, explained in Figure 3.

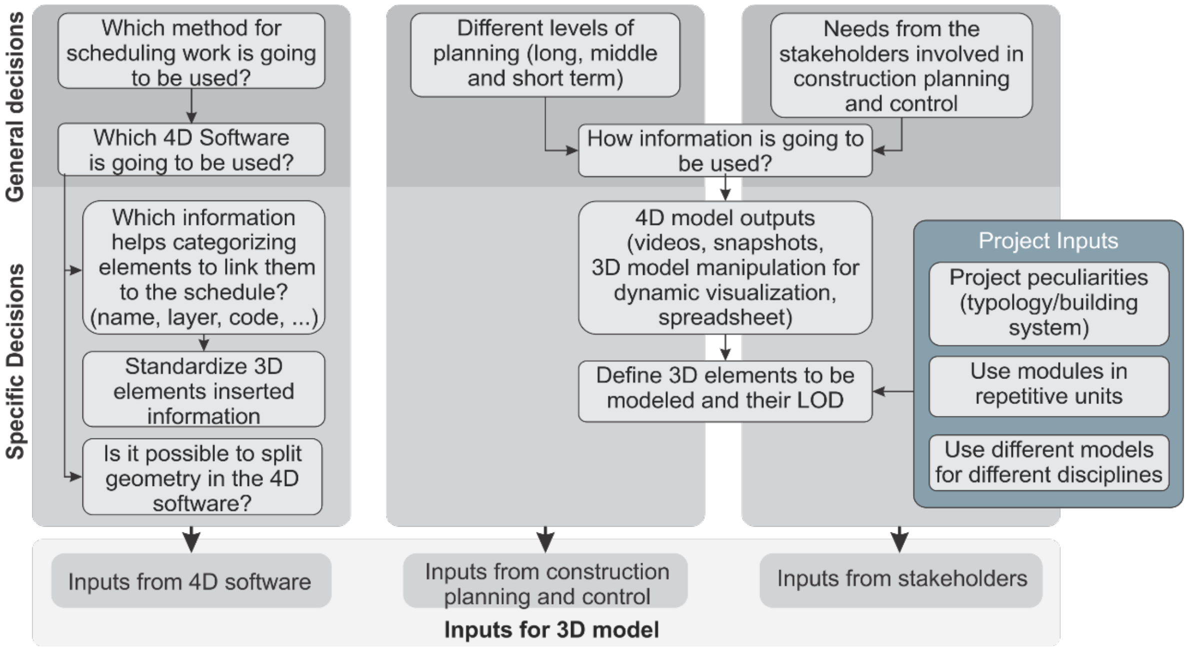

Figure 2: BIM model development inputs origins

Standardize elements according to planners use	The standardization can facilitate and reduce planners working time by addressing their specific uses, and also reduce planner non-value adding activities, by reducing time to perform planning related activities.
Identify stakeholder needs related to production planning and control and the appropriated 4D output for them	Addressing relevant information by enhancing requirements capture can increase the output value to stakeholders as they understand the processes and methods more easily.
Define to which level of planning (long, middle or short term) the 4D simulation will be used and establish elements LOD according to it	These definitions can reduce production variability by visualizing and understanding workflows, which can be simplified by a visual output. Moreover, it can improve planning by forcing planners to think about production levelling, which can be supported with enough information from 4D models.
Define if operations are going to be simulated and if so model inventory areas, equipment, temporary facilities and accesses	Modelling important elements to operations enable logistics simulation and consequently helps reducing cycle time by minimizing non-value adding activities related to these operations.
Define 3D elements to be modelled and their LOD	These definitions allow planners to visualize construction processes and methods with the level of detail needed. Moreover, it provides enough information for planners to detect and solve problems using 4D information before these problems interfere in the production planning.
Identify repetition inside the project	The identification of identical repetitive modules enables modeller to reuse model`s information.
Define the method for scheduling work that is going to be used, then chose the 4D software and identify if it enables splitting elements geometry	Identifying if the 4D software allow splitting elements geometry eliminate modellers need to split elements while developing the 3D model. By contrast, if the software does not do it, output value can be increased if modellers split them into the 3D software, as it enables more construction simulation options.

Figure 3: Guidelines to develop BIM models focused on production planning and control

VI. Conclusions

The main contributions of this study are concerning with understanding the sources of information for 3D modelling and how information should be gathered so that 4D BIM models can effectively support planning and control decisions. A model based on these guidelines should provide relevant information to support decision making, and consequently contribute to reduce variability, increase data reliability, eliminate non-value adding activities and reduce 3D modelling time. The understanding and engagement in the project by all parties involved increased the process transparency since it made clearer to people which information was relevant to the model and why it was not necessarily highly detailed.

Constraint Removal and Work Plan Reliability: A Bridge Project Case Study

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I. Background

Effective constraint removal is critical in Last Planner System (LPS®) in order to improve work plan reliability. While dealing with different types of constraints routinely, last planners need to understand the level of uncertainty associated with each constraint and have a mechanism to prioritize the constraint removal discussions. Revealing the uncertainty and difficulty level for constraint removal will help last planners and project managers utilizing meeting and planning time efficiently and improving work plan reliability at the same time. The research objectives are 1) quantifying the information gain for each constraint removal, 2) measuring the information transmission efficiency of constraint removal discussion in planning meetings, and 3) proposing a guideline to improving meeting effectiveness.

II. Current Conditions

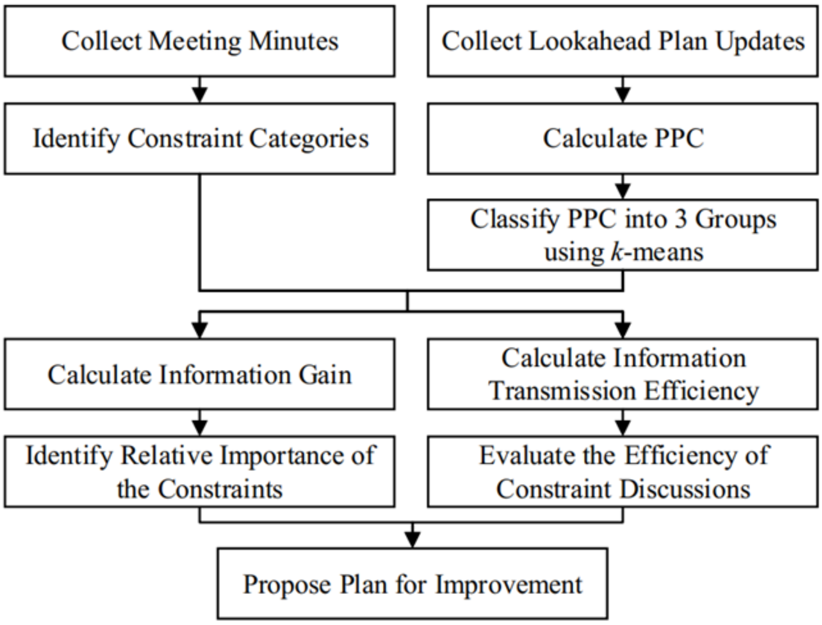
- Jang and Kim (2008) identified the significant positive relationship between Percentage of Constraint Removal (PCR) and Percent Plan Completion (PPC) by analyzing data from two bridge construction projects.
- In more recent study, Hamzeh et al. (2015) built computer simulation models and found that identifying and eliminating constraints impact project duration.
- In current practice, project managers and field managers hold planning meetings to identify constraints, discuss ways to remove constraints, and provide updates on the status of constraint removal.
- Further research is needed to better understand how constraint removal discussions in planning meetings impact planning reliability.

III. Working Hypotheses

- Weekly meetings do not address all the seven constraints equally. Weekly meetings may work best to solve issues related to sequencing and prerequisite work readiness, whereas other types of meetings are maybe required for more technical matters such as clarify design and required specifications.
- There is an optimal order for addressing constraints at planning meetings which can lead to more effective meetings.

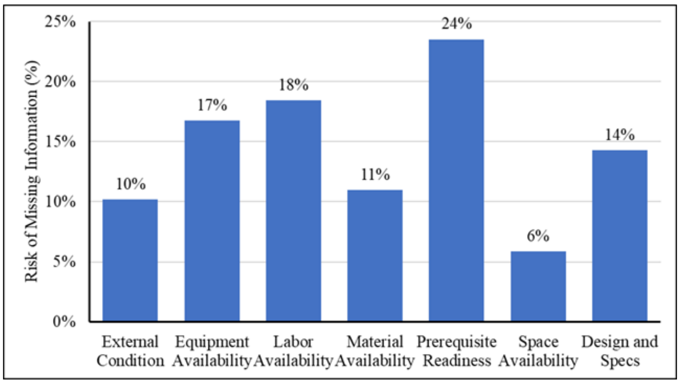
IV. Research Method

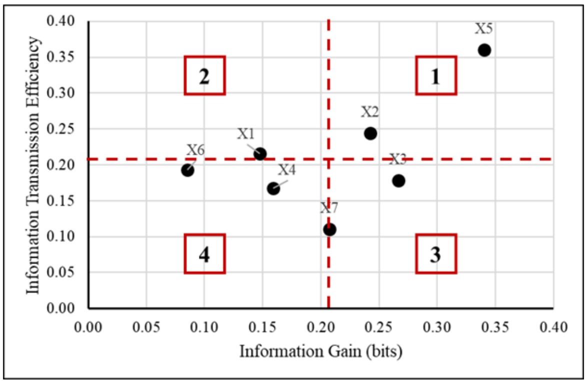
A case of bridge construction project in U.S. was used for this study. The project was a Design-Build project with an estimated cost of $200 million. The research design is illustrated in the flow chart below.



V. Research Findings

- In this case study project, the top three constraint categories that highly contribute to the total information gain for PPC improvement at planning meetings are “Prerequisite Work Readiness”. “Labor Availability” and “Equipment Availability.”
- “Prerequisite Work Readiness (X5)” discussion not only resulted in high information gain, but also the information was transmitted with high efficiency.





VI. Conclusions

- Different constraints have different levels of uncertainty and contribution to information gain for improving PPC. In this case study project, “Prerequisite Readiness” was the most important constraint and contributed 24% to the total information gain for PPC improvement.
- In this project, information gain on “Prerequisite Readiness” at weekly meetings improved PPC up to 15%, whereas information gain on “Space Availability”, “Material Availability”, and “Design & Working Method Clarification” improved PPC to 4%, 7%, and 9% respectively.
- Constraint removal discussion had different levels of efficiency. In this bridge project, “Prerequisite Readiness” had the highest information transmission efficiency of 36%, almost twice the average information transmission efficiency of other constraints.
- Some constraint removal can cause instant improvement in work plan reliability. Others need to take longer time to address the issue and reflect the results.

Combining takt planning with prefabrication for industrialized construction

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I. Background

Prefabrication and takt planning and control have been extensively discussed among lean construction researchers and practitioners. Literature has proposed various approaches and methods to industrialize construction, including lean construction, prefabrication, re-engineering processes, and new practices for planning and scheduling. However, the combination of prefabrication and takt planning as a way to promote industrialization in construction has been underexplored in previous research.

II. Current conditions

The purpose of this research is to analyze the potential synergies of combining prefabrication and takt planning for more industrialized construction. This is visualized in Figure 1.

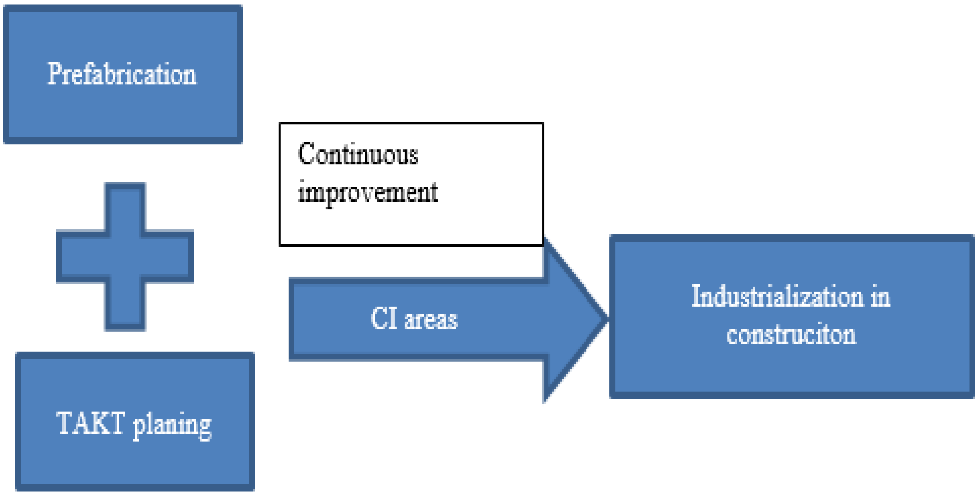

Figure 1. Prefabrication and takt role for the industrialized construction

III. Working hypothesis

- *What are the synergies of combining prefabrication and takt planning for industrialized construction on project level as opposed to utilizing them as separate strategies?*

IV. Research Method

- Literature review
- Multiple case analysis:

  Case I: The Van Ness and Geary Campus Hospital (VNGC) is a 91,974-square-meter, 2.1-billion-dollar construction. It is a 13-storey, 274-bed acute care hospital with a possible expansion to 304 beds and it will be built in downtown San Francisco. It has adopted both prefabrication and takt planning.

  Case II: The Capella project is a 7-storey residential building project in Helsinki, Finland. The building includes 42 apartments. Only takt planning has been implemented without prefabrication.

V. Research Findings

- In Case I, prefabrication and takt planing together have significantly helped overcome several challenges such as traffic, residential neighbourhood, logistics, storage and parking.
- Case II showed that several bottlenecks might appear during the takt implementation if the critical path on-site consists of long phases, such as drying, in which active takt crews are not needed (Figure 2).

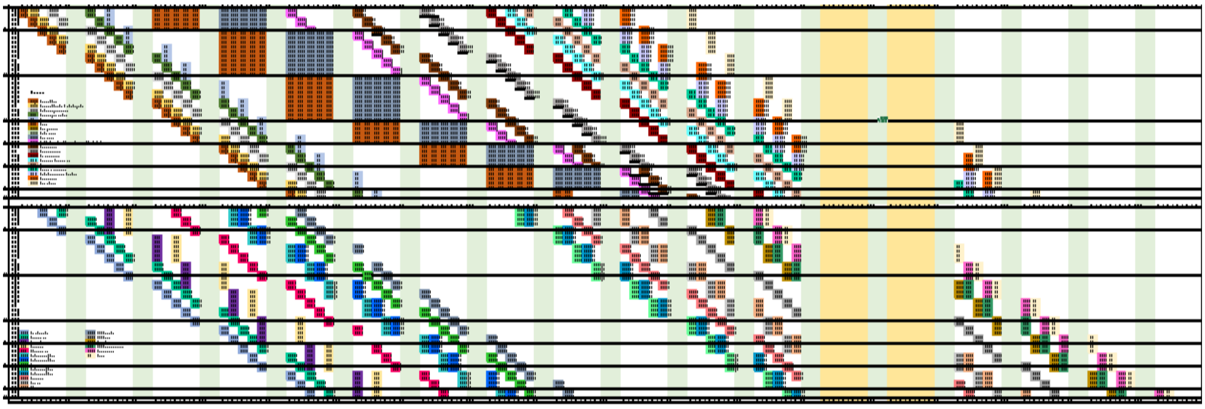

Figure 2. Takt plan of Capella project. The bathrooms are shown in the lower portion and are on the critical path. The drying time of concrete results in an empty area before floor tiling work.

VI. Conclusions

- Both takt planning and prefabrication play a significant role in various industrialization areas such as in logistics by smoothing the material and information flow, in speeding up the project, in planning and controlling the process, in reusing materials, in experiences and measurements, in focusing on the market and customer demand, and in improving the long-term relationship with project stakeholders.
- Instead of seeing different practices as separate strategies, adopting prefabrication and modern production planning methods such as takt planning together would be highly beneficial.

Is Integration of Uncertainty Management and Last Planner System a Good Idea?

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Managing the “Receding Edge”

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I. Background

Construction activities are bounded by a “leading edge” at their start and a “receding edge” at their end. Both edges are fuzzy in practice, especially when an activity comprises several sub-activities.

Fuzziness of the receding edge (this study’s focus) is a problem, e.g., when an activity drags out from one repetitive instance to the next, the increase in work-in-process and resource uncertainty may become costly to the contractor responsible for it as well as to the project overall as follow-on activities may be impeded by “leftovers” from their predecessor.

A presumed ideal is that, when repeating activities, the front and back of each activity remain connected with a constant distance in-between; this distance or time in-between defines the cycle time of the activity. Reliably achieving that cycle time is key to performance consistency (e.g., implementing a takt plan, though that is not the focus of this study).

II. Current Conditions

People pay more attention to starting activities, and starting new work at regular time intervals to a beat (aka. takt), than to finishing those very activities. As the leading edge progresses, activities thus stretch out: the distance in-between the leading- and the receding edge increases over time.

Activities may start despite being “unsound” as defined in the Last Planner® System (Ballard 2000, Ballard and Howell 2003), or without having a “Complete Kit” as defined by Ronen (1992) of what is needed to perform them, resulting in workers making-do (Koskela 2004, Formoso et al. 2011).

Unfinished work is observed and may get accomplished by means of informal work packages (activities) (Fireman and Formoso 2013).

Definition: The “receding edge” of an activity in a contractor’s scope of work includes the work that *appears to not have to be completed* in order for them to move on to their next activity (e.g., the next work location), but *must* be completed for the contractor to “handoff” their work to others, have finished their total scope of work on the project, and leave the jobsite.

“Done” vs. “done-done:” The receding edge articulates when work is not just “done” (as may be captured when using project controls metrics) but “done-done,” and the successor contractor may start their work, unimpeded by their predecessors’ unfinished work or “leftovers.”

While receding-edge work may appear to make up only a small portion of the required work on a project and to not be essential to work progress (i.e., the ability of workers to move on to the next cycle), it is not immaterial. It can cause unpredictability and delay, and costs the project money.

III. Working Hypotheses

- Construction processes are ill-defined in terms of their leading- and receding edge, steps to be performed to accomplish an activity, and process capability.
- Definition and standardization of receding-edge work leads to improved project performance.

IV. Research Methodology

1. Identify project and scope for gemba walk.
   Project: 55 story Transbay Block 8 in San Francisco, California. The building structure is erected using a 3-day takt between floors. Slabs are made of cast-in-place post-tensioned concrete. Each slab measures roughly 1,600 m^2 (~17,000 ft^2).
   Scope: receding-edge activities related to forming, placing, and finishing post-tensioned, cast-in-place concrete slabs.
2. Conduct gemba walk, observe, document, use 5 WHYs, exchange ideas with management and field personnel, analyze activities, identify countermeasures and test them.
3. Review literature on starting and completing activities, waste, unfinished work, making do, etc.

V. Research

Observations of Receding-edge Work and Proposed Countermeasures

1. Concrete floor finish was "done" but required patching before a smooth surface could be handed off as "done-done" to the finishing subcontractor.
   a. Proactive countermeasure: improve formwork lubrication practices.
   b. Reactive countermeasure: develop and implement a standard process for patching.

2. Wall/ceiling intersection leaked at the edge, causing excess concrete to dribble down and coagulate on the walls of the floor below. The resulting patches of excess concrete had to be removed by a returning crew before the floor is cleared and work is "done-done."
   a. Proactive countermeasure: close the gaps between sides of panels with cover or filler material.
   b. Reactive countermeasure: develop and implement a standard process for formwork stripping to ensure that any patchwork can be completed asap. after a placement is complete as concrete hardens over time.

Findings

- Construction work processes appeared to be defective or none-existing for receding-edge work.
- A process specification may fall short in terms of spelling out what is to be done, how, when, for how long, and in what order, i.e., it may be unfit-for-purpose in terms of process capability.
- Defects are one of Ohno's 7 wastes. Defective work processes may manifest themselves on site as unfinished- and make-do work. In this context, making-do is not an 8^{th} waste, but a means to mitigate a defect.
- Standard processes must be defined for all construction work, e.g., including clean-up work.
- Resources must be designated to accomplish all processes, whether it is for work at the leading- or receding edge.

Contributions to Knowledge

- Articulated the receding edge concept.
- Described challenges in managing receding-edge work.
- Documented lean methods as countermeasures to those challenges.

VI. Conclusions

All work, leading- or receding-edge, must have process definition.

When construction work is managed considering the production impact of receding-edge work on the contractor responsible for it and on follow-on contractors, the case for cycle time reduction is easy to make and worth the money.

KNOWLEDGE MANAGEMENT AND ITS APPLICATION IN DEVELOPING LEAN CULTURE

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I. Background

Construction projects have potential to be rich sources of knowledge for the organization. However, given the scale, complexity, diversity, uniqueness and geographic dispersion of these projects, acquiring this knowledge becomes a challenge. This challenging environment can result in this knowledge going uncaptured. This 'waste of knowledge' results in organizations 'wasting time and money' during a project's life cycle to 're-invent the wheel', to do re-work or for failed bids. This paper examines the role of Knowledge Management (KM) as an enabler in developing Lean Culture

II. Current conditions

- *Learn Before* - Project team can refer to the Lessons Learned reports, success stories and project completion reports of past projects which are readily available in KM portal as a guide in adopting right practices and avoiding mistakes.
- *Learn During* - The project team can get learning support during execution of work through Activity Based Classrooms, Classroom at Site, Ask an Expert, Technical Audio Visuals, Process Videos etc. as per their demands.
- *Learn After* - The captured lessons learned throughout the lifecycle of the project are consolidated in Lessons Learned session at the end of the project.
- Kindly refer to the paper for detailed discussion on each type of KM activity

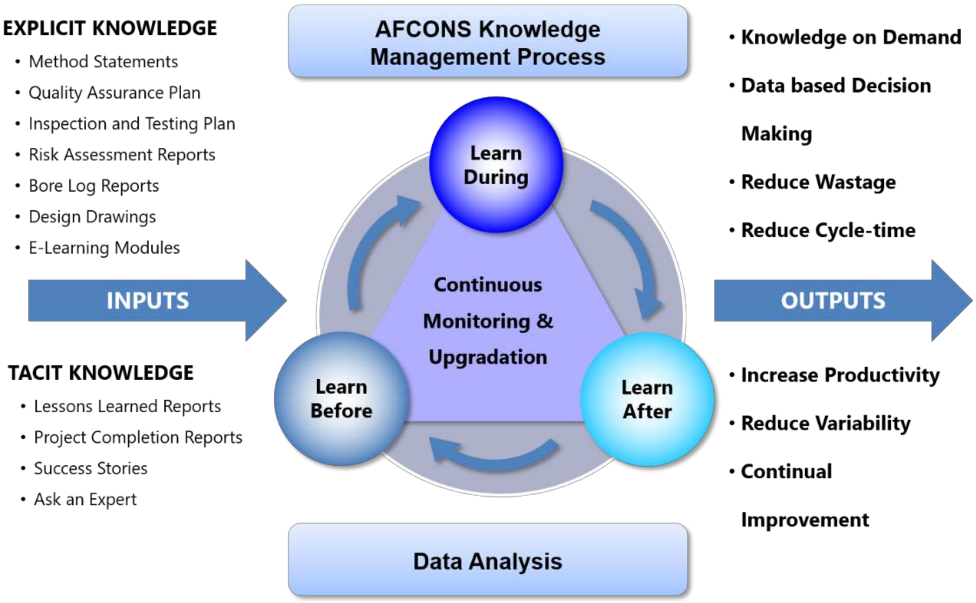

Figure 1. Afcons Knowledge Management Process

III. Working hypotheses

- Knowledge Management through sharing best practices and learning from past projects, can be an effective means of developing Lean Culture.

IV. Method

- KM promotes development of a learning organization and efforts to eliminate waste and improve construction processes will invariably require sharing and transferring knowledge from previous projects and later to transfer the learning from Lean initiatives to new projects.
- Learning can be pushed to Learner through Activity Based Classrooms, Classroom at Site, and Kick-off workshop.
- This content is decided based on the type of project, with the aim of ensuring that most project team members are made aware of the critical aspects and activities for the success of the project.
- Apart from this, the Learner can pull the Learning through the KM portal (Gnosis), E-learning, Ask an Expert, Project completion reports and Lessons Learned. This enables the learner to quickly reinforce or upgrade his skill, find solutions to problems and identify improvements/innovations to improved performance.
- This ensures that mistakes made in earlier projects are not repeated.
- Afcons KM system allows project team members to connect, explore ideas for improvement and build on previous successes and failures.
- Improvements made through lean initiatives can hence be effectively deployed horizontally to ensure transmission throughout the organisation.
- Refer Table 2 in the paper which describes the facets of our Knowledge Management system that supports and enables various Lean principles.

V. Examples

- Activity based classroom, conducted for a Metro construction project ensured that repeat errors were proactively avoided
- A checklist prepared after VSM exercise for a Wharf construction project was standardized and deployed horizontally to all projects
- An innovative method statement for underwater pile cleaning and painting was reused to solve a similar problem for a Sulphur handling jetty in an international project
- A group of experts conducted a Activity based classroom along with the project team to reduce segment launching time by half for a bridge over a major river

VI. Conclusions

- Knowledge Management can be an enabler for building a Lean Culture by
  - preventing ‘waste of knowledge’,
  - satisfying ‘information demand’ to the right person, at the right time and in the right form
  - and supporting transfer of learning from Lean initiatives to new projects
- Development of a Lean Culture is a slow and gradual process and an effective KM system acts a catalyst to accelerate the adoption of Lean principles.

Effective Project Delivery using Lean Principles across all disciplines of Construction in a Developing Country Environment

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Diamond Baretto, Assistant General Manager, Godrej Construction, Mumbai, India

I. Background

Construction Industry in a developing county has to counter many challenges. Research studies have indicated that large projects across various asset classes typically take longer to finish than scheduled and tend to overshoot the budgeted cost. In order to make the planning process predictable and create commitment based culture the organization amalgamated Lean into Critical Path Method by creating a Milestone Schedule given by the Top management and many such other processes. This paper portrays an organisation's Lean journey from residential to industrial projects using case studies with key learnings to explain how the success of Lean implementation is possible only when there is a cultural change brought among all the project stakeholders to strengthen team spirit and drive improvement initiatives.

II. Current conditions

Lean philosophy and practices are being followed by the organization in all its projects, and other businesses. Deployment of various Lean tools like Value Steam Mapping (VSM), Work sampling (WS), Last Planner System (LPS), Big Room Meetings, Steering committee etc. is being done. In the previous and current ongoing projects, the organization has some benefits such as reduction in wastages of time, resources, quicker decisions, collaborative working etc as compared to the traditional style of project execution which was used earlier by the organisation.

III. Working hypotheses

The organisation felt the need to apply the Lean Construction philosophy for continuous improvement and believed that Lean philosophy would help them create collaborative working approach, assist in reduction of wastes and increase of stakeholder value by deployment of various tools etc.

III. Research Method

I. Background	V. Proposed countermeasures
The organisation is a leading construction company having large industrial and residential projects pan India. The organisation felt that to strive to improve its project delivery, reduce wastages and create more customer value by inculcating a lean culture amongst all stakeholders. The organizations' rationale for implementation of Lean Construction and deploying its various tools and techniques was	The organisation conducted a Workshop / Partners Meet with all its vendors and the Top Management which involved team building games, sharing of project related experiences by vendors with Lean Construction. The focus at this preliminary stage was to gain trust by increasing transparency with stakeholders

with the intent of improving the cost, quality, and time safety metrics for a project to ensure that customer commitments are met.	necessary for creating a strong foundation for implementing Lean Construction.
II. Current conditions The organisation which started its Lean Journey in 2011 is practising Lean philosophy in all of its projects. Deployment of various lean tools like VSM, LPS, LBMS, WS, Big Room Meetings, Steering Committee etc had helped the organisation to reduce wastage and increase the stakeholder value. **III. Goals/Targets** To develop a Lean Culture amongst all its employees and stakeholders and collaborate to reduce the various wastages like time, resources etc to increase the end value of the product or the service.	VI. Plan The organisation has devised a road map for Lean Implementation - Implementing Lean right from the Conceptual Design to Customer Handover stages of the project. - Further improvement in the productivity rates at construction projects and its concrete manufacturing businesses. - Creating a Lean Culture in the organization through Human Resources Trainings. - Quarterly Lean Newsletters for creating awareness among all internal stakeholders about Lean initiatives and horizontal deployment.
IV. Analysis Improving labour productivity in all trades of construction has been found to be very challenging as compared to the manufacturing industry due to migrant labour, low skills and lower penetration of technology and mechanisation at the work sites. The high percentage of wastes generated in construction projects also puts tremendous pressure on natural and human resources. In order to mitigate the above mentioned challenges and risks and to improve our way of working, an organization embarked on the Lean journey starting with its Residential Towers using Partnering and other Lean principles for multiple stakeholder management across all our projects.	**VII. Follow up** - Ensuring ongoing PDCA for all the tools being deployed at various sites - PPC analysis is also being done and necessary CAPA is assured. - Capturing and sharing the learning of the completed projects are being done and the issues faced are listed. - Regular visits / audits by experts and Senior management to ensure that the lean journey is on the right track.

V. Research Findings

Based on our experience in Lean implementation across various projects we found that Lean helps in creation of better relationships with our stakeholders, early identification of constraints and non-value adding activities, increased trust and transparency, waste minimization, smoother process flow for efficient project delivery and better monitoring and controls using “pull” mechanism.

VI. Conclusions

The success of Lean implementation is possible only when there is a cultural change brought among all the project stakeholders to strengthen team spirit and drive improvement initiatives with strong support from the Top Management. A focussed approach and imbibing the cultural changes in the organisation help to overcome all the barriers faced in the Lean Journey.

Reaping the Rewards of Production Tracking

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Enhancing Labour Productivity in Petrochemical Construction and Maintenance Projects

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I. Background

Construction labour is a significant cost factor for petrochemical plant owners and their contractors. Despite the low cost of labour in several nations, concerns over societal issues like ageing and tightening immigration have forced governments to reorient towards productivity-driven economic growth. In the case of Singapore, a target of 2-3% annual productivity growth has been set for the decade up to 2020. Therefore, enhancing labour productivity in the energy and chemicals sector (which accounts for nearly 34% of the manufacturing output), is an indispensable requirement.

II. Current conditions

- Lean construction categorizes production activities as either a value-adding or non-value adding activity. The reduction of non-value adding activities (waste) has been identified as a fundamental driver for enhanced productivity. Source: Koskela (1992). *Application of the New Production Philosophy to Construction.*
- Continuous productivity measurement and comparison of data from different projects have been highlighted as key to improving construction productivity. Singapore uses the value-added per employed person as the labour productivity index which has limitations in international comparison. Therefore, there is a critical need for a common productivity measurement method fit for all projects, companies and countries.
- Activity Analysis is an indirect measurement method of labour performance. It is a continuous productivity improvement process that measures the time expended by workers on-site and determines hurdles to productivity which should be mitigated (CII 2010). Activity Analysis may be construed as a Value Stream Mapping tool.
- Activity Analysis involves an instant observation and categorization of labour activities at fixed or random, infrequent intervals through the day. This provides the estimated time spent by a craft labour on various activities at a plant or construction site. Based on the results, improvement strategies would be planned and implemented.
- Based on extensive background research, the following labour-activity categories were adopted for this study: Direct work, Supportive work categories including preparatory work, material/tools handling and Non - productive work categories namely waiting for permit/ material/ tools/ inspection/ instruction, travel or personal.
- Activity Analysis follows a multinomial distribution rather than a binomial distribution, as several activity categories are considered. The minimum number of observations per hour (for workers < 510) may be calculated as the reciprocal of the sum of reciprocals of the number of craft workers (N) and minimum observations (n_o = 510 for a confidence interval of 95%).

III. Working hypotheses

- *This research aimed to utilize Activity Analysis to (1) assess labour efficiency in Singapore's petrochemical projects in terms of craft-worker time distribution; (2) investigate reasons for non-value-added work hours; and (3) recommend best practices to reduce non-productive activities and therefore improve labour productivity.*

IV. Research Method

Activity Analysis was conducted in a five-step process: Plan Study, Sample, Analyse results, Plan Improvements and Implement Improvements (CII 2010). The study was conducted using an automated data collection software developed by CII and NUS researchers exclusively for this research study. The Activity Analysis method was modified substantially to reflect the site conditions and maintenance activities, shutdowns, and turnarounds. The first cycle of 10 pilot projects was selected from five facility owners. Another cycle of Activity Analysis was conducted to verify continuous productivity improvement.

Source: CII (2010). *Guide to Activity Analysis*, Construction Industry Institute, United States.

V. Research Findings

- In the first cycle of 10 projects, overall aggregate direct work percentage was 29.5%. Workers were found to spend significant time on travel (23.8%), material handling (15.7%), preparatory work (13%) and waiting during the first hour of a workday.
- The aggregate direct work percentage for construction was 33.73% and 27.00% for the maintenance and shutdown/turnaround projects due to differences in the work scope.
- Based on the first cycle, this study recommended strategies such as the advance issue of permits, utilization of weather delays and use of efficient material transport systems.
- In the second cycle due to time and site constraints seven projects were chosen. These projects had a similar scope of work as those in the first cycle so as to ascertain the effectiveness of the improvement strategies.
- The aggregate direct work percentage for the seven projects increased to 35.6% in the second cycle from 31.5% (for similar seven projects in the first cycle), indicating an improvement after implementing the solutions. The direct work increased from 32.7% to 37.9% in construction projects and from 30.4% to 30.8% in maintenance projects.
- Furthermore, waiting, material and tool transport, travel, and personal time decreased between the two cycles. Preparatory work time increased sharply from 13.3% to 21.3%. These results indicated a redistribution of worker time after implementing the interventions.

VI. Conclusions

- The study developed and implemented a modified Activity Analysis method suitable for the Singapore site conditions with a focus on maintenance activities and shutdown/turnaround projects, which were rarely considered in previous approaches.
- Conducted over two cycles, this study assessed the current labour productivity, identified barriers, and analyzed the efficacy of solutions implemented. The aggregate direct work percentage increased in the second cycle.
- The findings provide a basis for assessing and benchmarking labour productivity in the petrochemical industry.

A LEAN PERSPECTIVE OF STAKEHOLDER INTEGRATION IN PUBLIC PRIVATE PARTNERSHIPS

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I. Background

- Public Private Partnerships (PPPs) describe a procurement route that involves two main entities, the public sector and the private sector, for the provision of a public asset or service.
- The Special Purpose Vehicle (SPV) is the party representing the private sector in a PPP, and combines a number of stakeholders including equity shareholders, designers, contractors, and service providers under one umbrella. This entity is responsible for delivering the project from A to Z, starting from project design to construction and subsequent operation and maintenance for a relatively long period of time (20-30 years).
- Consequently, the key to ensuring successful project delivery is achieving the efficient integration of the different SPV stakeholders involved over the project life cycle to deliver the project as a unified entity.
- The above suggests a strong link between SPV project delivery and other forms of integrated project delivery (IPD) systems.
- Evaluating PPP project success therefore involves studying the degree of SPV stakeholder integration, considering that the latter is a keystone for successful delivery.

II. Current conditions

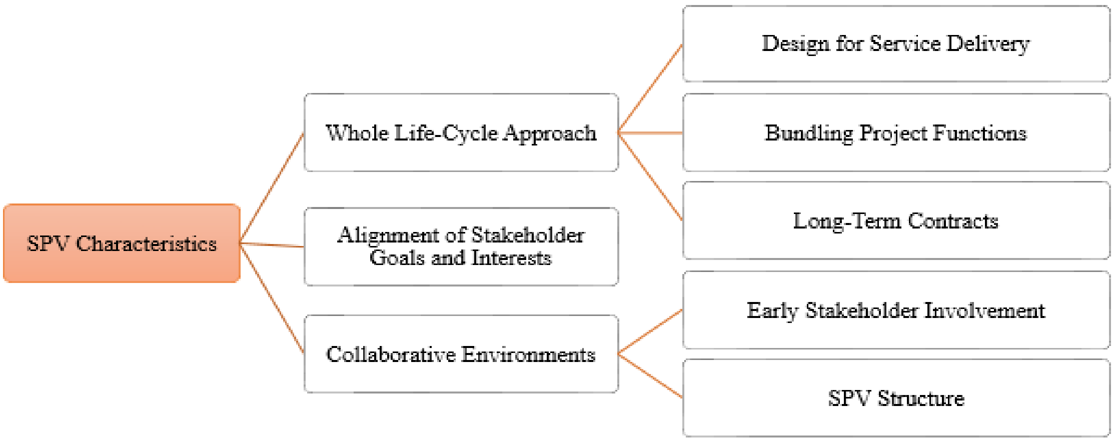
- PPP researchers state that project management studies have never focused expressively on SPVs and there is a lack of knowledge concerning the SPV's stakeholder management role and its internal stakeholder relationships and interactions.
- A review of the literature on PPPs reveals that there is a lack of a studies investigating SPV stakeholder integration or tying the delivery method to IPD forms.
- Therefore, there is a need to investigate and evaluate the efficiency of the SPV's management role, in terms of stakeholder integration, seeing that it is both a driver and a prerequisite for PPP project success.

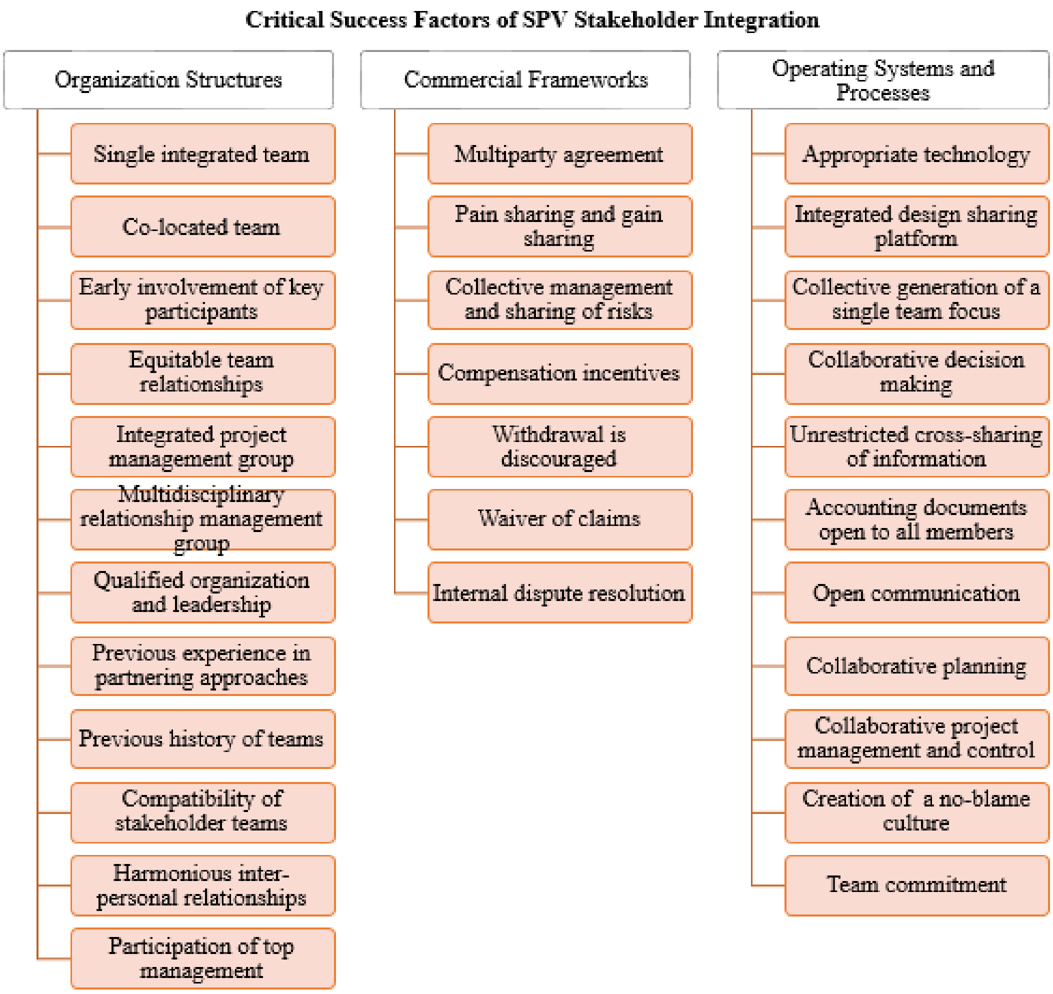
III. Goals/Targets

- *Identify the core characteristics of SPV procurement that reflect stakeholder collaboration and correlate it to integrated project delivery (IPD).*
- *Develop Critical Success Factors (CSFs) to measure the level of SPV stakeholder integration, based on concepts projected from the IPD system. The aforementioned factors relate to the project's organization structures, commercial frameworks, and operating systems and processes.*

IV. Research Method

V. Research Findings: SPV Characteristics and Integration CSFs





BEST VALUE PROCUREMENT (BVP) IN A MEGA INFRASTRUCTURE PROJECT

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I. Background

- Infrastructure projects grow in scale and complexity, at the same time as the construction industry has productivity problems.
- Norwegian government wants to more efficient implementation strategies in order to build faster and more cost efficient.
- The public road company decides to use a new implementation strategy called Best Value Procurement (BVP). BVP is new in Norway and no experience is documented.

II. Current conditions

- Cost overruns, time delays and conflicts characterize the Norwegian Infrastructure marked.
- No documentation of BVP experience is found in the Norwegian infrastructure marked.
- 0 BVP infrastructure projects completed in Norway
- A public road company implements BVP in a mega infrastructure project.

III. Objectives with implementing BVP

- Minimize inefficiency
- Implement ECI
- Up-front risk management
- Reduce waste of resources
- Award on qualification rather than price
- Cost efficient

III. Research Method

How the research was carried out:

- Literature review
- Single case study
- 11 in-depth semi-structured interviews
- Document study

Facts about the single case project:

Project Name	Description	Year	Cost (USD)
E6 Arnkvern – Moelv	24 km road expansion	2017 – 2020	$ 287,000 000

IV. Research Findings

The figure shows the structure of the findings and discussion section. It is structured using the three research questions and organized under the four phases in BVP.

How was Best Value Procurement implemented?			
• Education • Pre-qualification	• No information verification	• Clarify solutions • RMP	• Norwegian Standard • WRR
What were the participants' experiences with using Best Value Procurement?			
• Importance of BVP education • Qualified	• Subjective • Efficient procurement • Easy selection • Expertise over price	• Realistic expectations • Challenging with roles • Juridical risk	• BVP disappearing • WRR
How can Best Value Procurement be improved for future use?			
• Earlier involvement	• More objective • Information verification	• Education and experiences	• WRR as a part of the contract • Customise the contract to BVP

V. Conclusions

The BVP experience identified three major advantages of BVP over traditional procurement processes:

- Better risk management
- Realistic expectations of client's and vendor's performance
- Efficient procurement, with less waste.

A Comparison of Competitive Dialogue and Best Value Procurement

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I. Background

Competitive Dialogue (CD) and Best Value Procurement (BVP) are two different approaches to early contractor involvement (ECI) in public projects. However, it is not clear which approach is best suited for what kind of project situations, and which is better for implementing lean in public procurement. The purpose of this paper is to explore the similarities and differences of these approaches to develop recommendations for how to match approach with project situations.

II. Current conditions

- There is a limited examination of lean thinking in public procurement
- There is lack of research in the IGLC community in the area of public procurement
- There is no literature comparing BVP and CD

III. Research questions

- What are the similarity and differences between BVP and CD?
- Which approach is best suited for what kind of project situations?
- Which approach is better to implement lean in public sector projects?

IV. Research Method

With a supporting literature study, two cases were studied by conducting a document study and semi-structured in-depth interviewees with 12 key informants.

V. Research Findings

The two approaches have similarities such as 1) can be used as an approach to implement ECI, 2) can be used under the EU legislation, 3) work best with a design-build contract than design-bid-build contract, and 4) allow interaction between a client and suppliers during the procurement phase before contract award such as during interview, dialogue and clarification. A summary of major differences between the two approaches is presented in Table 2 without recommending one of them over the other.

Comparison between CD and BVP

No.	Comparison factors	CD	BVP
1	Timing of selection	Late selection	Early selection
2	Pre-qualification	Mandatory	Optional
3	Interaction	Dialogue	Clarification

4	No of competitors develop a project	≥ 3	1
5	Client’s control on the detail of the supplier's solution during procurement	High control (The client knows best – the contractor is hired to do the job)	Low control (The contractor knows best – they are selected because of their expertise)
6	Client’s role in the selection of solution	The client can filter the contractors’ solutions in the dialogue phase	The contractor present their solution in the clarification phase
7	Client’s resources need during the procurement	Demanding	Less demanding
8	Suppliers resources need during the procurement	All Shortlisted suppliers are required to develop solutions for the project, and it is demanding for all suppliers	Only one supplier develop a solution to a project, and it is demanding only for one of the suppliers
9	Selection criteria	Technical and varies with project	Non-technical and standardized
10	Weight qualification/ price	10% to 40% / 90% to 60%	75 % / 25 %
11	suppliers compete and evaluated based on	Project-specific solutions and price	Four standard criteria and price
12	Evaluation method/scale	Not standardized	Standardized
13	Documents from the competitors to be evaluated by the client	Comprehensive documentation	Max 6 pages document
14	Historical origin	EU	USA
15	On what kind of projects can it be used?	EU public procurement directive describes five circumstances in which the approach can be used	On all kinds of projects
16	Client access to suppliers’ idea	The client gets access to several ideas at a time	The client gets access to only one idea
17	In what situation is the approach suitable	If a client wants to choose a supplier based on their solution for a specific project	If a client is looking for an expert that has done relevant things several times with high performance

VI. Conclusions

The major similarity of BVP and CD is that public owners can use them to implement ECI. Since ECI is one of the important elements of Lean, BVP and CD can be used to implement lean in public sector. The other similarity is that they allow interaction between a client and suppliers before contract signing. Regarding their differences, the major ones are: In CD, several suppliers develop solutions for a project whereas only one in BVP. Furthermore, BVP is standardized and effective method compared to CD during the procurement phase.

The selection premises in BVP are based on the suppliers’ past performances and ability to understand the current project requirement. Therefore, BVP suits when a client looks for a supplier that has done relevant things several times with high performance. The selection premises in CD are based on the suppliers’ documentation of their solution to a specific project. Therefore, CD suits when a client is willing to invest more in the procurement phase to increase the product value by competing several suppliers based on their solutions to the project.

Both BVP and CD can be used to implement lean in public sector. BVP reduce waste and CD increase value. BVP is an effective procedure during the procurement phase, and it reduces waste in this phase. CD is relatively an expensive procedure during the procurement phase. However, it facilitates selecting and implementing project solutions that suit the project and the client needs. Therefore, CD increase project value with minor increase of cost during the procurement phase.

Design-bid-build vs. design-build contracts in road construction

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Process-based Cost Modeling Framework and Case Study

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I. Background

Findings from the literature review and observations of the current state of cost modeling during the Design Development phase in the Target Value Design (TVD) environment revealed (1) the lack of an effective cost modeling method to inform TVD during Design Development and (2) the lack of a framework to take advantage of BIM in estimating product- and process cost.

This paper delivers proof of concept for a PBCM framework and validated it through application on a case study using action research.

PBCM has more advantages in supporting TVD than traditional cost estimating methods have.

II. Current Conditions

In the current practice of collecting construction cost data, the cost of an installed component is compiled by adding up the cost of materials plus the cost of all resources used to install that component. This total includes inefficiencies and wastes which are inherent in construction processes, especially in projects that do not rigorously use methods to eliminate process waste or that do not use continuous improvement.

Traditional cost models such as Parametric, Assembly and System, and Unit Price and Schedule models rely on historical data to model the cost of new designs. These cost estimates are inflated by the wastes embedded in the historical databases, and result in increased estimated task durations and excessive estimated resource needs.

In TVD, product- and process design are integrated and the design team needs rapid cost feedback to trade off design alternatives. However, traditional cost models do not reflect cost changes due to changes in process design. Therefore, a cost model that takes into account the cost implications of logistics and construction processes can better support TVD in integrating product- and process design.

This raises a need for an alternative cost modeling method, able to specify: (1) cost changes due to changes in product design (i.e., changes in materials, shapes, or dimensions), and (2) cost changes due to changes in process design (i.e., changes in sequencing, logistics plans, or construction processes).

This research provides a framework for a Process-Based Cost Modeling (PBCM) method including three phases: (1) collecting process- and cost data, (2) mapping process- and cost data to objects of a Building Information Model (BIM), and (3) providing cost feedback to inform TVD.

III. Working hypothesis

In TVD, product- and process design are integrated and the design team needs rapid cost feedback to trade off design alternatives. However, traditional cost models do not reflect cost changes due to changes in process design. Therefore, a cost model that takes into account the cost implications of logistics and construction processes can better support TVD in integrating product- and process design.

IV. Research Method

'Proof of concept' experimentation expands the theoretical understanding of the cost modeling and cost estimating practices in the construction industry.

The authors used action research to develop the PBCM framework. The researchers promoted the change from a conventional elemental cost modeling method to a PBCM method. They joined and worked with project team members to design and execute a case study, collect data, and help to make adjustments during case-study implementation.

V. Research Findings

Research findings illustrate the effectiveness of PBCM in providing rapid cost feedback to designers so as to facilitate the process of design to targets. In addition, PBCM helps to make both process-related cost and product cost explicit to designers when they are analyzing design alternatives.

PBCM facilitates the coordination between specialists, assists in look-ahead planning, integrates product- and process design, and yields reliable estimates of manpower and process-related cost.

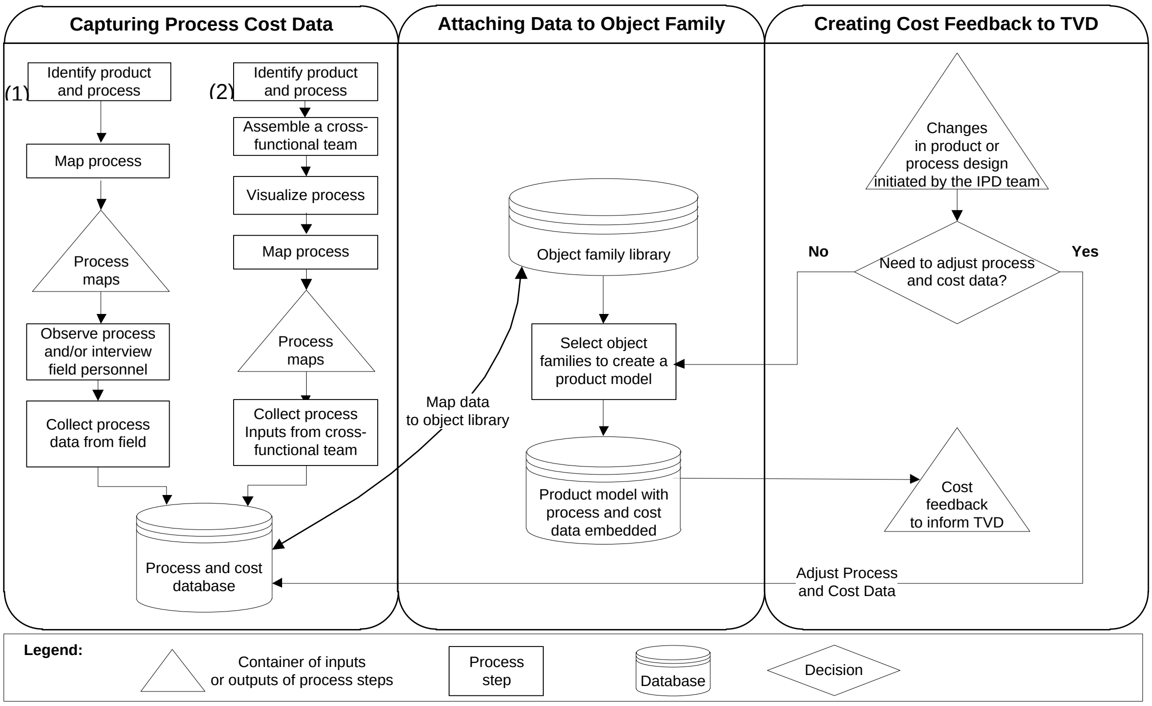

Figure 1: PBCM framework

By linking cost data to a product model (BIM), a PBCM provides rapid cost feedback to designers and lessens the time required to assemble cost updates that are to inform TVD.

By integrating process- and product cost data with BIM, an integrated product/process/cost model helps to streamline the design process and reduce rework in the design/estimate/re-design iteration. Implementation of the PBCM method helps the IPD team to maintain a knowledge database of product design, process design, and their costs for future projects.

VI. Conclusions

This paper delivered a proof of concept for a PBCM framework and validated it through application on a case study using action research. PBCM has more advantages in supporting TVD than traditional cost estimating methods have.

By integrating process- and product cost data with BIM, an integrated product/process/cost model helps to streamline the design process and reduce rework in the design/estimate/re-design iteration.

A New Perspective of Construction Logistics and Production Control: An Explanatory Study

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I. Background

Construction logistics and production control can enhance project performance. Research addressing site material management mainly aims at reducing hauling distances and transportation costs. Other studies address the effects of logistics on labor productivity, proposing partial solutions instead of comprehensive optimization. Moreover, previous research on logistics optimization covers various stages of supply chain, but stops once materials reach the construction site. However, different techniques can be used to haul these materials from storage areas to workplaces, including push and just-in-time techniques. These methods along with the effects they can have on crew performance still need to be studied. Pull and push techniques have been studied and applied for production control purposes. However, zooming into the level of project locations, the effects of production control approaches on crew performance still need to be studied. This paper reviews onsite construction logistics and production control techniques, studies them at the level of locations, and proposes hypotheses to be evaluated in future research, relating logistics mechanisms and production control systems to productivity.

II. Current conditions

A push technique applied for onsite material replenishment is applied though procuring materials to areas/workplaces based on a pre-set schedule, regardless if these materials are to be used straight away by a crew or not, or even if they are replenished with the right amounts and to the exact areas. Push technique used for onsite material replenishment and its effect on crew productivity is illustrated in Figure 1.

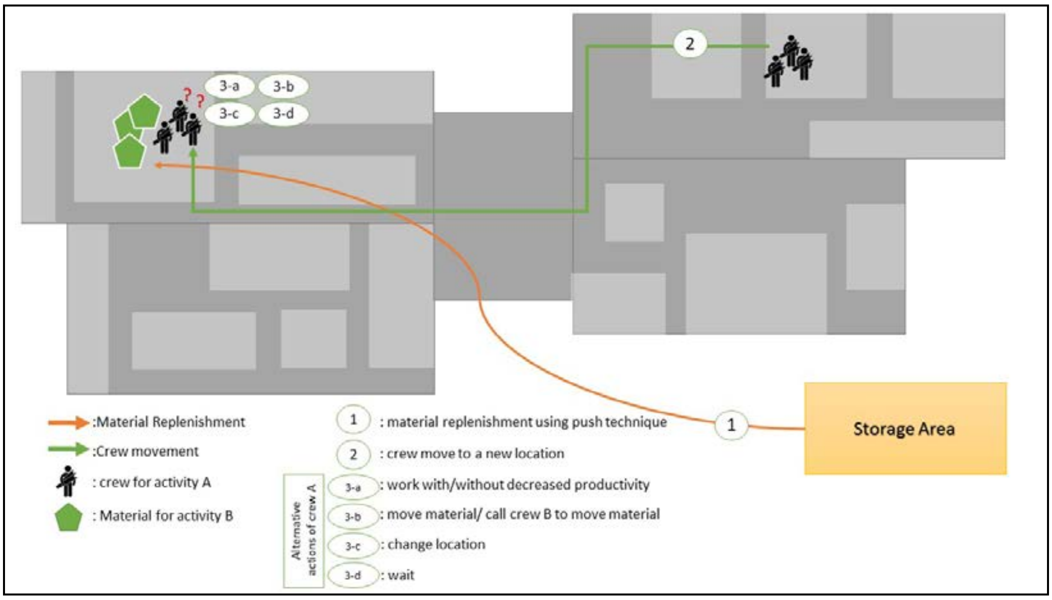

Figure 1 Effects of push technique used for onsite material replenishment on crew performance

Moreover, a push technique applied in production control at the level of locations means forcing the implementation of the schedule through assigning crews to activities as per the plan, paying less attention to their anticipated productivity. This technique is demonstrated in Figure 2 that shows crew logistics between areas following a push system.

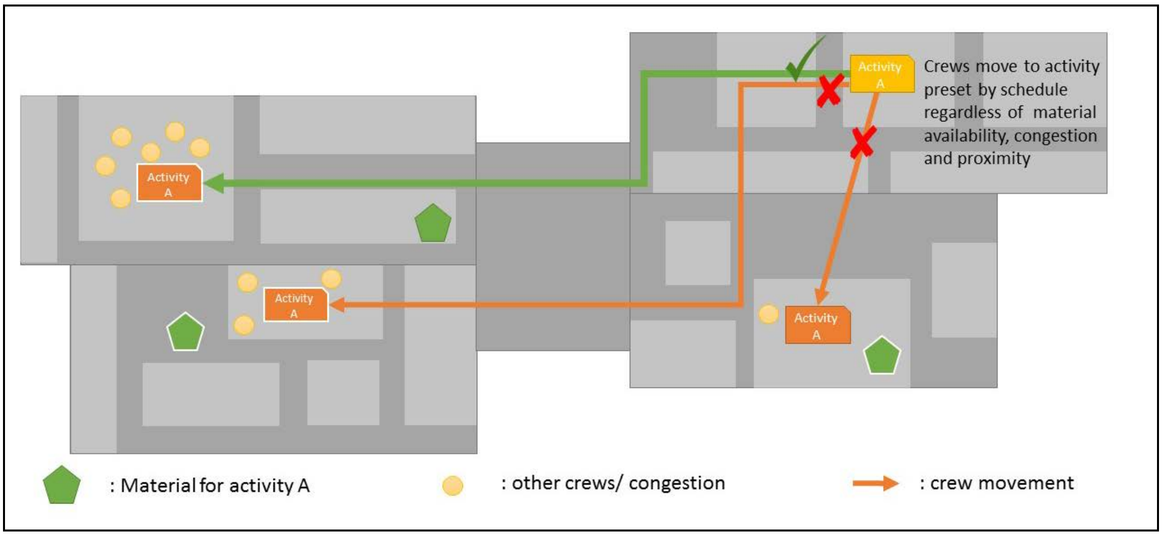

Figure 2 Push technique applied in production control at the level of locations

III. The need to add a new layer of production control and construction logistics at the level of locations

Different techniques used to procure materials from storage areas within a construction site to workplaces have different effects on crew performance and productivity. These methods along with the effects they can have on crew performance have received little attention in the literature. Therefore, this research studies push and just-in-time material replenishment systems, applied to material handling between areas within a construction site.

Moreover, traditional push method applied in production control has been compared to pull technique from scheduling and control perspectives, considering tasks and project durations. However, zooming into the level of crews and locations within the project, the effects of production planning approaches on crew productivity, crew allocation to areas, and interactions between crews on the same location are still not thoroughly covered.

All of these gaps bring the need to study these issues and add a new layer of production planning and construction logistics at the level of project locations.

III. Research Findings

- With a just-in-time technique for on-site material replenishment, productivity may be preserved in a better way. Materials are replenished to areas with the right amount, to the right location, and at the right time, based on actual demand of the corresponding crews, so they do not cause obstruction and productivity loss.
- Adopting a pull system in production control does not only consider the schedule, but also focuses on material availability, and anticipated production rate or congestion in the available locations. The main purpose of evaluating these factors is to choose the location that allows for higher labor productivity through pulling from milestones (schedule) and from the state of the system (actual conditions of congestion, material availability, etc.)

V. Conclusions

Extensive research is performed on many aspects of construction logistics, including research on site material management and delivery approaches to construction sites. Far less attention has been put onto construction logistics of crews and materials between areas within a construction site. Applying a push technique for material replenishment to workplaces shows negative effects on labor productivity. This can be avoided through applying just-in-time material logistics between locations. As for production control, it was shown that push and pull are compared based on their effects on tasks and general project performance without going deep into the level of crew logistics between areas within a project. This paper added this missing layer through showing how a push method reduces crew productivity despite increasing production rate, and hypothesizing that applying pull systems increases both productivity and production rate.

ISO and Lean can contribute to a culture of continuous improvement

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I. Background

This paper is presented as a timely, reflexive response to the critical view on lean construction presented by Green (1999, 2001, 2011) and those whom he cites in support of his arguments. The earlier response provided by Howell and Ballard (1999) dismisses much of the claims made by Green (1999) against lean construction; primarily addressing his disconnect with lean construction's emphasis on reliable workflow centred around production management. In this paper, the response to much of Green's lamentations is done by 'revealing' the inability of ISO 9001:2015 practice as a compliance standard to institute a CI culture, and proposing that ISO and Lean practice can contribute to a culture of CI within construction projects.

Green (2001) apparently views lean production, partnering and business process engineering as exemplars of the predominant 'best practice' agenda, serving the narrow cost efficiency interests of the technocratic elite (Green, 2000). Additionally claiming that lean construction as being amongst one of the many construction improvement 'panaceas' that are non-contextual, generic solutions that are reductionist 'bolt-on' models of change.

LPS and other primary lean construction practices are based on valid theoretical contributions that have clear interpretive flexibility to be contextually relevant. Viewing the unwarranted criticism levelled against lean construction and in the light of the 'growing acceptance' of ISO 9001:2015 as an option to deliver CI, an evidence-based research was undertaken to verify the inability of ISO to be a vehicle for instituting a culture of CI and instead propose the Last Planner System® (LPS).

II. Current conditions

- Much work has been undertaken by the lean construction community on planning in design and construction underpinned by the philosophy of CI, especially the work of Ballard (2000) on the Last Planner System® (LPS). However, in general such efforts have not been well received by the wider construction management community.
- Although, there have been recent developments within the industry regarding the implementation of CI, however it is evident that this concept is being incorporated within the many generic organization-wide initiatives, such as TQM, ISO 9001:2015 and business models of organizational excellence assessment.
- There is increasing "acceptance" that compliance to International Organization for Standardization (ISO) Quality Management Systems is adequate to secure the full benefits of CI practice. This appears to detract construction organizations from developing CI practice that can significantly contribute to a *culture of CI*.
- It is noted by Murphy (2002), that with the release of ISO 9000:2000, an unprecedented emphasis has been placed on customer satisfaction and continual improvement. Based on the current scenario in Malaysia and worldwide, an increasing number of construction organizations are now accredited with ISO 9001:2015 (previously being ISO 9001:2008) Quality Management Systems (QMS) standards. Based on the statistics provided by the Department of Standards Malaysia, updated to the 3rd Quarter of 2017, there are 1,357 ISO 9000 QMS certified construction organizations, the highest amongst all industries.

III. Working hypotheses

- *From a methodological perspective, this piece of work relies on the researcher's interpretive sensemaking of the limitations of ISO management systems to embed CI as a practice, whilst taking on a generative research prospect for implementing CI through the LPS for planning and scheduling to contribute to a culture of CI.*

  The research hypotheses is as follows: H_o: $\mu_{ISO} \neq \mu_{non\text{-}ISO}$

  There is a significant difference in CI maturity level in the area of planning and scheduling amongst major ISO and non-ISO of construction contracting organizations.

IV. Research Method

A CI maturity model for construction project P&S process was developed as a questionnaire form in order to measure the CI practice of both ISO-certified and non-ISO certified large construction contracting organizations. From the distributed questionnaires, 39 ISO certified and 57 non-ISO certified major contractors belonging to the grade G6 and G7category responded. These two grades of contractors, are viewed here as major contractors.

The categorization of the CI maturity levels is based on the work of Bessant and Caffyn (1994) and validated by Delphi experts. It consists of 38 CI critical success factors (CSFs) identified through a 3-round Delphi survey of P&S CSFs identified from literature (see Table 1).

Table 1: The eight latent CSF constructs for planning and scheduling

CSF1	Development of Continuous Improvement System for Planning & Scheduling (P&S)
CSF2	Development of Performance Measures for P&S
CSF3	Management Review for P&S
CSF4	Analysis of Processes to Identify Improvement Actions
CSF5	Implementation of Improvement Process for P&S
CSF6	Variation Management (general) for P&S
CSF7	Variation Control Method for P&S
CSF8	Variation Management Activities for P&S

V. Research Findings

- With respect to the research hypotheses stated above, the result of independent sample t-test shows that there are 37 correlations at significant level, α = 0.05. Whilst, the calculated probability (p values) for 37 CSFs out of 38 are less than 0.05 for ISO certified and non-ISO certified large construction contracting organizations. Hence, there is a significant difference in the CI maturity level between ISO and non-ISO certified construction contracting organizations, although the CI maturity is <u>not at a high level</u>.

VI. Conclusions

- Thus, this paper proposes that the application of the LPS, which is customized and structured based on the concept of transformation, flow and value (TFV), as being key to the implementation of CI with respect to the process of Planning and Scheduling (P&S). The implementation of LPS within the dynamic P&S process (which is central to the management of construction projects), is seen as being significant to the establishment of a culture of CI within construction contracting organizations, complementing the already established ISO compliance culture.

Studying the Mindset of Corruption in the Construction Industry - A Lean Perspective

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I. Background

Studies have shown that the construction industry practice involves corruption. Several factors such as the complexity of the project and organizations involved coupled with scarce sanctions on corrupt activities are basic hurdles for reducing corruption. Lebanon's construction industry is no exception since it is one of the developing countries that lack anti-corruption processes. The aim of this study is to (1) investigate the mindset behind unethical behavior in construction that has detrimental effects on the community and (2) suggest lean-based frameworks that can impact processes and behavior to reduce corruption. Surveys were conducted to better assess the level of awareness of the Lebanese community with regards to corruption, identify existing mitigation methods, and evaluate the importance and feasibility of integrating lean culture into the construction industry. Respondents do not consider some basic corrupt actions to be a serious problem indicating that there is a need for more efforts to raise the community's awareness to the significance of fighting corruption. An anti-corruption framework was designed using lean principles and tools was suggested to better mitigate and control corrupt acts in the Lebanese construction industry. Results show that the construction industry seems ready to accommodate this change. Nevertheless, it must happen at a low pace.

II. Current conditions

- Corruption has always existed in Lebanon. However, its effects increased after the end of the civil war in 1990.
- Corruption in Lebanon occurs in all its forms including nepotism, patronage, bribery, embezzlement, vote-buying and many other forms.
- Political corruption has been identified as Lebanon's the most serious corruption challenge.
- When it comes to the Lebanese construction industry, around 50% of the construction firms are expected to "give gifts" to obtain construction permits, and around 20% of the firms do the same for operating license or labor inspection.

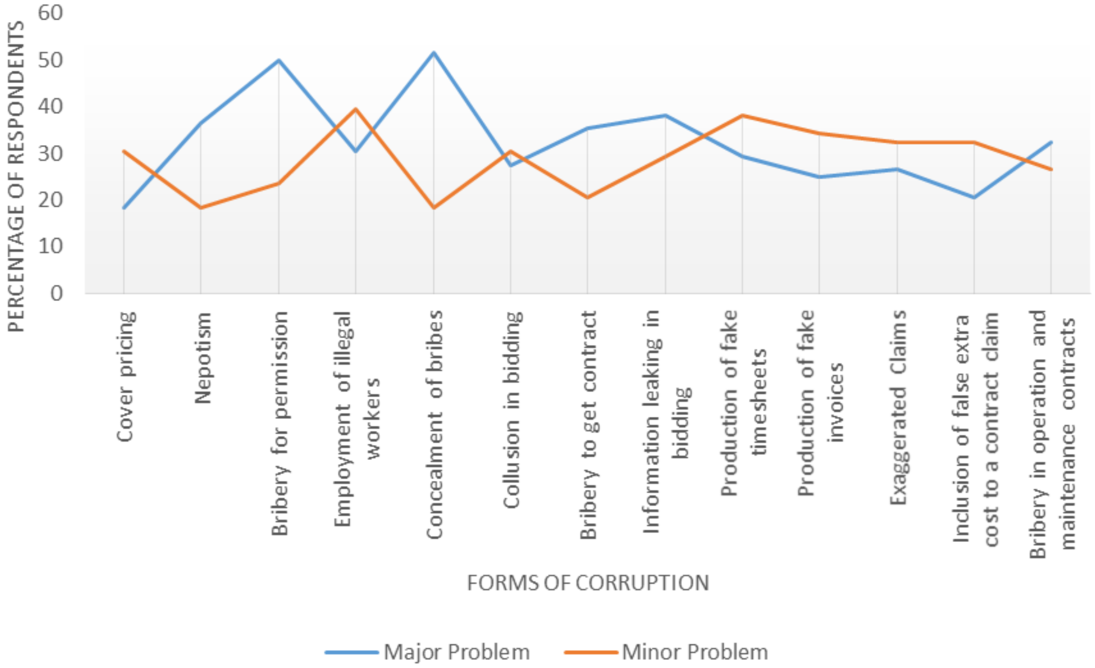
III. Working hypotheses

- *Study construction professionals' perspective on unethical behavior.*
- *Suggest lean-based frameworks that can impact processes and behavior to reduce corruption.*

IV. Research Method

To better understand the topic at hand, the authors looked at previous contributions on corruption in the construction field. A survey was developed based on a previously designed questionnaire by The Chartered Institute of Building (Tanzi, 1998). It was modified to fit the Lebanese environment and construction industry. The general structure of the survey consists of two parts; demographic related questions as well as questions related to perception towards unethical behavior and the frequency of it happening. The survey included two matrix questions which were recorded in the 4 point Likert Scale to ensure accurate mapping (Marsden & Wright, 2010). Pilot testing was done randomly to make sure the proposed questions are clear and the results were effective.

V. Research Findings



- The industry is structured in an adversarial and myopic manner that leads individuals and corporations to deprive others and possibly commit illegal actions in order to get their bigger share of the pie.
- Anti-Corruption Framework for Governmental Practices: Awareness campaigns, E-governance, developing people, measuring corruption KPIs.
- Anti-Corruption Tools For the Construction Industry: Last Planner System, Building Information Modeling, Value Stream Mapping.

VI. Conclusions

- Construction project participants are insufficiently aware of all the unethical behavior that may lead to corruption in such an industry.
- Integrity, accountability, and transparency are among the key characteristics of the suggested tools needed to mitigate for corruption.
- The increased added value to seeing everything early on, capturing problems, and being proactive is essential to the practice of the construction industry without fraudulent acts.
- A step by step procedure should be followed to implement the anti-corruption framework.

Framework for Progressive Evaluation of Lean Construction Maturity Rating using Multi-Dimensional Matrix

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I. Background

Lean is a culture-based management system essentially aimed at waste elimination, thereby creating value for the customer. Lean is a transformation journey and to evaluate the progress on this journey at any time, the achieved state of maturity has to be assessed. Its implementation needs to be measured periodically to make it function well and suit the organization at broader level. This paper is an attempt at that.

II. Current conditions

- Several papers have come out on Lean maturity assessment models proposed by various earlier investigators. Nesensohn (2017) showed a detailed framework comprising various maturity levels, "ideal statements" and corresponding factors, whereas the UK Highway Agency has also developed an in-house Lean Maturity Assessment Toolkit (HALMAT), but this paper adopts new approach towards providing a through outlook at the quantitative process of the model.
- We also argue that Lean Construction management spans three stages or phases - P*hysical (Activity-based) Manifestation, Behavioral (Culture-based) Manifestation and Strategic (Long-term) Manifestation* and will evolve from basic Operational or Physical levels through an evolution in Behavioral levels to a permeating Strategic level which is depicted using normative Lean maturity progression curve (Figure 2).

III. Working hypotheses

- *The model was developed based on data collected from 25 Lean practitioners across six organizations which was then applied to project and the Lean Construction Maturity Rating was calculated.*
- *These scores were then discussed with experts to validate whether the scores appropriately reflected, in an overall qualitative sense, the Lean maturity of the projects surveyed.*
- *In view of the low level of spread of Lean practices across the Industry in this country, assessment of Lean maturity across an entire organization has not been taken up so far.*
- *The critical Lean Concepts and Practices can be prioritized for the three stages by observations in projects and taking inputs from expert Lean practitioners.*

IV. Research Method

The following stepwise methodology approach is used in the process of developing the proposed framework:

- Step I – Exploratory study (Literature review & Lean academic expert opinions).

- Step II – Industry Lean practitioner opinions/input.
- Step III – A five-point Likert scale Questionnaire Survey.
- Step IV – Development of Framework (Figure 1).
- Step V – Case Study for validation.

V. Research Findings

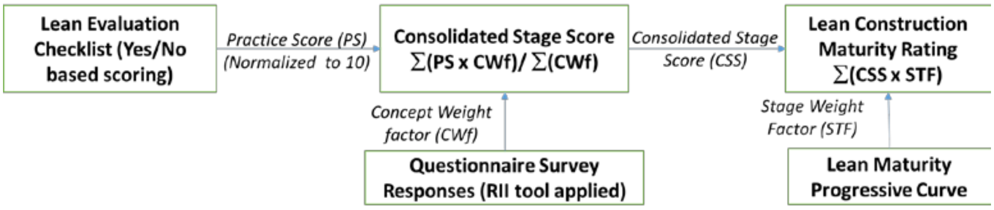

Figure 1: Framework for assessing LCMR

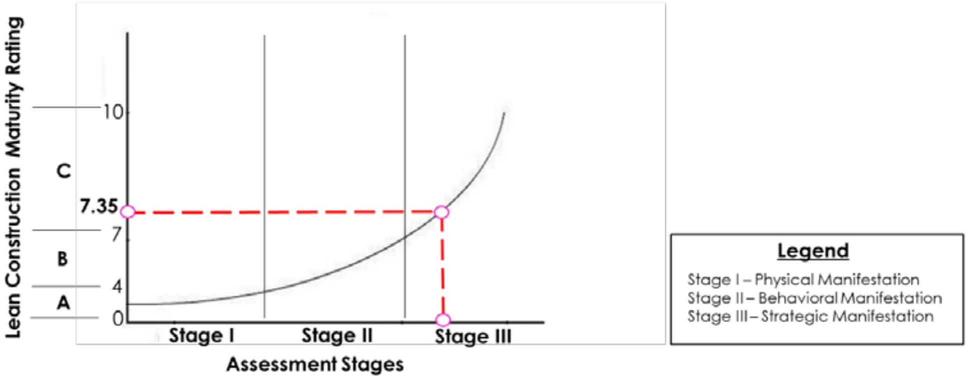

Figure 2: Lean Maturity Progression Curve

Table 4: STF (Stage Weight Factor) percentages for the three Stages for various LCMR ranges

		STFj		
Zone	**LCMR**	**Stage I**	**Stage II**	**Stage III**
A	0-4	70%	20%	10%
B	4-7	55%	25%	20%
C	7-10	40%	30%	30%

- LCMR is evaluated by trial and error. Initially it is assumed that the Project would be in Zone A and the STF percentages are applied accordingly.
- If the resulting LCMR is not compatible with Zone A , i.e. it is not within the range of 0 to 4 then Zone B percentages are tried out and then Zone C percentages, till convergence is reached for one of the three Stages. Thus the final LCMR is obtained.

VI. Conclusions

- This framework should be used as an audit based model providing a periodic means to measure the current state of Lean maturity and to understand the areas requiring improvement. An example highlighting the same has been specified in the paper.
- This model would also help an organization to focus on qualitative aspects such as people development, culture building and strategic leadership to drive Lean, apart from the usual implementation of Lean tools and processes as only tools or only culture cannot bring about the change that is desideratum to construction industry.
- Appropriately designed training programmes and workshops can be conducted to sensitize the industry and the construction personnel to realize the aspects and help them learn the processes to go further on the path of Lean Maturity.

Indicators for observing elements of Linguistic Action Perspective in Last Planner System

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I. Background

The implementation of the Last Planner System increases the reliability of planning and performance levels through the management of commitments. So far, the conversations during which commitments are set at planning meetings have not been analyzed in sufficient depth. However, this analysis is essential to generate reliable commitments that reduce the uncertainty and variability of projects. The research reported in this paper moves toward this analysis by developing indicators of commitments based on the Linguistic Action Perspective, developed by Fernando Flores. Indicators of commitments (i.e. definition of roles and responsibilities, declaration of the relevance of each commitment); requests and promises (i.e. making the deadline explicit); and foundations of trust (i.e. reliability), were developed and tested based on the methodology "Design Science Research".

II. Current conditions

- The main problem of the construction industry is that the productivity factor has not increased as in other industries over the last fifty years (Eastman et al. 2011). To improve productivity, efficiency must be increased through better planning and control of projects, standardization and strengthening of the technical and operational capacities of workforce (McKinsey & Company 2009).

- Therefore, it is necessary to generate changes in behavior and training in the use of Lean tools and concepts in the construction industry (Salem et al. 2006), mainly because it differs from manufacturing due to its structure, which presents greater complexity and uncertainty (Ballard and Tommelein 2016). Last Planner System developed by Glenn Ballard and Greg Howell in the 90's (Ballard and Tommelein 2016), is one of the methodologies that has led the introduction of concepts and principles of Lean Production in construction (Daniel et al. 2015).

III. Working hypotheses

- *The indicators that were validated are a useful tool to measure, control and improve the management of commitments in planning meetings, as they provide fast and specific feedback on these aspects, which undoubtedly enriches implementation of the Last Planner System.*

IV. Research Method

To fulfill the objective, the research methodology was based on Hevner's "*A Three Cycle View of Design Science Research*" (2007). The following steps were carried out:

1. To study the Linguistic Action Perspective, to generate a *Knowledge Base*, based mainly on F. Flores (2015).
2. To identify the elements of this perspective that were potentially quantifiable, creating a list of concepts and data to be measured.
3. To develop indicators that could measure and control the previously identified elements, to generate the *Design Science Research*.
4. To discuss with a panel of international experts the feasibility of measuring and controlling these indicators, which allows improving the initial design.
5. To validate proposed indicators, verifying the feasibility of observing these indicators by means of a Villego simulation applied to a group of students as a pilot test, to validate them through the *Environment* in a controlled situation.

V. Research Findings

- The authors created and validated a set of Key Performance Indicators as a proposal for measurement and control of fundamental aspects of the commitments, requests, promises and foundations of trust.
- Given the nature of this simulation, only able to verify the indicators of commitment; compliance network or chain of commitments; definition of roles and responsibilities of the performers; fulfillment of the roles and responsibilities of the performers; specify the deadline; compliance of the performer's competence; and engaged participants.
- On the other hand, indicators of: declaration of the importance of the commitment; compliance with priority commitments; verification of availability of performers in agreements; verification of availability of performers in execution; unnecessary requests; incomplete promises and promises; and reliability compliance, are currently under verification process in construction projects in Chile.

VI. Conclusions

- Project planning and control must be improved to generate a change in the industry.
- Linguistic Action Perspective developed by Fernando Flores, proposes a basic and universal structure of the conversations by means of which said commitments are established, based on the performance of certain speech acts.
- The authors propose as future lines of research: apply case studies in weekly planning meetings in construction projects and other industries, worldwide and determine the recommended values to improve communication and achieve a proper implementation of Linguistic Action Perspective in Last Planner System.
- The authors consider that this first generation of validated Key Performance Indicators are a useful tool to measure, control and improve the management of commitments in planning meetings, as they provide a fast and specific feedback on these aspects, which without doubt undoubtedly enriches Last Planner System.

Innovation in the New Zealand Construction Industry - Diffusion of The Last Planner System

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I. Background

As is true across the rest of the world, New Zealand (NZ) has been dealing with and looking for answers to low productivity rates within its construction sector. A key contributor to low productivity, as noted in the literature is the industry's aversion to change and its slow uptake of innovation. This research sought to illustrate that the complexities and challenges faced worldwide in implementing new innovation, were also relevant in NZ.

The innovation of Lean Construction, and in particular The Last Planner System (LPS) was then explored in order to develop a dialogue questioning whether Lean Construction has, or could be widely adopted within NZ as a means to improve construction productivity.

The research ultimately endeavoured to bring together the two streams of research - the first being innovation in the construction industry, and the second being Lean Construction.

II. Current Conditions

There was a distinct lack of information around the adoption and implementation of Lean Construction and LPS within the NZ construction industry. Anecdotal evidence of its use within a small number of the larger general contractors was known but its diffusion throughout the wider industry was unknown.

The research was exploratory in nature and sought to start a conversation around the potential benefits of Lean Construction and LPS within the NZ construction environment.

The construction industry has the lowest rates of innovation across any industry. The key reason for this being the complex nature of construction in its many forms. The fragmented, diverse and bespoke nature of the industry fundamentally creates a challenging environment in which to implement innovation.

III. Working Hypotheses

From the outset it was thought that the same complexities which inhibit the adoption and spread of new innovation in construction, across the globe, would be evident in NZ.

It was believed that participants would have a general lack of knowledge around Lean Construction and LPS - suggesting that the NZ construction industry on the whole was yet to embrace Lean Construction.

IV. Research Method

The research was separated into two phases. Phase one was a literature review exploring innovation in the construction industry. Phase two employed the qualitative research methods of a questionnaire and semi-structured interview to assess the research objectives. Two sets of interview questions were prepared, one each for those familiar and unfamiliar with Lean Construction and LPS. In order to obtain relevant insight from those unfamiliar with Lean Construction and LPS a 20 minute introductory presentation was prepared on the topic.

V. Research Findings

Smaller construction organisations in NZ struggle to adopt and implement new innovation, let alone develop innovation.

All participants relied heavily on their personal industry relationships as the key means of learning about and being exposed to new innovation.

A low level of trust, and little significance is placed on academia within the NZ construction industry.

The social and ideologic split between contractors and consultants was evident.

There was a distinct lack of knowledge about Lean Construction and LPS.

All participants saw value in the implementation of LPS, however the majority were hugely skeptical about the likelihood of wide spread adoption across the industry.

The implementation of pre-tender elements of LPS or integrated projects was seen to be ‘a step too far.’

Reverse Phase Scheduling was seen as the easiest element of the LPS to adopt and implement.

There was a disconnect in understanding across the different stakeholders (owner, contractor, consultant) regarding who would incur the additional costs involved, and take on the day-to-day running of LPS.

VI. Conclusions

The adoption of innovation within the NZ construction industry is fraught with the same complexities which see slow rates of innovation the world over. These complexities see the status quo maintained and only gradual advancements achieved over time. The study suggests that knowledge levels of Lean construction and LPS are low across the wider NZ industry, and there was a great deal of apprehension shown by participants about the chances of its widespread adoption throughout the industry.

The paper presents a number of ways which could advance the diffusion and adoption of Lean Construction & LPS in NZ but which could also be applicable across the world.

1. Improved platforms of engagement between academia and industry. This would enhance networking as a means to incubate research collaboration on Lean Construction, also boosting levels of wider innovation within the industry.
2. A greater role played by Universities in facilitating adoption, largely through the undertaking of empirical research on the implementation of the LPS, to demonstrate that benefits are not confined to overseas applications.
3. The Government as a driver of Lean Construction, through promoting awareness throughout the industry, as a sponsor of academic research and through incentivising its use within the industry. Ultimately change should be industry driven, however, due to the economic benefit proposed by increased construction productivity, a proactive approach should be taken by central government.
4. Little research has been undertaken into the marketing and advertising of Lean Construction and LPS as means of improving its diffusion throughout an industry. Much could be done to increase the flow of Lean Construction knowledge throughout NZ

Explaining the Benefits of Team-Goals to Support Collaboration

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I. Background

The importance of a collaborative environment to achieve success in projects has been widely discussed in the literature and different mechanisms have been developed and introduced to support a collaborative approach to construction projects, i.e. new forms of agreement, new office arrangements, financial incentives, a shared risk and reward approach, the development of shared goals, etc. However, the literature related to these mechanisms is predominantly prescriptive, with little evidence and justification on why some of these mechanisms might be important to support collaboration. The benefits of goal setting and tracking techniques to support collaboration have not been fully explored in the lean construction community. Thus, the intent of this paper is to report some of the benefits that a goal setting exercise brought to two construction projects while having a theoretical discussion to explain why such process can be beneficial and should also be considered - along with other mechanisms - as an important element to support collaboration.

II. Working hypotheses

Collaboration can be understood as an "interorganizational relationship with a common vision to create a common project organization with a commonly defined structure and a new and jointly developed project culture, based on trust and transparency; with the goal to jointly maximize the value for the customer by solving problems mutually through interactive processes, which are planned together, and by sharing responsibilities, risk, and rewards among the key participants" (Schöttle et al. 2014). Thus, the aim of this research was to understand the theoretical contributions of an explicit process for goal setting and progress tracking to support collaboration.

III. Research Method

A literature review was carried out to explain the theory of collaboration. Then a framework with the key characteristics of collaboration was developed to support the analysis of empirical data. A case study approach was chosen for this research as it allows for a deep understanding of the subject (Yin, 2014). Two case studies were carried out. Both cases had limited ability to introduce other mechanisms to support collaboration (i.e. multi-party agreements, shared financial structure). However, in both cases, a goal setting and tracking exercise was utilized. In order to support data collection and analysis, an analytical framework was developed based on the reviewed literature. Data was mainly collected through interviews. The interviews were carried out in November 2014. Participants of the interviews were the owner, general contractor, and the architect in case 1 and project manager and general contractor in case 2. Open-ended questions were asked regarding the project delivery system, implemented methods and tools as well as about the working environment. All interviews were transcript and based on Mayring (2010) and Kuckartz (2014) qualitative content analysis used to analyze the interviews.

IV. Research Findings

Even though these case studies didn’t have an integrated agreement, no arrangement to share risks and rewards, positive results were found. Teams observed improved relationships, greater empathy, an enhanced ability to candidly talk about problems and engage in problem-solving to support continuous improvement. Project team members highlighted the following major benefits:

- Open and increased communication among team members;
- Aligned expectations and improved team focus;
- Possibility to communicate dissatisfaction, talk about frustration and address issues;
- Smoother workflow;
- Development of an understanding of different personalities, while building relationships;
- Developing collaboration and building Strengthened trust; and
- Influenced the working environment and improved satisfaction.

The following table gives an overview of collaboration characteristics based on the definition of Schöttle et al. (2014) evaluated based on the authors observation and on the interviews.

Affected characteristics	**Case 1**	**Case 2**
Interorganizational relationship	Yes	Yes
Common vision	Yes	Yes
Common project organization	No	No
Commonly defined structure	No	No
Jointly developed project culture	Yes	Yes
Trust	Yes	Yes
Transparency	Yes	Yes
Jointly maximize customer value	Yes	Yes
Interactive processes, which are planned together	Yes	Yes
Sharing responsibilities	No	No
Sharing risk and rewards	No	No

- Goal-setting and tracking process impacted collaboration, despite the fact that not all supporting mechanisms were in place.
- In the process of agreeing on goals, expectations were clarified, and the team got a better understanding of each other’s perspective.
- Targets were defined bottom-up, so that the different team members identified themselves within the goals
- Setting and tracking also social goals helped the team members to pay more attention to issues regarding the working environment and define countermeasure for team building.
- Goal measurement helped to see if things were going in the right direction

V. Conclusions

- Establishing common goals in construction projects, even when companies are not aligned commercially, supports collaboration among the team members.
- A goal-setting and tracking processes makes explicit important issues which are usually not verbalized by project teams.
- By clarifying goals and defining actions jointly, individuals focus on problem solving and achieve a greater alignment among themselves.

The Last Planner® System Path Clearing Approach (LPS-PCA) in Action: A Case Study

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I. Background

The benefits of the LPS are already very well documented in the literature. Despite this, LPS implementations often fade off due to issues reported at organisational, project and external levels. How to sustain implementations through a standard approach and how to overcome barriers (including resistance) during the implementation are not as prevalent in the literature. This paper reports how the LPS-PCA's 15 Step Actions were used in action for the first time to address the gap in the literature on how to overcome resistance to the LPS. This was done by abstracting LPS principles, thinking and language from the LPS and using them to through a "shallow and wide" approach in a Business Delivery Meeting (BDM) to address organisational culture constraints. This followed the more traditional "narrow and deep" approach which transpired as inappropriate due to the significant passive resistance experienced and the innovation, initiative and meeting fatigue that was embedded in Organisation X (the case study).

II. Current conditions

The LPS-PCA's 15 Step Actions in Table 1 can be used as a benchmark to identify what actions are being addressed and what future actions are required to embed LPS in an organisation or on a project. The tick (√) adjacent to each step action in Table 1 and under "P" and/or "B" refers to a process and/or a desired behaviour required to influence each step action.

Table 1: LPS-PCA Step Actions (after Daniel, 2017)

Level	#	P	B	Description
Organis-ation	1	√	√	The imperative for LPS & Lean leadership
	2	√		Identify and understand the need for LPS
	3	√	√	Strategic capability and commitment to support implementation
	4	√	√	Behaviours arising from the contract
	5	√		Create awareness of Step Action #3
Pre-Project	6	√		Develop and realise implementation strategy
	7	√		Review current planning practices
	8	√		Evaluate and review Step Action #7 using LPS principles
	9	√	√	Create physical and human enablers for implementation
	10	√	√	Adopt a standard approach
Project	11	√		Implement LPS
	12		√	Instil desired social behaviours in the team
	13	√		Gauge LPS practice
Ext.	14		√	Engage with proven LPS experts
	15	√		Feed learning continuously back into the system

III. Working hypotheses

Can the LPS-PCA helps consultants, researchers and other interested stakeholders identify organisational culture constraints and other project specific constraints that block or constrain the sustainable implementation of the LPS?

IV. Research Method

A researcher was embedded within Organisation X with support from a principal investigator to design, develop and test a Lean Project Delivery System. To identify prevailing issues qualitative research methods were used including interviews and focus groups (n=18), observation, listening, open surveys on "Last Minute Requests" (n=20), and thematic analysis. An action research approach was also taken to implement interventions in practice so their effect could be clearly monitored and measured for effectiveness. As a result of initial findings covert research methods using direct questioning (Socratic Method), listening, and introducing new language around commitments were used.

V. Research Findings

- The 15 LPS-PCA step actions are very helpful as a benchmark to identify organisational culture constraints but they are not hierarchal and many require interaction with each other to be effective.
- The narrow and deep approach did not work primarily due to a lack of Lean Leadership from formal and informal leaders (#1), little awareness of strategic capability, a lack of commitment to support the implementation (#3 & #5), and discipline to adhere to a standard approach (#10).
- LPS thinking & metrics can be embedded through a "shallow and wide" organisational/business approach (BDM) rather than a more traditional "narrow and deep" project approach.
- If senior management insists on implementing the LPS without sufficient buy-in and leadership from the PM to actively use the LPS, the implementation will fade off once the external LPS facilitator steps back. Some aspects of the LPS are discontinued over time without sufficient leadership, coaching and guidance which results in the benefits not being fully realised.
- Resistance to LPS can be set up in an organisation if the LPS facilitator is inexperienced with the LPS and/or without the relevant design, engineering and construction experience. A Toyota trained expert is unlikely to be an expert in LPS. It is highly desirable the LPS facilitator has the relevant experience required in order to build credibility with the team.

VI. Conclusions

- Action and covert research methods are useful to introduce LPS principles, thinking and language without attributing them to LPS if resistance to the actual LPS is encountered.
- Lean Leadership for the LPS and engaging with proven LPS experts are critical step actions. Without appropriate Lean Leadership (including informal leaders) LPS should never be pushed unless an organisation is willing to pay consultants to facilitate every LPS session.
- Organisations without a Lean Strategy Team (with CI Departments) do not foster the required Lean Leadership to sustain Lean transformations – informal leaders, senior and middle managers must be fully engaged to maintain momentum.
- A key sustainability test is when the proven LPS facilitator steps back and the team keep up momentum.
- Depending on the Lean maturity of an organisation the level of difficulty implementing LPS will differ. Step Actions #7 (review current planning practices) & #14 (engage proven LPS experts) are safe places to start.
- Before designing a Lean Project Delivery System identify the current state issues related to production planning in order to clearly understand the problem and demonstrate the need for LPS (#7 & #2).
- The use of the LPS-PCA is recommended before, during and after organisations engage with LPS Consultants if organisations are serious about sustaining the implementation of the LPS.

UNDERSTANDING THE EFFECTIVENESS OF VISUAL MANAGEMENT BEST PRACTICES IN CONSTRUCTION SITES

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I. Introduction

- Visual Management (VM) is a strategy for information management strongly related to one of the core concepts of Lean Production Philosophy, the increase of process transparency (Tezel et al. 2016).
- This study aims to analyze the role of a set of VM best practices to support production management, understanding the features that distinguish these practices as advanced ones, i.e. the reasons behind the effectiveness of some VM systems.
- Another contribution is concerned with classifying VM best practices according to the degree of integration to the managerial routines.
- It is based on two case studies carried out in leading companies in the implementation of Lean Construction in Brazil.

II. Research Method

Design Science Research was the methodological approach adopted in this investigation. Figure 1 presents the delimitation of the study.

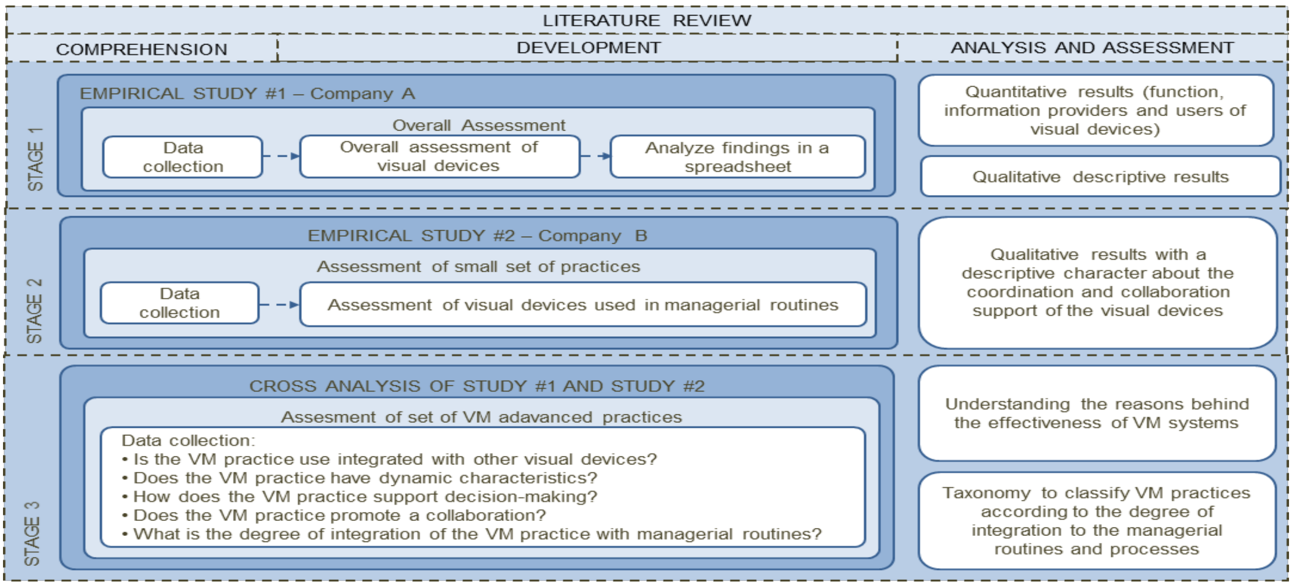

Figure 1: Research method delimitation

II. Research Findings

Figure 2 establishes the criteria to understand the reasons behind the effectiveness of VM systems and why some of them can be considered as advanced. Figure 3 proposes a taxonomy to classify VM best practices and subsystems according to the degree of integration to the managerial routines.

- **(i) whether a practice is integrated or not with other visual devices** (isolated VM practice or VM sub-system);
- **(ii) whether a VM practice can be used dynamically** (rather than being static);
- **(iii) ability to promote collaborative processes and support decision-making**;
- **(iv) whether a VM system promotes autonomy to the workforce**; and,
- **(v) the degree of integration with the managerial routines and processes**.

Figure 2: Criteria to understand the effectiveness of VM systems

One-to-one	Coordination	Collaborative
• The most basic form of visual devices in production processes; • Information rapidly and easily understood, being a channel between a sender and a receiver.	• Used to share information and coordinate activities between several stakeholders; • Usually produces routine information.	• The highest level of integration; • VM devices are dynamic and intend to support collaborative processes among different departments or hierarchical levels.

Figure 3: Taxonomy of VM best practices according to the degree of integration to the managerial routines

Figure 4 presents the summary of advanced VM practices analysis and advanced VM sub-systems identified on Company A and Company B, and Figure 5 shows some examples of them.

Example	Company	Integrated use with other visual device	Dynamic characteristcs	Support in decision-making	Promotion of collaborative process	Degree of integration with managerial routines
Spray markings	A	No (VM Practice)	Yes	Yes	No	One-to-one
Kanban	B	No (VM Practice)	Yes	Yes	No	One-to-one
Andon	B	No (VM Practice)	Yes	Yes	No	One-to-one
Standardised work visual routine cards	B	No (VM Practice)	No	Yes	No	One-to-one
Installation of drywall partitions	A	Yes (VM Sub-system)	Yes	Yes	Yes	Coordination
Visual board for communal areas	B	Yes (VM Sub-system)	Yes	Yes	Yes	Coordination
Customization choice board	B	Yes (VM Sub-system)	Yes	Yes	Yes	Coordination
Visual performance and planning boards	B	Yes (VM Sub-system)	Yes	Yes	Yes	Collaborative
Physical Prototyping	B	Yes (VM Sub-system)	No	Yes	Yes	Collaborative

Figure 4: Advanced VM practices and advanced VM sub-systems

Figure 5: Example of VM best practices identified: (a) (b) Spray marking of the kind of roughcast and it explanatory sheet (Company A), and (c) Visual performance and planning boards (Company B)

IV. Conclusions

- The more dynamic, collaborative and well-integrated into managerial routines and processes, the more advanced a VM practice or VM sub-system can be considered, being these some of the reasons behind the effectiveness of the VM systems identified.
- The analysis of some visual practices that support production management resulted in the proposition of a taxonomy to classify them according to the degree of integration in managerial routines. Lean Construction benchmarking companies in Brazil has successfully implemented those practices. Besides, it is worth emphasizing the importance of understanding visual devices as directly and specifically associated with each process context and users in production management.

Characterization of Waste in Ethiopian Building Construction Projects

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I. Background

An assessment by Mckinsey Global Institute in February 2017 indicated that only 25 % of construction firms matched with productivity growth of the overall economies of their respective countries. According to this report Ethiopian construction industry is the last in the list of countries with poor productivity as compared to other sectors of the economy within the country and labor productivity of its counterparts elsewhere. Propelled by this report, this study aims to investigate the most significant waste out of the seven common types of wastes using a local data. So that professionals in the sector can recognize the extent of the problem and pay attention on the subject of waste and lean construction at large.

II. Current conditions

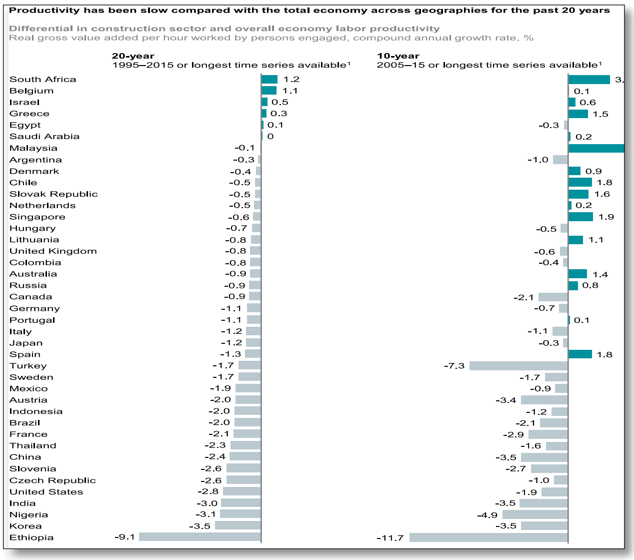

Fig. 1: Labor Productivity (Barbosa et al., 2017)

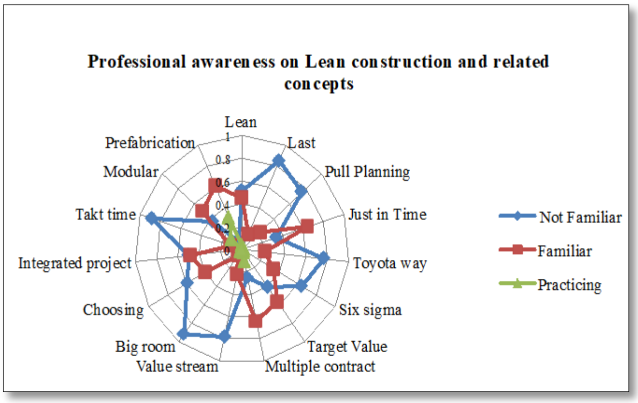

Fig. 2: Professional Awareness on Lean Construction (Ayalew et al., 2016)

- Labor productivity of Ethiopian construction industry is very poor as compared to other sectors of the economy with in the country and labor productivity of its counterparts elsewhere. As shown in *Figure 1*, Ethiopia is the last in the list.

- Significant number of studies (Egan, 1998)(Ballard & Howell, 2004) (Alarcón, Diethelm, Rojo, & Calderon, 2005) indicated that lean construction has a potential to improve such performance challenges.

- However, lean construction is not yet practiced in Ethiopia. A study by (Ayalew *etal.* 2016) indicated that most of Ethiopian professionals are even not well familiar with most of lean construction concepts, principles, tools and techniques.

- This indicates that there is a need to study the subject of lean construction from its basics which understanding the characteristics of for waste.

III. Working hypotheses

Envisioning a middle-income country by 2025, Ethiopia is investing massively on infrastructure projects. However, due to its poor performance, the industry fails short to fulfill the perceived need of the nation as expected. Contemplating these challenges and the potential of Lean Construction as solution, this research aims to initiate a research agenda on lean construction in Ethiopia with good understanding of waste and its characteristics. To start with this paper answers;

- *What is the extent of waste (time loss) in Ethiopian building projects?*
- *Which aspects of wastes (time loss) are more significant?*

IV. Research Method

The study applies structured questionnaire, which was considered to be more appropriate method to reach the population of the study from a distance at a time. Accordingly the designed questionnaires were distributed to professionals selected through stratified random sampling from construction & consulting firms as well as client's organizations in the following proportion.

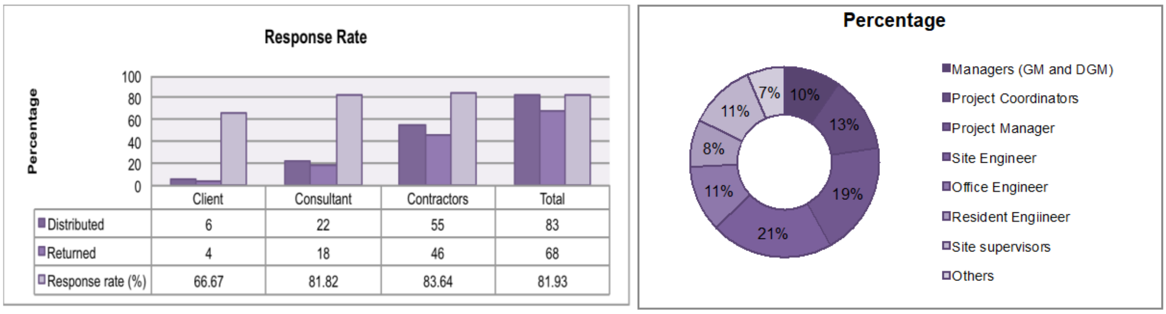

Figure 3; Response rate and respondent background

The data obtained from the survey was analyzed using mean score in order to rank the major types of waste in Ethiopian building construction projects.

V. Research Findings

In order to rank the seven types of waste identified from literatures, professionals working in the sector were requested to rate each type of wastes based on their frequency of occurrence using a 4-point scale and the result is presented in Figure 3 below.

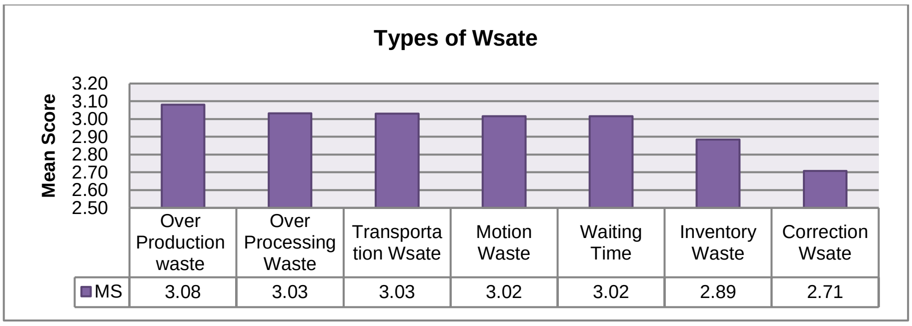

Figure 4; Respondent response on types of waste

VI. Conclusions

- The study investigated the extent of waste (time loss) is in Ethiopian building construction projects lies in the range of 30-40%.
- The major types of wastes that cause the above level of waste (time loss) in Ethiopian building construction projects are; over production waste (3.08), over processing waste (3;03), Transport waste (3.03), waiting time (3.02) and motion wastes (3.02).

Buffer Management in Construction - A New Zealand Study

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I. Background

Buffers in the form of extra capacity, time, or inventory can help stabilizing construction workflow. Despite the benefits of using buffers, they represent non-value-adding components of systems. Accordingly, lean ideal suggests avoiding the use of buffers to the maximum possible extent. It presents a dichotomy in the use of buffers that calls for the establishment of a balance between the theoretical goals and the practical norms. Therefore, projects are obliged to adopt a definite buffer management strategy that can simultaneously address the practical requirements and the lean ideal.

II. Current conditions

Despite all the advancement in developing buffer management techniques, the construction industry acknowledges the use of informal and intuitive approaches for buffer management.

III. Working hypotheses

There are some prevailing features in ongoing buffer management processes in construction that can give an overall picture of the current state.

IV. Research Method

A systematizing expert interview was undertaken to obtain complete information from the participants by using spontaneous communications. This type of interviews focuses on knowledge of action and experience derived from practice. Accordingly, twelve semi-structured face-to-face interviews were conducted with the industry professionals, which collected qualitative data on the active state of buffer management in construction sector across the country. The responses from the interviewees were transcribed and developed into coherent essays suitable for thematic analysis. The analysis results provide an insight into the operational condition of buffer management in construction projects, which is of particular importance for designing further steps to advance from the conventional management practices to the lean construction concept.

V. Research Findings

Nine major themes were identified in the responses provided by the interviewees explaining the active state of buffer management in New Zealand construction projects:

- Projects Realize The Use of Buffers As an Inevitable Component
- No buffer management method with a holistic view is pursued
- No systematic strategy is employed to allocate buffers

- The current buffer management methods are not effective
- The financial penalties are the real drivers
- The contractual issues may curtail the use of buffer
- New buffer management technologies are resisted
- Current buffer management tools and techniques are challenging
- The main features that can promote the use of a buffer management tool

Even though the respondents recognized the use of buffer as an inevitable component of their projects, it was found that buffers were being incorporated into the project program as a fixed percentage added to the expected duration of each operation. The majority of the respondents were relying on CPM as their main scheduling method. However, this method has proven to be unable in providing a holistic view of the potential operational status of the project network. The lack of a method that could provide this holistic view of the project network was one of the main challenges identified by the experts in dealing with buffer management. As a result, the projects still deal with time overruns that could cause substantial financial penalties for the construction firms. The firms may try to minimize these financial penalties by reducing the quality of work. Additional issues, such as the fixed-price agreements, which are typical to construction projects has been found discouraging the adoption of an enhanced buffer management strategy. Despite the resistance from the construction professionals in changing their buffer management routines, the experts indicated that automation, customizing ability and involvement of visual presentation could be the three fundamental features to promote the use of a new buffer management approach.

VI. Conclusions

These findings suggest that in order to establish a balance between the lean theoretical goals and the practical norms in buffer management domain, a method must be established that could indicate the theoretical optimum allocation of buffer, while supports a holistic view of the project. The method should be included by customizing features to incorporate the specific requirements of any particular project. The implementation of this method in an automated tool with the ability to provide a visual presentation of the buffering solution can promote its function in the construction projects.

The results of the study pave the road for designing the next development steps to accommodate shifting from the standard buffer management practices to the lean ideal.
The study, however, mainly focused on New Zealand construction environment, where the majority of firms are of a small to medium sizes with the number of employees fewer than 50. Further studies are required to elucidate the applicability of the results to the projects undertaken by firms with larger sizes.

EVALUATION OF A CASE STUDY TO DESIGN A BIM-BASED CYCLE PLANNING CONCEPT

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I. Background

A construction section such as a floor consists of multiple work zones, which should have continuous flow and similar cycle times to efficiently coordinate needed resources. However, for concrete structures it is often difficult to find suitable sizes of casting segments and their grouping into work zones. The proposed solution is a BIM-based Cycle Planning concept for the cast in-situ construction method of walls.

II. Current conditions

Nowadays, scheduling experts usually use their practical experience to find an intuitive solution for Cycle Planning (CP), which might be sub-optimal. Even for the same floor, experts design different layouts of CP (Figure 1).

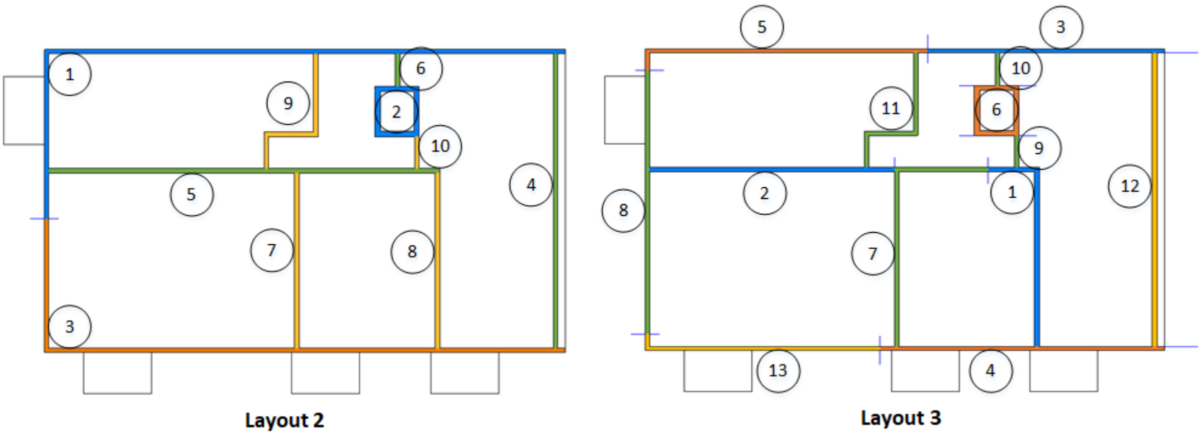

Figure 1: Visualization of two different layouts provided by the experts related to their work zones (same colored walls) and associated casting segments numbered 1 to 10 (Layout 2) and 1 to 13 (Layout 3).

III. Working hypotheses

The process of designing a floor's CP and their layouts is mainly manual and intuitive. The design rules are mostly soft constraint, so that many possible but not necessarily optimal solutions exist. The generation of a Cycle Planning layout consists of creating casting segments and their grouping into work zones. With the knowledge about the rules and the construction method, it is possible to generate such a layout semi-automatically. Optimization methods can help to find an optimal solution in terms of continuous flow and cycle time.

IV. Research Method

The basis is a Building Information Model with wall objects. Combining such objects into casting segments and work zones is an optimization problem. Our first approach is to use simulated annealing in combination with a discrete event simulation. Due to combine objects into castings segments, we developed a rule-based splitting algorithm, which splits wall objects into smaller sections (Figure 3).

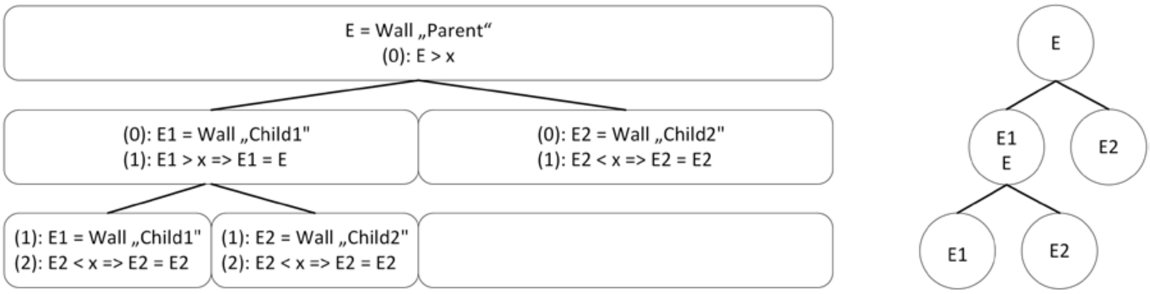

Figure 2: Binary tree approach for a semiautomatic rule-based splitting of objects

V. Research Findings

Our approach is a BIM-based Cycle Planning concept (Figure 2).

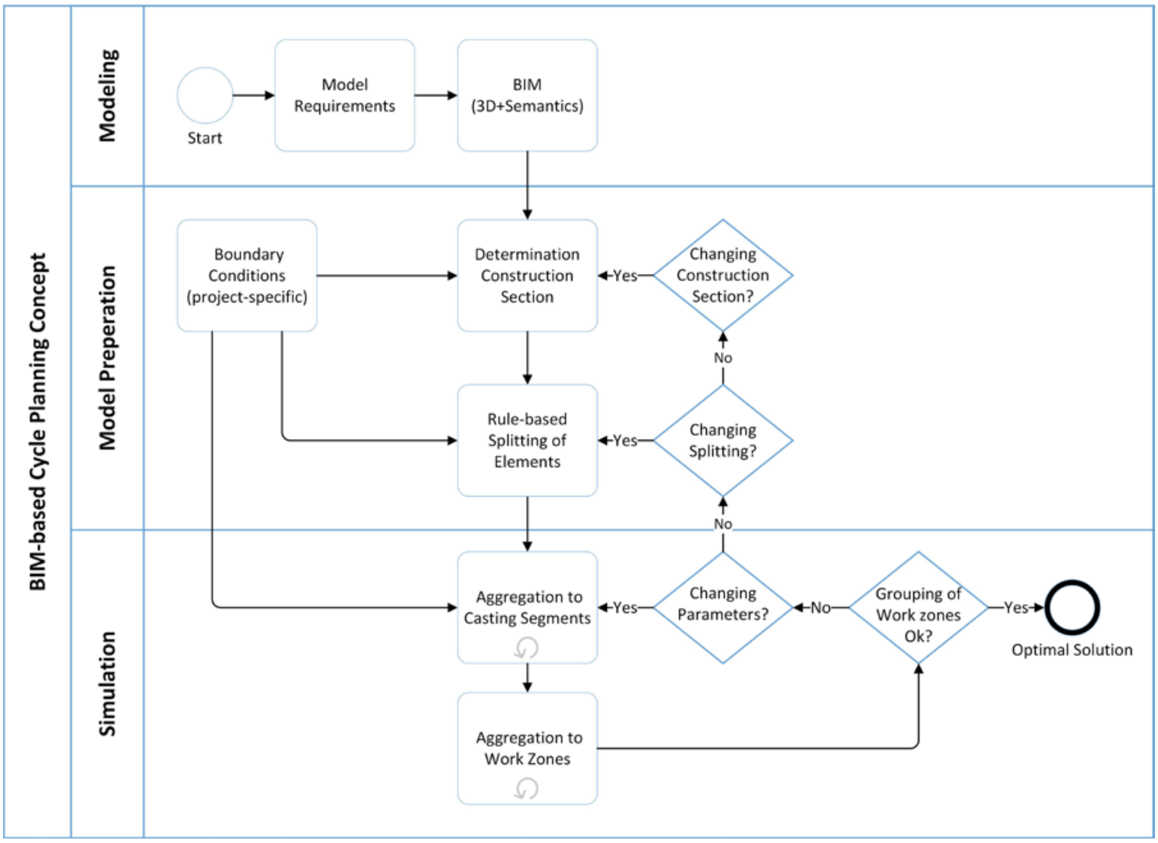

Figure 3: Design of our BIM-based Cycle Planning concept

VI. Conclusions

The presented concept facilitates the generation of Cycle Planning layouts automatically. Our implemented prototype is the first step in generating suitable sizes of casting segments automatically and considering the variability between activities.

DIGITIZATION FOR CUSTOMER DELIGHT IN READY MIX CONCRETE BUSINESS IN INDIA

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I. Background

The concrete industry in India is subjected to challenges such as aggressive work schedules, space constraints and requirement of concrete with high strength and quality which has created an increasing awareness of Ready Mix Concrete (RMC) due to its many advantages. However, RMC Industry has been always being plagued by issues such as ensuring proper understanding of customer requirements, tracking of product delivery during transit from manufacturing plant to site, unceasing follow ups, and planning error free concrete pours. Improper handling of these issues leads to losses in man-hour, time and quality and cause customer dissatisfaction. In this age of digitization, a leading RMC company felt the need to formulate a customer service oriented mobile based application (App) for addressing customer concerns.

II. Current conditions

The App for RMC operations has been made relevant with real-time updates and addresses the identified customer issues. The journey for the development of RMC App is explained and how it serves as a virtual assistant to enhance the customer experience by easy tracking and real-time product updates right from the concrete booking to delivery at project sites. The approach for App development based on Lean principles is brought out covering strong orientation for customer value creation, innovative approach for operational efficiency and waste minimization by continuous improvement etc.

III. Working hypotheses

The organisation felt that in addition to focussing on the financial parameters it needs to improve the customer experience by addressing relevant issues and identifying focus areas for improvement. Internal and External Third-Party Feedback Mechanisms were deployed to analyse stakeholder pain areas and highlight possible areas of improvement. Detailed analysis of customer grievances and issues faced right from Order Booking to Delivery across its entire production lifecycle were mapped.

IV. Research Method

I. Background	**V. Proposed countermeasures**
A Third-party survey conducted showed customers faced problems in order booking, follow up for orders during a concrete pour resulting in losses of manpower, time and thus increasing the cost and wastages.	The company decided to leverage technology to enhance customer experience by providing a hand held virtual assistant for the Concrete Supply business. The company collaborated with their internal IT team to develop a customer friendly Mobile App which would address customer concerns and reduce wastages in time and material by creating a platform for effective communication management across all stakeholders.

II. Current conditions

The company collaborated with their internal IT team to develop a customer friendly Mobile App which would address customer concerns and reduce wastages in time and material by creating a platform for effective communication management across all stakeholders.

III. Goals/Targets

1. Online Order Booking and Live Updates eliminate the need for calling the RMC Sales Team, the Customer Care and rigorous follow up hence saving time and better communication.
2. Real Time Order Tracking for effective site planning by customer.
3. Waste Reduction: Morale boost in Concrete Production teams due to reduced wastages in time, cost and increased productivity due to reduction in non-value adding work.
4. Improved Distribution and Logistics: App acts as a seamless mobile app to address most concerns.

IV. Analysis

The root causes identified were -

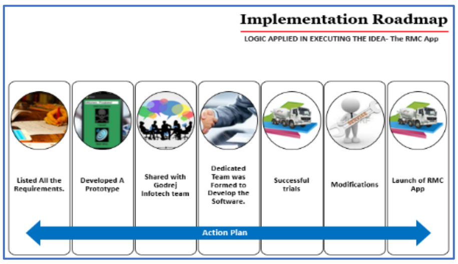
By Customer: - Cumbersome booking process; Non- adherence to committed delivery timelines; Multiple telephone calls for Transit Mixer(TM) follow-up; Non- availability of detailed metrics of order i.e. dispatched and pending loads to all relevant teams.

By Supplier: - High wastages in concrete supplied due to improper communication received pertaining to the Concrete Grade, Quantity, Time etc.; Multiple requirements and multiple calls from single project involved in Order Booking often resulting in confusion and wastage.

VI. Plan

Following road map was followed for the inception of the Lean based Mobile Application

1. Management of customer needs and expectations
2. Idea generation
3. Concept definition
4. Planning and design
5. Mobile app development
6. Test and evaluation of app
7. Mobile app launch post testing



VII. Follow up

Lean way forward and proposed initiatives for RMC app continuous improvement:

1. Editing of the Live Order.
2. Introduction of Quality Features.
3. Inbuilt Feedback Mechanism.
4. Additional Text (SMS) alerts.
5. SMS will be sent to customer on completion of Order through Web portal to collect feedback.
6. Improvements in Web portal like “Scheduled time of Dispatch” and “Pour Duration”
7. Customer access for editing Order.

V. Research Findings

Online Order Booking and Live Updates eliminate the need for calling the RMC Sales Team, the Customer Care and rigorous follow up hence saving time and better communication, Real Time Order Tracking for effective site planning by customer, Waste Reduction: Morale boost in Concrete Production teams due to reduced wastages in time, cost and increased productivity due to reduction in non-value adding work and Improved Truck Turnaround Time(TTT).

VI. Conclusions

Digitization helps to a large extent to address customer and supplier issues in a service industry such as “Ready Mix Concrete “where multiple stakeholders need to be given product related real type updates and communication management poses challenges.

In today’s technology driven era, adopting digitization to improve customer satisfaction and to make the organisation “Lean “in terms of process optimisation, waste minimization is the need of the hour.

Using BIM-based sheets as a visual management tool for on-site instructions: a case study

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I. Background

In recent decades, as a result of the growing complexity of projects, design and construction have had to specialize, leading to a gradual fragmentation in the industry (Dainty et al. 2001; Love et al. 2002), where the number of specialties involved increases in relation to the complexity of the project. Generally, design and construction teams work at different stages of the project, and their interaction is mainly through plans, technical specifications, Request for Information (RFI), etc. (Sacks 2014). This information is dispersed in different documents, with limited structure and available in inadequate visual formats, slowing down processes, hindering information flows and increasing response latency (Mourgues et al. 2007). The workflow described above does not respond to the requirements of current projects, as they demand a high level of interaction requiring new management approaches and technologies to respond to these challenges.

Visual Management (VM) is one of the key elements for the correct implementation of Lean Production, as it provides an easy way to understand the production information (Liker 2003). In recent years, there has been an increase in the use of Building Information Modeling (BIM) in construction; it is therefore interesting to link this methodology with Visual Management (Khanzode et al. 2006).

The use of the BIM methodology with VM would help to correct the waste identified in Table 1. An example of this is the experience reported in the use of BIM-station onsite. BIM stations are tools to improve transparency of information in the field for all stakeholders, where the BIM coordinator keeps the models and drawings updated through a server (Murvold et al. 2016).

II. Objective

The objective of this paper is to describe the use of Visual Management using BIM to deliver instructions on the tasks that must and can be done in the field. To fulfill this objective, a case study of a hospital in Chile is described, whereby through the active participation of the consulting team, the use of visual instruction sheets was gradually implemented, using the BIM product and process model as input information.

III. Research Method

To achieve this objective, a case study of a healthcare center in Chile is described. Through the active participation of the consulting team from GEPRO and researchers from the Production Management Center of the Catholic University of Chile (GEPUC), the use of visual instruction sheets was gradually implemented, using the BIM product and the process model as input information. The case study was intervention of consulting team in development of design and construction of the project, for 18 months approximately.

The consulting team was tasked with supporting the owner in project management to ensure deadlines and quality standards. To guarantee the fulfilment of these objectives, Lean and BIM were planned to implement together and form an integrated project team, where owner, designers, contractors and consultants would actively participate.

Through experience acquired in other projects, the consulting team was certain that the field workers themselves can provide the best feedback on how to communicate the information extracted from the BIM models. Therefore, based on this feedback and supported by the collaborative environment of the project, different schematics of sheets were iterated, and testing was conducted to include information, such as 2D drawings and 3D images.

IV. Research Findings

Each sheet is presented in an A3 format which contains a series of drawings and images obtained from the updated and coordinated BIM model. Generally, the information contained on these sheets consists of a floor plan, 3D images and sections to effectively communicate the solution of a complex sector of the project. The elements included in each A3 sheet were defined at the weekly LPS meeting and respond to specific requirements of each sector or specialty.

BIM sheet contains different 3D images and 2D drawings, depending on the need of each subcontract. The previous work of coordinating the designs of the specialties in a BIM model and its previous verification with the installers in the weekly meetings, ensured that in addition to compatible and error-free designs, A3 sheets were obtained with the specific information requested by those who would use them.

The final evaluation of the construction company, client, designers, suppliers and subcontractors was positive, highlighting that they achieved greater reliability in the construction processes and certainty of deadlines. In an interview at the end of the process, 76% of the respondents stated that the use of the cards was decisive in saving time in the field. 46% stated that they had interacted directly with the model on some occasion to resolve conflicts virtually. Finally, 67% consider the BIM model and the A3 sheets as a fundamental communication tool in the field.

Considering the initial conditions of the project and the uncertainty at the time of construction, a large amount of RFIs could have been generated, which would have led to continuous review and clarification of problems. With the proposed methodology, the number of RFIs was significantly reduced, as the problem-solving was carried out in the working meetings with the integrated team, recorded in the BIM model and taken to the field in a sheet format. Fifty-six BIM-based sheets were generated in addition to the traditional construction documents (plans, technical specifications, RFI), during the execution of this project over a nine-month period.

The BIM sheet was used as a systematic communication tool for coordination of specialties and conflict resolution in site. The process and solution embodied in the file, brought together the efforts of all actors promoting a collaborative climate and committed to work, achieving greater integration of the end user, who contributed with their operational experience to improve efficiency in the life cycle and not only during design and construction.

Among the quantitative data, the estimated deadlines for execution of the work were met without delays. This should be considered a success because in similar projects previously carried out by the same client, the project schedules were exceeded by 50%. Further, without the proposed methodology, it was unlikely that the information required in the LPS meeting was available in due time, whereas when implementing the integrated team methodology, pull signals and work instruction sheets, the information was available just-in-time.

V. Conclusions

From the case study we concluded that the use of BIM tools or instruction sheets alone does not guarantee success, time related benefits or reduction of rework. It is necessary to use a collaborative working methodology in which the work processes follow the principles of the Lean philosophy. This is fundamental in complex brownfield projects with multiple and numerous specialists. The use of these sheets directly addresses the root causes of construction information management problems and of the main waste. For example, the tab visually consolidates information, deletes waiting for information, extra processing and defects. This workflow makes sense in projects where the design stages overlap with construction, better known as Fast-Track projects, because the information must be handled in a just-in-time way.

MODELLING AND SIMULATING TIME USE OF SITE WORKERS WITH 4D BIM

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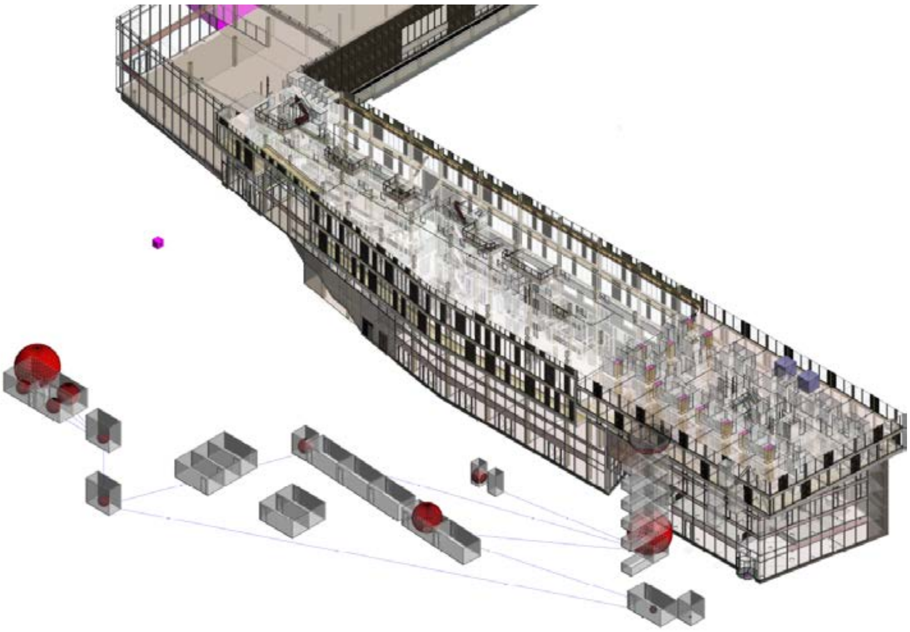
I. Background

With labour productivity on construction sites between 40 and 50% it is relatively low compared to other industries. The improvement of labour productivity can have advantages for the profit of contractors and lead to lower costs for the clients. Problems that contribute to this low labour productivity are for a large part related to waste and inefficient organisation of labour, materials and equipment.

II. Current conditions

The problems causing low labour productivity are mostly related to time and place planning flaws. Different solutions can be found to solve these problems. Currently building information models are mostly used in the design and engineering phase of the project combining the data of different parties into one model. 4D building information models provide the link between space and time.



As basis for the final model a backbone had been deduced from the Revit model of the case project. Next the construction site lay-out and waiting and working times in spaces had been added. The next step was to map the rooms and the room locations with their coordinates. With the coordinates of the rooms the lines of the walking paths and distances were calculated. The vertical distance together with the means of transport, and the average speed related to that mean of transport gives the time needed for the vertical travel.

III. Working hypotheses

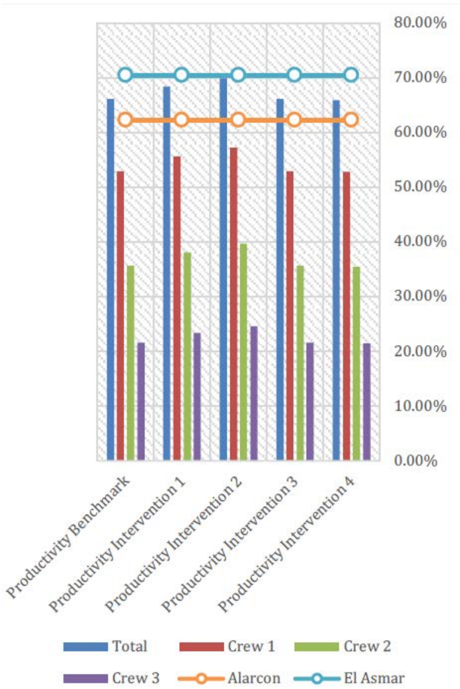
If time use by site workers could be modelled in a 4D model, it could help clarifying solving part of the productivity problem. In a 4D building information model the 3D data should then be linked not only to the schedules but also to site work information and show various types of time use, productive and unproductive.

IV. Research Method

The exploratory design is chosen to conduct this research. According to Fellows and Liu (2015) the exploratory design is to test, or explore aspects of a theory. As this research look into the extent in which a 4D building information model can provide insight in labour and movements of workforce and can help to indicate potentials for the increase of productive time, further research has to find out what the actual change in productive time when this framework is applied. Because the theoretical framework that largely derived from an in-depth literature study, provides the theory behind the research. This theoretical framework acts as a guide for which variables to collect, adopt and analyse. Since this research is mainly focussed onto a single construction project and does not provide concrete number, qualitative research is chosen as the overall strategy.

V. Research Findings

Of all categories, the working time stays constant among all categories. The other categories do change due to the simulations. The sum of those categories is called ‘travelling time’ i.e. the sum of horizontal city-block time; vertical time by elevator; vertical time by stairs and waiting time. This figure shows the results of all changeable categories during simulations per level. The time calculations due to interventions have been based on changing distances multiplied with known speeds of people and elevators, and reduced waiting in case of additional elevators.



The differences between the different simulations, show that the Intervention 4 seems the least effective in improving in productive working time shares among all crews. It even seems to reduce the productive time slightly. Second is the Intervention 3 which improves the productivity just a small bit, but it is almost equal to the benchmark. Third, is the Intervention 1 which shows the second best improvement of the share of productive time. For the total productive working time the improvement is approximately 3.5%. Fourth, the best improvement would be achieved applying Intervention 2 i.e. an improvement of approximately 5.5% of the share of productive time.

Benchmark: Standard site layout
Intervention 1: Extra elevator added
Intervention 2: Putting toilets on levels
Intervention 3: Elevator displacement near exit ground level
Intervention 4: Elevator displacement near work on floor

VI. Conclusions

Improvement have been found in the increase of the share of productive time, when the share of walking and waiting time were reduced with the interventions presented.

Typical workdays can help generate certainty. As the typical workday is used as part of the model to help make decisions in i.e. the construction site lay-out, it helps to provide information within the process.

the different simulations can be compared with each other to show which construction site lay-out is the most productive, since the model focusses on the decrease of time used for waiting and walking.

The ratio between walking, waiting and working time can be calculated and results can be compared to optimize routing and equipment and maximize working time available.

GOVERNING FLAT-ROOF CONSTRUCTIONS: A CASE STUDY

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I. Background

This paper examines the case of flat roof constructions. In Nordic climates, constructing flat roofs are more vulnerable to roofing defects than traditional pitched roofs, and largely avoided on small buildings if sloped, ventilated roofs can be built instead. As such, in Norway, flat roof constructions are mostly limited to large commercial or public buildings. However, flat roofs see use on row houses and detached houses in functionalist style. The prevalence of single-dwelling houses in Norway sustains a large industry of local construction companies specializing in building them.

II. Current conditions

The roof is usually the most exposed façade of a building, and its protection is crucial to secure the integrity of the rest of the structure. A study by Gullbrekken et al. (2016) revealed that roof defects made up 22 % of all building defects investigated by the SINTEF Building and Infrastructure.

III. Working hypotheses

A lean construction process depends on reliable procuring and proper workmanship. The research presented is based on the assumption that current practices during construction may lead to an increased risk of using sub-par materials or errors occurring during assembling due to lack of proper workmanship. Governing these challenges is not a trivial task – and at the cornerstone of viable lean construction practices. Within the case of flat roof constructions, we address the following research questions:

- What are the main threats to the value for the client in the case of flat-roof constructions?
- How does the client govern in order to oversee that requirements are met regarding construction materials- and assembling?

IV. Research Method

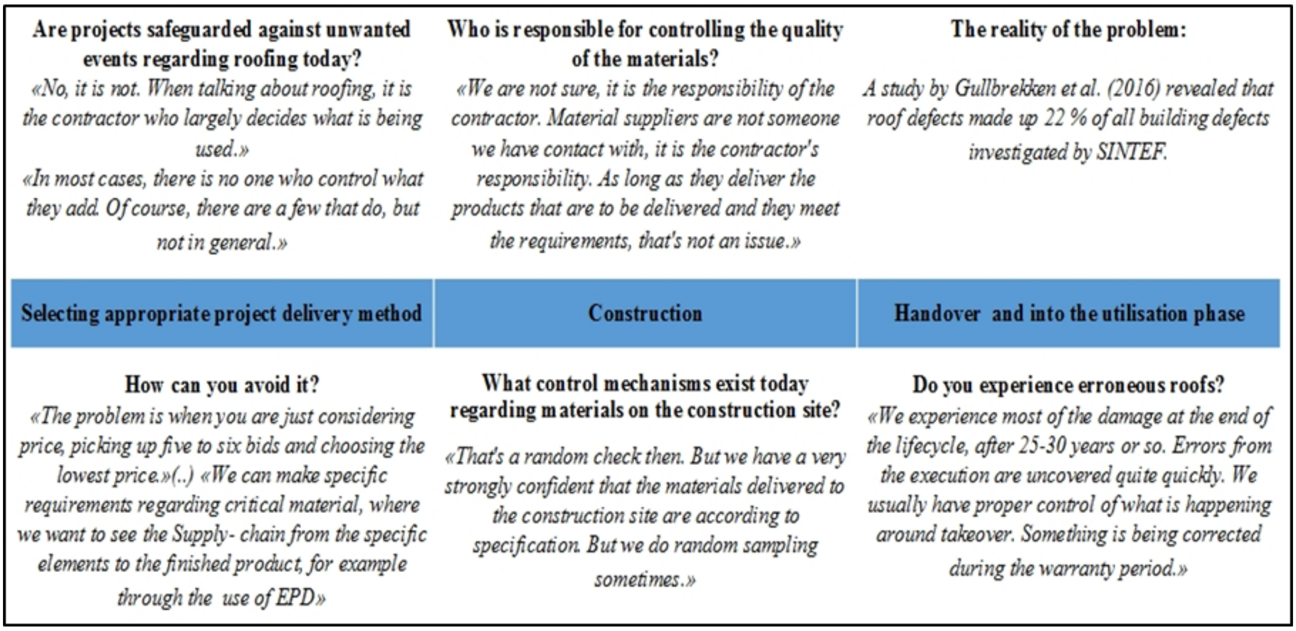
A case study approach with the use of interviews as the main source of collecting data was chosen. The use of semi-structured interviews was considered convenient. An ‘interview guide’ was developed, covering the topics thought to be relevant for the outlined research purpose. The interview guide was structured according to the research questions. The respondent were encouraged to elaborate on topics beyond the interview guide.

The study is limited to the case of flat-roof constructions. The context of the study was a seemingly growing concern in industry-specific newsprints regarding errors related to flat-roofs. One specific article, written by a supplier, and aimed at clients caught our attention. We, therefore, emphasized on the clients, with the purpose of increasing our insight into how clients consider such particular- and critical part of many building projects.

V. Research Findings

Premature roof failures present a great threat to the value of a roof, especially so if the failure is not discovered and repaired before excessive moisture damage has happened underneath the roof membrane. There are undoubtedly problems related to flat-roofs, problems that affect the value of the client. Furthermore, due to their complexity, flat-roofs should be viewed as a critical part of the delivery.

Clients seem to focus on shifting risk when choosing the delivery model. Thus, when asked about governance during construction they tend to emphasize that the responsibility is with the contractor. Finally, when asked about previous experiences with erroneous roofs, everyone has a narrative to describe. Figure 1. shows an illustration of our findings.



VI. Conclusions

What are the main threats to the value for the client in the case of flat-roof constructions?

- Design flaws and construction errors are more common than material faults. Perforations and transitions of the roofing material stand out as the most risky elements on a roof. Additionally, failure to maintain the roof may also cause roof defects.

How does the client govern in order to oversee that requirements are met regarding construction materials- and assembling?

- In the context of such complicated constructions as flat-roofs, both the client and the responsible contractors need to be aware of the possible risks described above. There seems to be an outlook that emerging forms of project delivery such as relational contracting that emphasise on lean principles – such as the focus on people, relationships, and integration – may prove to be more effective in counteracting the problems than the conventional methods are.

Several of the interviewees suspected that conditions were “less tidy” in the part of the industry focusing on smaller-scale projects. Therefore, future research should be directed towards the perspective of the sub-contractors that specialises in constructing flat-roofs. Especially focusing on supply-chain management and the relation between the sub-contractor and the main-contractor and the client.

ANALYSIS OF THE ACTIVITIES OF SITE AND PROJECT MANAGERS – IMPLICATIONS FROM THE PERSPECTIVE OF CREATING VALUE

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I. Background and current conditions

The position of a construction manager plays an important role in the management and coordination of construction projects. This key position has a very wide spectrum of tasks and a high level of responsibility. Studies show construction managers are typically exposed to a high level of stress. One German study from 1997 shows clearly the degree and effects of a high stress level. A major factor for inefficiency and a catalyst for stress could be a lack of transparency and missing communication inside a construction team.

II. Research Question

- How can the stress level of construction managers be reduced?

III. Research Method

In the first part of this paper the existing situation of the daily activities of a construction manager is described based on literature. Additionally information on the fundamentals regarding the study of stress is given.

For this research, six construction managers were accompanied and observed for a total of 55 hours during their daily activities to enable discussion in terms of the current situation, including the influence of digitalization. The data was systematically recorded and validated through interviews.
In the third step various solutions with a focus on increasing the proportion of value generating activities in the daily activities of construction managers will be proposed. The result, which will be described in the final part of the paper, is a structured daily routine to serve as the basis for targeted communication and increased transparency within teams.

IV. Research Findings

The results of the study underlines the high stress level and the overtime. Also the reasons for the stress level could be allocated. Some findings are frequent changes between different tasks, long working hours, increased effort for particular tasks and frequent disruptions are characteristic of the working day of construction managers. Figure 1 shows the average duration of a process (one task) per construction manager. The mean value for all construction managers is 8:03 minutes.

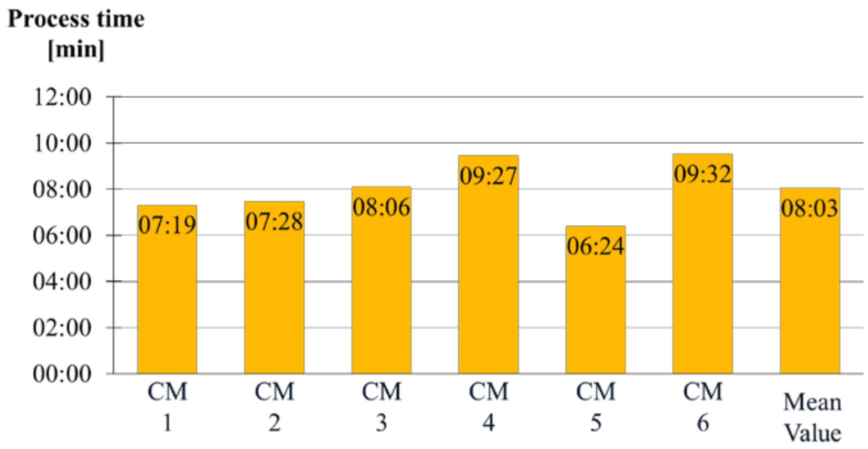
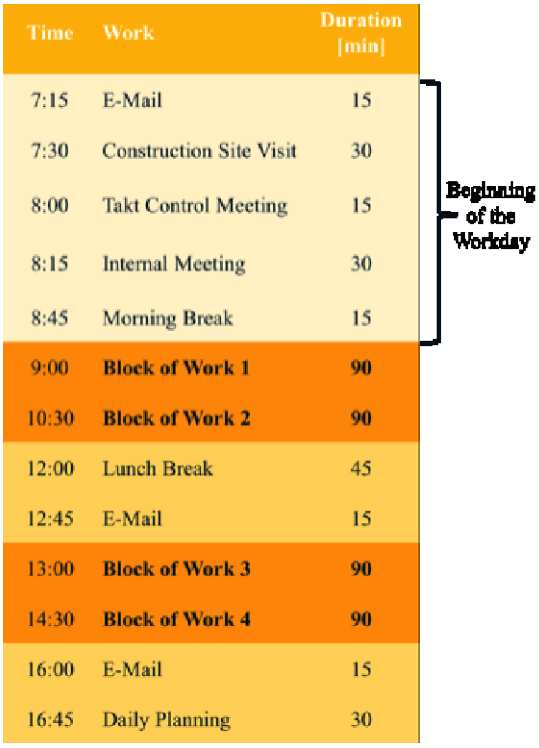


Figure 1: Average process duration CM 1-6

IV. Solution

The findings of this study point towards a need for improving the way construction managers' tasks are organized. The paper shows a possible solution for this issues by arrange each workday into work blocks.



Time	Work	Duration [min]
7:15	E-Mail	15
7:30	Construction Site Visit	30
8:00	Takt Control Meeting	15
8:15	Internal Meeting	30
8:45	Morning Break	15
9:00	**Block of Work 1**	**90**
10:30	**Block of Work 2**	**90**
12:00	Lunch Break	45
12:45	E-Mail	15
13:00	**Block of Work 3**	**90**
14:30	**Block of Work 4**	**90**
16:00	E-Mail	15
16:45	Daily Planning	30

Figure 2: Example for Structured Daily Routine consisting of the Beginning of a Workday and of Blocks of Work

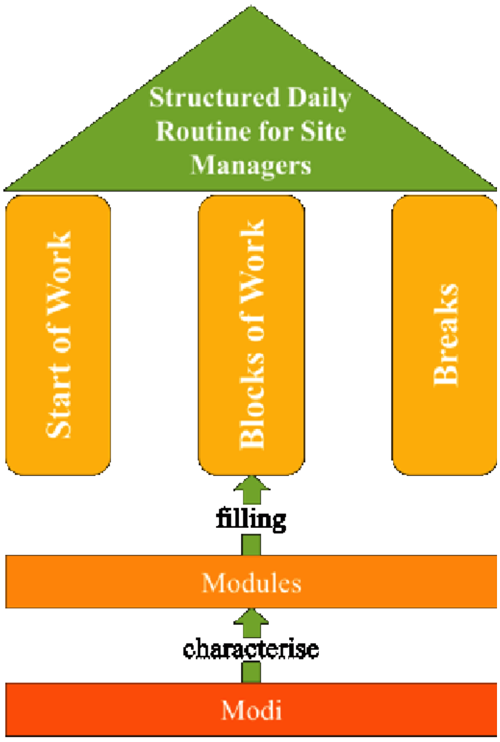


Figure 3: Fundamentals of a Structured Daily Routine

This structure could reduce disruptions to work, the frequency of task changes and the number of overtime hours and therefore reduce stress on construction managers. This structured daily routine could give specific standards, but also be flexible enough to take into account individual circumstances of each construction manager.

Innovation with creative collaborative practices

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I. Background

The goal of planning and executing projects while minimizing waste and maximising value comes from the mindset of lean construction (Ballard and Howell, 2003), and is increasingly implemented in a conservative and traditionally bounded industry, as construction is perceived today. Simultaneously, a complex project design demands uniqueness and higher level of specialization (Lombardo, 2014), yielding a need for interaction and involvement of multidisciplinary stakeholders on another level than before (Bygballe and Swärd, 2014).

II. Current conditions

Problem-solving processes are often carried out as mapping of previous solutions and experiences, moving along patterns of existing knowledge (de Bono, 2009), thus limiting the number of possibilities. By using a structured and conscious approach towards creative processes leading to innovative and improved solutions (Amabile et al., 2002), future projects are able to combine the mindset of lean with the demand for complexity and uniqueness. Implementing problem-solving practices of this kind requires close facilitation (Lombardo, 2014; Amabile and Khaire, 2008) with internal as well as external, multidisciplinary stakeholders, and should aim at crossing these established patterns in problem-solving processes. Thus, creative practices demand and yields collaboration, as a partnering relationship requires interaction to reach its full potential (Bygballe et al., 2010). In total, a new approach to problem-solving practices should involve the two elements creativity and collaboration, while emphasizing the development of innovative solutions.

III. Working hypotheses

This study aims to discover how creative cooperative practices are used in production of innovative solutions in a multidisciplinary engineering project. More specifically, to identify:

1. Creative collaborative practices concerning procurement and design in a case study,
2. The experiences of these practices from the main contractor's point of view, and
3. The potential for improvement of these practices for future projects.

Regarding limitations, the scope is narrowed to concern mainly two project activities: procurement and design. Further, the study is restricted to the view of the main contractor. The research period is limited to a timeframe of six months. The time limitation also makes the follow-up of a specific case through its respective phases of the creative process constraining. The solution has thus been to collect a representative number of observations from each phase.

IV. Research Method

The context for this research is the case of Team Bispevika in Oslo, Norway, a project aiming to contribute to an innovative change of project management in the industry. All interviewees, documents and observations are related to this case. The project is the first in a long-term goal of the main contractor to use innovation in order to increase the added project value by 40%. The plan is to reduce costs by implementing innovative solutions and increasing quality for the end-users. Towards innovation, the project uses creative processes in problem solving incidents.

The case study contains of five interviews in total, and all interviewees hold key roles in the project management. The intention of the interviews has been to unveil the mindset of the project, and how they work differently than traditional construction projects. Three project documents are used to examine the intentional purpose and framework for the practices, contributing and supporting collected data from interviews and observations. Observations consisted of participation in sessions related to procurement and design, presented in table 1.

Table 1: Observations of the case study

Topic for innovation - Activity	Focus	Idea generation	Evaluation & assessment
Waste recycling - Procurement	X	X	
Roof construction - Design		X	X
Concrete: Con Form - Procurement	X	X	
Discipline Strategies - Procurement & Design	X		
Sunblind - Design			X
Timber - Procurement	X		
Logistics - Procurement			X

V. Research Findings

Important findings from the study are presented through three phases of the creative process, covering focus phase, idea generation phase and finally assessment and evaluation phase. Among identified practices with following experiences are the use of resource personnel to facilitate innovation through creativity and interaction, time differences in the creative process of procurement and design, and demanding documentation of presented ideas for further treatment.
By setting ambitious goals and focusing on creating trust in creative collaborations, the case study works towards creating a new framework for future project management and innovative solutions through creative collaborations. Co-location with design consultants and suppliers, careful guidance from the meeting's facilitator and the development of winning teams are found to be important practices towards innovative solutions in this project.

VI. Conclusions

The paper sums up several identified practices with experiences and future improvements. In addition, potential preparations and deliveries from each phase of the creative process is presented through a figure.

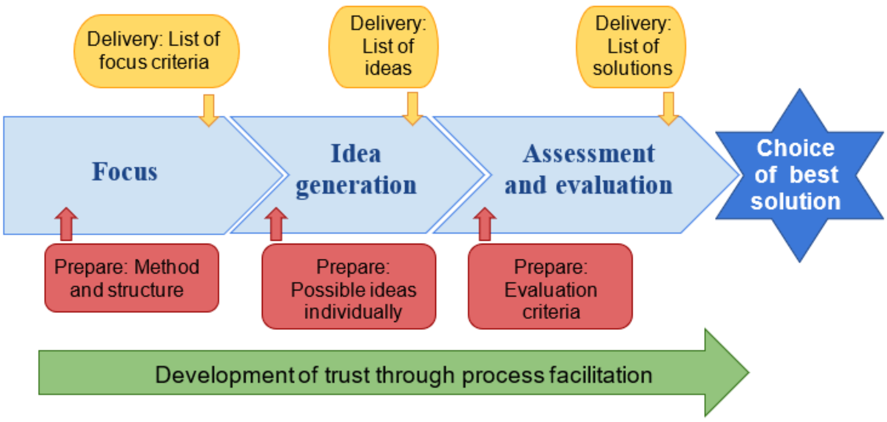

Figure 2: Identified creative collaborative practices in Team Bispevika, freely adapted from Lombardo (2014).

Integrated Project Delivery for Infrastructure Projects in Peru

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A LEAN APPROACH TO IMPROVE PRODUCTIVITY IN A COKE OVEN REFURBISHMENT PROJECT: A CASE STUDY

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I. Background

The paper presents a 3-phased Lean Construction Project (LCP) implemented in a specialized and integrated service company. The purpose of the LCP was to increase productivity and to re-structure Production Planning and Control routines. It was undertaken by a group of internal and external consultants for a period of four months of workshops and more four months of sustainability on-site. The construction project focused by the LCP was the refurbishment of a Coke Oven in a Brazilian Steel Mill.

II. Current conditions

The scope of the contract foresees the hot repair of 253 combustion chambers of the steel plant. The contract was implemented over 6 phases, called “steps”. The scope of the repair comprises, in a simplified form: (a) removing the metal structure, (b) demolishing existing walls to their floor, (c) evaluating the quality of the refractory floor, and (d) constructing new walls to the top, a stage that is called refractory assembly. The current conditions are described:

- The first phase (Step 1) found a delay and an addition of 7% in mh/ton compared to the predicted budget;
- Company A recognized problems that must be controlled in Planning and Construction Management for the success of the contract;
- Lack of routines for production control;

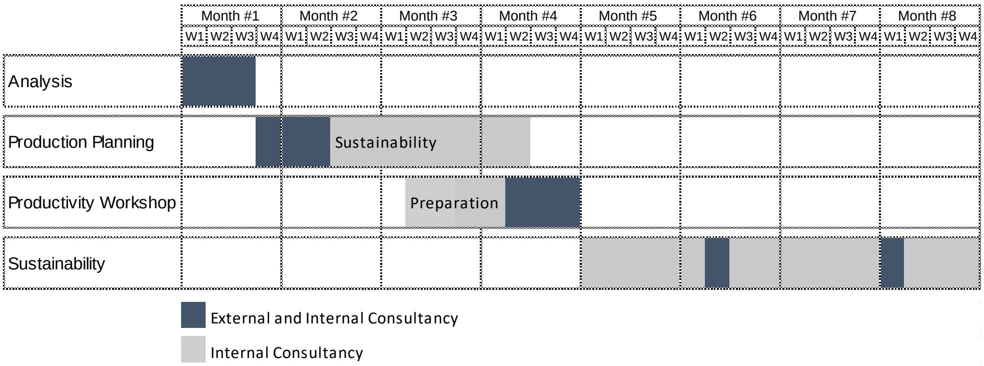
III. Goals and Targets

The objective of the study was to increase the operational efficiency of the coke oven refurbishment case study by increasing its productivity. To achieve the general objective, three specific objectives were proposed:

- To catch the delay in the first phase (step 1) of the construction project;
- To structure the contract planning process by drawing up long- and medium-term plans using the takt time;
- To implement a system for managing the routines and production control considering takt time and the Last Planner methodology;
- To balance and stabilize refractory assemblage by making use of improvement initiative

IV. Research Method

The project was defined in a group of workshops which were held over a period of twelve weeks: (a) Analysis, (b) Production Planning and (c) Productivity.



V. Research Findings

Workshop	Qualitative Results	Quantitative Results
Analysis	Full analysis of the contract status; Opportunity survey to reduce costs in the order of 60% of the contract margin; Identification of planning gaps and planning routines not implemented Office-field communication failure → absence of indicators	59% of front-line production activities do not add value Only 27% of the predefined activities of the Planning standards were met
Production Planning	Definition of responsibilities matrix and schedule of production planning and control Implementation of Last Planner and control of deviations at each change of shift with the holding of quick response meetings Definition and implementation of operational and managerial indicators	93% of the predefined activities of the planning standards were met; Average PPC of 80% over the project follow-up year Reduction of staff by detailing the production strategy for each new production step → 6% reduction in each new step
Productivity Workshop	Definition of production takt and scaling of resources to achieve it (OBC) Review of the plans of attack and change of the conception of work performance on site Development of tools and devices that help the activities of production and inspection of activities Paced supply and Quality inspections of the fronts according to takt	Reduction of direct labor to each phase (step) Step 3 - reduction of 42% mh/ ton Step 2 - reduction of 37% mh/ ton Step 6 - reduction of 7% mh/ ton 20% increase in overall contract productivity Global increase in gross margin of 46%

VI. Conclusions

- Overall, the general objective was met: the delay in the Step 1 was recovered; the activities and teams were sized to take account of takt time and the routines for managing goals acted to guarantee this pace;
- The overall productivity was increased by 20%, when compared to the estimated budget;
- The operational efficiency guaranteed an increase of 46% in the gross margin of the contract;
- The case study succeeded in helping the team to internalize changes and to guarantee their motivation in constantly seeking continuous improvement.

Short Takt Time in Construction – A Practical Study

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I. Background and current conditions

Takt Planning and Takt Control (TPTC), as a method of Lean Construction, is already applied in some projects over the last years. Planning and Control according to a standardized unit of time - the Takt Time - is a unique aspect of this method.

There are many advantages to this method in comparison to traditional time planning. The method of TPTC supports the construction process, reduces waste and thereby increases productivity (Vatne & Drevland 2016, 173). Takt Planning allows work to be completed at a consistent rate and allows reliable pre-planning of activities. Additionally the Takt Plan is built upon a mathematical-algorithmic approach and can be easily adapted with few changes to the basic parameters. This is the key to reduce the duration time in a systematic approach.

It is often used when there is a high level of repetition in the structure of a building project. The common understanding is that this method can only be used for projects with a high degree of repetition in the composition of the building.

II. Research Question

The method is often used if there is an obvious repetition in the project. One purpose of the research was to figure out if the use of TPTC is possible for projects with non-obvious repetition in the projects. Based on this idea the paper will answer the following research question:

- Is it possible to apply this method in projects with non-obvious repetition?

The freedom in finding and defining the repetition leads to wide latitude in setting the Takt Area and Takt Time. The paper shows a comparison of different variations, the benefits and the effects induced to the project lead-time. The second research question is:

- What is the impact of varying Takt Times on project lead-time?

III. Research Method

A real case study is the base of the research. In the first stage the as-is situation of the current state of the project was derived from interviews, site-observations and reviewing the project documentation. The main part of the as-is analysis was on-site observations over a week-long period as well as a visit to the client and client representative.

In the second stage Takt Plans with different basic parameters of time and space were developed and critically discussed.

IV. Research Findings

The takt time and space was reduced over six steps (table 1). Compared to step 1 the completion time is reduced by 69% to 17.5 hours.

#	Takt Time [h]	Size TA (compared to 1))	# TA	# Waggons	# Waggons incl. empty Waggons	Through-put Time [h]	Finish Time [h]	Time Improve-ment [%]
1)	8	1	1	7	7	-	56	-
2)	4	½	2	7-8	9	-	36	36
3)	2	¼	4	11	14	22	28	22
4)	1	1/8	8	15	22	15	22	21
5)	0,5	1/16	16	23	38	11,5	19	14
6)	0,25	1/32	32	39	70	9,75	17,5	8

Table 1: Overview of the Takt Area reduction steps

As shorter the takt time gets as higher the influence of the drying time will be. Figure 1 makes clear the significant impact of the drying time (red waggons) for the plasterer. This timeframe occupies a large part of the train and the surface area of the Takt Plan. This is the applicable size for calculating the duration of fit-out works for a Takt Time of 15 minutes.

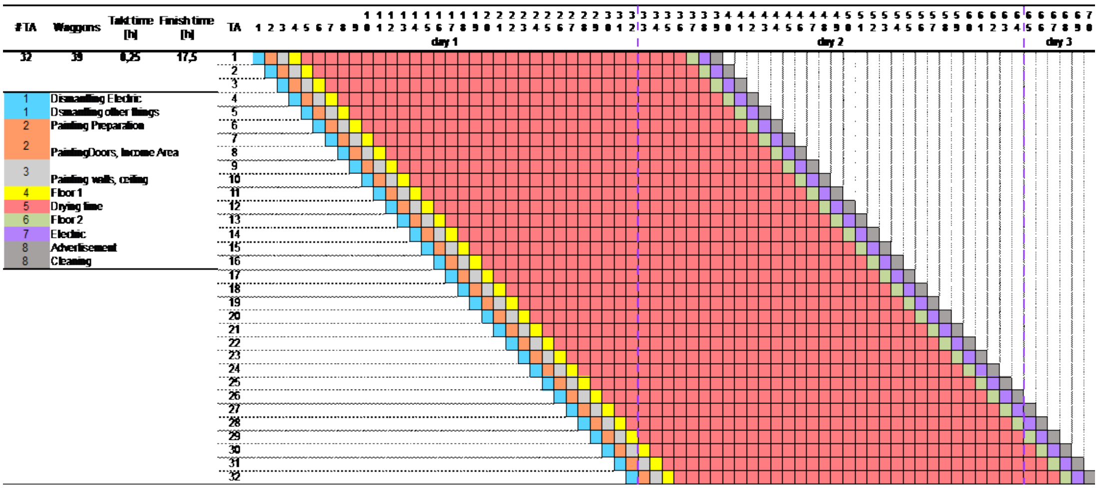

Figure 1: Takt Plan with a Tatk Time of 15 minutes and a Takt Area of 1/32 of the total area. (Option 6)

V. Results

The results achieved matched the predicted three-day duration of construction. Hereby the pilot project was able to achieve a 70% reduction in construction duration. This is however, not the only effect.

In summary, it could be determined that in the pilot project the using Takt Planning enabled a significant reduction in construction duration. Through close supervision and comprehensive documentation additional potential was uncovered.

PROMOTING COLLABORATIVE CONSTRUCTION PROCESS MANAGEMENT BY MEANS OF A NORMALIZED WORKLOAD APPROACH

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I. Background

Traditional construction projects are characterised by *schedule and budget overruns identified too late to apply recovery actions.* This is partly caused by a coarse planning and management of the construction execution process. The hypothesis is that the interplay of the three main phases of project management - planning, scheduling, and monitoring - can be improved by collecting highly detailed information early on in each phase, and making it available to the other phases at a high frequency. The here presented ongoing research project COCkPiT (**Co**llaborative **C**onstruction **P**rocess Mangemen**t)** aims at providing methodologies and IT tools especially targeted to SMEs to circumvent the mentioned abuses.

II. Current conditions

The Italian construction industry consists of a great amount of small and medium sized companies (SMEs), that makes the sector highly fragmented and as a consequence:

- Limited resources are available for planning and managing the execution process.
- Limited knowledge of construction management theory and sophisticated IT-tools.

This results in a lack of *systematic and detailed* planning, schedule and monitoring routines.

III. Goals

By applying a *Normalized Workload Approach,* COCkPiT aims to:

- Enhance process stability as well as time and budget control in construction projects.
- Lay the basis for a more efficient management and execution of construction processes.

IV. Analysis

Coarse and not systematic planning and management of the execution process:

- Planning does not involve the responsible actors.
- Scheduling is not systematic, not detailed and not updated according to the progress on-site.
- Monitoring is not quantitative and not connected to the schedule.

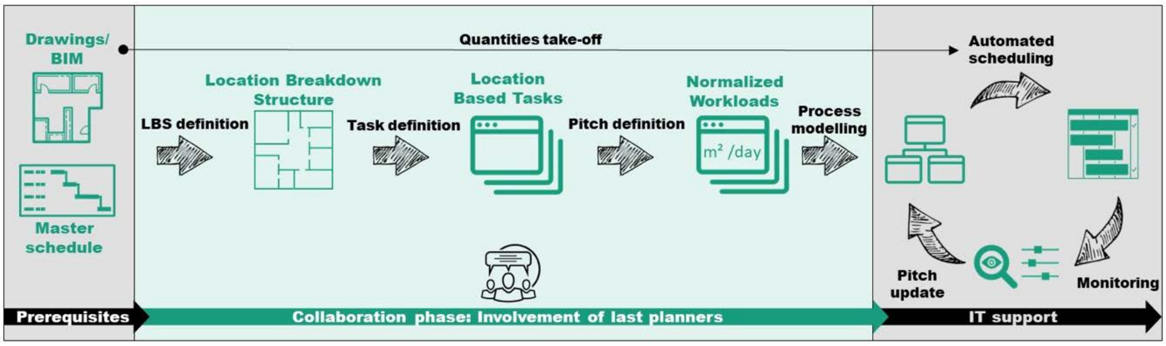
V. Proposed Countermeasures

Process Management in COCkPiT forsees the three phases:

1. *Collaborative Process Modeling*
    - The concept of *Pitch* is introduced.
      The Pitch is a Normalized Workload Approach to *quantitatively* specify tasks' production rates and required number of workers for a defined time interval.

$$Pitch_{CA_i, Task_j, Crewsize_k} = \frac{Quantity_{ij}\,[MU_j]}{time\ interval}$$

    - Tasks, resources, locations, dependencies and the *Pitch* are collaboratively specified.
2. *Short-term Scheduling*
    - Weekly work plan + Lookahead window.
    - Possibly generated automatically from a model and satisfying all its boundary conditions by applying constraint solving techniques. Considering the *Pitch*, all generated short-term schedules implicity entail the commitment of last planners.
3. *Real-time Monitoring*
    - The *Pitch* is used to measure the construction progress and to forecast the consumed labour budget at completion.
    - Data from the monitoring is used to update *Pitch* and thereby making new schedules more and more reliable with every planning cycle.



VI. Plan

COCkPiT actively involves three SMEs companies and follows an agile development approach. Efforts so far resulted in a first prototype as MS Excel workaround which will be used as a basis for further development.

VII. Follow up

Among the challenges, the interesting feedback provided by the companies were *i)* the requirement to limit the time they have to spend for the modeling and *ii)* the preference of mimiching the graphics and interaction of tools they are already familiar with (e.g., MS Excel, Gantt Charts).

Winning the bid – a step-wise approach using BIM to reduce uncertainty in construction bidding

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I. Background

The paper reports from an ongoing development project in a construction company, to improve their bidding process. Each year, about 30 bids are prepared by the business unit. The percentage of projects won vary significantly among different markets, with a total average of between 40 and 50 per cent of the bids being realized each year. The share of projects won is too low considered the efforts made to win them. Of concern is also the substantial variation between markets in acquired projects.

II. Current conditions

Our current bidding process is characterized by a lack of standardized procedures. Too often, we initiate a bidding process without a clear idea of why, with the risk of prioritizing the wrong projects. Likewise, the estimation of costs is sometimes misguided by wrong assumptions, with the subsequent pricing of simple things as too expensive and complex things as too low-priced. To make sure we end up with the right projects, and costs, an effort is thus needed to streamline how we do the bidding, where we want to use BIM to make sure all significant cost elements in the projects are understood, linked together and communicated effectively.

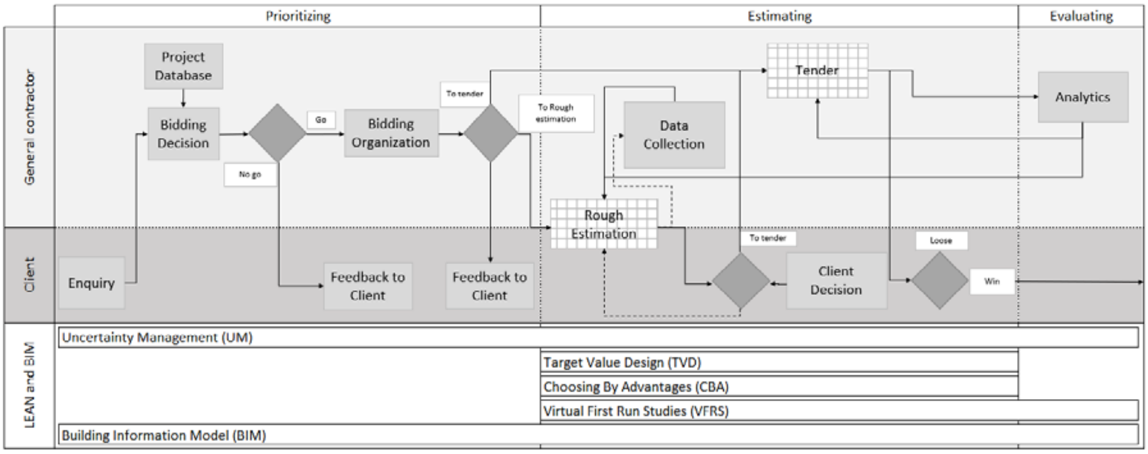
III. Working hypotheses

The development work intends to solve the following problem:

- *How can we reduce the uncertainty in the bids we offer?*

VI. Research Findings

The step-wise approach to construction bidding presented in the figure below sums up our initiative to improve the bidding process. It is explained in further details in the subsequent sections.



Two steps to bid – one step to learn: We suggest the bidding process to be divided in three steps to define its main activities, and to rapid the process up by pulling it towards a decision point at the end of each step. By this, we hope to make for a more concentrated effort in the bidding work.

- “Prioritizing”: Projects are to be chosen based on the unit’s business strategy. Main decision criteria to go further to bidding can be:
    - A reasonable chance to win
    - Good prospects for making a decent profit
    - Strengthen positioning in a market of significant importance
    - Develop in-house competencies.
- “Estimating”: Estimating is to be released from a decision to prioritize the project. It can be done either directly as a detailed calculation of the various posts included in the project, or it may start as a rough estimation to come up with a preliminary guesstimate:
    - Rough estimation: Developed from a list of geometric factors, which are merged with cost components from our calculation program – to be visualized in a BIM model
    - Detailed calculation: Calculating costs for the in-house production, for rigging and management on the construction site, besides adding incoming bids from subcontractors and suppliers to the calculus. Also included are analyses of opportunities and risks, and the formulation of actions to reduce the uncertainties uncovered.
- “Learning”: Takes place after the bid is submitted, to continually learn and improve from what we do:
    - Follow up closely with the client to clarify confusions and issues that need further explanation
    - Invite the bidding team to do an evaluation of the bidding process
    - Collect information from the competition regarding assignment criteria, ranking of bidders, feedback from the client and so on

V. Conclusions

- We propose a step-wise approach to construction bidding supported by Target Value Design and its belonging processes related to structured decision making (Choosing By Advantages) and virtual mock-ups (Virtual First Run Studies), to win bids at the right costs
- We conclude that the general contractor is boundedly rational in his or her bidding behavior, because the inclination to maximize the outcome is moderated by factors such as the need for work, market penetration, and in-house competencies.

CAN BIM FURNISH LEAN BENEFITS- AN INDIAN CASE STUDY

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I. Background

BIM has been identified as an effective process for achieving various lean benefits in the construction sector. It has been recognized as an enabler for proficient accomplishment of projects in construction industry at different levels. BIM implementation embodies various benefits including enhanced visualization, collaboration between stakeholders throughout the project life cycle, time and cost savings, value engineering, change management and many others. Having realized this, the relationship between BIM and lean by studying the use of various BIM capabilities on construction projects from initiation stage till operations and maintenance stage has been established through this study. Lean benefits corresponding to each BIM capability have been reported. The paper is based on exploration case based research methodology wherein, both literature review and semi-structured interview have been done.

II. Research Focus

- What capabilities of BIM have been implemented on selected construction projects in India?
- What potential lean benefits can be accrued by implementing BIM?
- What lean benefits have actually been accrued in the selected case studies?

III. Research Methodology

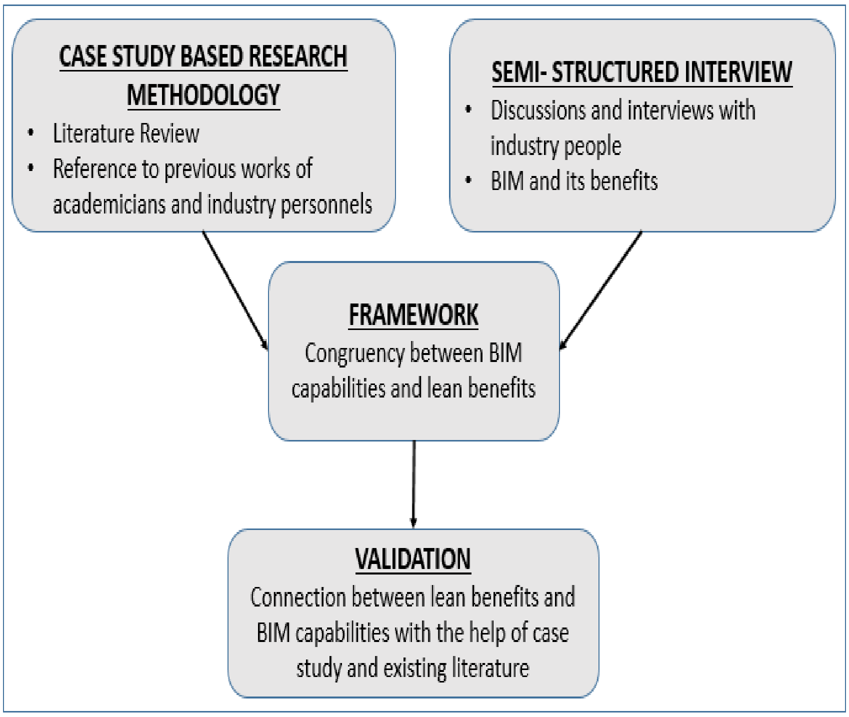

Figure 1 outlines the research workflow for the conduct of the study. Initially an extensive literature review was done to discover all the possible BIM capabilities and their benefits. Many discussions and semi-structured interviews were conducted to understand the status BIM adoption and use of capabilities around the globe. Two detailed case studies for use of BIM in India were examined and a framework to establish congruency between BIM Capabilities and Lean benefits was developed which was further validated with help of existing literature.

Figure 1: Research workflow

IV. Research Findings

STAGE	BIM Capabilities	Worker safety	Increased staff productivity	Improved communication	Reduced project schedule	Reduced lifecycle cost	Continuous improvement	Better risk management	Waste minimization	High quality construction	Improved team dynamics	Greater Customer satisfaction
PRE-CONSTRUCTION (Project 1 and 2)	Design coordination	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Visualisation/ walkthrough	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓
	Quantity take-off	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4D Construction Sequencing and Scheduling	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓
CONSTRUCTION (Project 1)	4D construction sequencing and tracking	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓
	Cost Tracking	✗	✗	✓	✗	✓	✓	✓	✓	✗	✗	✓
	Safety Management	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓
	Collaboration and coordination	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OPERATIONS and MAINTENANCE (Project 1)	As-built drawings and models	✗	✗	✓	✗	✗	✓	✓	✓	✗	✗	✓
	Facility management	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓

Figure 2: BIM-LEAN Framework

V. Conclusions

- BIM enhances coordination and collaboration between various stakeholders, thus saving time, money and human efforts.
- BIM yields lean benefits hence, there is demand for adequate and proficient BIM training in the Indian construction sector
- BIM is majorly used in pre-construction stage in India which is largely affected by societal demand, organizational acceptance and technical complexities.

RICS School of Built Environment
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‘Site Layout Planning Waste’ Typology and its Handling through AR-BIM Concept: A Lean Approach

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I. Background

Lean construction is applied to minimize waste, with a motive towards value creation, and addressing the end user requirements. In construction, “Waste” is defined as any deviation from the absolute minimum in terms of labor, equipment and material required for creating a product. The basic premise of lean philosophy is to enable stronger collaboration and coordination among the project participants to streamline the construction process flows. The process of site layout planning (SLP) pulls in project stakeholders to plan and fix the location, shape and size of the temporary facilities required. Consensus on the decisions towards SLP is achieved utilizing two-dimensional (2D) drawings. These 2D drawings lack the three dimensional (3D) spatial constraints, due to which the wastes are generated. SLP is a decision-making process that calls for better visualization, coordination and collaboration so that an efficient layout can be prepared. Emerging technologies like Building Information Modeling (BIM), Computer Simulations (CS) and Augmented Reality (AR) promise better coordination and collaboration among project stakeholders. The applicability of these technologies has been explored in all phases of construction project, either individually or in integration with one another. The present research understands how the visualization of the process helps in adoption and implementation of lean and can aid better coordination and collaboration among the project stakeholders by enhancing the process transparency. Thus, this paper presents a conceptual tool and highlights its applicability for making lean site layouts by bringing leanness to the process of SLP.

II. Literature Review

The existing literature was comprehensively reviewed and some inferences on “wastes due to faulty SLP”, “SLP” process, “BIM for lean construction” and “implementation of lean thinking through visualization” were deduced. The understanding of the above mentioned knowledge areas, brought up the gap and inefficiency in the traditional SLP process utilizing 2D drawings to fore. The research on BIM and visualization provided an approach to implement lean at the initiation phase of project by making the SLP process lean. Several research studies were found reporting the resultant wastes due to improper site layouts but a few have investigated the root cause. Thus the novelty of this research study is the investigation of the root cause of improper site layout and how the lean thinking can be brought to the construction from the initial phase of the project.

III. Research Method

The study adopts a qualitative approach through expert interviews to achieve the above objective. To identify the themes to be discussed with the experts a comprehensive literature survey was done. A semi-structured open-ended interview on waste in the SLP process and waste due to improper SLP, adoption of BIM and Lean and potential of BIM and AR in Lean was conducted with 15 SLP experts.

IV. Research Findings

The identified wastes in and due to faulty SLP, from the literature and expert interviews were classified into two major categories as identifiable and unidentifiable to the layout planners as depicted in Figure 1.

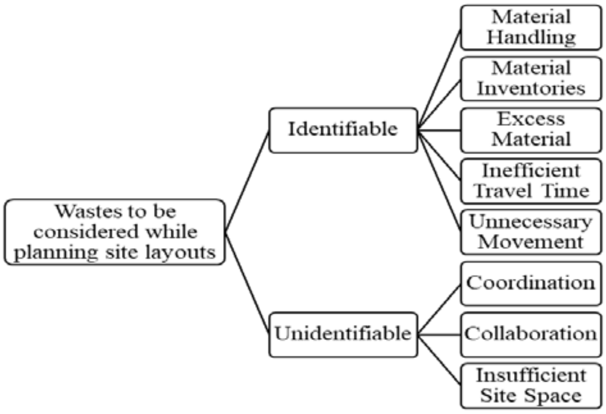

Figure 1: Developed 'SLP Waste' Typology

The interviewed experts highlighted a pressing need to have some tool which can make the decision-making task easier and can aid the planners in eliminating the identifiable and unidentifiable wastes.

Proposed Conceptual Tool: The developed typology indicates the coordination and collaboration among project stakeholders as unidentifiable wastes involved in the process of SLP and the identifiable wastes are resultant of an inefficient SLP process. The deficiency of 2D drawings and the dynamic nature of construction site, motivated the authors to propose a conceptual tool that can aid the stakeholders, in enabling a better platform to collaborate and coordinate. The tool is defined and proposed to mitigate the wastes in the process of planning site layouts and the resultant wastes due to the improper planning of layout. The proposed tool is in the development phase, and thus the working presented here is an anticipation. The tool will help in 3D visualization of the site scenarios by superimposition of the digital model on the real world, utilizing the basic functionality of augmented reality as shown in figure (2a).

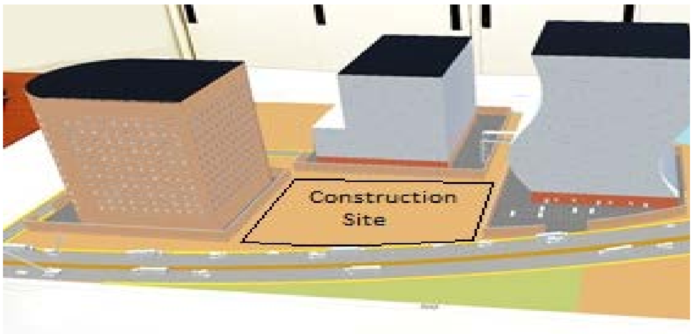

Figure (2a)

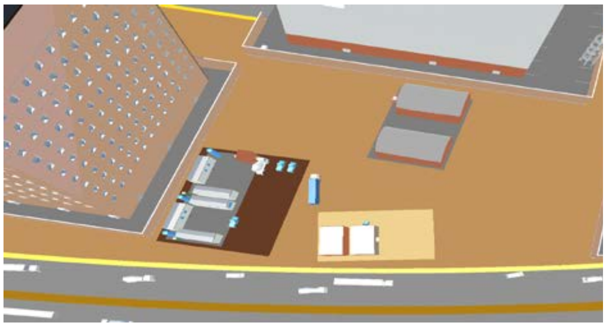

Figure (2b)

The integration of AR and BIM will help out in planning for site layouts by superimposing the BIM models of the site and the required TFs over the 2D drawings using the fiduciary marker technique for target tracking as shown in figure (2b). The tool is expected to enhance the big room concept involved in the lean construction by eliminating the delays in decision making and improving the trust among the stakeholders involved in SLP by enhancing the process transparency.

V. Conclusions

The study was conducted to understand the construction sites' wastes and the wastes resulting due to bad site layout planning. The approach was constituted such that the process of site layout can be made lean by eliminating the wastes involved in the process of SLP and the wastages due to the improper planning of site layout. The experts' interview helped in identification of the anticipated wastes by the planners as well as the wastes that remain unnoticed. To this end, it is a preliminary study concerning the waste of inefficient SLP, and a conceptual tool is proposed. The proposed AR-BIM tool is an integrated result of the visualization technology and a collaborative tool. The applicability and adaptability of the proposed tool remain questionable and provides the future scope of research.

REDUCING HUMAN FAILURE IN CONSTRUCTION WITH THE 'TRAINING-WITHIN-INDUSTRY' METHOD

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Fidelis Emuze, *Professor, Central University of Technology, Free State, South Africa*
John Smallwood, *Professor, Nelson Mandela University, South Africa*

I. Background

This study is intended to address the problems of human failure encountered during the process of delivering the construction projects in South Africa. Human failure in a form of an active errors and latent conditions is a set of unplanned actions that produce unforeseen incidents and accidents within the workplace. Accidents produced by human failure are part of the waste in the workplace. An accident is a waste that is linked to people in construction because it cost both human and non-human lives and it results in either minor or major injuries or even fatality. To solve this reported problem, a lean production tool, the 'Training-within-Industry' (TWI) is used as a start, to help to identify and eliminate safety related waste in construction. TWI is commonly used to transfer knowledge and skills needed to improve work methods. The tool also helps to maintain a good working relationship between the employers and employees.

II. Current conditions

- Human failure is always blamed on individuals at a lower level in the construction industry.
- There are limited published work addressing the subject of human failure in the South African construction industry.
- In the South African construction industry, the application of the TWI method concepts appears to be unfamiliar.

III. Working hypotheses

- *There are four essential elements of human failure. These include the intention, the action, the outcome, and the context.*
- *The application of the TWI method could be used to identify and reduce human failure by training within each individual in the construction industry.*

IV. Research Method

- *A case-based research strategy was adopted.*
- *Four case projects, three in Sandton and one in Bloemfontein.*

V. Research Findings

- As an illustration, figure 1 gives insight into the proposed conceptual human failure resolution framework.

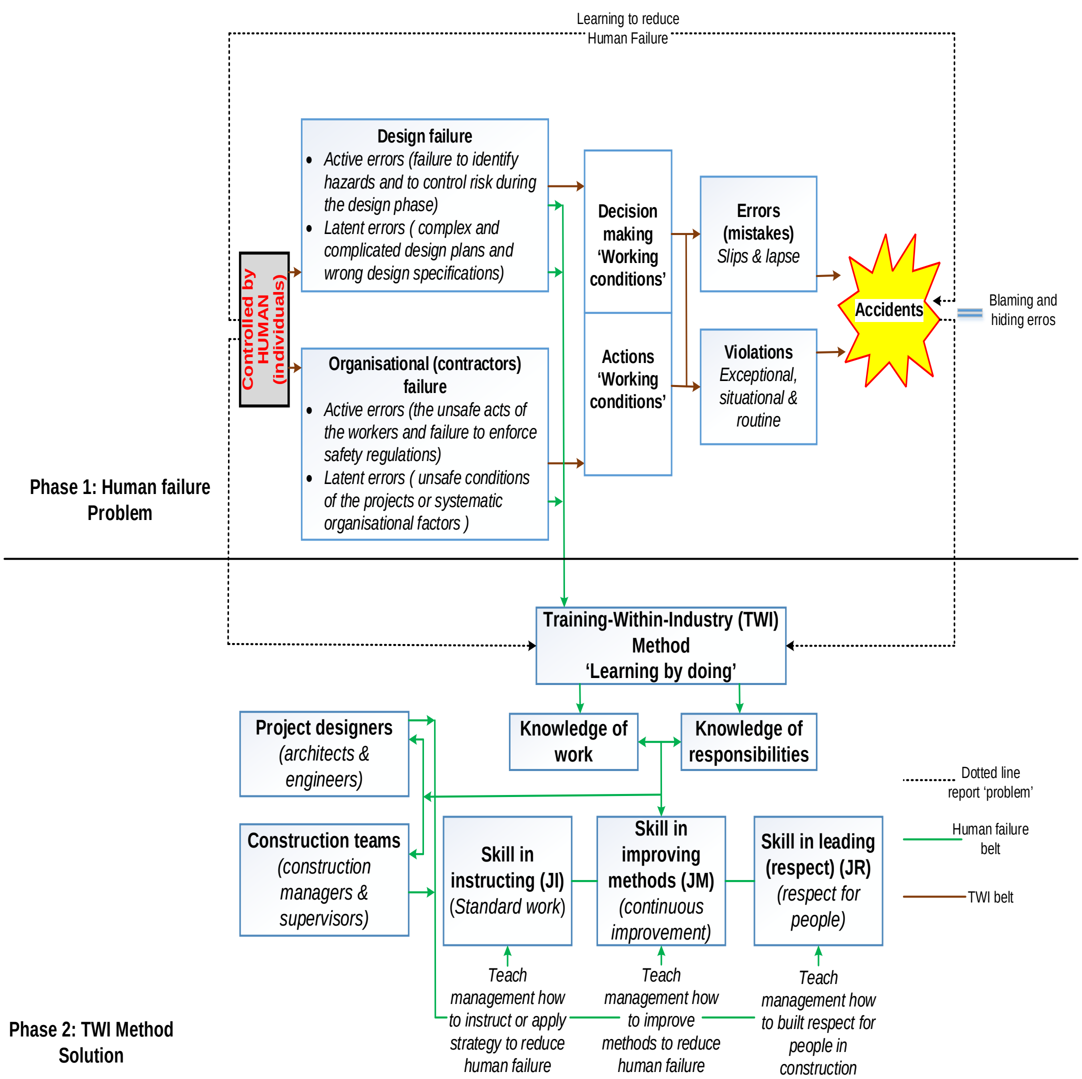

Figure 1: A conceptual human failure resolution framework

VI. Conclusions

- Inadequate training of workers contributes to the variability and waste manifestation that precede accidents in construction.
- There is a significant scope TWI deployment in construction due to the inability of supervisors and working to "see" safety wastes unfolding on their worksheets.
- The guidelines herein outlined could reduce human failures (safety errors and violations) with the use of the lean construction tool, the TWI method.

LEVERAGING TECHNOLOGY BY DIGITALIZATION USING "I REPORT APP" FOR SAFETY AT CONSTRUCTION SITES

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I. Background

Construction industry is a highly unorganized industry and prone to major risks and safety non-conformances. Reporting of unsafe conditions and unsafe acts at construction sites becomes a huge challenge due to less participation from stakeholders, reluctance in filling up the manual formats and inconsistency in hazard reporting & ultimately timely closure of same. This paper explains how a mobile App, I-Report was developed to address stakeholder's issues by collaboration and how it helps succeed in improving the safety performance of the organisation. This paper is an example of digitization helping create safe work sites thereby reducing incidents and continuously improving safety processes on the basis of enabled data analytics.

II. Current conditions

All the hazards identified are captured using the "I- Report" app. Given below is the flow which explains the sequence of capturing a hazard to its complete closure.

1. Hazard is captured using the phones camera by the end user.
2. A Unique number ID is generated for the hazard captured.
3. The Concerned engineers / line managers/ supervisor responsible receives a flash message.
4. The concerned engineer/manager closes the hazard with immediate action and Corrective and Preventive Action (CAPA), which is then filled in the App along with the photographic evidence.
5. Post closure of the hazard by the engineer / line manager, the Departmental Safety Officer gets a notification on his system and he validates the CAPA and ensures proper Root Cause Analysis (RCA) and subsequently approves the closure.
6. The loop is closed by a mail generated by the system to the end user and all concerned reflecting the details in one-page sheet.
7. Post validation of CAPA and RCA necessary changes are communicated by the Senior management and accordingly organisation's safety strategy is reviewed and decisions are made.
8. The system also has special features of timely escalation, forwarding and partial closure.

III. Working hypotheses

Maximum hazard identification levels were found to be 89.9% for a construction project within the nuclear industry, 72.8% for a project within the railway industry, and 66.5% for a project within both the railway and general construction industry sector. The use of advanced information technology can provide great benefits to this important safety aspect of construction operations and use of these innovative tools could result in safer jobsites. The organisations idea of creating an App was also to generate, trace & compile data in no time which would include Data Analysis, Aging Analysis, CAPA, RCA, Site Safety Performance and so on.

IV. Research Method

<table>
<tr>
<td>I. Background
Construction Industry is unorganised and there is no proper and immediate way to report a hazard at site which may lead to accidents and near misses.</td>
<td>V. Proposed countermeasures
Following be the focus areas to capture all the countermeasure
1. Capturing Needs and Expectations of the Application
2. Adoption of a Focussed Approach for Lean App Development
3. Exploration other Digital Platforms
4. The Design, Development and Launch of the Lean App</td>
</tr>
<tr>
<td>II. Current conditions
Any authorised stakeholder who sees a hazard immediately reports it in the I report application and immediate closure with proper CAPA is done and it is ensured that the hazards are not reported, changes if any in the SOP or Policy are made in line with the CAPA.

III. Goals/Targets
To capture all the hazards immediately when observed by any stakeholder and get it resolved immediately with proper CAPA and RCA to avoid its future occurrence.</td>
<td>VI. Plan

</td>
</tr>
<tr>
<td>IV. Analysis
Following Root cause(s) were identified.
• Real time information about hazard available only with the individual observing hazard
• System inaccessibility leading to reluctance in filling up the formats etc.
• Reporting done only when on duty.
• Delayed recording and closure of safety issues
• System generated Trends Analysis not available</td>
<td>VII. Follow up
Post the closure of the hazard CAPA and RCA is done and necessary changes in SOPs and policy is done aiming for continuous improvement.
Also, the application is being updated as and when required to meet new requirements.</td>
</tr>
</table>

V. Research Findings

Technology helps to improve psychological safety by empowering every stakeholder working for the company with the ultimate aim of making construction sites in the organisation safe and motivating.

VI. Conclusions

Apps such as "I report" facilitate collaboration for creating accident free sites by providing a platform for quick hazard reporting and their immediate closure thereby reducing probable accidents which can cause human losses, productivity losses ultimately affecting overall project performance. Diligent Root Cause Analysis and Corrective and Preventive Action for repeated hazards leads to elimination of unsafe conditions by driving change initiation activities in conventional operational procedures or workflow methodologies followed in the industry thereby setting a benchmark by for continual improvement, enabling the organisation set standards to the nation in safety.

Towards Creative Lean (Clean) Construction: From Lean Production to Lean Consumption

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I. Background

The current approaches in lean construction are primarily production oriented. More recently, there has been greater attention towards what we design, based on approaches such as Target Value Design. Despite these developments, the need for production is taken as the default starting point in the design explorations. In contrast, it is occasionally possible to deliver the target value through alternative approaches such as service innovation, without the need for any physical production. Such 'Lean consumption' models can potentially eliminate waste in the consumption patterns itself. However, alternative approaches require divergent thinking. Hence, we need to integrate creative design methodologies in lean construction practice. This paper aims to initiate this discussion on Creative Lean (CLean) Construction, as a step from lean production to lean consumption.

II. Current conditions

- Lean construction models and theory are primarily production oriented
- There is increasing recognition of the importance of design phase, e.g. Target Value Design (TVD), Lean Design Management (LDM), etc.
- Nonetheless, the current understanding in LDM provides an operation view of design management, ie., the management of the design process.
- Also, 'design management' is different from 'design process' (cognitive view) and 'design methodology' (both cognitive and operational view). LDM does not cover all these, and hence provides only partial opportunity for improvements in the design phase.
- Like many other sectors, the construction industry is currently seeking paradigm shifts, with wide-ranging explorations and ideas, ranging from technology explorations to service-oriented business models. These explorations are often opportunistic, random and experimental, but difficult to explain using current lean methodologies or LDM. Nonetheless, a comprehensive theory should be able to explain such phenomena as well!

III. Working hypotheses

- *Current 'production based' theory of lean construction limits opportunities for wider exploration of 'value delivery'. Therefore, we need to extend the theories and models in lean construction by incorporating and developing an understanding of 'lean consumption', which explores wider solution space for alternatives to deliver value.*
- *Since 'lean consumption' approach requires divergent thinking, lean construction theories and models can be extended using theories and models from 'creative engineering design' and 'design research'.*
- *Current lean theories and models, including LDM, are well-suited for continuous improvements, but may not be adequate to support and explain paradigm shifts and disruptive innovation.*
- *Current approach to LDM provides only an operational view of design management. Therefore, to realize significant improvements in the design phase, we need to extend LDM using theories from Cognitive View of design, as explored in Design Research.*

IV. Research Method

This paper is based on theoretical arguments, reflective research (Fook 1996, Schön 1983) and thought experiments (Brown and Fehige 2017). Both reflective research and thought experiments are qualitative research methods suitable for abductive reasoning on topics where inductive and deductive reasoning is difficult, and where empirical data is either not available or not very useful.

Brown, JR and Fehige, Y (2017) Thought Experiments, *The Stanford Encyclopedia of Philosophy*, https://plato.stanford.edu/archives/sum2017/entries/thought-experiment/

Fook, J. (ed.) (1996) *The Reflective Researcher: Social Workers' Theories of Practice Research.* Sydney: Allen & Unwin.

Schön, DA (1983) *The reflective practitioner: How professionals think in action*. NY: Basic Books.

V. Research Findings

- LDM explains design iterations using the PDCA (Plan-Do-Check-Act) cycle, which suits an operative view of design. Since PDCA is activity-based, the steps are overt, observable and trackable. This suits LDM goals of monitoring productivity and delays. In contrast, cognitive view explains design iterations in terms cognitive processes such as Exploration-Generation-Evaluation-Communication or the iterative Function-Behaviour-Structure (FBS) framework. The cognitive processes remain mostly opaque, and hence, difficult to track and identify productive and non-productive sessions. Nonetheless, cognitive processes are the basis of decision making, and cannot be overlooked for the lack of adequate measures to track and assess productivity.
- The cognitive view of design is more open to problem reformulation, making it more suitable to radical and disruptive changes, unlike the operative view which tends to limit iterations to continuous improvement on the initial problem formulation.
- Based on the above, and related arguments, ‘Missed Opportunity’ is proposed as another category of waste that subsumes previously suggested wastes such as ‘Not listening’ and ‘Not speaking’. ‘Missed opportunity’ is well suited to design phase, where potential new ideas are not exploited, or in production when new methods or tools are not adopted, despite having an opportunity to do so! One of the key reasons for ‘Missed opportunity’ waste is the sunk-cost effect.

VI. Coclusions

- We need to extend lean construction research beyond ‘lean production’ to ‘lean consumption’.
- We need to create a framework for ‘Creative Lean Construction’ drawing upon theories from creative engineering design and design research.
- We need to integrate cognitive models of design iterations with operative view of design iterations if we aim to achieve greater improvement in the design process and LDM.
- We need to recognize the distinction between the PDCA cycle and the cognitive design cycles. A combination of these will address the strengths and limitations of both these models.
- ‘Missed opportunity’ is proposed as another kind of waste to address through lean methodologies and practice.

Enabling Lean Design with Management of Model Maturity

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I. Background

Traditional construction management has struggled with an ad hoc approach to design, increasing the number of negative iterations and sacrificing potential value. Last Planner™ has shown significant improvements in management practices when applied in production stages of AEC-projects, but has only seen limited applications in design. Building Information Modelling (BIM) has been driving information management in design, although there lacks an orderly process of work which would make it compatible with management tools such as Last Planner™. Level of Development (LOD) could allow for this by attributing maturity to the BIM, although previous studies of LOD implementations have shown potential for improvement.

LOD100 **LOD200** **LOD300** **LOD350** **LOD400**

II. Current conditions

Recent developments in the Norwegian AEC-industry has seen the application of a LOD-based framework with a greater emphasis on process management called Model Maturity Index (MMI) in a few large construction projects using Last Planner™. Experiences from cases and success factors for sound implementation strategies are relatively undocumented.

III. Working hypotheses

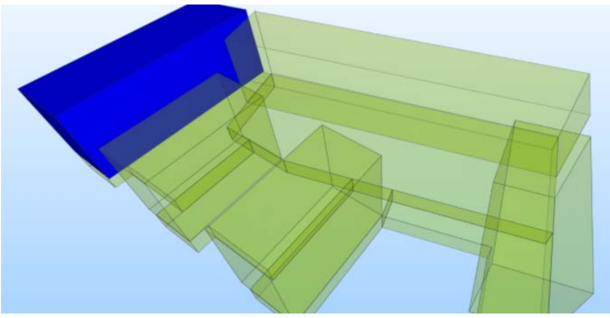
The following study presents the hypothesis that approaches to managing model maturity can provide the necessary conditions for managing BIM-based workflows using Last Planner™.

IV. Research Method

A literature scoping study was conducted to in order to formulate five key aspects of managing maturity in design. These aspects were used as an explanatory framework for assessing cases and suggesting recommendations for sound implementation strategies. Two pilot cases were studied using interviews and a document study. Cases include Tiedemannsbyen, an apartment complex of five, six-storey buildings (Skanska Norway, approx. $54M, ~14 designers), and E6: Arnkvern-Moelv, a 24km long Class A road project, part of the international E-road network (Veidekke Entreprenør AS, approx. $260M, 30+ designers).

V. Research Findings

Successful implementations of maturity-based management emphasize simplicity, managing maturity as attributes of entire disciplinary models associated to certain sections of the BIM. Maturity levels are formulated as functional requirements related to project needs rather than specific amounts of geometrical complexity. By representing MMI-deliveries as milestones in Last Planner™, project progress is expressed more easily by integrating model development in planning.



The use of model maturity in planning received positive sentiments from practitioners when compared to traditional approaches, citing several perceived benefits:

- **Increased understanding of the current state of the BIM**
- **Increased understanding of needs and responsibilities**
- **Increased sharing of incomplete information**
- **Increased ability for project participants to express project development**
- **Less rework and greater ability to meet deadlines**

Factors enabling adoption was found to be the management of maturity for larger sections rather than individual objects, application of visual aids, simplicity and flexibility in tailoring adoption according to project-specific needs and employing open-minded participants. Factors barring adoption were found to be lack of clarity in MMI-level requirements, poor usability in BIM software and cultural inertia in adoption.

VI. Conclusions

Findings show that the theoretical case to be made for management of model maturity is evident in practical implementations as well. Success in adoption of new practices can be attributed to approaches emphasizing simplicity and utilizing standardization and continuous improvement, while allowing for project-specific flexibility in tailoring approaches according to their needs. Based on literature and case experiences, the study presents the following recommendations for sound maturity-based construction design management:

Recommendations for management based on theory and case experiences

Aspect	Recommendations
Specification of maturity levels	Maturity-levels are based on the future functional needs, formulated as specific tasks. Tasks are specified for each level, per respective discipline.
Degree of model disaggregation	Segregation of model into sections as large as possible without making the amount of information for each discipline within each section incomprehensible for designers.
Communication of model maturity	Visualization of maturity per discipline, per section in a chart, possibly excel.
Planning and control of workflow	Last Planner™ and ICE. Milestones for maturity-levels are attributed to post-it notes used as deliveries in collaborative planning.
Responsibility for assigning maturity	Designers should feel ownership to the maturity of their tasks, although an independent evaluation of maturity may prove necessary until level-requirements has been sufficiently standardized to avoid misunderstandings.

It should be noted that the positive yields represented in this study have not come from any radical change in practice, but rather a simple approach of associating existing work and tools to project development. In conclusion, one could make the case that previous failed implementations of LOD have been a result of pushing needless functionality on project workflows instead of pulling tools based on their needs.

Tolerance Compliance Measurement Using Terrestrial Laser Scanner

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Lauri Koskela, Professor, University of Huddersfield, UK

Patricia Tzortzopoulos, Professor, University of Huddersfield, UK

I. Background

Fixing defects associated with tolerances, called tolerance problems hereafter, is time consuming, costly and onerous. Tolerance problems can be mitigated by changing the inspection techniques and gaining better control of the magnitude of dimensional and geometric variations. Conventional inspection methods often cannot identify tolerance problems early and comprehensively. Communication of surveying results obtained from conventional methods is another problem area.

The terrestrial laser scanner (TLS) has been proven to be useful for deviation analyses. Various methods for: (a) data acquisition (b) registration, (c) deviation analyses, and (d) visualisation/demonstration of deviation have been proposed. However, there is not any holistic process consolidating these four independent fields of research for measuring geometric variations while they are interdependent. Moreover, most of the existing research works in this realm of research are about the assessment of surface flatness, whereas the capability of existing commercially available software for deviation analyses can also be used to assess not only flatness other types of geometric variations. Here the question arises: What method of deviation analysis is most suitable for each type of tolerances?

This research employs one of the foundational elements of lean which is process standardisation. It is a first attempt to propose a standardised process termed Tolerance Compliance Measurement (TCM) using TLS that consolidates the main four fields of research, and explores appropriateness of common methods of deviation analyses available for each type of tolerances.

II. Research Method

- The paper consists of a review of the literature and collection of empirical data.
- The practice of a firm delivering 3D laser scanning services and the practice of a software vendor company have been observed.
- The empirical data was collected by scanning a building and a warehouse. All scans were acquired by FARO Focus 3D X130. The 3D data sets were registered using the FARO SCENE software. The deviation analyses were performed in: (a) the FARO SCENE software with deploying a plug-in application provided by a third party, and (b) CloudCompare, an open source software. A total station was used to obtain the coordinate system for the reference targets.

III. Research Findings

- A standard approach for TCM using TLS is proposed. The approach has four standard steps to be followed (Figure 1).
- First step (acquisition of 3D data sets using TLS) – This step comprises four practical recommendations to acquire point cloud data sets using TLS with the highest accuracy. The recommendations include preparation of scan map, placement of scanner and targets, and configuration of scanner settings.
- Second Step (Registration) – A minimum viable workflow for registration of 3D data sets is proposed (Figure 2) for both Target-based Registration and Target-less

Registration. Following this workflow, the alignment deviation between targets should be less than 3 mm.

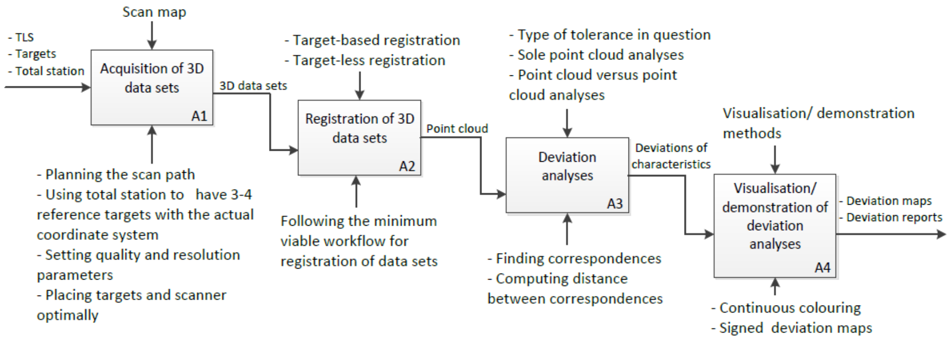

Figure 1: The proposed tolerance compliance measurement using terrestrial laser scanner.

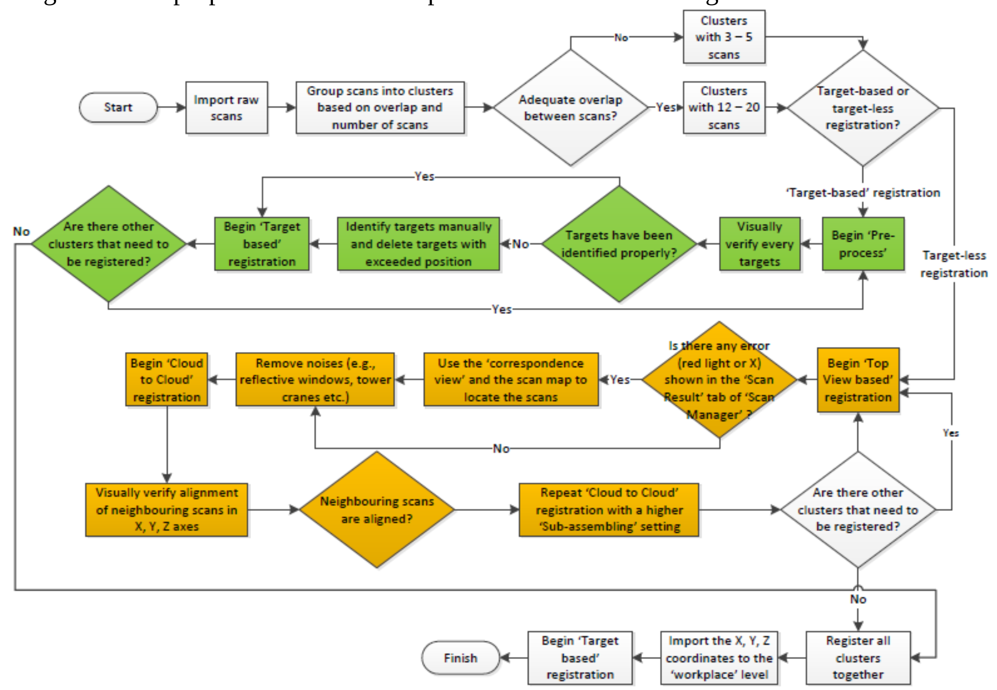

Figure 2: The proposed minimum viable workflow for data registration when using FARO SCENE software.

- Third Step (deviation analysis) – Deviation analyses based on the data acquired from TLS are divided into two categories, namely: (a) sole point cloud analyses, and (b) point cloud versus point cloud analyses. These analyses have distinct algorithms to compute deviations, they employ a different number of data sets, and each analysis should be used to quantify a specific type of variation (i.e., straightness, flatness, perpendicularity, parallelism, position).
- Fourth Step (visualization of results of the deviation analyses) – The deviations are visualized through deviation maps or are demonstrated numerically to reveal deviation patterns.

IV. Conclusions

- This paper aims to document a formal and holistic method termed TCM using TLS according to the literature, the best practice observed, and the field researcher's experience.
- This method has four steps: acquisition of 3D data sets, registration of data sets, deviation analyses, and visualisation/demonstration of deviation analyses.
- Different geometric deviations were correlated with different algorithms of deviation analyses. The results show that the algorithms for deviation analyses do not automatically measure all types of tolerances.

Language, Moods, and Improving Project Performance

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I. Background

Compared to other industries, the construction sector has lagged in improving productivity. Effective performance, of which productivity is an indicator, is facilitated by conversation that clearly identifies necessary steps to achieve common goals. The type of language used in productive conversation can be referred to as the language of action; similarly, the term "linguistic action" denotes a domain of effective speech to facilitate action. However, even when linguistic action is employed, teams may struggle to communicate effectively when the speech or moods of individuals, or the environments in which they are operating, are not conducive to either productive action or dialogue. This paper proposes direct relationships between linguistic action, positive moods and team performance.

II. Current conditions

Flores, F. (2012) writes about using "action language" to install a culture of commitment in working relationships. Expanding on the linguistic action work of Austin, J. (1975) and Searle J. (1969). Flores (2012) defines six basic speech acts:

Act	What it Does	Elements
Declare	Open a new world for action	Infers authority
Assess	Open new possibility or prepare for action	Futuristic, grounded, or ungrounded
Request	The speaker is asking a potential performer for action around a concern	Conditions of satisfaction, background of obviousness, time
Offer	Performer promises to care about something he/she perceives the listener to be concerned about	Same as request
Promise	Commit self/enterprise/team to bring a new Condition of Satisfaction	Same as request
Assert	Speaker reports facts and is prepared to offer evidence	Report of fact

Projects are organizations. They are groups of people assembled to take action towards accomplishing a common goal. Skilful conversation and language informed by Flores' speech acts strengthens communication and thereby facilitates action.

Flores, G. (2016) makes the distinction between moods that are either unproductive or conducive to learning. In addition, moods affect the possibilities that people see for their future. She observes that moods are contagious and invisible and that moods can be cultivated. She also states that moods are not emotions, moods are in the background and are not about a particular event. Humans are historical beings whose possibilities are shaped by historical occurrences. She states that moods are triggered by assessments that are usually automatic. Examples of negative and positive moods, and assessments that trigger them in construction projects are:

Negative	Positive
• **Resignation:** There is nothing I can do to make this project better; even if I work hard, these subcontractors will not do their part. • **Arrogance:** I have experience in this type of project, and I know what I have to do. I do not want to waste my time planning.	• **Wonder**: I do not understand the whole design but I wonder if there is a better way to create the value for the client. • **Serenity/Acceptance**: The future is uncertain, there will be surprises, but our team will be able to get through it.

- **Confusion:** I don't understand what is going on. No one is letting me know what I should do. I am just going to keep myself busy.
- **Frustration:** I have tried to change this project to be a more effective and productive team, but everyone goes back to work in the same old way.
- **Impatience:** There is no value in planning. This is a waste of everyone's time. We should be working on site!
- **Distrust:** I do not trust these subs. These guys are just unreliable. I cannot ask for their help. We will need to add more contingency to this job.
- **Overwhelmed:** There is so much to design in this project and people are not even talking to each other! We will make mistakes for sure.
- **Powerless:** I don't like how things are, but there is nothing I can do to change the system.
- **Ambition**: I see opportunities to improve and I am willing to convince others to try them. I am committed to taking action and lead the way.
- **Resolution**: I see opportunities to implement lean in this project and I will take action right now.
- **Confidence**: We have been successful in complex projects in the past and I know we will be able to do it again.
- **Trust**: I am confident that the team will deliver what we need to succeed in this project.

The speech acts and the role of moods are in play in conversations whether or not the team acknowledges their presence. For example, a simple commitment such as a promise to finish the foundation concrete requires the use of the speech act "promise." Similarly, other conversations, such as requesting work from another subcontractor or requesting concrete from the concrete provider, require the use of the "request" speech act.

III. Research Questions and Method

The research questions are: 1) What research has connected Linguistic Action and Lean to increased project performance? 2) What are potential new opportunities for connecting Linguistic Action and mood to performance on projects?

This paper shows the results of a review of previous research studies exploring "linguistic action" in the lean construction literature; past IGLC papers were given particular attention in the analysis.

V. Research Findings

From the summary of previous studies, the lean construction community has discussed connecting the linguistic action perspective to lean methods and project performance. However, less has been said about the connection between mood, learning behavior and improved project performance. While the connection between improved project performance and communication makes intuitive sense, design and construction teams do not explicitly talk about how language is used on projects or how the project team's mood affects their work. There are numerous examples of conversations that are detrimental to the progress of the project, and regular project participants can easily identify with them, but standard methods of recognizing and changing language habits on projects have not been developed or even seriously considered.

VI. Conclusions

Changing the norms of communication, the use of language and the recognition of moods on projects could revitalize the construction industry by increasing more than just productivity but also overall project performance and drastically improving the workplace culture. How project managers and team members use or don't use language in the working environment directly impacts their ability to establish an environment of positive moods conducive to increased performance. The efficiency and follow-through of project tasks, and good intentions on the part of communicators alone is not enough to prevent misunderstandings - particularly when teams lack the sensibilities to differentiate between speech acts and a systematic method for approaching conversations. Based on a review of relevant texts that emphasize the connections between productivity, language, and mood, evidence indicates that shifting to a positive mood is synonymous with a shifting to a mood of high productivity and high performance. More experimentation and research should be done to explore how these observations can improve systems and methods in the construction industry and how to effectively shift teams toward high performance by steering them into positive moods.

Guidelines for Public Project Design

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I. Background

Research on public works projects reports that project failures and changes in projects during the project are pointed out as the main causes that impact on cost increases of works. As it is observed in the literature, the architectural and engineering (AE) projects are pointed like preponderant items for assertiveness in the anticipated costs in budgets of real estate ventures. This context is the main justification for the present study.

The proposal for the development of the study is characterized by the investigation process of the context of project development in public enterprises, through case studies, using theoretical process Target Value Design (TVD). The present work aims to propose guidelines to the project development and budgets (PDB) process of public enterprises based on the TVD process and the identification of practices used in the investigated institutions.

II. Current conditions

The TVD is based on lean thinking and uses 17 theoretical elements that relate stages of the development process of AE projects with the objective of guarantee the value established by the client. The process considers the participation of the customer (owner or responsible) and the suppliers in the stages of development of real estate products, besides emphasizing the importance of budget cycles to guarantee the established cost (Ballard 2011).

TVD aims to have a construction done within a desired budget, according to a detailed estimate. For this, value, cost, schedule and constructability are established as basic components of the project criteria (Forbes; Ahmed 2011).

The Last Planner System (LPS) and Building Information Modeling (BIM) are considered catalysts for the TVD process and are not mandatory. However, it is emphasized that, in order to achieve higher levels of collaboration, these catalysts become mandatory (Oliva; Granja 2015).

Target Cost (TC) has a strong relationship with TVD, considering that the two methods aim to reduce costs, ensuring quality, reliability among other attributes, thus generating value for customers (Miron; Kaushik; Koskela 2015).

III. Research Method

This work was carried out in four public institutions in Brazil, through qualitative research. The study approach was subdivided into three stages: process investigation based on the TVD; elaboration of guidelines for the process; and evaluation of these guidelines. As a result, the paper presents 13 guidelines distributed in three axes: project budgeting process; planning and process control; and BIM process.

IV. Research Findings

	Guidelines - Project and Budget Process
1	Implement a process of integrated development of projects and budgets, also considering the Definition of Financial Resource (DFR) phase, among the participating members, these being: clients; managers; architects; design engineers; budgeting; and working inspector (WI). This action must be preceded by selection of participants and duly registered. It is important that the technical team share the same physical space in their work routine.
2	Standardize and systematize the DFR and PDB processes, as well as the documentation pertinent to these processes.
3	Conduct presentation to participating members about the needs of customers as well as the benefits planned for the venture. This action should also include guidance on possible cost constraints and deadlines of the enterprise.
4	Define the costs for execution and operation of the project still in the DFR phase.
5	Use creative costing-goal process tools to optimize and reduce costs.
6	Develop budget and work schedule in advance, starting at the DFR stage and subsequently developed during the project and budget process.
7	Establish cost goals and schedules for each project discipline. This action must be carried out through updates of estimates by area throughout the project and budget process, and it is necessary to evaluate the predetermined targets.

	Guidelines – Planning and Process Control
8	Implement planning and control system in the projects and budgets development process considering: long-term planning; medium-term planning; and short-term planning.
9	Program the short-term planning in an integrated way, considering the participation of the management and operational teams, so that the planned activities are controlled, as well as exist the feedback of the long and medium planning, aiming the learning and evolution of the system.

	Guidelines – BIM use
10	Select a key team of servers, architects and engineers, for training and qualification in BIM, aiming the development of pilot model. The main purpose of said model is to provide data for structuring process standardization in BIM.
11	Prepare standard specifications to meet the technical information needs of BIM. This booklet should consider the complete chain of information on the components, elements and building systems commonly used by the institution.
12	Establish work cost parameterization based on BIM models from the LOD 100 and LOD 200 classification, considering that these classifications are pertinent to the financial resource definition phase, being characterized as conceptual studies or preliminary studies.
13	Adapt the function of employees, architects and engineers to the new working paradigm established by BIM, considering that the models provide the quantitative from the parameterized geometric basis. This adaptation is directly correlated with the budgeter, which should contribute to the process assuming a new role. In the latter case, the learning process is the function adjustments basis.

V. Conclusions

- This study aims to propose guidelines to the participants in the project development of public enterprises, considering that the said process shows weakness in the preliminary definition of costs, which begins to reflect in the whole subsequent process.
- The research contributes to the discussion about aspects that directly affect the quality of projects developed in public institutions in Brazil.
- Public institutions commonly estimate the cost of new projects by considering the cost history of similar existing buildings, or use information based on the Basic Unit Cost (BUC), a cost indicator for the construction industry in Brazil.
- Therefore, this integration proposal is not only a theoretical discussion, as observed in the results of the research, but also reflects a need pointed out by the servers investigated.

A relook at plan reliability measurements in lean construction and new metrics from digitized practical implementation

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I. Introduction

Lean construction is increasingly being adopted in many countries as a means to improve construction project performance and productivity. Measuring the various improvements towards achieving the outcomes of reliability, preparedness, commitment and collaborative culture is crucial for a sustained successful practical implementation of Lean. Among various Lean techniques and tools, the Last Planner System (LPS) method has been widely used in construction projects for its simplicity and applicability to the construction environment. With LPS, the plan reliability is measured by Percent Plan Complete (PPC). The PPC as a single metric has been found to be insufficient in providing actionable information in understanding the root cause of challenges faced in different projects nor in improving the reliability nor in getting valid commitment of key project parties. It is also ineffective to symbolize as the metric to represent the preparedness, capacity or performance of the different sub-contractors. This paper introduces a framework for practical implementation of Lean construction. It also proposes new metrics to supplement PPC to accurately represent plan reliability for better understanding of the root causes. The proposed indices are validated using data obtained from the digital application of Lean construction processes using Lean PlanDo. Lean PlanDo is digital tool embedded with Lean principles for construction planning and management based on LPS with a key emphasis on Value Stream Mapping (VSM) and constraint management. The proposed indices will provide the project teams with practical measurements and to build upon their understanding of Lean, measure the effectiveness of planning and the application of Lean methods in the project.

II. Lean construction planning & management framework (Lean PlanDo)

The kernel value of LPD centres at its ability to marry strategic long-term planning (CPM) with Lean construction techniques (LPS and Value Stream Mapping) and constraint-based planning. LPD allows for collective planning, inclusive team involvement and real-time collaboration, keeping the master plan live and fit to the site conditions.

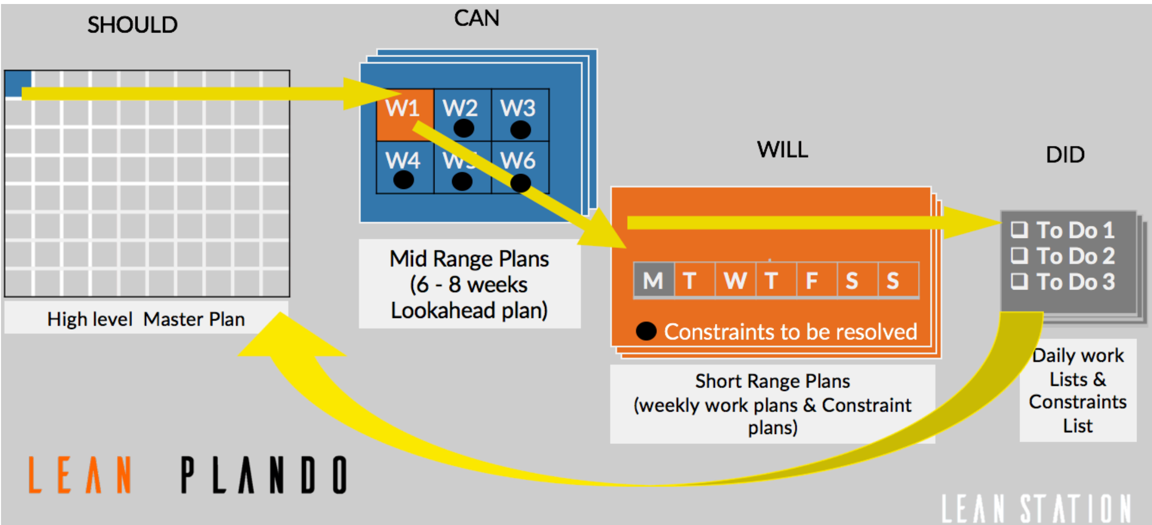

Figure 1: Lean construction project planning and management framework (LPD)

III. Plan reliability indices

A set of four reliability indices are introduced to provide more insight to the plan reliability at different planning levels.

(1) **Constraint resolution level (CAN vs SHOULD)**: The percent of task that can be done (constraint-free) in compared with tasks that should be done to achieve the milestones required by the master plan. The difference between CAN and SHOULD demonstrate the ability of identifying and resolving the recognized constraints.

(2) **Site readiness level (WILL vs CAN)**: The percent of tasks that the team will take up against the total number of tasks that can be done. This metric represents the readiness level of the project team including site condition and site team.

(3) **Commitment level or PPC (DID vs WILL)**: The percent of tasks that are done against the committed tasks. The difference between DID and WILL can express the lack of capacity from the execution team or unanticipated constraints that hinder the site works.

(4) **Construct Plan Reliability (CBR) (DID vs SHOULD)**: The overall reliability level of the dynamic plan strategy is presented as the percent of tasks that are done and tasks that should be done. The difference between DID and SHOULD presents the gap between what is achieved and what is planned, and thus the reliability of the plan. This gap can be linked to all the delay reasons that affected in the past weeks for better understanding of the root causes of plan variations, from which improvements can be implemented in the future planning cycles.

IV. Case project

Lean PlanDo is commercially implemented in various projects in Singapore. Weekly data from one of the projects are presented in this section to validate the proposed indices. The results show that although the PPC achievement is at the high range (median PPC = 86.2%), the project CBR is achieved at a median range of 63.5%. This low plan reliability can explain the delays of the project.

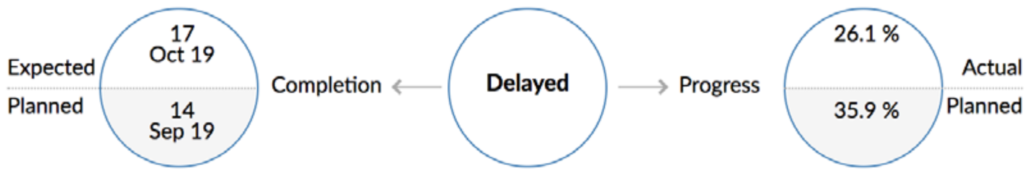

Figure 2. Overall status of the project

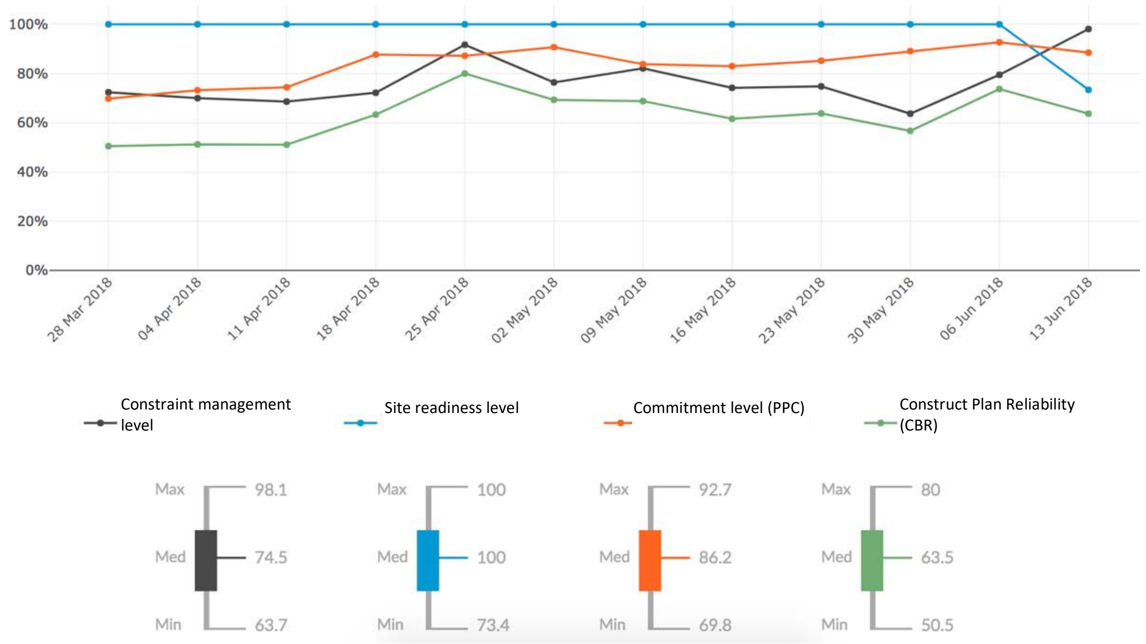

Figure 3. Plan reliability indices

Leveraging Advanced VDC Methods and Reality Capture to Increase the Predictability for Prefabrication

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I. Introduction

Construction processes happen in partially controlled environment; resulting in prefabricated components being vulnerable to variances resulting from deviation in quality of work put in place. However, wider and deeper implementation of VDC methods allows to leverage the technology to prefabricate different building elements. This work attempts to showcase an approach for enhancing predictability for variances and accommodate for tolerances present on site.

II. Current conditions

At present there is limited active construction quality predictability approaches being leveraged for prefabrication. The quality of work put in place on the site is subject to a larger tolerance than most activities that are machine controlled. Current surveying and quality checks are not effective. They only provide data that is interpreted manually and is not integrated electronically into project design model and prefabrication spooling information set. However, in digital fabrication, robotic welders use laser for accurate placement– straight from MWF model. Robot welds at +/- 1/8” tolerance for placements taking accurate data from model.

III. Approach

The study identifies the problems which lead to waste during construction relating to the prefabricated elements –

> -waiting: for preparation of element which doesn’t have enough clearance, or needs to be provided opening/beam pocket etc. in the prefabricated panel or for chipping of nearby structural element
>
> -defect: in vicinity of location of installation of prefabricated element

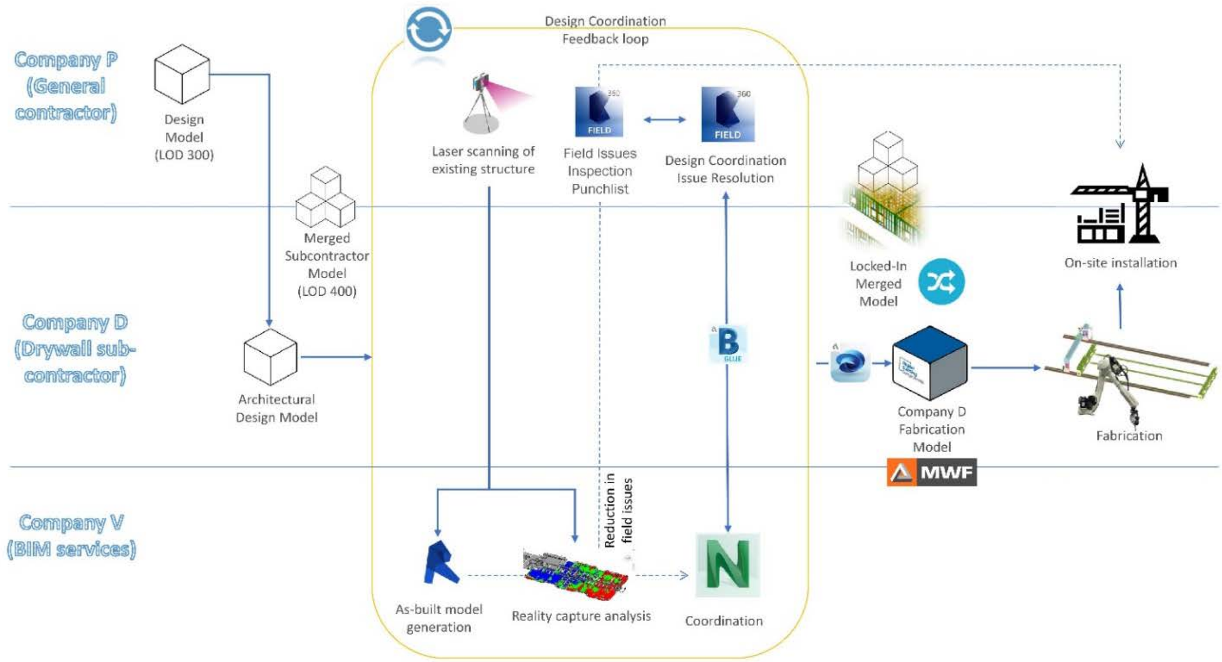
The paper demonstrates solutions using case studies to implement lean philosophy with the help of advanced VDC methods and Reality capture. The paper outlines the implementation of different approaches at different stages of the project.

The context of this study is defined by two case projects based in the U.S.A., carried out by company P, a general contractor. Company V, based in India, works extensively with Company P for implementation of VDC efforts. Project G is a tenant improvement effort for a commercial development in high-tech business park located in San Francisco, USA. Project M is tenant improvement effort for a pharmaceutical research laboratory building in San Francisco, USA. Company D is the drywall contractor for both projects.

Personal interviews were conducted with personnel from project team representing company P & company D. The interviews and questionnaire administered helped to validate the approach conceptualized through the course of the projects demonstrated here via case studies.

IV. Challenges addressed

Company D manufactures wall panels, complete with framing for MEP openings, using computer numerical control (CNC) machine based on 3D models developed by company V. 3D model allows to check for constructability & model integrity. In addition to the elements required for coordination, the model also incorporates location of punches and welds to inform the CNC machine. The use of reality capture feedback addresses field deviations efficiently.



V. Current Limitations

Though Laser Scanning provides the most accurate way to capture field conditions, it is a time and money consuming effort and requires careful planning. Secondly, it is essential that the level of detailing required of non-fabricated systems incorporates the needs of a prefabricated system. Such factors should be identified early on and incorporated in BIM Implementation Plan and in buy-out.

VI. Conclusions

- Use of VDC methods increases predictability and provides feedback loop. Coordination of different trades allows for greater predictability. Creating an accurate as-built model using laser scans enables a feedback loop for digital fabrication of building components.
- Modelling using BIM facilitates digital fabrication. Using this approach company D observed ~25% productivity gains due to quicker installation and lesser labor involvement on-site.
- The use of heat & contour maps from laser scans of floors allowed for adjusting the prefabricated panels in the factory, with minimal impact to installation on site.
- Higher operating cost and processing time of point cloud data are the top challenges in wider implementation of feedback loop using reality capture.
- Prefabrication alters the sequence and priority of systems. Preconstruction processes and buyout must be adapted to maximize the adoption and success of prefabricated building components.

An Exploration of BIM and Lean Interaction in Optimizing Demolition Projects

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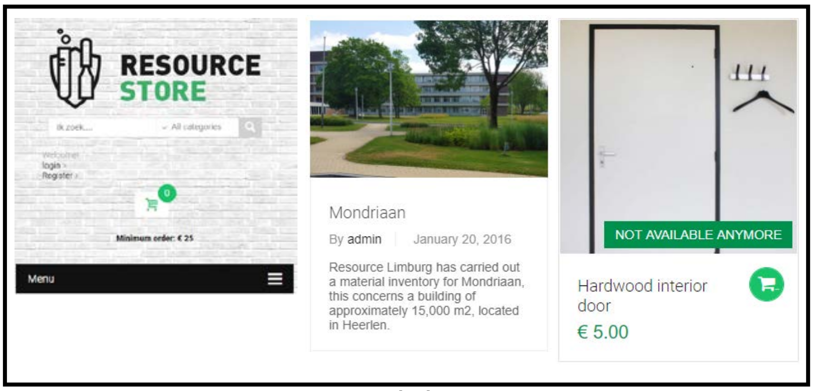
I. Background

Construction industry is the major contributor to the overall waste streams generated worldwide. For instance, 25 to 30 % of all the wastes generated in EU is owed to construction and demolition wastes (C&D). The current practice of buildings demolition undergoes a linear economic approach. Large portions of wastes are generated and less amounts of salvaged materials are being recovered and pumped back into the supply chain.

II. Current conditions

Current demolition projects were studied including case studies from the Netherlands involving new approaches in optimizing the deconstruction process. Some Projects were showcased on a Web-Shop to allow interested clients in buying these elements sufficient time before demolition activities take place.

On-site Storage



Web Shop

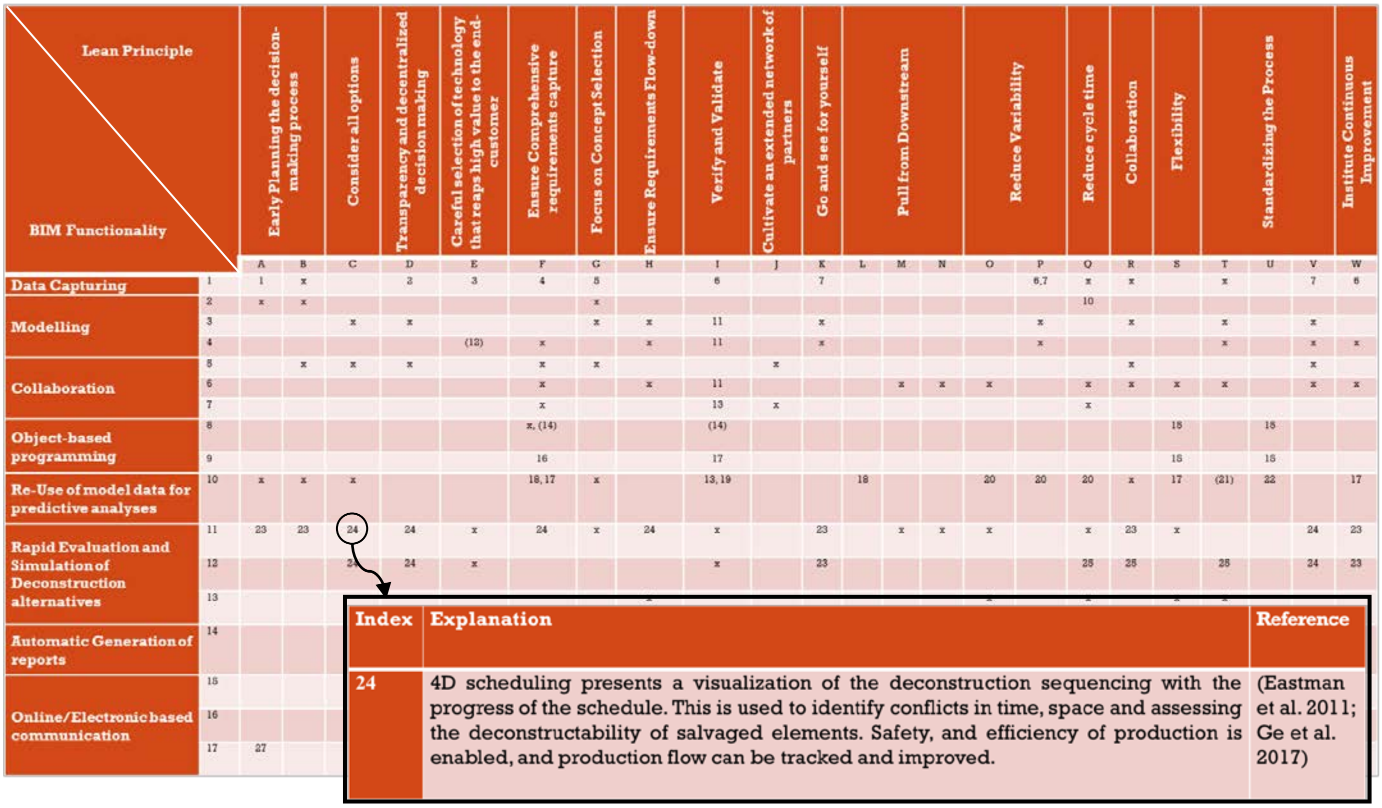
Source: www.materialenmarktplaats.nl, (images on the left courtesy of Resource Limburg).

III. Goals/ Targets

- *Determine an initial indicator that reflects the degree of synergy between BIM Functionalities and Lean Principles in Deconstruction Projects*
- *Explain the applicability of these interactions to leverage the deconstruction process.*
- *Explore the potential of this synergy in the formulation of a full deconstruction planning framework*

IV. Research Method

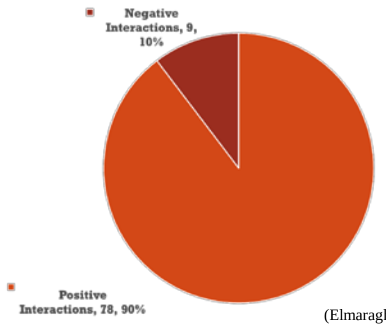
Provided earlier by (Sacks et al, 2010), the Lean-BIM interaction matrix is extended to explore deconstruction planning. Several BIM functionalities are introduced to detect their compliance and possibility of use in deconstruction processes. Explanation for each interaction is then provided.



(Elmaraghy et al, 2018)

V. Research Findings

Almost 90% of the total number of interactions were positive. This indicates a high degree of compliance of BIM interactions with Lean Principles in deconstruction context.



(Elmaraghy et al, 2018)

VI. Conclusions

This paper extended the BIM-Lean interaction matrix to cover the deconstruction and demolition processes. The synopsis of interactions was supported by evidence from literature and practice. The interpretation of the matrix interactions could be directed towards the adoption of a BIM-Lean approach in future deconstruction projects. For example, the exploitation of BIM related technologies can be used to apply the lean principles in the context of showcasing the salvaged elements on a Web-Shop. This platform can be linked to the BIM model for updating the deconstruction scheduling. Finally, this exploratory research can yield, in the future work, a generic framework for the planning of deconstruction projects both on the strategic and operational level

ENVISION OF AN INTEGRATED INFORMATION SYSTEM FOR PROJECT-DRIVEN PRODUCTION IN CONSTRUCTION

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I. Introduction

Construction frequently appears at the bottom of productivity charts with decreasing indexes of productivity over the years. Lack of innovation and delayed adoption, informal processes or insufficient rigor and consistency in process execution, insufficient knowledge transfer from project to project, weak project monitoring, little cross-functional cooperation, little collaboration with suppliers, conservative company culture, and a shortage of young talent and people development are usual issues. Whereas work has been carried out on information technology and automation in construction their application is isolated without an interconnected information flow.

III. Working hypotheses

This paper suggests a framework to address production issues on construction by implementing an integrated automatic supervisory control and data acquisition for management and operations. The system is divided into planning, monitoring, controlling, and executing groups clustering technologies to track both the project product and production. This research stands on the four pillars of manufacturing knowledge and lean production. The framework offers benefits such as increased information flow, detection and prevention of overburdening equipment or labor (Muri - 無理) and production unevenness (Mura - 斑), reduction of waste (Muda - 無駄), evidential and continuous process standardization and improvement, reuse and abstraction of project information across endeavors.

II. Current conditions

In manufacturing, the production moves from machine to machine, worker to worker, or a combination of both. The route of production is fixed. Thus, the positions of sensors and actuators are fixed and planned according to the production routes and its flow. Once set, the positions only need to be modified if the production routes change. In construction production routes are flexible. Some production routes will only exist long after the beginning of the project by the time that others would be extinct. Construction must then rely on general purpose sensors that, as the equipment, can be used in different applications through the project life-cycle, often, requiring those also to be mobile. Hence, traditional instrumentation used in manufacturing SCADA systems do not work in construction, as the instrumentation must be mobile.

III. Framework

The suggestion stands on two tenets: observer effect and *Genchi Genbutsu*. In physics, the term observer effect defines the influence of the observation act to the event. It means that by observing an event, the observer may alter the event, and consequently modify the observation. This effect is also known in the human sciences, where subjects have their behavior affected by being observed. In this sense, the awareness of being observed may modify the production system and its model. Thus, production is constantly observed, and the information is used to modify production. *Genchi Genbutsu* means 'go to the source and get the facts to make the right decision.' In this approach, instead of asking for information updates the progress status is obtained in real time from positioned sensors or upon inspection from the drones. Next, the machine learning engine will merge the information (LiDAR, images, sensors) with BIM to identify the product progress and deviations from the specifications (similarly as in the SCADA). In parallel, the production information (progress and workers information) is checked against the production theory and models to evaluate productivity, forecast conclusion dates and assess corrective actions. These two combined and jointly with the project plan are then presented to the 'control room.' Therefore, the 'control room' can rely on accurate information in the decision-making process, which results in a data-driven continuous improvement loop (Figure 1).

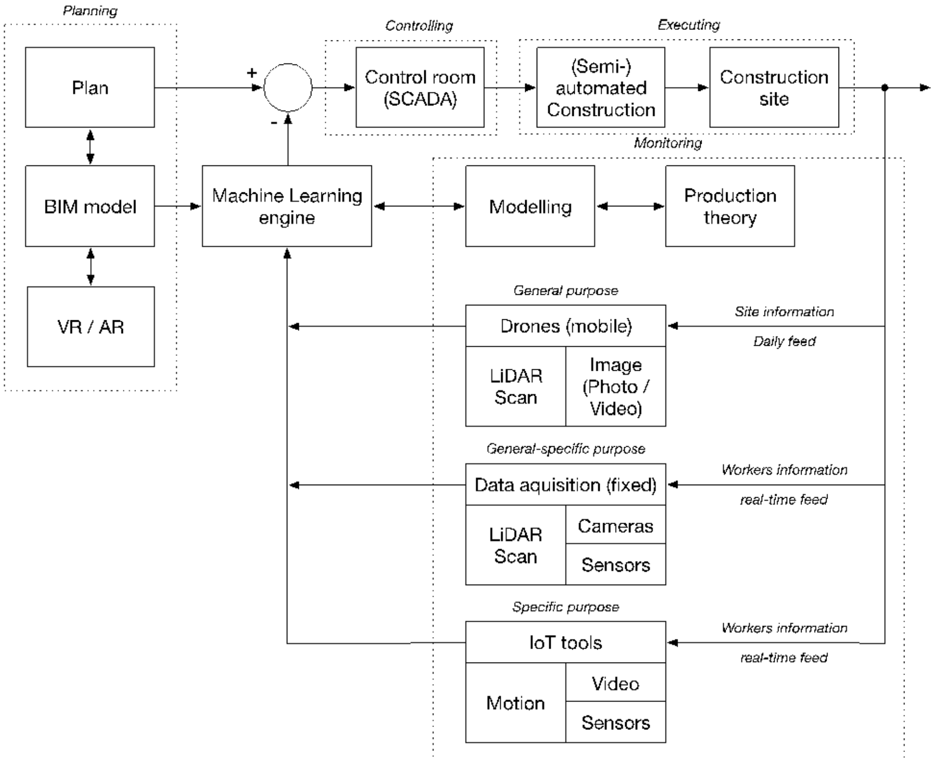

Figure 1 Theoretical framework for an information integration system for construction

VI. Conclusions

- Cross-functional cooperation in construction is low mostly because the parts have no information about what is happening outside their area. The same can be said about suppliers. The establishment of the 'control room' centralizes information from the plan, labor, process, and production. Moreover, once the control-room has information about the progress of the current and next activities on-site, it will be able to coordinate cross-functional activities and supply chain.
- Building information security and maintenance may use the product legacy information gathered in construction eliminating redundant work by analyzing the building. This work has already been done during construction (reducing over-processing). There is a compiled log of who did what, when and how for every part of the building including divergences between the original design and every change and defect occurred during construction. There can be extensive details of how the process has been done (and evolved). The production knowledge has further benefits. Especially, due to the network effect. The network effect adds value to this framework with use and adoption. This means that data can be generalized to a broader audience with more information such as season of the year, weather condition, geo-localization, altitude, winds, local culture, diversity, or any other feature. Hence, future endeavors will establish the production base-line using historical evidence rather than the usual labor/time relationship.
- Using the chrono-analysis continuous assessment jointly with the data (production progress and workers effort) from previous projects informal processes tends to be eliminated. Better processes are developed and standardized. More accurate historical information is persistent and can be generalized to different projects enabling comparison and continuous improvement methodologies from project to project. New builders will be trained in the benchmark process instead of the "I have been done this for the last x years" (and repeating the same mistakes over and over) approach.

Ad Hoc Data Analytics and Business Intelligence Service Framework for Construction Projects

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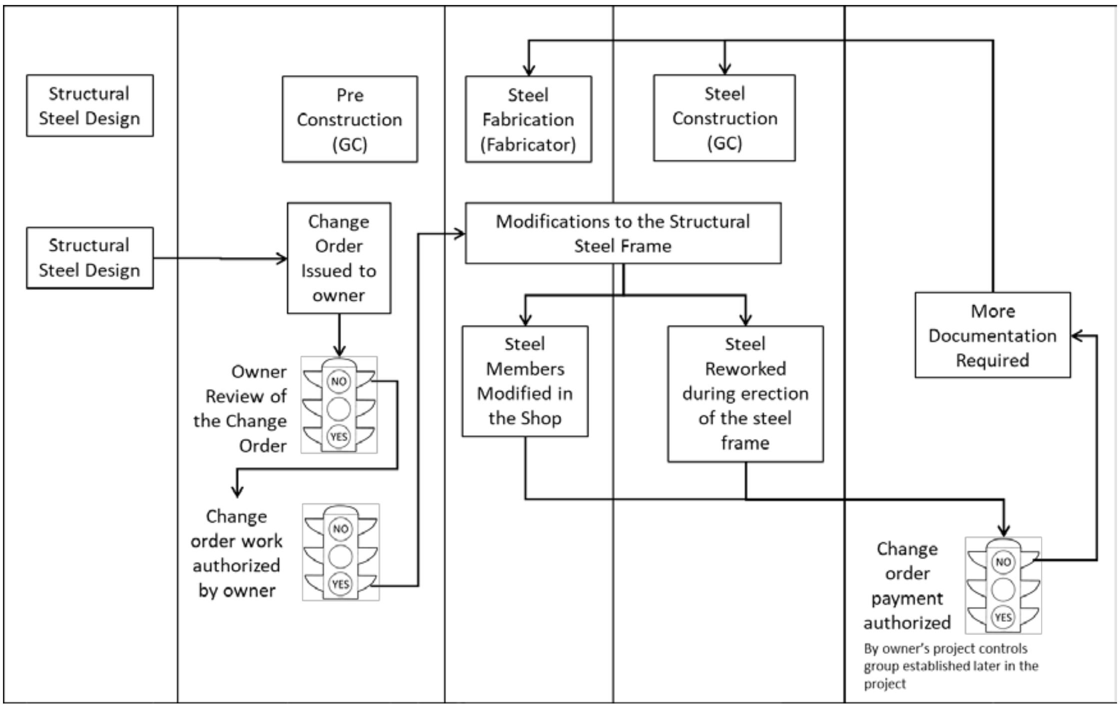
Leonardo Rischmoller, Business Analyst, DPR Construction,
Dean Reed, Lean/Integration Advocate, DPR Construction,
Atul Khanzode, Technology and Innovation Leader, DPR Construction.

Background

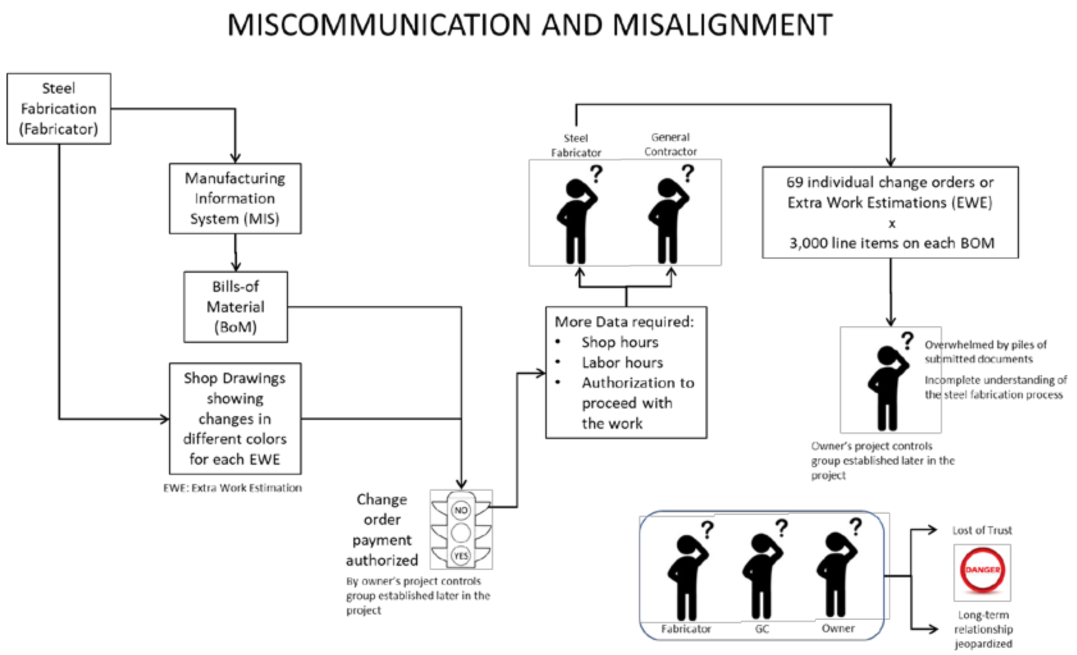
The lack of customer requirements captured by the design team or available during the design, suitable capability of the production system, and construction requirements satisfaction; as well as the loss of value expressed as ignorance of client requirements, bureaucracy and paper work, information not available, poor interdisciplinary coordination and rework are Lean Construction related problems identified in the case study presented in this paper.

The owner team of a new life sciences laboratory building wanted a thorough review of the change order for significant modifications to the structural steel frame they had requested. Originally, the work was authorized without review in the interests of time so that steel members could be modified in the shop during scheduled fabrication. While a majority of the modifications were made in time, other steel had to be reworked during erection of the steel frame.



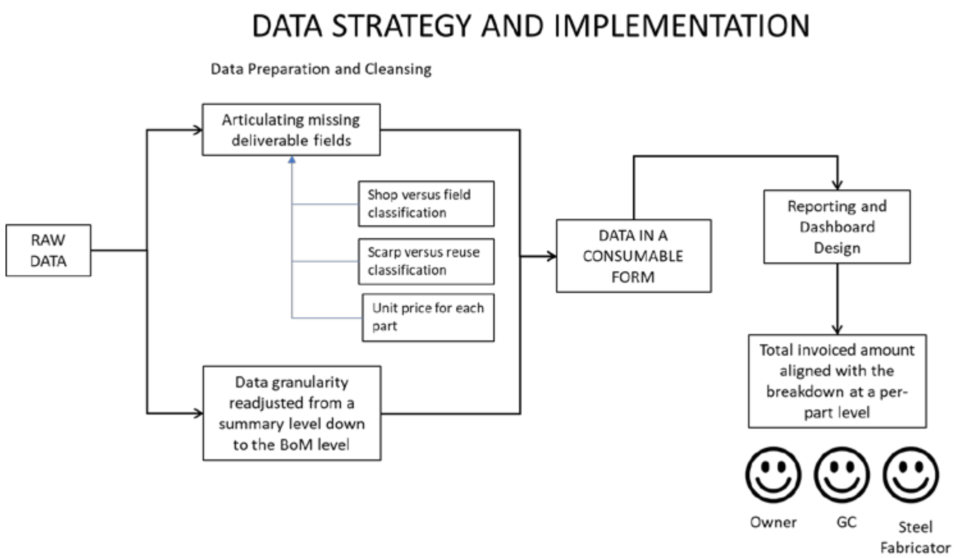
Current Conditions

Miscommunication, misalignment, and lose of trust among the owner, general contractor and steel subcontractor, increasing waste and reducing value in the project.



Proposed countermeasures

An analytic data model was created and implemented to transform raw data into consumable forms for connected reporting systems.



The owner's project controls team was able to verify that the fabricator and GC had properly accounted for all the modified steel and priced the changes fairly, including credits for scrapped steel.

Follow up

An ad-hoc solution tailored for unforeseen and unexpected, one-time, data analytic challenge that frequently occurs during construction was developed. The solution combines data science advances with value adding and waste reduction Lean principles. Future work based on this study includes continuously enhancing the framework into a formal curriculum along with proper tooling, and training for greater dissemination.

Using Technology to achieve Lean Principles

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I. Background

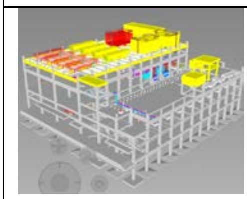
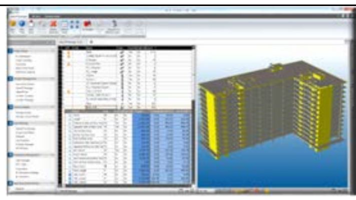
The construction industry is facing increased challenges and becoming more and more complex due to number of factors. Whether it is constructing a Building, Infrastructure or Industrial plant, the challenges remain there in every type of the project. This results in delays, waste, overruns and claims. So we need to develop new ways of doing things to manage the construction process. Adopting lean manufacturing principles in construction industry is an effective approach to bring improvements in design, procurement and construction to reap benefits and add value to the project.

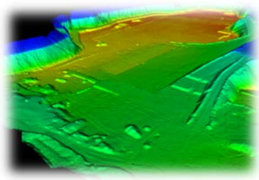
II. Introduction

Our organization is involved in constructing mega projects from concept to commissioning. In order to overcome the production and profitability challenges, the organization is continuously improving its design, procurement and construction processes and adopting the various technologies that support to achieve Lean Principles.

III. Technology Implemented

Some of the technologies available today to achieve Lean Principles include:

3D Models	CDE	4D Planning	5D BIM
			

AR/VR/MR	Prefabrication	Mobile Devices	Laser Scanning	IOT
				

- 3D models and visualization techniques to improve planning and communication,
- 4D planning to improve workflow, look-ahead scheduling, identifying the processes that deliver customer value, Just-in-time (JIT) deliveries and 5D BIM for value management techniques.
- Improve accuracy and efficiency through Prefabrication, Mobile Devices, AR/VR/MR, Lidar, Laser Scanning, RFID and Equipment gateways.

IV. What was done

- A Project BIM strategy was developed to support design and construction and encourage collaboration and communication.
- Developed interactive 3D models for all disciplines. The 3D models were delivered to act as a 'single source of truth' and facilitated the use of 4D planning and 5D estimation and costing.
- High levels of collaboration and integration ensured amongst all project partners through BIM models. HoloLens was used to improve visualization, collaboration and better communication. Mobile devices and Cloud collaboration were implemented.
- Precast system was used against conventional construction system.
- Weekly meeting through 3D model for coordination and constructability reviews.
- Planning and progress monitoring done through 4D BIM.

V. Benefits Achieved

- Facilitated clear communication within project teams by sharing 3D models to Construction team, enabling them to visualize the design intent clearly before executing the work. This encouraged better collaboration between the design and construction teams and reduced the number of RFIs.
- Reduced the amount of time for approving and implementing changes to the design resulting in cost and safety benefits.
- Use of 3D models on mobile devices improved visualization for site personnel and they were able to propose easy/ alternate methodologies for construction resulting in lesser duration and costs. Better communication and clear understanding of critical interfaces.
- Use of 4D enabled the project to be delivered as per the challenging program by facilitating continuous monitoring and extracted look ahead quantity schedules. Better understanding of associated risks and reduction in planning errors.
- Quantity take-off through BIM enabled the team to reduce the time required to quantify the complete building, when compared to manual take-off. Value engineering improvements were more easily identified and communicated.
- Using Precast Technology, high quality concrete was produced. Reduction in the number of activities resulted in lesser material, labor and costs. High speed and quality was achieved with the deployment of lesser resources.

VI. Conclusions

To sum up, construction needs to be Lean and Digitized. The emerging technologies are enablers and if they are harnessed well one could see the industry delivering consistent high quality products on time within estimates. The industry will continue and adopt various technologies to add value to the customers.

Towards Facility Management Participation in Design: A UCSF Case Study

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I. Background

The discipline of Facility Management (FM) emerged in the 1970s triggered by:

1. increasing complexity in the workplace and
2. understanding of an interdependence between user behaviors and building design.

Breakthroughs in telecommunication technology drastically changed how information was distributed and shared.

The built environment became more dynamic.

Customers became more vocal, and what they valued became more varied.

FM was created to operate and "steer" the building upon delivery by the Design and Construction (D&C) team, so that the building would continue to deliver customer value for many years.

II. Current Conditions

- Buildings continue to become ever-more complex.
- A number of buildings today still fail to deliver the value they were intended to deliver during the occupation phase.
- FM helps close the feedback loop between building users, owners, and designers, so that buildings more fit-for-purpose can be delivered.

III. Working Hypotheses

Lack of strategic FM involvement in project delivery is one (of several) causes of building failure.

IV. Research Method

- The review of the literature about FM shows that (1) the discipline of FM encompasses many activities and (2) no consensus exists on how to do FM.
- A case study describes how an organization, namely the University of California, San Francisco (UCSF) has—in the course of its Lean journey—learned the importance of

considering FM requirements during design, and more importantly of engaging FMs early in the design process.

V. Research Findings

A critical component of Lean project delivery is the early involvement of key project stakeholders. Yet, UCSF being a large organization, has projects with many stakeholders. The difficulty that arises then is answering the questions: "Whom to involve in project delivery?" and "When to involve them?" UCSF has identified FM as a key project stakeholder.

Figure 1 depicts the evolution of FM integration in project delivery at UCSF.

Below the timeline, the evolution of FM integration is illustrated using five UCSF projects: (1) Genentech Hall, (2) Helen Diller Family Cancer Research Building, (3) Smith Cardiovascular Research Building, (4) Mission Hall, and (5) Block 33.

Above the timeline, for each project, a Lean Project Delivery System (LPDS) schematic indicates, using shaded triangles, when FM got involved in its project delivery. The triangles represent the five phases of the LPDS, from left to right: (1) project definition, (2) lean design, (3) lean supply, (4) lean assembly, and (5) use.

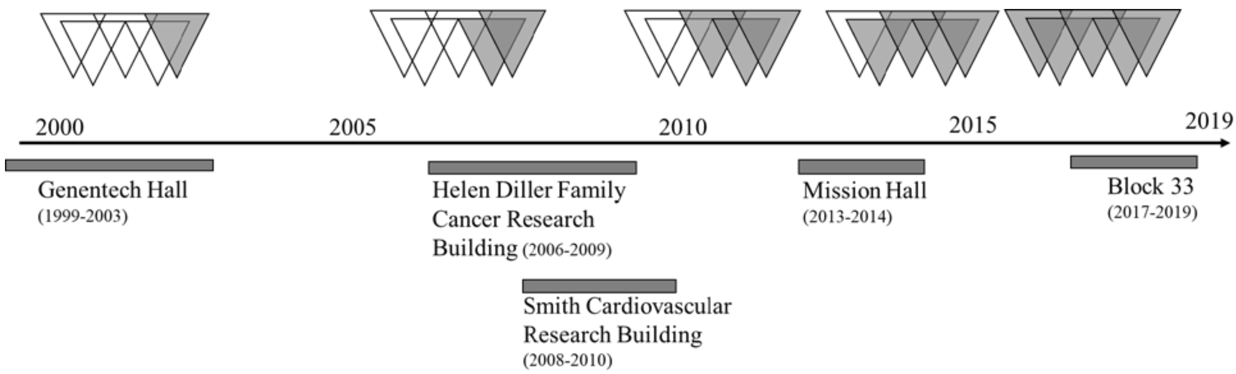

Figure 1: Evolution of FM Integration in Project Delivery at UCSF

From involving FM in the project use phase only (Genentech Hall) to engaging FM in writing a Technical Performance Criteria book in the project definition phase (Block 33), UCSF has been bringing in FM earlier in project delivery.

- UCSF sees value in FMs' active participation in the design of facilities.
- While UCSF has benefited from engaging FM earlier in their projects, their experimentation and learning when and whom to best involve from FM in project delivery is still ongoing.

VI. Conclusions

- While FM may prefer systems that are simple, maintainable, reliable, cost effective, and that they are familiar with, the design of high-end facilities involves one-of-a-kind interdependent systems that require training and expertise to maintain.
- Late FM involvement in the design of high-end facilities makes conflicts likely to arise between FM's requirements and the developed design, causing design iteration (at best) or FM's dissatisfaction.
- Early FM involvement can help them better understand the programmatic requirements of a project. This, in turn, helps them specify maintenance requirements that are compatible with programmatic requirements.

Applicability of Value Stream Mapping and Work Sampling in an Industrial Project in India

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I. Background

Poor productivity and inefficiencies in the production process are alarming issues in the construction industry. Value Stream Mapping (VSM) and Work Sampling (WS) are two important techniques in the 'Lean' philosophy that aim at reducing and minimizing 'waste' in the life cycle process of activities and thereby aide in maximizing productivity. In this paper, we discuss the implementation challenges and benefits of these two techniques in an industrial project in India through an action based research methodology.

II. Current conditions

- VSM is a comprehensive model to reveal issues that are hidden in current approaches and raises the possibility of maximizing performance at the project level (Howell and Ballard, 1998).
- In WS, a series of instantaneous observations as 'snap shots' of work in progress is taken randomly over a period of time (Jenkins and Orth, 2003) to measure productivity.
- VSM and WS are both elemental time studies. While VSM maps the time taken to perform a task and WS describes how much time is spent on the task productively (or non-productively).

III. Working hypotheses

- *The strength of these two techniques might benefit industrial projects, particularly in India, where the lean principles and methods are still in its nascent stage.*
- *The study aims to understand the implementation of VSM and WS in an industrial project and assess its impact with respect to cost, time and overall productivity.*

IV. Research Method

VSM was adopted for Vacuum Dewatering Concrete Flooring works in manufacturing plant-4 and Tour based WS for block-work activity in Plant-1. An action-based research approach was adopted to collect and analyze data from the site.

For VSM, the process was captured through photographs, videos and hand-written notes. The sequence was further transcribed, documented chronologically and a flow chart prepared to depict the current state map. A committee of experts including in-house experienced contractors, site engineers, concrete technicians and the project manager analyzed the sequence, identified wastes in the process and suggested alternative methods and materials to overcome cost and time over-run. Based on recommendations of the committee, the future state map was implemented on site.

For WS, the activity was observed and diagnosed for a period of 30 days. Information on VA, NVAN and NVA was manually recorded on worksheets and Pie-charts were generated to illustrate time spent by job site workers on the identified categories.

V. Research Findings

- Through VSM, the duration for VDF flooring was reduced from 27 days to 24.5 days by segregating the channel fixing activity and transferring of reinforcement bars from the main streamline (see figure 1). Cost and quality improvement methods were also implemented for optimization of the process.
- Through WS, it was observed that the most common NVA was idle time and that was caused due to lack of effective supervision. The consolidated percentage of VA was 34%, NVA - 27% and NVAN - 39% (see figure 2). Further recommendation and action plan were provided such as inclusion of tool box meeting and effective supervision.

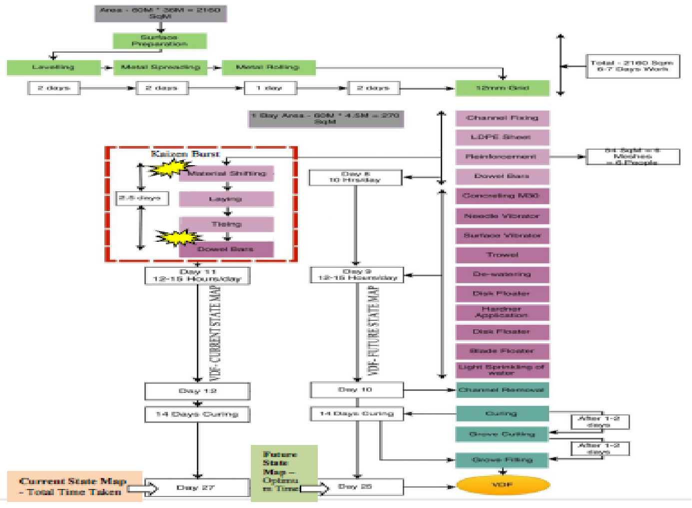

Figure 1: VSM and the Current and FutureState Map of VDF activity

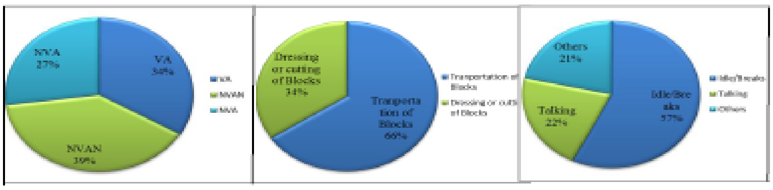

Figure 4: (a) Consolidated Percentage Contribution of Work, (b) Percentage Contribution of Work (NVAN), (c) Percentage Contribution of Work (NVA)

Table 3: VA, NVA and NVAN activities in Block-work

Value adding activity (VA)	Non-Value adding but necessary activity (NVAN)	Non-Value adding activity (NVA)
Placing Mortar & Blocks	Transportation of Blocks	Idle time, Breaks
Layer wise placing of Blocks with proper masonry bond	Dressing or cutting of Blocks	Talking
Checking alignment & final fixing with mortar	Others including inspection, approval	Others

Figure 1 above – VSM and Figure 2 below – Pie-chart for WS

VI. Conclusions

- Value stream mapping technique for VDF proved to be beneficial to visually map the process and optimize the operation with respect to cost and time. In specific, it helped to measure the time taken for supporting activities such as channel fixing and transporting of wire mesh and optimize the process by 2.5 days.
- Work sampling helped to identify and eliminate non-productive time spent by workers and allowed the contractor to improve the productivity of block-work activity above average level.
- Thus, by adopting similar approaches, project managers will be able to take key decisions to enhance productivity and optimize performance. Future studies could also explore the combined effects of these lean tools in construction projects.

Impact on the Design Phase of Industrial Housing When Applying a Product Platform Approach

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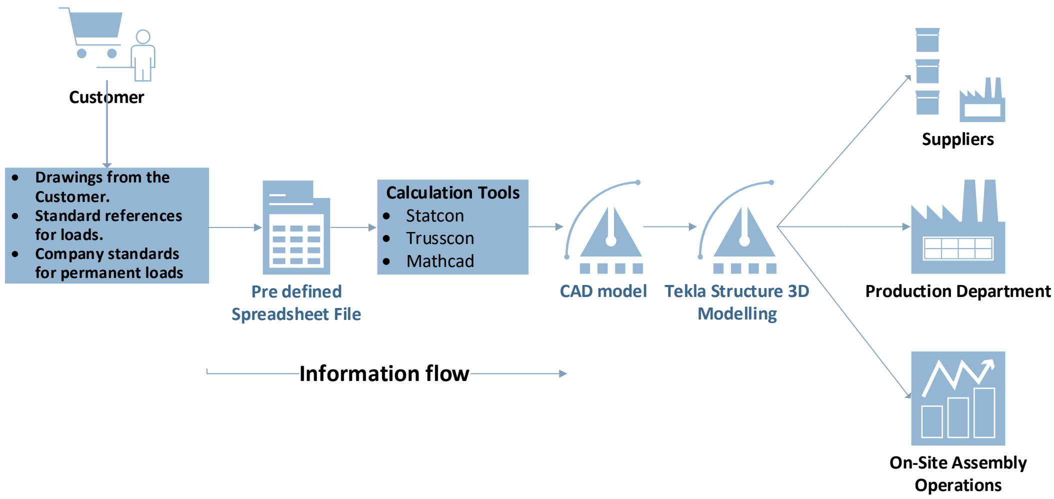
I. Background

The demand for industrialized timber house buildings is getting increased attention, where the glulam-based post and beam building system has been acknowledged as a feasible option for multi-storey buildings with timber. The industrialized house building sector strives towards standardized and controlled processes in the design phase. The use of product platforms has been acknowledged as an enabler to manage external (customer) and internal (production) efficiency. One of the main reasons for less development of platform thinking in the house building industry is the high amount of customization from the customer. A set of methods and tools is needed to support the design work and to ensure that solutions stay inside the boundaries of the platform definition. The aim of this work is to map the state-of-practice in the design phase for a glulam building system from a platform theory perspective and outline a path forward for applying a sustainable platform development in companies where a component-based product platform does not suffice. The impact on the current practice and future state of the design phase has been analysed and discussed. The scope is delimited to the design phase where a single case study has been carried out.

II. Current conditions

The company functions both with the engineer-to-order and modify-to-order strategies.



Current state of design phase at case company

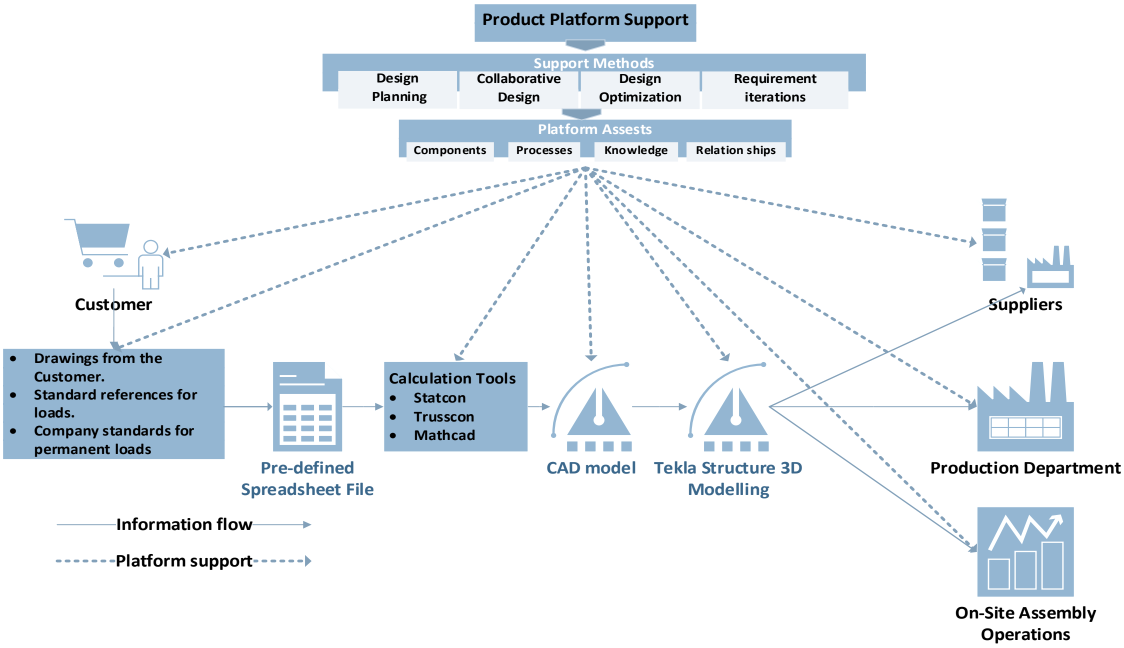
- **Component** asset has been partly defined and no product family has been developed from the building system
- **Processes** in the design phase has not been standardized and the sequence of work is not clearly defined which makes difficulty to manage many projects at same time.
- **Knowledge** asset, where an individual learning and assessments during the design of building components is happening between the projects
- **Relationships** are not well aligned internally and externally, and no procedure to follow currently. There is no formal system to manage the customers feedback as well.

III. Research Method

The Design Research Methodology (DRM) was adopted for this study and used as a framework for the whole research project. The paper covers the two initial phases where a literature review was done in the research clarification phase followed by the collection and analysis of empirical data from the case company as part of the first descriptive study phase. Empirical data were gathered from an on-going platform development and multiple sources of evidence were scrutinized with semi-structured interviews and document analyses.

IV. Research Findings and discussion

As an act to improve, the support methods such as **Design planning, Collaborative design, Design optimization and Requirement iterations** should be developed in the design phase. The support tools for daily engineering works could benefit the company to gain reduction of non-value adding works, variability, less lead time, which is the **lean way of design and manufacturing**. It is significant to develop **support guidelines in the design phase** that helps to evaluate and guide in developing solutions ably by design for manufacturing (DFM) and design for assembly (DFA).



Platform support in the design phase

V. Conclusions

- The mapping revealed the lack of definition in platform-based product development from theoretical point of view. However, company has the potential to achieve high levels of product variety, reduced time-to-market, better operational efficiency and responsiveness to the market needs with the **support of product platform approach.**
- The state of practice shows that the company cannot develop a **fully predefined and fixed platform system** for all the products as the projects are customer-driven.
- The combination of production strategies suits better for these types of companies in the construction sector where some sub-components from the building system suits for **configure-to-order**, few parts fits in **modify-to-order** process and rest to fulfill the unique needs of customers under **engineer-to-order**.
- The results point out the need of development of **platform support methods and tools in the design phase** and to ensure that solutions offering to customer are within the boundaries of the platform.

Exploring Product Development in Industrialized Housing to Facilitate a Platform Strategy

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I. Background

Industrialized house-building is a complex field, consisting of several constructs that need to be integrated and continuously developed, where the building system is a key asset. The challenge for house-building companies is to balance standardisation and customisation to reduce uncertainty in the supply chain. Construction is identified as a sector employing an Engineer-to-order (ETO) production strategy. Lately, there has been an increased focus on the platform concept in the construction sector. Robertson & Ulrich (1998) describes product platforms as "The collection of assets [i.e., components, processes, knowledge, people and relationships] that are shared by a set of products", not only including artifacts in the concept. Through product platforms, companies achieve high levels of product variety, a reduced time to market, improved operational efficiency and responsiveness to market needs. Improved customer value is targeted by adaptation of product solutions and swift introduction of new technologies combined with cost-efficiency and lead-time reduction. The use of a product platform, where external and internal efficiency are well balanced, has been acknowledged as a strategic enabler for mass customization and increased competitiveness. Source: Robertson, D., & Ulrich, K. (1998). *Planning for product platform. Sloan mgmt rev, 19-31.*

II. Current conditions

- ETO-companies struggles with adopting the common platform approach building upon pre-defined modules and components.
- Coordination between market and manufacturing is a crucial capability when engaging in platform organisation.
- For an ETO-based context and integrated product architecture it is difficult to apply modularity and platforms. Still, from a modify-to-order/configure-to-order perspective, platform theory can be applied by incremental development.
- When an ETO strategy is applied, from a platform perspective, for the design phase, the balance between distinctiveness and commonality is crucial to master.

III. Working hypotheses

- The paper analyses current strategies and support to master the balance of external and internal efficiency in product development within industrialized house-building to facilitate the development of a product platform strategy.

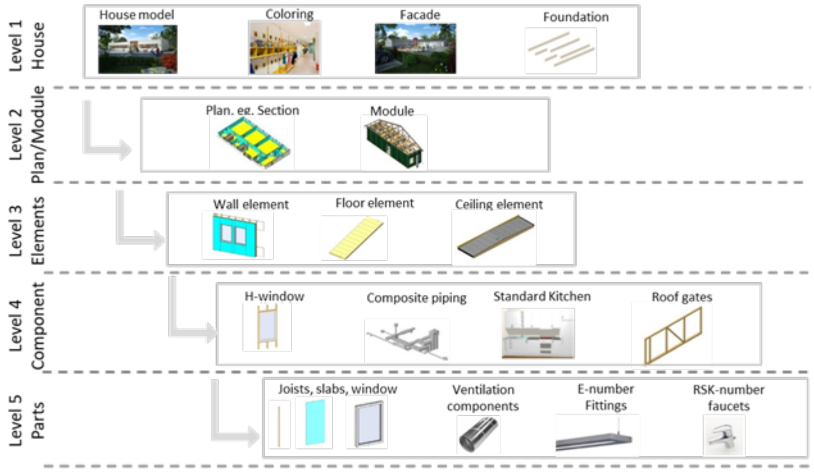
IV. Research Method

Two data collection methods were used: interviews, and analysis of internal documents from the case company. A set of semi-structured interviews regarding the current product development process was conducted with five respondents (technical manager, structural manager, HVAC coordinator, electricity coordinator and design coordinator). The questions were separated into different domains: product and technology development before and after order point; demands; information sources, tools and models; process development and; platforms. Internal documents describing the current strategy for product development was scrutinized. The primary source is the technical platform, where product families and house models are described. Types of documents include, drawings needed to produce standard configurations, but also design templates and standard operations (STD), which describe a variety of issues, e.g. technical solutions, bill of material and way of working.

The studied company is focusing on products such as, schools, kindergartens, elderly homes and offices, which demands knowledge of their client operations. The company applies an industrialized house-building strategy and off-site construction with up to 90 % of completion in a factory. A fundamental idea is to maintain a high level of standardisation in the production. The building system is based on volumetric elements in turn-key contracts, meaning that the company is covering all disciplines and the entire construction process.

V. Research Findings

The case company has developed a modular product structure. With the use of a Technical Platform (TP), the company competes using a product platform in the business model. The assets [components, processes, knowledge, people and relationships] are fairly well-described in the case with (1) a modular structure of the product, (2) a well-described production process, and (3) know-how. The asset [people and relationships] was not in focus. Still, the way product development is carried out, i.e. lack of cross-disciplinary coordination, improvement areas can be identified. When scrutinizing the way that the company manages the balance between distinctiveness and commonality, it becomes evident that there are parts missing. The expansion of the number of documents in the database along with the testimonials from the interviews where a holistic view is missing.



Modular structure of the Technical Platform (TP).

- There is no clear distinction between standard components and variant components.
- No reduction of the variant components to the carrier of differentiating properties.
- One-to-one mapping for differentiating properties and variant components is missing.
- The degree of coupling of variant components to other components is unclear.

VI. Conclusions

- The instrument used to balance external and internal efficiency is the Technical Platform. There is an imbalance where external efficiency is prioritized over the internal efficiency.
- The results show that customised solutions outside the TP boundaries are allowed, e.g. a large number of variants in the product offer and a sliding document database. Having a large portion of public clients with specific demands reinforce this situation.
- Better management of distinctiveness and commonality from a platform strategy perspective is needed. The absence of a holistic view obscures the potentials of modularity.
- The file system database needs to be mapped in terms of what information is included in the drawings and files, identification of systems running across different levels of the TP. The range of documents can then be reduced, and redundant variants can be excluded.
- An increased integration between the different parts of the platform should be facilitated.

Using BIM and Lean for Modelling Requirements in the Design of Healthcare Projects

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I. Background

Healthcare facilities are well known for their complexity. Frequent changes in healthcare processes, as well as the introduction of new technologies, demand changes in the internal layout and in the performance of buildings. Moreover, there are several stakeholders involved, with distinct and sometimes conflicting requirements, which makes the processes of capture and assessment difficult to perform. The use of IT has been suggested to support requirements management for a number of years. BIM-based tools such as dRofus® and Solibri® have been developed for this purpose. Both allow connecting requirements and different parts of the product model by using the IFC Open Standard, to ensure that the design solution satisfies the requirements. The aim of this paper is to understand how user requirements can be modelled to support decision making in order to facilitate the assessment of healthcare building designs. This paper reports the initial results of an investigation that explored opportunities for improving value generation in the design and installation of healthcare facilities by using BIM and Lean concepts.

II. Research Method

An empirical study was conducted in close collaboration with a University Hospital in Porto Alegre, Brazil (Hospital A) and has focused on the redevelopment project of an Emergency Unit. Multiple sources of evidence were used in this investigation, such as: (i) 26 unstructured and 6 semi-structured interviews with the hospital staff and architecture and engineering team members; (ii) document analysis (2D and 3D designs, internal operational process descriptions, regulation RDC 50, reports from the hospital staff to the design teams, regarding design modifications); (iii) design assessment reports; (iv) direct observations at the emergency unit, in order to identify new user requirements and assess previous captures; and (v) meetings with engineers, architects and contractors from the undergoing expansion construction project. Five main activities were developed so far, and they are mostly related to the phases of the research process, understanding the problem and development of the artifact:

Identification and understanding of the client requirements and regulations → Structuring and modelling requirements (dRofus) → Modelling the building project (Revit) → Translation and modelling of rules (Solibri Model Checker) → Assessing the design project

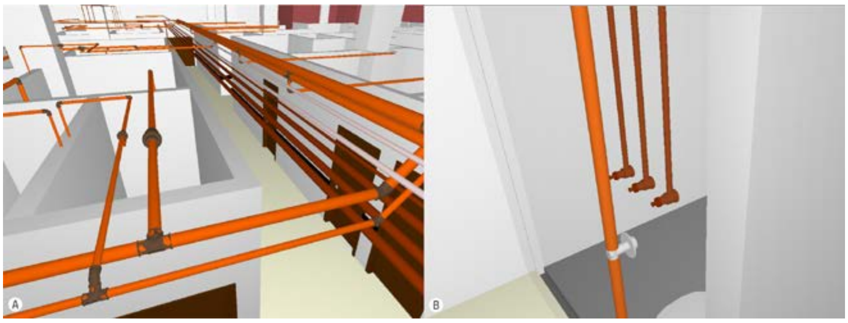
III. Requirements identified in the existing unit and regulations

From the interviews and observations made in the existing emergency unit, as well as information from documents containing requests for changes on the future emergency project, were identified 177 clients' requirements. These requirements have been structured and classified according to 13 categories and 32 subcategories. From the Brazilian Standard for healthcare design, were identified 1284 regulatory requirements. These requirements were connected to the building model and encoded to logic rules by using the concept of atomic sentence.

IV. Assessing the building design

The task of verifying semantic-rich data in the 3D model is not an easy step in the assessment process and sometimes might result in inconsistent outputs. Thus, for this empirical study, the assessment process was made by using three different approaches:

- **Automated checking**: Solibri® was successfully used to automatically verify requirements related to accessibility, properties of spaces and installation of systems in specific areas. The main issue regarding the use of automated rule-checking systems, especially hard-coded approaches, such as this one, is that some of the healthcare requirements are too complex and subjective to adapt to the software demands.



Automatic rule-based verification of cold water supply system (A) and medical gases supply (B). Developed by the authors.

- **Semi-automated checking**: defined as a human judgment, which is made by assessing computer-processed data. This approach was used in the study for situations in which it was possible to use structured data from both the 3D model itself, as well as from the modelled requirements, to verify certain criteria with some degree of subjectivity.

- **Manual checking**: The use of manual checking in this study was restricted to some highly-subjective requirements, which could not be verified in either of the previous approaches.

In relation to the 177 user requirements identified in this research, 23% were able to be automatically checked, and a further 23% could be verified by semi-automated checking, while 54% of user's requirements still required manual checking, because of the subjectivity related to the requirements. Regulatory requirements were analysed based on the possibility of translating requirements into logic rules. This analysis was made based on the levels of subjectivity necessary to assess the requirement in the design, as well as the possibility of re-writing sentences into logic clauses. Based on that, 63% of requirements could be translated into logic rules. Of these requirements, 39% were qualitative, 53% quantitative and 8% were ambiguous.

VI. Conclusions

- The process of modelling requirements allows structuring, classifying and checking semantic-rich information on design projects.

- The relationship between Lean and BIM-based tools appears to be a promising way of mitigating some of the negative effects in the healthcare context, by means of providing some degree of automation.

- The automated processes for structuring requirements and assessing designs may provide opportunities to minimize waste during the design process and to increase the overall quality of healthcare projects, as well as a means of ensuring that design specifications will fulfill clients' needs. This is an opportunity of increasing value for the customer.

- Currently not all requirements can be fully translated in terms of automated rule processing and checking. Although this decreases the overall degree of automation in the processes, this fact may provide benefits to the healthcare context. In some complex situations, a fully automated scenario could not allow human-creative solutions to emerge.

The Dual Nature of Design Management

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I. Background

Design management has received little attention in the construction industry. One reason could be the lack of explicit conceptualizations about its nature, subject matter, and principles. In this article, a conceptual design management framework is proposed based on two major premises: 1) as design management is the management of design activity, it is dependent on the way design is conceptualized; and 2) design is a human activity, but not a thing (e.g., representation) or an event (e.g., decision-making). Based on an integrative literature review, this study is conceptual in nature: the emphasis is placed on the conceptualizations of design activity and its relation to design management. This paper consists of three major sections: the conceptualization of design from the activity approach and theory perspectives; the lean and social conceptualizations of design management; and construction of a new framework and a visual model.

II. Current conditions and Working Hypothesis

Although the first practices of managing design were documented in Germany as early as in 1907 (Schwartz 1996), it is only in the recent decades that design management has gained widespread scholarly interest. But despite numerous efforts, the design of buildings is still suffering from many failures (Pikas et al. 2015). Literature review reveals that one primary cause of these problems could be the poor conceptualizations of design management (Koskela et al. 2002; Pikas et al. 2015).

Building on this insight, a new design management framework, together with a visual model as a mediating artefact, to facilitate the conversations about design management within the design management academia, and hopefully also in practice, is proposed. **The new framework is proposed on the premise that design management is the management of a structured system of object and subject-oriented, technical and social design activities.**

III. Design Activity: Paradigms, Activity Theory

Design activity is a complex phenomenon, defined in many different ways and on different levels. There is hardly any consensus on what design is (Love 2000).

In the design literature, four design paradigms have been defined (Dorst 1997; Stumpf 2001): design as rational problem solving, design as reflective practices, design as a social process and design as hypothesis testing. The first two lean towards the naturalistic (descriptive) approaches of design conceptualization, while hypothesis testing and experiential learning lean towards the activity (prescriptive) based conceptualizations of designing.

Activity Theory (AT) is a holistic psychological approach to the study of human activity, a structured system of conscious and unconscious, goal-directed object (technical) and subject (social) oriented actions and operations. The different levels of human activity based on the AT formalism include activity, task, action, and operation. The two first levels of the activity structure are the objects of study (emerge from the last two levels), the two last are the units of analysis (are the most basic). Based on the Activity Theory, a building design activity can be defined concerning the purposes of a building project and designers' behaviors (Bedny and Harris 2005):

> *Building design is a purpose directed system where motivation, cognition, and behaviors are integrated with respect to the 'bringing-into-being' of a new building.*

IV. Design Management Concepts: Technical and Social

In this section, the focus shifts from describing the design activity to describing the managerial activities. Lean design management conceptualization (LDM) has been based on the Transformation, Flow, and Value (TFV) theory (Koskela et al. 2002).

Although the different methods of lean design management embed the management of the social aspects (such as the Language-Action Perspective (LAP) in the Last Planner System (LPS) (Ballard 2000)), it is essential to clarify the function of design management concerning the social dimensions more explicitly.

Rekola et al. (2012) identified three other essential levels of design management: the substance level, the communicational/interaction level, and the personal level. These collectively refer to the social dimension of design management.

In the social dimension, design management is responsible for the facilitation of communication to develop shared mental models throughout all phases of the design process by using different means to explicate the tacit knowledge. This requires a shift from focusing on the problem solving to facilitating the co-evolution of shared understanding of needs, requirements, ideas and solution principles.

V. The Dual Nature of Design Management

Table 1 depicts the mapping of concepts to technical and social views, the partial models for conceptualizing the different dimensions of design management. The proposed framework demonstrates the dual nature of design management, the technical and social perspectives of management functions and operations.

Table 1. The technical and social perspectives of management functions and operations

	Production Management Functions				
	1. Design System Design	**2. Design System Operation**			**3. Design System Improvement**
		2.1 Planning	2.2 Execution	2.3 Control	
Technical view of design	TFV	Management-as-planning	Communication theory	Thermostat model	Metrics
Social view of design	Design-as-argumentation Design-as-knowledge-explication	Management-as-organizing	Language-action perspective	Scientific experimentation	First Run Study

VI. Conclusion

Design is a complex phenomenon, and so is design management. Design management is influenced by how a design activity as such is conceptualized. In turn, this is dependent on the particular design paradigm that has been chosen by the researcher for studying and developing the descriptive as well as prescriptive concepts and related practices. In this article, designing was conceptualized as a human activity, not as a thing or event. Based on these premises, a comprehensive framework supported by a visual model for conveying conceptual ideas was proposed. Holistic design management has a dual nature: design management is the management of a structured system of conscious and unconscious, object (technical) and subject (social) oriented mental and practical actions of design.

Identifying Value Enhancing Factors and Applicability of Visual Management Tools

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I. Background

Large investments are made in the construction industry by private and public sectors as a result getting reasonable value from the investment is pivotal. Interpretation of the value varies according to the importance and influence of the stakeholders in the project hence knowing its perception is significant. Maximizing value is one of the foundations of the lean construction approaches which is now welcomed by Indian professionals. Moreover, visual management and its applications in construction have shown promising results. Therefore, how well they can address value maximization in Indian construction context is answered via conducted research.

II. Current conditions

- Major philosophy of the lean theory is to reduce the waste and increase the value. Started with the production system, it has made benchmarking results in construction industry too. On the other hand, the term value is defined according to the local context and the interest and expectations of the stakeholder. Thus, understanding about the concept of value among Indian construction projects is required.
- To maximize or increase the value of the construction project it is necessary to understand the perception of the construction clients, internal and external both. Moreover, organizations from Indian construction industry welcome lean construction.
- To enhance communication and to control operations and processes in real time, the visual management and its tool have been developed and is used by lean practitioners. Moreover, the successful application of visual management in construction has been proven in the transportation sector, building sector and industrial sectors.

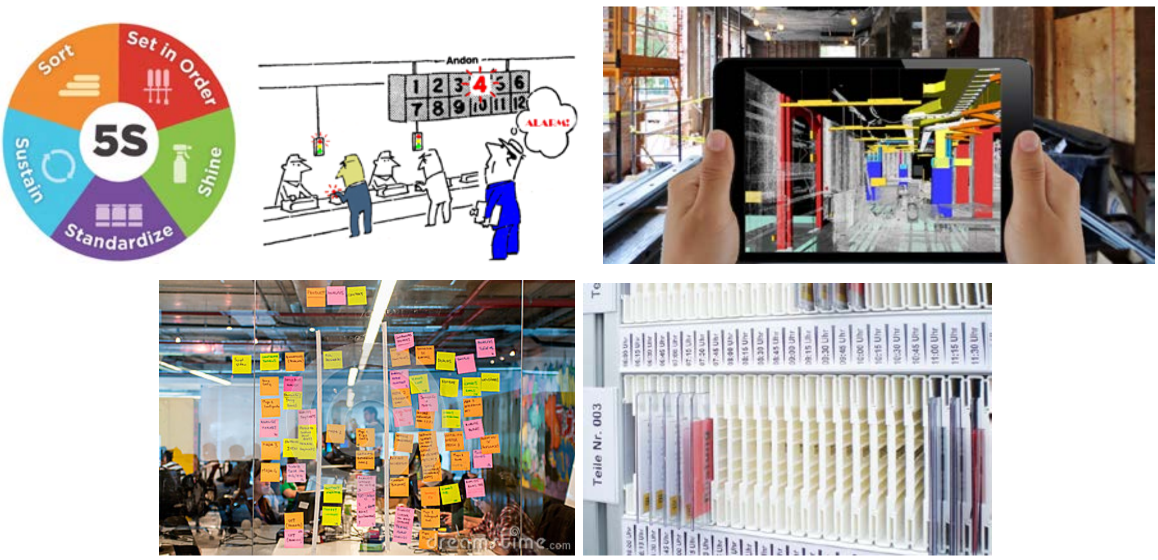

Figure 1 Visual tools used in construction industry
(© 5S today, science gate, Comarco, Shopify, Orgatex – clockwise)

III. Working hypothesis

- Application of the visual management tools enhances the value of the project.

IV. Research Method

This study comprises of three main objectives as stated in figure 1.

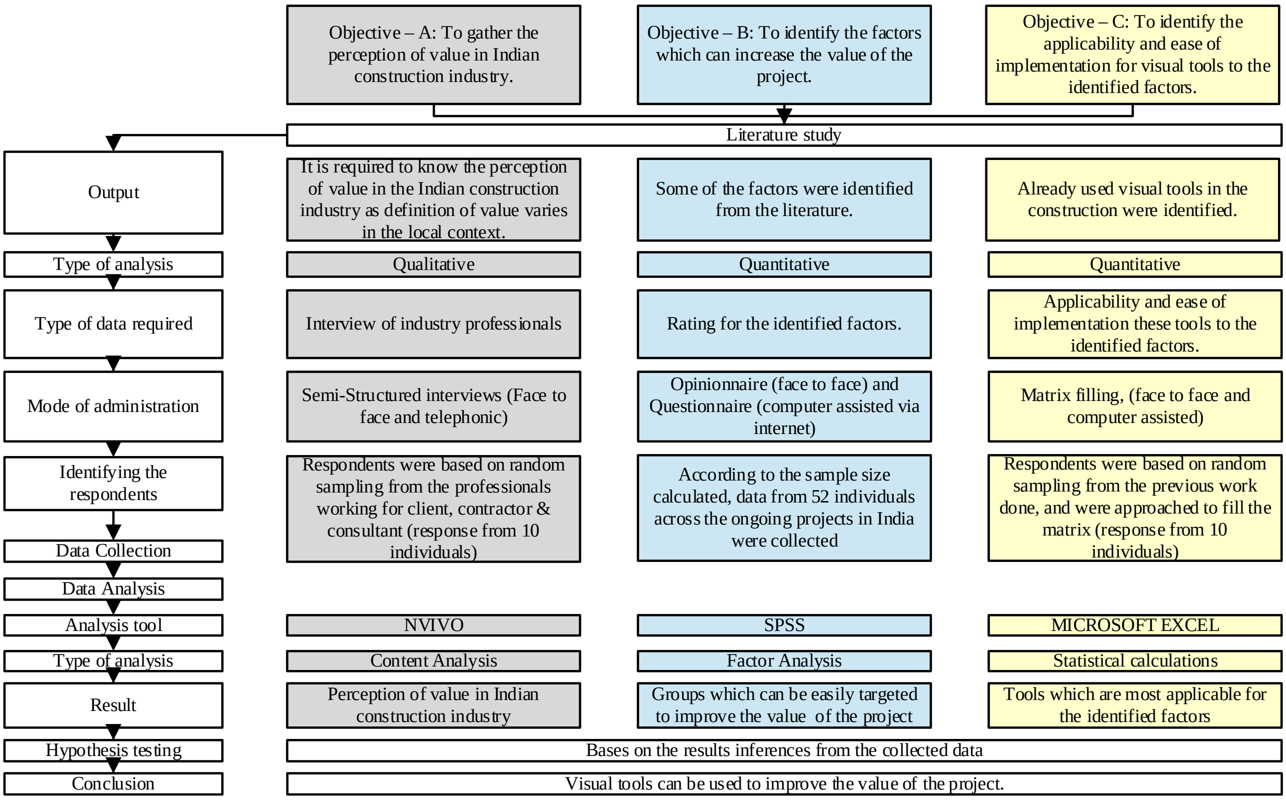

Figure 2 Research method flowchart for conducted research.

V. Research Findings

- In India, construction industry professional believes that equal efforts in process and product are required for the value enhancement.
- Total 33 factors are identified that can increase the value of the project and they are distributed into 9 groups using factor analysis as administration, work environment, culture, human resource, compliance, management, planning, rework, and transparency. This grouping portrays those zones where value improvement can tremendously affect the value of the construction project.
- Results from the matrix show that visual tools can be used on the construction projects and they can help to improve the value. Most relevant tools to enhance the value of construction project include 5S, display boards, collaborative process mapping /LPS, Kanban cards, Obeya rooms, Poke-yoke. Whereas BIM, display boards, collaborative process mapping / LPS, color coding, end product samples are easy to implement on-site for improving the value.

VI. Conclusions

- Thus, to improve performance in Indian construction industry, the lean construction has been welcomed by many professionals believing in client's value and overall optimization. Moreover, the study results in that, the use of visual management tools in the areas where its specific applicability and effectiveness increases the value of construction projects.

Assessment of Organizational Culture in Construction – A case study approach

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I. Background

Lean construction has been adopted by many organizations across the globe. But the success rate of sustaining Lean construction is low, which might be related to reasons such as cultural issues, lack of management support and resistance from people. Among these reasons, "culture" is the key. When we examine the current scenario, organizations are not able to align themselves to the Lean culture. So, it is important to understand the organizational culture (OC) and the impact of cultural parameters in enabling Lean.

II. Current conditions

- When we see the current state of the construction industry, aligning OC with Lean culture (LC) seems to be a challenge due to the inherent culture of the sector.
- In addition to the uniqueness of construction projects, unskilled and changing workforce, mindsets of the construction community and organizational structure disables the effective adoption of Lean construction.

III. Working hypotheses

- *There is a significant influence of cultural parameters in an organizational change.*
- *There is a strong correlation between cultural maturity and Lean adoption.*

IV. Research Method

<table>
<tr><td>I. Background
Lean construction has been adopted by many organizations across the globe. But the success rate of sustaining Lean construction is low. One of the key reason for it is "culture".</td><td>V. Proposed countermeasures
The study is exploratory in nature. Any definitive countermeasures can only be provided after detailed study.</td></tr>
<tr><td>II. Current conditions
Aligning OC with LC seems to be a challenge due to the inherent culture of the sector. In addition to the uniqueness of construction projects, unskilled and changing workforce, mindsets of the construction community and organizational structure disables the effective adoption of Lean construction.</td><td rowspan="2">VI. Plan
It is not possible to draw any definitive conclusions in this study, as it exploratory in nature. The type of organizational culture required for sustaining lean is not simplistic but a complex multidimensional issue. But, the present study helps to understand that there are different perceptions about organizational culture among the employees.</td></tr>
<tr><td>III. Goals/Targets
The target of the paper is to explore the organizational culture in a Lean organization.</td></tr>
</table>

IV. Analysis	VII. Follow up
OC has been studied using Competing values framework, which analyses the organizational culture using six dimensions in order to classify it as hierarchical, clan, market or adhocracy culture.	This study has adopted an exploratory research methodology to understand the organizational culture in the construction sector with respect to Lean adoption. The study helped to understand that the perception of employees regarding the organizational culture at different management levels varies, which is a potential threat to sustain Lean.

V. Research Findings

- It is found that the perception and views of employees of different management levels are different. Top management employees view the organizational culture as clan whereas the middle management employees view it as hierarchical.
- The top management believes that the organization is more formal and collaborated, and the procedures and standards govern the working of the organization; whereas the employees of middle management level perceive that the organization is more goal oriented and the leaders are demanding.
- Further analysis has been done with respect to the six dimensions of the CVF model, in order to understand the impact of these dimensions on the overall organizational culture.

VI. Conclusions

- It is not possible to draw any definitive conclusions in this study as it is exploratory in nature.

Application of Social Network Analysis in Lean and Infrastructure Projects

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I. Background

Over the past two decades productivity in construction remained meager, in comparison with other industries. Many root-causes of this problem are related to communication issues: a) informality and corruption distort the market, b) construction is opaque and highly fragmented, c) design processes and investment are inadequate, and d) poor project management and inefficient on-site execution. When it comes to infrastructure projects, other factors related with communication play a greater role: a) communication with communities neighboring the project: lack of confidence, misinformation and confusion about roles, rumors, community conflicts, expectation management b) engagement with stakeholders: specially involving the private sector in "reality checking" the results of planning, in particular relating to the financing of projects, and c) poor execution: incomplete design, lack of clear scope, ill-advised shortcuts, etc.

The communication structures between project participants have a great influence on the success of a project. Some can be described explicitly but most are informal and tacit. Social Network Analysis (SNA) is a tool to identify and model actual social structures with a set of metrics.

II. Current conditions

Over the last 5 years, several studies have been carried out on SNA around the world.

- Some of these implementations have proposed the analysis of networks such: interaction, relevant information, problem solving, successful planning, innovative ideas, leadership, trust and professional feedback. Also, they are pointed out the effectivity using SNA to detect unethical behavior in the construction industry.
- In the SNA implementations, data was collected through web-based surveys and through indirect sources of information (meetings, conversations, e-mails, phone calls, etc.)
- Analyzed SNA-Metrics were: network density, network diameter, average path length, average degree, modularity and the characteristic of the network shape.
- The conclusions after the analyses were: higher density reveals a higher level of communication, large modularity may imply the creation of isolated groups, increasing of the average shortest path reveals a possible threat of future isolated populations to appear, thus leading to poor utilization of individual knowledge and experience. Project participants having high number of connections and centrality have more to lose from unethical conduct than those who are isolated in the network; as they are under an increased surveillance due to their multiple connections, which determine the extent to which news of unethical behavior are disseminated to other project participants.

III. Working hypotheses

The aim of this work is to carry out a comprehensive investigation about how SNA can be integrated into Lean construction projects, with a special emphasis on infrastructure projects. In particular, the research aims to answer the following questions:

- How important are cultural aspects when implementing SNA?
- Is SNA equitably suitable for the analysis of projects and organizations?
- How does project complexity influence the applicability of SNA?
- Is it possible to use SNA-metrics for statistical benchmarking of projects?

IV. Research Method

To answer the previous questions, a literature review was carried out to select the best proven concepts of past SNA implementations (listed in section II) and to build a first conceptual framework of a SNA-Instrument. Then, the instrument was tested and improved in iterative loops each time in a more complex project scenario: firstly, in a simple organization (consulting office), secondly in two construction projects, thirdly in a complex organization (6 subsidiary consulting offices) and finally in an infrastructure project. The iterations were done in Germany, Switzerland and Chile.

V. Research Findings

- Cultural aspects are an important factor to be considered to implement SNA because the instrument involves obtaining data directly from people.
- SNA is suitable for the analysis of both projects and organizations. The SNA-Instrument can be used more than one time, to compare and register the evolution of the social network along the time.
- The full potential of the instrument in identifying conflicting communicational configurations was witnessed in the most complex scenario (infrastructure project).
- If the SNA-Instrument comes into use in a regular basis, it will be possible to create **a) statistical benchmark**, which would make it possible to compare the SNA-metrics, obtained with historical average values, and **b) best practice comparison of SNA-metrics**, which would make it possible to compare the SNA-metrics of a certain project with the SNA-metrics of best practice projects.

VI. Conclusions

- The application of SNA in construction projects promotes an improvement of information flows, cooperation and mutual trust.
- The SNA-metrics can be used to identify formal and underrated or informal links between project participants, tacit knowledge networks or even network-structures prone to unethical behavior.
- The metrics allow a cross-project comparison and benchmarking in order to identify best practice applications on the basis of described patterns.
- Even complex project environments can be described well with SNA. Such projects usually have great potential for improvement, which can be identified with SNA-metrics.
- The results of the SNA analyses are directly dependent on the openness and participation of the respondents, which is why cultural aspects play an important role.

Collaborative Design Decisions

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I. Background

When decision making teams are detached from one another the integrity of projects is compromised by miscommunication, leading to ungrounded assessments, lack of shared understanding, and frustration in the team. Usually, miscommunication leads to poor design outcomes, late changes in the design to reduce cost, and rework. Lean Design methods and practices such as Target Value Design (TVD), Set Based Design (SBD), A3 reports, Choosing By Advantages (CBA) and The Last Planner System® (LPS) present an opportunity to reduce waste in the design process, reducing unproductive iterations and helping the design team define and deliver value for the client. The researchers used a unique approach to observe the decision-making process as conversation for action to help the team overcome challenges. This paper quantifies the impacts of simultaneously implementing A3 and CBA in terms of saving money and reducing time in meetings. In addition, the research presents qualitative results in terms of improving the project design and creating a team capable of making efficient and sound decisions.

II. Current conditions

The decision-making process requires a transparent process in which SBD, A3 reports and CBA are well aligned. Several studies have demonstrated case studies in which SBD, A3's and CBA were implemented mostly as independent elements, not synergistically combined as in this case study. In addition, the implementation of lean tools with coaches observing the decision-making process as a conversation can help teams to manage unproductive moods.

III. Research Questions

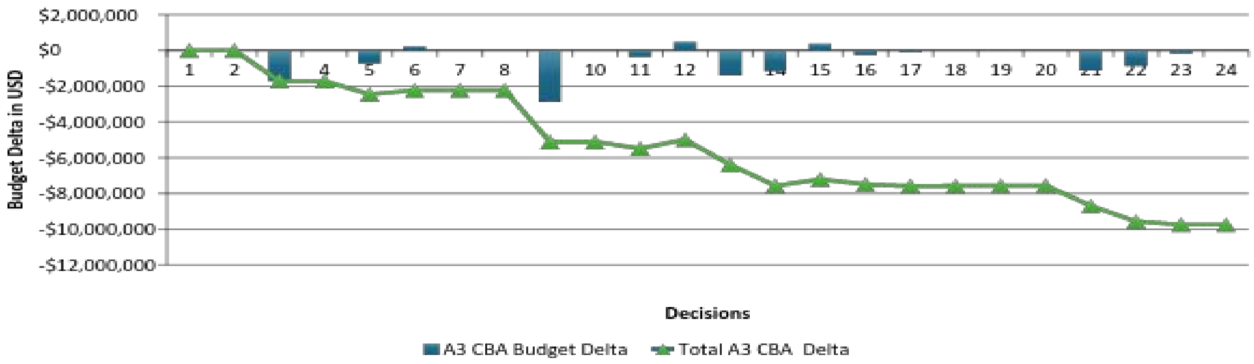
The research questions are: 1) What is the impact of implementing A3 with CBA systematically on a project? and 2) What observations can be made when coaching the decisions of a team as conversations for action?

IV. Research Method

To answer these questions, a project was used as a case study for the utilization of A3 and CBA for dozens of design decisions pertaining to programing, mechanical and geotechnical systems, site safety and other design elements. The sources of evidence used were 1) direct observation, since both authors were coaching the design team to implement lean design principles and methods, 2) A3 reports, schedules, and budget documentation, and 3) Interviews with project managers and design specialists after the coaches interacted with the team.

V. Research Findings

1. **Cost reduction:** Considering 24 decisions where the A3-CBA system was fully implemented, most of them resulted in cost savings; in total all A3's documented decisions resulted in approximately $9.7M in savings or 11% of the budgeted amount for these items.



2. **Decision time reduction:** In terms of time invested for each decision, early A3's with CBA averaged 5.3 meetings per decision and reduced to 3.3 meetings per decision representing a 37% meeting efficiency increase.
3. **Team ownership of the decisions:** The design team members came to the meetings more prepared and developed a common language by which they more effectively communicated how to make decisions as well as why they were making the decision. The team created a new collaborative practice and project managers were able to lead conversations and decisions, less intervention from coaches was required. The new process minimized future negative iterations and led to changes in habits.
4. **Higher client satisfaction and less negative iteration:** Design teams reported increases in client satisfaction; better decision documentation; and more lasting, logical and reasonable decisions with increased design efficiency and velocity.
5. **Increased team trust:** The teams developed increased trust and respect and were better able to work together across contractual lines.

VI. Conclusions

This research is based on observations of the implementation of CBA with A3s in a large complex project. These observations where made while coaching the decision-making process as conversations for action. This case study answered two research questions. Firstly, that the impact of implementing A3 with CBA systematically on a project is quantifiable in measurements of 11% savings on budget and a 37% increase in meeting efficiency. The qualitative benefits reported by the team were increasing value for the client and improving their overall performance. Secondly, when coaching the decisions of a team as conversations for action we observed that implementing A3 and CBA evolved the mind-set and mood from one of confusion to one of resolution. Finally, qualitative data suggests that the results on costs savings and meeting efficiency would not be possible by mechanically implementing CBA with A3.

Building Shared Understanding during Early Design

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I. Background

At early design stage conflicts can emerge due to different language and other forms of representation (upon which participants' express their different responsibilities and interests) usually leading to lack of shared understanding on which design factor is most important in the task (Maher et al. 1996; Kleinsmann and Valkenburg 2008). In this context, Valkenburg (1998) proposed that *shared understanding* is a mutual view amongst the team members on a relevant design topic and design activity. Moreover, shared understanding faces the challenge of integrating various perspectives emerging from different descriptions of the world and, it depends on reasoning around conflicting arguments and goals among design participants (Arias et al. 2000). In this study, adapting Bittner and Leimeister (2013), *shared understanding* is defined as the collective and dynamic ability of multiple agents within a group, to conceive and coordinate actions towards common goals or objectives, based on diverse knowledge, beliefs and assumptions on the task, through the use of tools. Shared understanding is thus an enabler for collaboration, in which collective actions are complementary or compatible with each other, when evaluated against a common goal (Smart 2011). Consequently, it is possible to say that, lack of shared understanding about the design object and task can hamper the team's progress and can negatively influence the design outcome (Valkenburg 1998). In this case, there is poor understanding of what actions collaborators need to do when combining different design representations and how these actions can be implemented (Snodgrass and Coyne 1992; Qu and Hansen 2008). Therefore, this paper addresses the following research questions: How misunderstandings emerge in early design? What participants do in practice to avoid and resolve misunderstandings?

III. Working hypotheses

Lack of shared understanding usually occurs because each participant interacts with their own set of assumption guiding their interpretations and actions (Hey et al. 2007). These assumptions emerge from what Schön (1983) called *frames*, and Bucciarelli (1988) called *object worlds*, as underlying structures of belief, perception and appreciation, comprised of implicit understandings about what issues are relevant, what values and goals are important, and what criteria can be used to evaluate success.

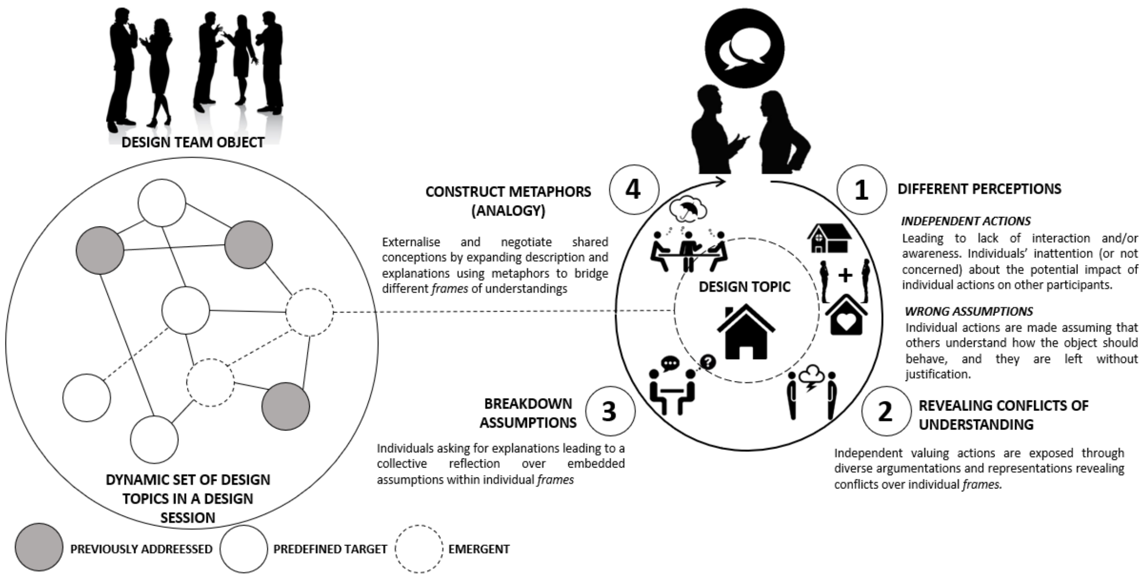

Figure 1: Dynamics of Shared Understanding at Early Design

When conflicts between participants' individual frames are made visible, common frames can start to be negotiated (Hey et al. 2007). Such externalization of individual frames expands the design team object, which allows other participants to expand their engagement in what Schön (1983) calls "*conversation with the materials of the situation*" (Arias et al. 2000). Here, metaphors play a key role, because they embody symbolic representations that implies socially shared ways of perceiving a situation, as well as, the ability to conceive changes in it (Tomelleri et al. 2015).

IV. Research Method

This paper presents an exploratory case study aiming at understanding how misunderstandings emerge between design participants during early design and how these participants resolve such situations. This study involved the observation of a design team working on a one-day charrette at the schematic design stage of a Medical Office Building (MOB) in USA. According to the brief of the activity, participants were expected to contribute in exploring alternative ideas for the building envelope. During the Charrette, the participants interacted via verbal and graphical representations to explore different design ideas. Such interactions were video-recorded for Protocol Analysis.

V. Research Findings

At the Early Stages of the activity, there was a moment when one of the participants indicated that she had a **different interpretation** about the representations (Foot Plan + Perspective Images of the proposed building) presented to the group earlier, which **revealed a conflict of understanding**.

Figure 2: Participants interactions during the Design Charrette: MOB - Envelope

Later in the task, that lack of shared understanding was exposed again but more in-depth to the whole group, which supported the **breakdown of their assumptions**. At this stage, the participants engaged in a set of questioning and explanatory actions to collectively understand the reasons behind the emergence of diverse interpretations, and what were the assumptions embedded on these perspectives. In another occasion, one of the participants tried to build shared understanding about an *Emergent Design Topic*: the idea of "*Pyramid*", by **questioning and then discussing her conception** of a *Sculptural Element* in the building design with Lead Architect. The **use of a metaphors to bridge and convey understanding** on design topics was noticed a few times. The most significative one happened at the end of the *briefing* stage, when the Lead Architect tried to explain her perspective about how they should approach the main objective of the session: design the exterior of the MOB. In her concluding argument she used two metaphors within a comparison (the "*cousin*" vs. the "*twin*" building) to make it clear that the new MOB should fit into the context of the campus, but at the same time it should not look exactly the same as the existing buildings.

VI. Conclusions

According to the proposed framework, building shared understanding requires that participants perceive and embrace the dialectical nature of collaborative design, and work upon contradictions emerging from different perceptions founded on individual frames that manifests through diverse artefacts of interaction (i.e. verbal argument, graphical representations, organisational processes). Through such dialectical activity, participants in Early Design Collaboration can potentially review, reposition and construct, in the sense of a bridge, their collective interpretations and actions.

Lean Leadership Training: Lessons from a Learner-Centered Analysis

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I. Background

The lessons learned reported in this paper are the result of a large training program under development at a company based in the Redwood City, California. The company founded in 1990 is a commercial contractor and construction manager and has been ranked in the top 50 general contractors in the United States since 1997. It currently has 26 offices in the United States and three abroad. So far, the Lean Leadership (LL) program has reached over 280 participants. The program is constantly analyzed via feedback provided by participants, however, no detailed analysis like the one presented herein has been conducted and shared. By sharing the lessons learned about this program, the authors expect to contribute to the change management and education literature within the Lean community.

II. Current conditions

The organization currently has 160 open positions across the country. Many of these roles are new to accommodate our growing needs. This rapid growth means we need to keep building lean leaders to reinforce our cultural bond and have the leaders be the teachers. One of the goals of the Lean Leadership training is to continuously align values/people/departments regarding important core values (Figure 1). Data revealed that respondents with different roles, mostly related to field tasks, are attending the program and would recommend it to others. Most respondents consider themselves Lean leaders and educate others on Lean content. Respect for people, use of visuals, go and see, and use of Plan-Do-Check-Act (PDCA) have been reported as Lean tools and principles constantly used.

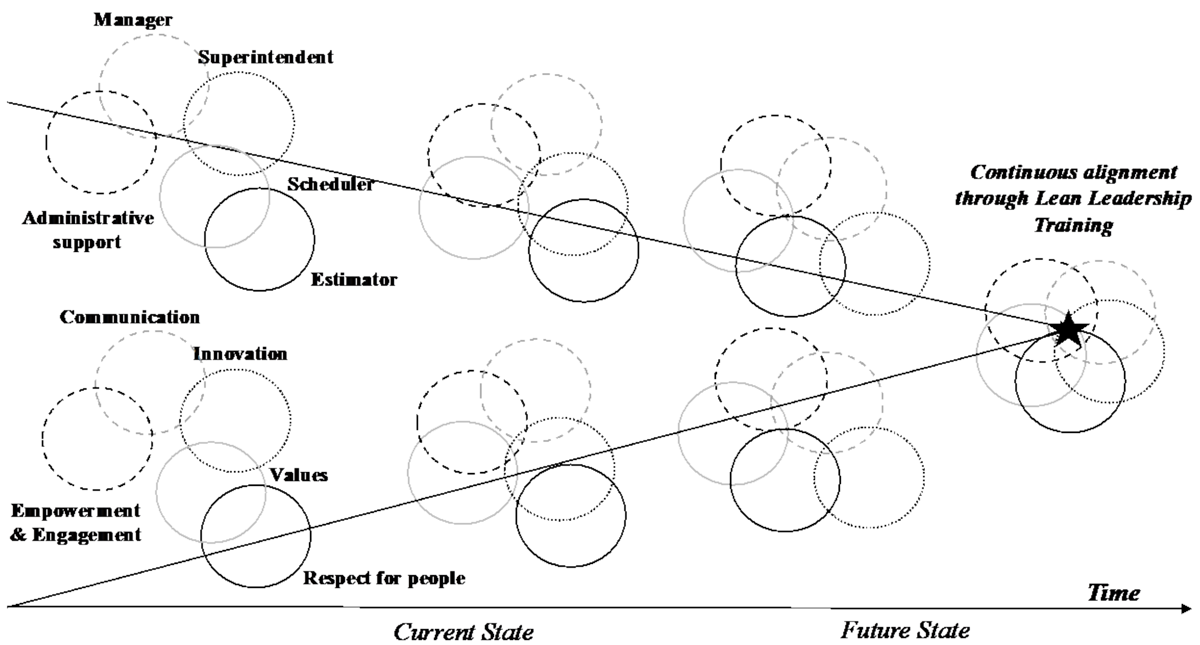

Figure 1: Building alignment through the Lean Leadership training.

III. Conditions of Satisfaction (CoS)

As results were being analyzed, the first two authors who work as leaders of the LL training program defined the conditions of satisfaction (CoS) for this program and divided them into personal CoS and Team CoS as shown in Table 1.

Table 1: Conditions of Satisfaction for the LL Program

Personal level	Team Level
Behavioural changes	Consistency among projects
Improved Quality of life (what's in it for me)	Teams are aligned around project learning
Engage in the material practice skill and implement ideas of lean	Empower LL to educate and change team dynamics and inspire breakthrough performance.
Develop 1,000 LL in the company by the end of 2019	Change perception that people are lean but teams are not.
Maintain 10% drop our rate per class	Lean champions on every team – project and office.
Live in the PDCA cycle every day	

IV. Research Method

The main tool used to develop the assessment of the LL program presented in this paper was an online survey deployed to current and former participants of the training. The authors brainstormed a set of questions that would capture some of the respondents' background as well as their feedback about the course modules and what they are doing with the knowledge they are gaining from the course. Finally, the survey tried to capture what can be improved in the program and how.

V. Findings

When asked about how the knowledge gained from the Lean Leadership training was used in their daily routines, participants pointed to the: need to identify and eliminate waste; use of the Plan-Do-Check-Act (PDCA) cycle to identify problems and potential solutions (P), implement the solutions identified to solve the problems (D), check how the solutions are working (C) and act to correct deviations and promote continuous improvement (A); use of visuals to promote communication and more transparent environments, and respect for people. Selected quotes from participants include:

- "I use inquiry much more and focus on process".
- "I'm not sure I can say much of this was new to me personally. Rather, the training is giving me greater context to understand how we intend to incorporate these principles on our projects".
- "Open Communication - Allowing open door policy where everyone feels safe to bring forward issues and feel they are heard when providing solutions. Recognizing potential problems before they arise and having options for solutions".
- "Greatly increased visual planning and communication of the plan. Daily huddles for accountability of the last 24 next 24. Use the ideas in the course to better explain my intent to the team".

VI. Conclusions and Future State

Moving forward we are sticking to what has worked which is PDCA and asking the students (our customers) what they think will improve the course. For 2019, we will replace some of the content purchased from an outside vendor with our own employee's videos. We will choose one chapter and then ask our customers if they prefer our employee's examples or the examples given in the existing modules. If they like the changes, our plan will be to replace all content with internal examples. We will continue to drive toward a learning culture and want to see the numbers of people that say they are lean (82%) to match the number of people that say their project are lean (60%), if we are able to change this number then our workers are teaching and educating others and promoting the lean culture of learning.

EVALUATION OF CUSTOMER VALUE BY BUILDING OWNERS IN THE CONSTRUCTION PROCESS

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I. Background

Customer Value is a fundamental concept in Lean Thinking. Simultaneously, understanding Customer Value is the first and foremost Lean Principle to which all others (value chain, pull, flow and continuous process improvement) should align. It is therefore important to define the term Customer Value and to understand what factors influence it. This is especially true for the utilization of Lean Principles in the construction industry, since construction projects are inherently customer driven.

II. Current conditions

Contrary to the importance of Customer Value stands the existence of many non-value-adding activities in most construction. For this reason, it seems as if Customer Value is not given enough attention in construction practice. In addition, Lean Construction theory states that its biggest weakness lies in understanding the nature of Customer Value. However, Customer Value has been investigated outside the construction industry for a long time and many of these resulting insights have not been transferred yet.

III. Working hypotheses

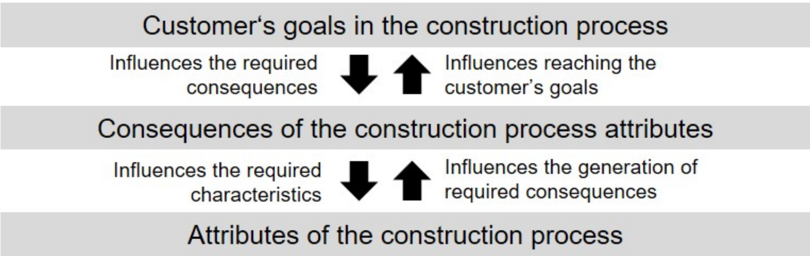
Based on existing knowledge a model can be build, that describes the relation between customer value and its influencing factors during the construction process. This model can also serve as a basis for a definition of Customer Value in the construction process.

IV. Research Method

With the goal to develop an approach to describe and relate influencing factors on Customer Value, a literature study is conducted. Existing types of models are studied and their applicability onto the construction process have been analysed.

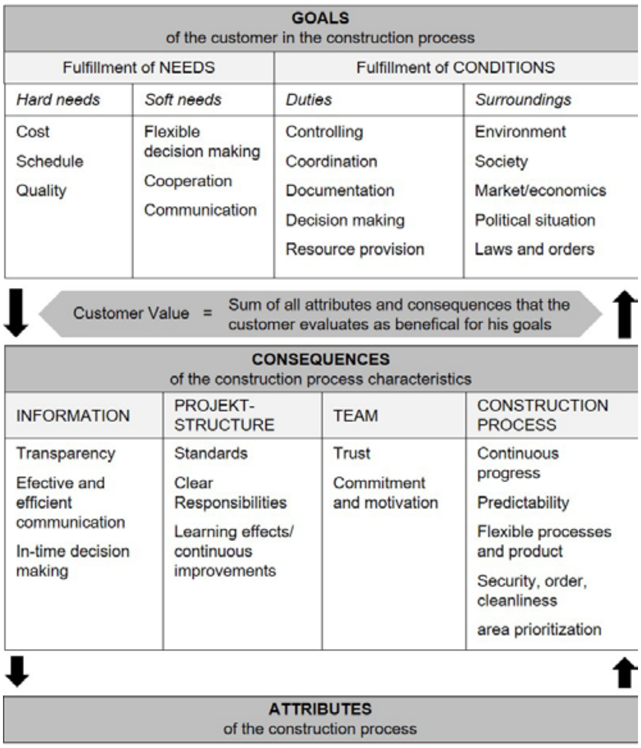
V. Research Findings

Many models for the structure of Customer Value are existing in the field of marketing and business research. They can be sorted into three categories: Component, Relationship and Means-End Models. The Means-End approach by Woodruff is best fitting to describe the Customer Value in the construction process. It states that Customer Value is the sum of all product or process attributes as well as its resulting consequences that facilitate reaching the customers goals.



Concept of a Means-End Model for the Construction Process

The three levels of the Means-End model can be detailed by looking at the goals, rights and duties of the building owner in the construction process.



Detailed Means-End Model for the construction process

The Means-End approach shows, that Customer Value is not a characteristic of the customer and is not equal to ethical or personal values. Similarly, Customer Value cannot be considered equivalent to requirements, wishes, goals or demands. Rather, Customer Value is the sum of the attributes and consequences which the customer has evaluated as useful for achieving his or her goals. A conclusion of the system is therefore:

Fulfilling customer requirements = Value Creation

but: Customer requirements ≠ Customer Value

Moreover, the system provides a framework for categorizing many other terms that play an important role in the construction industry. In this way, for example, the significance of trust and cooperation in the construction process have long been known.

VI. Conclusions

Utilizing existing knowledge from the fields of marketing and business research, a model is developed to describe Customer Value in the construction process as well as its influencing factors. The Means-End Model defined by Woodruff not only conceptualizes the customer value, it also serves as a basis for a definition of this term. This approach and definition, can be adapted slightly to include the construction process as well:

“Customer Value is the result of a customer's perceived judgement of those product or process attributes, attribute performances, and consequences arising from those that facilitate (or block) achieving the customer's goals and purposes in a product’s use situation or in a process.”

According to this, it is not goals that define Customer Value, but rather the attributes, attribute performances, and consequences that lead to achieving the goals of the customer.

The model and definition should also serve as a basis for targeted and consistent use of terminology for describing Customer Value and for further research.

Using design science research and action research to bridge the gap between theory and practice in lean construction research

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I. Background

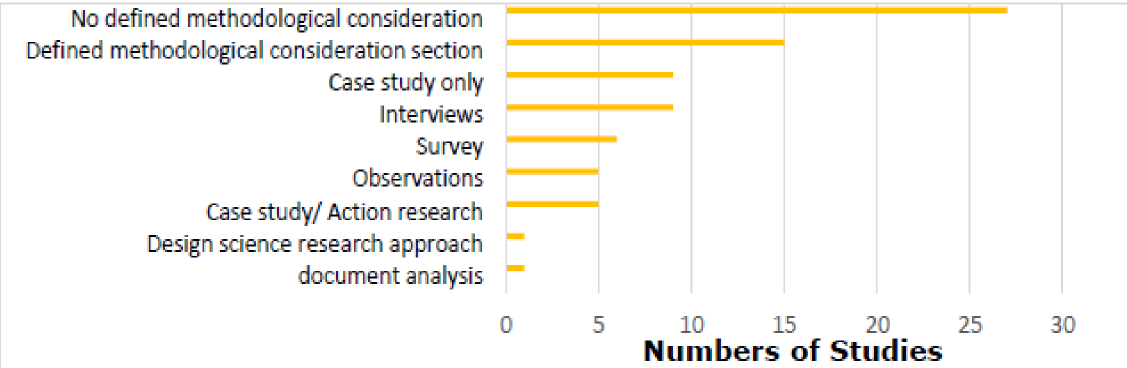
In this paper, the authors briefly describe design science research (DSR) and action research (AR). They argue that the Last Planner System (LPS) is a good example of an output of what may be considered design science research and demonstrate how action research was used in two PhD investigations to implement LPS in two building projects and evaluate its effectiveness in increasing production planning reliability.

II. Current Conditions

Daniel et al. (2015) found that the vast majority of studies with defined methods published by the International Group for Lean Construction (IGLC) on the implementation of LPS in building projects used descriptive research methods like case study, interview, survey, observation and document analysis (see Figure 1). According to them:

> *…this should be a point of concern to the IGLC research community that is seeking to build lean construction on sound theories and principles for better practice. Sound theories can only be developed from sound methods and methodologies…*

Figure 1: Research methods used in LPS implementation reported in fifty-seven IGLC conference papers (Source: Daniel et al., 2015, p. 159)



III. Working Hypothesis

The authors believe that DSR and AR are sound methods for studying, understanding and solving practical problems and testing innovative solutions in design and construction management, for bridging the gap between theory and practice and for making academic research more relevant to practice.

IV. Research Method

Literature review of LPS, DSR and AR.

V. Research Findings

Ballard and Howell did not characterize the approach they had adopted to develop LPS as DSR (Ballard, 2000). However, when the authors examined the approach adopted by Ballard and Howell and the methodology used in DSR, they found remarkable similarities between them. The literature review revealed that AR can be used to implement LPS during the design and construction stages of building projects and evaluate its effectiveness in improving production planning reliability.

VI. Conclusions

Lean construction is the adaptation of lean manufacturing principles to building design and construction processes. Adaptation of lean principles from the manufacturing industry requires the development of valid and reliable knowledge that can be used to create lean solutions to practical problems in the construction industry like LPS. DSR is an ideal approach for developing such knowledge. AR is the best approach for implementing and evaluating lean solutions to practical problems in the construction industry in their organizational context.

Determining Benefit - Understanding Buildings as Production System Assets?

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I. Background

Maximizing the client value delivered from construction projects is to large degree a matter of maximizing the benefit in use of the built asset. To do so, we must be able to accurately assess the benefits of a proposed solution at the time of design. While some authors have looked at simulation solutions for examining this issue, we believe that this research is putting the proverbial cart before the horse. A more fundamental understanding of what answers we seek is needed before considering how this technically speaking could be done

II. Current conditions

- The role of buildings is to serve as production infrastructure
- There exist no theoretical frameworks for explaining what this entails

III. Working hypotheses

- Fundamental production theory can be used as a basis for describing and optimizing buildings as production system infrastructure

IV. Research Method

- Anchored in the pragmatic research paradigm
- Abductive reasoning based on Scoping study to identify relevant literature

V. Research Findings

Production Systems Theory

- Two fundamental activity types in production systems
    - Transformation – Value adding processing of product or service
    - Flow – All non non-value adding activities (e.g. waiting, moving, inspection)
- All productions systems contain variability
    - Variability must be buffered
    - If variability is not buffered ad-hoc buffers will appear

Production system model

- To determine if a proposed building design can support the production system that will be housed in the building, a model of the production system is needed.
- We refer to such as model as a Building Activity Model (BAM)

Evaluation methods

- Two fundamental evaluation methods:
  - Analytical
    - Verification – Showing that all system trajectories satisfy the desired property. Yields binary yes/no answers
    - Calculation – Doing mathematical operations on system variables. Yields numeric values
  - Simulation - techniques for using computers to imitate the operations of various kinds of real-world facilities or processes
- Models can be either:
  - Deterministic – all the input variables are known
  - Stochastic – One or more of the input variables are uncertain

BAM evaluation

- Can the activities be done?
  - Verification suffices to determine if an activity can be performed at all
  - Calculation or simulation is required to determine if the building has sufficient capacity
    - Calculation can suffice for simpler scenarios
    - Simulation is required for complex scenarios such and for systems with high variability
- Can the activities be done well?
  - Activities can underperform due to flow issues or due to process issues.
    - Flow issues – Those that cause an activity to be starved of some material or input. For example, staff spending a disproportionate time waiting in line or hunting for bathrooms if the capacity is too low.
    - Process issues – Do not cause non-performance but rather degrade performance. Could be related to the characteristics of the building, e.g. suboptimal lighting, or caused by other activities in the system, e.g. noise in an office landscape.
  - Some aspects could be considered using simple calculation.
  - The interdependencies in production systems entails that simulation is required to fully determine how well an activity can be done in a building.

VI. Conclusions

- Evaluating the benefits of a building at design time requires an analysis of its ability to support the production system that it will house.
- To do so there are two fundamental questions that we must be able to answer:
  - Can the activities of the production system be performed?
  - How well can they be performed?
- To fully determine to which extent a proposed design will support the activities that will take place in it, computer simulation is required.

Conceptual Framework for Capability and Capacity Building of SMEs for Lean Construction Adoption

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I. Background

Lean construction (LC) is a production delivery system with the potential to deliver exceptional performance improvement and a possible solution to the many problems faced by construction SMEs. However, Construction SMEs lack the needed resources which constraint their lean implementation efforts. SMEs provide a challenging context for the implementation of LC due to their lack of the needed resources. The outcome of this study is to focus attention on building the capability and capacity of Construction SMEs to fully adopt LC. This will help reduce the incidence of high failure rates of LC implementation recorded amongst SMEs. Previous works have concentrated on what SMEs can and should do within their limited capacity. However, the use of the isolated tools and practices fail because lean is a system that has to be implemented holistically. A conceptual framework for building the capability and capacity of SMEs for LC adoption is therefore proposed

II. Current conditions

- Construction SMEs do not have the capacity to implement LC
- SMEs are constrained in terms of the needed resources to fully adopt LC
- SMEs are more focused on securing the next project, rather than on implementing contemporary management approaches such as LC.
- Much effort, with initiatives such as lean thinking, have been and continue to be concentrated on Large Enterprises to the neglect of SMEs
- Lean initiatives have concentrated on tools and practices affirmed to be within the capacity of SMEs
- There is incidence of high failure rates of LC implementation recorded amongst SMEs due to the use of isolated tools

III. Working hypotheses

- *SMEs do not always have the resources to develop and adapt lean construction*
- *The use of isolated LC tools by Construction SMEs leads to a high incidence of failure.*
- *Construction SMEs capabilities and capacities need to be developed to adopt wider lean construction principles.*

IV. Research Method

Systematic literature review was utilized because of the rigorous and transparent form of the review. This study follows the comprehensive stages for the systematic review developed by Tranfield et al. (2003).

V. Research Findings

- LC is a potential solution to the many problems faced by Constructions SMEs
- Construction SMEs lack the needed resources to fully adopt LC principles
- There is a lower uptake of LC principles by Construction SMEs.
- Construction SMEs use of isolated lean construction tools leads to high incidence of their LC implementation efforts.
- Any improvement efforts in SMEs will result in a huge impact on the construction industry as majority of firms belong to this critical sector

VI. Conclusions

- The development of the SME sector is of paramount significance for any country irrespective of its level of development.
- SMEs are faced with fundamental problems that lead to defects, high costs, safety issues, customer dissatisfaction, decreasing competitiveness, etc.
- This, in effect has led to widespread underperformance within this sector and a high attrition rate.
- LC implementation within SME context is challenging, as these firms lack the needed resources to fully implement this management philosophy. .
- A successful adoption of lean by construction SMEs will heavily depend on their capability and capacity for easy implementation.
- To overcome this gap this study has developed a conceptual framework for building the capability and capacity of Construction SMEs to fully adopt the LC philosophy.

Product Modularity, Tolerance Management and Visual Management: Potential Synergies

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I. Background

Building should not be designed as an unconceivable large number of small parts but rather as a manageable set of large chunks that can be mixed and matched to meet all customisation requirements. In addition, work should be structured so work packages deliver modules rather than indistinctive combinations of small parts. There are several challenges involved in bringing this re-conceptualization to practice. Two of these can be summarized as follows: (i) *How to communicate this new understanding of buildings (as a set of modules) within and across design and production*? and (ii) *How to ensure an appropriate connection among modules in design and production?*. This paper seeks to address these inter-related research questions by reviewing and examining Tolerance Management and Visual Management and their conceptual underpinnings.

II. Current conditions

- Visual Management (VM) - It is a close range communication management strategy that relies on the effectiveness of sensory stimuli (Figure 1). VM systems are often divided into four: (i) visual indicators, (ii) visual signals, visual controls and (iv) visual guarantees (poka yokes). In the latter case, the contact surfaces of two modules are deliberately designed to allow only the correct assembly of modules. In a slot architecture, the distinct interfaces design avoids incorrect assemblies. Differently, a sectional architecture does not guaranty a correct assembly as all modules are connected via the same interface type.

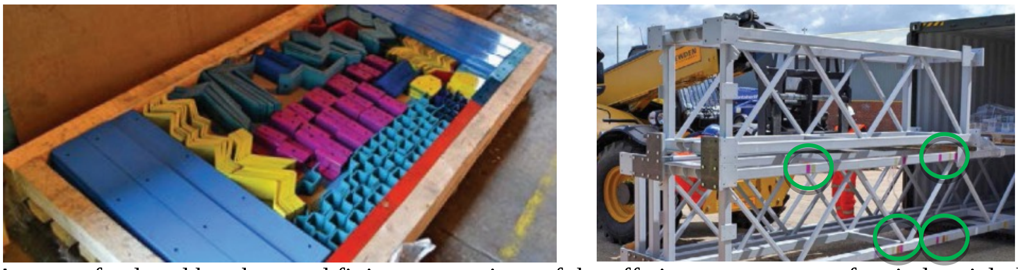

Figure 1: A crate of colored brackets and fixing connections of the off-site components of an industrial plant, which match to colored stickers positioned on the structural components (circled above) during the manufacturing process (Falmer 2016).

- Tolerance Management (TM) - It includes planning to achieve the required accuracy, accommodate tolerances into design, and control whether tolerance requirements have been obtained. Tolerance problems can be defined as when two or more modules are connected tolerance-wise but either they do not satisfy functional requirements or there is a fit-up problem with them due to exceeded variations. In this paper, a method termed GD&TIC is proposed. This method groups the geometric variations of a feature into four categories, geometric characteristics and symbols (Table 2).

III. Synergies

- VM provides a number of tools to improve the communication within and across design and production regarding: (i) what are the modules and (ii) what modules are connected/combined to create the product variants to meet distinct customisation requirements.

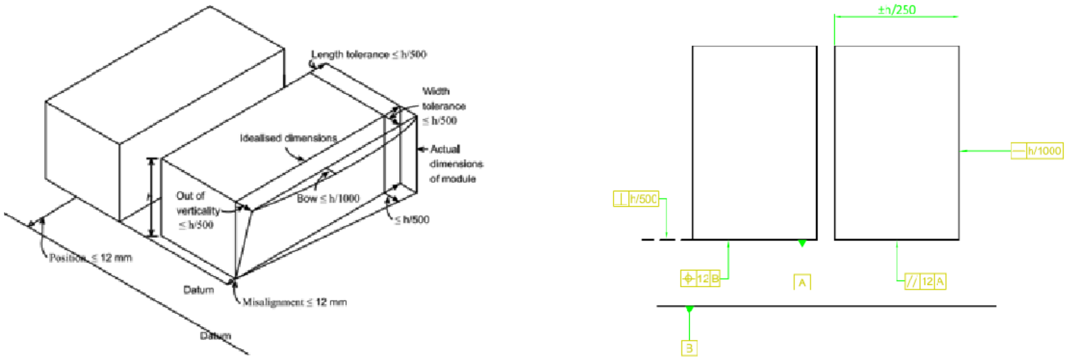

Figure 2: (a) The maximum permissible variations in geometry of a two modules (adopted from Lawson et al. 2014), and (b) application of GD&TIC for the modules.

- PM provides inputs to TM, particularly in standardising the type of parts that make up a building and types of connections between modules.
- TM provides an input to PM by systematically identifying critical interfaces between modules based on the type of modules and type of interfaces.
- TM can shed some light, especially by recognizing that the tolerances in connections between modules using GD&TIC.

IV. Embedding Information in Product Design

Considering the potential to embed information in product design (more specifically here in modules design), Design for Behaviour Change including specific application such as Design for Sustainable Behaviour (DfSB) can provide important insights. For the synergies considered here, ten patterns are particularly applicable and are adapted to construction (Table 1).

Table 1: Adaptation of design patterns (Lockton 2015) to construction

	Design Pattern	Adaptation to construction
Design	Colour association	Use colour to indicate association among design elements
	Proximity and grouping	Group design elements to indicate similarity or joint usage
	Similarity	Make design elements look similar to indicate they share characteristics
	(A)symmetry	Use symmetry to make elements look related and asymmetry to show difference
	Implied sequence	Organize design elements to indicate the sequence to be followed
	Possibility trees	Provide a " map" of routes or choice that can be made to achieve different goals
Production	Matched affordances	Design modules and interfaces so they fit together only in the right way
	Interlocks	Design modules and interfaces to be combined only in the right way or sequence
	Task lock-in/out	Design modules and interfaces to support only the correct assembly
	Feedback through form	Design modules and interfaces to give feedback or suggest cues for assembly
	Prominence	Exaggerate or make more obvious features of modules and interfaces that require attention
	Perceived affordance	Design modules and interfaces to suggest or constraint inappropriate assembly

V. Conclusions

- This paper examined the synergies among PM, TM, and VM to ease the understanding and communication of the re-conceptualization of buildings from product and process design viewpoints for the successful application of the first concept.
- TM is particularly relevant to address the interface among connecting modules.
- VM can help in the problem-solution process of modules definition and also product variants definition.
- Eventually, the potential of Design for Behaviour Change conceptualizations to improve and expand the scope of VM tools for construction is demonstrated.

Lean-driven Passenger Experience Design

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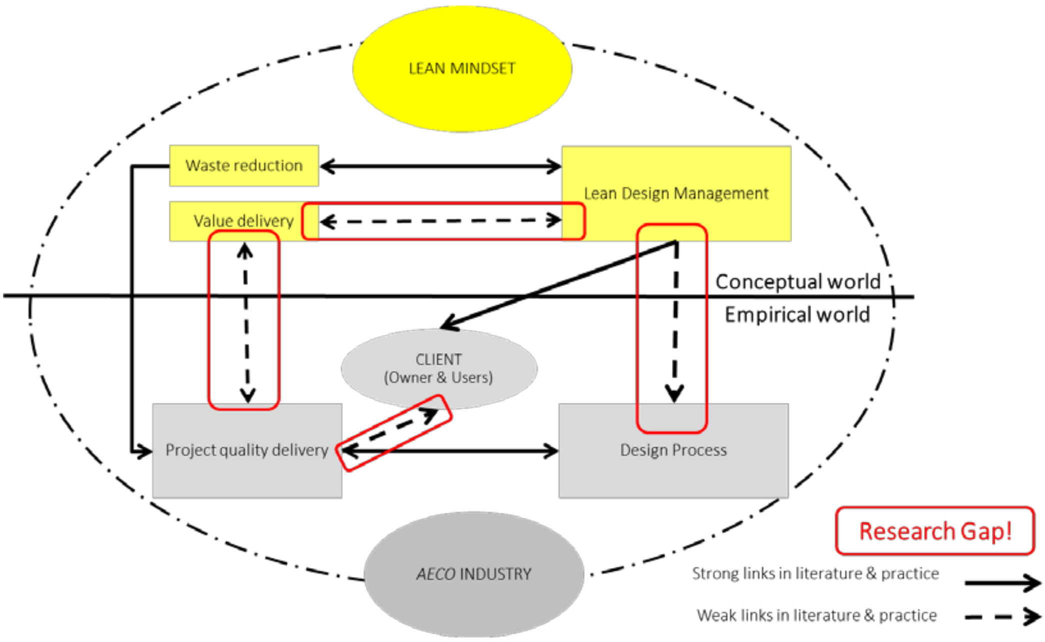
I. Background

In the contemporary agenda of airport design, good spatial design is fundamental to properly and efficiently manage boarding and disembarking processes. Current practices of airport design do not properly cope with its requirements and the subsequent operation phase. Lean Design could have important outcomes in the search for project design integration, effective solutions, quality and all-encompassing sustainability. This exploratory paper investigates the current challenges of airport terminal design and Passenger Experience design and discusses the transfer of Lean process logic to airport terminal project development.

Table 1. Synthesis of the research framework and explication of Airport terminal design drivers

Research framework definitions		**Airport Terminal Design drivers and key factors**	
Airport Terminal	Service generator	**Optimization of passenger flows**	Time saving and travel stress-relieving strategies
Passenger/Visitor	Service Consumer	**Levels of Service enhancement**	Compromise between resource consumption, investments, perceived quality and allocated space
Optimization and enhancement of P.E.	Value for the consumer	**Architectural features**	Use of consistent architectural language and coherent design choices to avoid “airport blues”
Passenger Experience (P.E.)	Consumed Product	**Passenger Experience (P.E.) optimization**	Sum of the airport project and the ancillary business processes ongoing in its premises

II. Current conditions

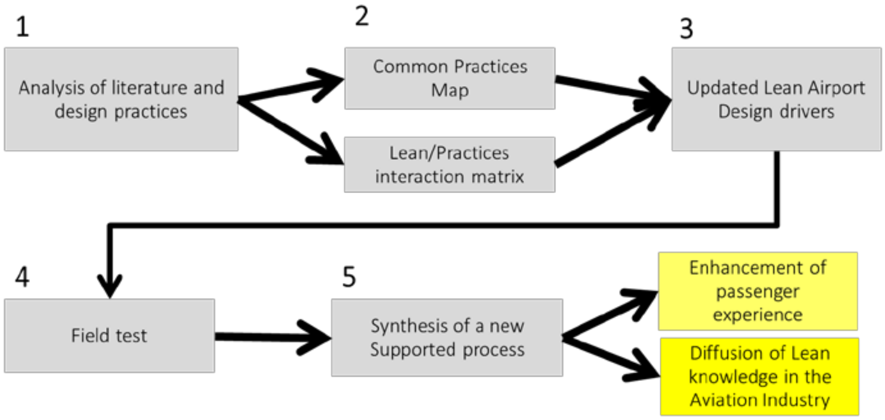


Source: Bosi, F. (2016). *Airport Lean Integration*, PhD Dissertation, Università degli Studi di Firenze and Technion - Israel Institute of Technology

III. Working hypotheses

- *We argue that implementing Lean principles in design drivers for Passenger Experience improves travel quality perception and reduces the perceived travel cost.*
- *We discuss the development of a customizable and flexible process methodology, adding to our understanding of Airport Project Development.*

IV. Research Method



V. Research Findings

Table 2. Comparison of common airport operation design practices and Lean terminal design

Design Aspect	Common Airport Design Practices	Lean Terminal Design
Design priority	Satisfying traffic/capacity demand	Design flexibility and perception of service quality
Scope	Space program optimization	Passenger Experience optimization
Main evaluation metric	Processing capacity of the terminal	Perception of infrastructure by users, passenger experience
Design goal	Passenger processing activities	Passenger processing flow
Project management focus	Project delivery	Management of project information during the service life
Technology integration	Technology integration in operation is functional to improve operations efficiency	Technology integration in operation is functional to improve Passenger Experience
Functional priority	Controlling environment: pyramidal hierarchy of operation over business processes	Integrated environment: parallel ongoing operations and business processes
Design driver	Operation design is driven by the terminal project	Operations and passenger processing is a driver for terminal design
Terminal function over time	Operations change in time according to the evolution of the terminal space program	The space program and terminal operations' evolution is intertwined
Process planning	Process planning does not allow variability and adaptability	Process planning has a margin of variability and adaptability

VI. Conclusions

- Integrating Lean principles in passenger experience design results in an innovative design philosophy for airport project organizations, whose priorities and targets are connected to passengers' behavior and their perception of the infrastructure, travel cost and quality.
- Methodologies originating from this theory could be tested in airport project case studies dealing with the development of a new terminal project, creating a passenger experience from scratch, or extension of existing airport terminals - confronting the challenge of design to avoid disruption of the Passenger Experience during the construction phases.

Assessment of Lean practices, performance and social networks in Chilean airport projects.

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I. Background

Poor integration in work teams of the AEC industry can generate deficient performance, both in the realization of each of its stages (design, construction, maintenance, operation and deconstruction) and globally in the product's life cycle (Baiden et al. 2006). Low performance is generated due to the realization of activities that do not add value and that are considered as project wastes, such as rework and waiting times, among others (Aziz & Hafez 2013). In particular, the design stage is fundamental in the life cycle of a project because the decisions taken in this instance can significantly affect the following stages. In addition, the costs of changes in the design stage are negligible compared to the costs of changes in future stages (AIA 2007), which represents a great potential to make improvements to the project.

Airport projects are complex in nature because they include several specialists from the public and private sector who must interact temporarily for the fulfillment of previously defined objectives. These objectives come from the transportation demands coming from the community, the requirements and needs of the airport organizations and the standards and regulations required for the airport's proper functioning. In addition, most airport projects require that the airport, or aerodrome, continue to operate normally during the construction phase of the new project.

II. Objective

It is fundamental to assess the relation among lean management practices, performance and organizational logics (interaction patterns) in the design team of these types of projects. Thus, the objective of this paper is to understand the functioning and performance of the temporary organizations that design airport projects, making a comparison between projects in preliminary and final design.

III. Research Method

The research methodology is a case study of nine airport projects developed by the Ministry of Public Works of Chile. Five of these projects were in the initial study phase and preliminary projects, and the other four were in the final design and detail stage. In each project, the level of implementation of Lean practices, key performance indicators and social network metrics were assessed to understand the interaction of organizations.

Lean practices in the design stages were defined based on an extensive literature review which was then analyzed in interviews with ten professionals and academics. Performance indicators in the design were created based on the results of the team of researchers and professionals of the Ministry of Public Works. These indicators are: rework, waiting times, quality defects, and commitment achievement. These KPIs were measured during 5 weeks of each of the projects. The analysis of social networks (SNA) was carried out according to the methodology proposed by Alarcón et al. (2013), and included the following dimensions: knowledge of roles, complete interaction, work information, planning and problem solving, learning, and trust. The following indicators were obtained from each of the dimensions: number of people, number of connections, density, diameter and average length. To collect the data for these networks, an online survey was used, and the data were processed with the Gephi Software.

IV. Research Findings

The airport projects in Chile are supervised in the design and construction stage by the Airports Department (AD) of the Ministry of Public Works, while the person in charge of the operation is the Directorate General of Civil Aeronautics (DGCA). The AD hires a consulting company to carry out the design of the project in its stages of preliminary design and final design.

The practices with the highest level of implementation have to do with the surveying of stakeholders' requirements in a comprehensive manner and with the participation of the client in a systematic and empowered manner. Both practices have an outstanding level of implementation due mainly to the fact that the AD functions as a technical entity for the revision of designs rather than only for administrative purposes. In contrast, the practices with the lowest level of implementation are those that must have early involvement of the builders, and therefore the design of the construction process is not carried out simultaneously with the design of the product. In addition, the use of information from previous projects for planning, problem solving and decision making of current projects have a low level of implementation. Finally, a last low-implementation practice has to do with the collaborative work at the time of planning and with the standardization of the process of monitoring the projects.

The average weekly rework of the nine projects oscillates within 20% of the hours dedicated; that is, one in five days is dedicated only to rework. It is important to mention that the airport projects of Chile define instances of revision and correction; therefore, there are weeks in which the projects have a high level of rework. This explains the high variability of the percentage of rework among the nine projects. The average waiting time for information is 9.78 hours; that is slightly more than a day of work. Again, there is a significant difference between the projects in the PD stage and in the FD stage, with the longest duration in the first stage (12.55 average hours), while in the FD stage, the average time is 6.44 hours. The average number of quality errors detected per week fluctuates between 0 and 6. This is mainly due to the revision and correction times that exist in the planning of the project. Finally, the fulfillment of the weekly commitments in each project, which averages approximately 75%, without significant differences in the different stages of the projects.

One of the fundamental characteristics is that the network of knowledge of roles is practically the same as the network of complete interaction, both in the form of the network and in its metrics. This means that if people do not know what another person does in a project, they do not interact. After a workshop with the study participants, an emphasis was given to the kick-off meetings of each project. Another important element to emphasize is that the learning network is born from the trust network; this means that there is no learning among people as long as there is no trust relationship that supports it. On the other hand, the network for planning and solving problems always focuses on positions with responsibility in the project team, which is directly related to a poor practice of collaborative planning

V. Conclusions

From the results, it is possible to draw the following conclusions: At the level of literature review and interviews with experts, Lean practices in design focus on stakeholder management, planning and monitoring, and problem solving and decision making. In the public projects that were evaluated, it was possible to identify that the practices with the greatest development are the management of requirements and the systematic participation of the clients, while the ones with the worst performance are the early involvement of builders and collaborative work. The projects in the preliminary stage stand out in the involvement of designers from the beginning and the projects in the final design stage in the planning and monitoring tools. These practices have a direct impact on the interaction between the different professionals in the organization, which is represented by a low level of work information flow and in the planning and resolution of problems. Considering that the members of the temporary organization do not necessarily know the role that other members of the team have, the kick-off meetings are essential to initiate the expected interaction between the different professionals. The low level of interaction directly affects the performance of the project, especially about rework (average 20%) and design quality errors (average 3 per week), since this generates unplanned work that permeates the PPC of each project.

Designing as a court of law

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I. Background

The rich connections between rhetoric and design have been analysed in prior research. Classical rhetoric originated from the need of citizens in ancient Greece to make speeches in a court of law. Understandably, the discipline of rhetoric was then built up around the unit of a speech. Unfortunately, this notion of rhetoric has largely side-tracked the related innovations in how legal proceedings, as a whole, should be organized. It is contended that legal proceedings, as they have evolved from Antiquity onwards, embrace important and effective principles for collaborative – but simultaneously competitive – pursuit of a common goal, in the considered context, justice.

II. Current conditions

Seven principles contributing to collaborative, but simultaneously competitive, pursuit of a common goal can be recognized from legal proceedings:

1. **Hear both sides:** The principle of “hearing both sides” of the case, *audiatur et altera pars*, is fundamental to the idea of fairness. It implies accommodating the proceedings so that both sides have an equal opportunity for presenting their case and responding to evidence against them.
2. **Reasoned judgment and fact finding:** To explicitly present the reasons for the judgment, *ratio decidendi*, is another idea stemming from ancient Rome. These reasons cover both rules of law and facts of the case.
3. **Right to appeal:** The right to appeal, besides giving the possibility of correcting obvious mistakes and poorly prepared judgements, has a proactive impact to the judge, trying to avoid judgements which are overruled by a higher court.
4. **Not only logical but also rhetorical reasoning:** The mainstream assumption has been that legal rules and decisions are deduced directly from legislation, previous cases, and secondary authorities. However, since the 1950’s, the rhetorical approach to legal reasoning has been forwarded. This approach emphasizes the content (rather than logical form) of arguments and the context-dependent aspects of acceptability.
5. **Public nature of proceedings:** The court sessions were public already in ancient Greece and Rome. This ensures that no party could make claims that would have been generally known to be incorrect. Also, this creates a situation where the judges, the witnesses and the jury are publicly accountable.
6. **Standardized procedures:** From early on, it has been found useful to standardize both court procedures and the contents of documents and presentations. The standardized order of presentation helped to communicate the case in a logical and persuasive way. In turn, the standard procedure let both sides to be fully heard and brought order and certainty to the process.
7. **Dedicated and structured space:** Since Antiquity, a dedicated place for court hearings has been found helpful. The dedicated venue for court proceedings emphasizes, for its part, the authority of the court, and focuses attention to the matters being handled.

III. Working hypotheses

Arguably, the law court can be used as a metaphor of what is happening in design. In all stages of design, there are wishes, concepts and solutions competing against each other. For reaching the best outcome, each wish, concept or solution needs to be promoted and defended in the best possible way, and a reasoned judgment among them has to be made. We hypothesize that the principles of legal proceedings can effectively be used in this endeavour.

IV. Research Method

To test the hypothesis, we explore, through a case study, whether in the advanced practice of lean construction project management, methods and tools would resonate with the principles of legal proceedings. The case study was done in retrospective for a design of a large complex campus. Researchers collected evidence of the application of legal proceeding principles in a portion of the project where advanced lean design was implemented. The benefits of using lean in design were calculated and reported by the project manager, and validated by the owner.

V. Research Findings: how were the seven legal procedures realized in principle?

1. **Hear both sides:** All relevant stakeholders were invited to each of the 52 meetings held to select from design alternatives. Even where there was not a physical meeting, everyone had the chance to participate in the decision remotely through a videoconference. If any of the relevant stakeholders could not attend, the meeting was rescheduled.
2. **Reasoned judgment and fact finding:** The method of Choosing by Advantages (CBA) was used to evaluate design alternatives by considering their attributes (characteristics relevant to determine if and how well they meet agreed criteria). Facts were also documented in A3 reports.
3. **Right to appeal:** The right to appeal a decision was always available. Further, anyone could offer new information, a new alternative, a new factor to consider, and new facts that help differentiate the alternatives, perhaps correcting a mistake in previous assessment of attributes.
4. **Not only logical but also rhetorical reasoning:** Both logical and rhetorical arguments were used several times at each decision. CBA is well aligned with the use of different types arguments, which have been divided into three types: *logos, ethos and pathos*.
5. **Public nature of proceedings:** All records were public to the design team. Everyone in the project had access to the A3 files, and can see the status and history of each decision. Decision meetings were mostly held through videoconferences.
6. **Standardized procedures:** This was one of the main points of the lean design implementation, where everyone has a standard to process an issue in the design, documented in an A3 report, exploring alternatives (using Set Based Design when needed), and CBA when decision was complex and required multiple criteria.
7. **Dedicated and structured space:** The project had critical team members working remotely in several different locations, therefore physical co-location was not always possible (in contrast to many other current projects organized in similar lines). However, one week per month the team had a big room dedicated space, the remaining weeks virtual co-location was implemented.

The savings from lean design practices were 9.7 million USD (11% of the original design budget). Increased efficiency in design process was measured through meeting records (time reduced by 37% per decision in a four month period). The results were validated and approved by the owner.

VI. Conclusions

The performance outcomes of implementing lean practices embodying the principles of legal proceedings were clearly better in comparison to the situation before. Although it is not possible to trace back the benefits only to the principles of legal proceedings and related practices, their emergence, and continued use, provide solid circumstantial evidence on their efficacy.

Last Planner System: Comparing Indian and Norwegian approaches

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I. Background

LPS intends to improve the reliability and predictability of the plans used for construction activities during the implementation stage through an integrated approach (Mossman, 2014). It has proven benefit on project performance for more than 20 years in multiple countries, across building construction, heavy civil engineering construction, highway and infrastructure projects, including ship building and pit mining (Liu and Ballard, 2008; Ballard, 1993; Ballard and Howell 2003; Alarcón et al. 2008). Engebø et al. 2017 found that, adjusted for the number of inhabitants, the interest for Lean Construction is much higher in Norway than in India. This correlates with previous experience of the first author from both the Indian and Norwegian construction industry and is a key motivation to compare the implementation of the last planner system between India and Norway, respectively.

II. Current conditions

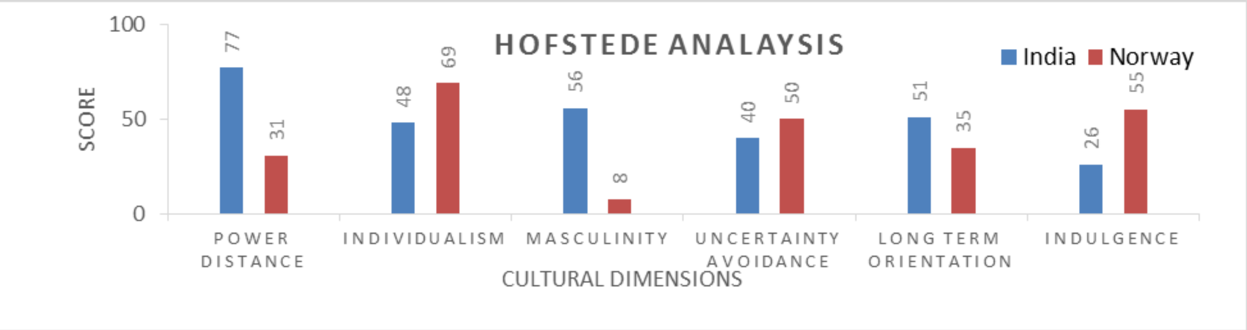
Several research papers have concluded that LPS in India is still in its infant stages and it has in usage in Norway since 2000's. However, both the countries have had both ups and downs in the projects using LPS. As success in LPS in achieved only with the help of active participation of various stakeholders in the project, a study from Johansen and Porter (2003) reveals that cultural barriers like attitude to work have a say when LPS is implemented. In an attempt to get a better insight in this statement, the authors have studied a cultural assessment field called Hofstede's cultural dimensions theory. Hofstede, who is more known in fields such as sociology and psychology than engineering, presents six different cultural dimensions for country comparison namely Power distance, Individualism, Masculinity, Uncertainty avoidance, Long term orientation and Indulgence., However the authors argue that with culture and people being such a strong proponent of Lean practices, such cultural analysis tools could provide valuable insights into factors of success or failure of certain practices in certain cultural conditions.

III. Research Method

A literature search for LPS theories and its components was carried in research databases, both with keywords and by using backwards snowballing. Case projects were studied, where in India two cases were studied from Nadhi Information Technologies namely one Marine jetty project and one residential project. Since, contractors in Norway have a longer history of Lean practices three cases from Skanska and three from Veidekke Entreprenør AS were studied and the projects range from residential, commercial and office building projects. Document studies were undertaken, where the Indian documents were mainly project details (location, project cost, type of project etc.), changes caused in the project by implementing LPS, PPC measurements, productivity reports from site, cycle time charts etc. and the Norwegian documents were mainly handbooks explaining their LPS implementation. Interviews were conducted with various lean coaches from both the countries, four lean coaches and two lean coaches in India and Norway respectively.

IV. Research Findings

- Indian projects use LPS in the middle of projects only during crisis, whereas Norwegian contractors have LPS inbuilt in their systems.
- India and Norway have the same practice for creating phase, lookahead and weekly plans except that Indian projects have had daily stand up meetings and daily PPC measurements, whereas Norway did not have that practice.
- Hofstede scores for India and Norway were obtained from the official website of Hofstede and the scores are presented in the figure below. Findings from interviews regarding the experiences gained by Lean coaches from both the countries, have been related to the six cultural dimensions.
- **Power distance** - Norwegian workers have a better ability to say "NO" to their weekly plans than Indian workers. **Individualism** – Norwegian workers tend to be more concerned with their work where Indian workers appreciate working with teams. **Masculinity** - Indians have assertive decision-making power within a few individuals of a group, while Norwegians might rather listen to all opinions before making collective decisions. **Uncertainty avoidance** – Norwegians have a better practice of making work ready by resolving constraints at the right time, whereas Indian workers tend to leave it unnoticed till the last moment. **Long term orientation** – Lean coaches in both the countries have struggled in making the site workers to think ahead for a 6-8 week lookahead plan. **Indulgence** – Norwegians tend to have team bonding sessions outside work life whereas Indian workers did not have the same social life outside work.



V. Conclusions

Based on differences between the Norwegian and Indian cultures, the potential improvements that could be made in order to improve the process that could involve change in their cultural ethos include:

- **Norway**: Use a Bottom up approach for LPS on the Norwegian side, where the subcontractors and foreman can be taught to plan for the next day in the beginning and a step by step increase to asking them to do the lookahead plan for 6-8 weeks. The foreman who has to lookahead plan for 6-8 week ensure that their actions do not disrupt the 1-2 week plan of the sub-contractor. Norwegian contractors could try other aspects of LPS particularly the daily stand up meetings.
- **India**: Indian counterparts could try LPS at two levels (learning from Norway): a short-term one that only involves coordination among contractors and a medium-term one that involves owners and contractors coordinating design and procurement. The execution engineer, in India, or the person responsible for the activity should be given the freedom to say "No", so that he can make reliable commitments. Owners should not involve in disrupting the planning ability of the contractors in the Indian side; they should be less "masculine" about it in the interest of the project. Higher management should empower entry-level field engineers to have opinions. Especially if just asked to do short-term daily planning, one could increase responsibility to do lookahead planning and have more impact on identifying and handling constraints.

Enabling Lean among Small and Medium Enterprise (SME) Contractors in Sri Lanka

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I. Background

Small and Medium Enterprises (SME) contractors are pursuing to overcome problems through embedding lean. The first principle of lean construction is to identify Non-Value-Adding Activities (NVAA). NVAA in the lean construction lexicon add no value as per the requirements of customers to a product or a service.

They are categorised into eight areas namely transportation, inventory, motion, waiting, overproduction, over-processing, defects and skill misuse. Hence, identification of these eight types of wastes and addressing them accordingly will affect both cost and the time. However, the underlying nature of waste in the construction industry is not clearly visible compared to manufacturing and production. Similarly, neither NVAA nor value-adding activities to enable lean in organisations have been explored in detail with reference to construction SMEs in Sri Lanka.

II. Current conditions

SMEs form a significant pillar of the construction industry in many economies. Lack of sufficient attention to the possible benefits of adopting lean concept has hindered the performance of SME contractors in Sri Lanka. Insufficient knowledge on minimising NVAA is considered as the major barrier for implementing lean. Although the challenges of lean implementation in construction and solutions to overcome them have been previously explored in construction industry, there is a dearth of research on lean implementation in construction SMEs in Sri Lanka. Investigation of the extent to which NVAA are identified by SMEs in Sri Lankan construction is a starting point in this regard. Hence, the paper investigates NVAA, their significance and the causes, which hinder lean implementation in Sri Lankan SME contractors.

III. Research Method

Five case studies were conducted to explore NVAA in Sri Lankan SME contractors. The data collection methods adopted within the case studies were semi-structured interviews with project participants, non-participant observations of progress meetings and study of substantial of the project (tender documents, meeting minutes). The data from case studies were collected and analysed using 5-whys analysis to identify the root causes of NVAA.

IV. Research Findings

Lean construction is still a relatively unfamiliar approach among SME contractors in Sri Lanka. Some organisations follow lean techniques in an ad-hoc manner without an adequate understanding of the concept. Defects, inventory and waiting are the major NVAA categories relevant to SME contractors. Lack of finance, insufficient training, cultural inertia, lack of individual capacities, lack of networking and collaboration, and lack of action learning are identified as the root causes for NVAA of SME contractors.

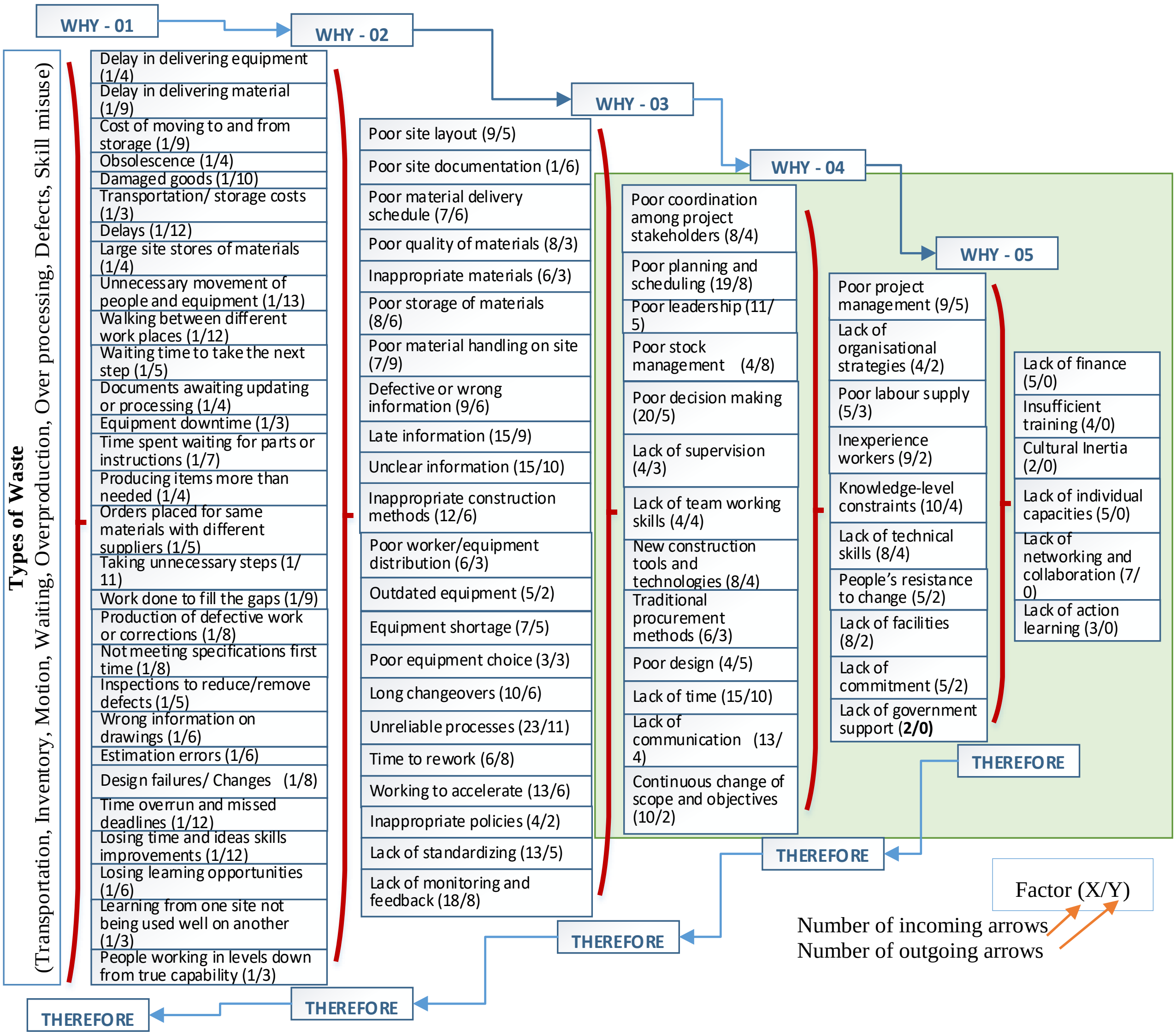

Figure 1: 5-whys analysis for NVAA in construction projects of SMEs

The causes identified under 'WHY 3', 'WHY 4' and 'WHY 5' collectively can be considered as the major causes and should inform the development of capacities necessary for an organisation to implement lean (refer the causes within the green outlined area in Figure 1). Hence, construction SMEs in Sri Lanka require identifying the gaps in their organisations' capacities to reduce NVAA. Therefore, an effort towards capacity building for construction SMEs is an important step to overcome the NVAA.

V. Conclusions

Sri Lankan construction SMEs have not adequately identified the majority of their NVAA and their causes. Hence, the research findings will guide construction SMEs to understand the importance of identification of NVAA in construction projects and their root causes. This study further proves that a detailed understanding of the processes and extensive explorations of all possible causes using the 5-whys analysis will reduce NVAA. In addition, it was also evident that inexpensive or zero cost solutions could be implemented to reduce NVAA. Although respondents expressed their willingness to implement lean to enhance value, they identified lack of capacities as a major constraint against enabling lean adoption among SME contractors in Sri Lanka.

BUILDING A LEAN CULTURE INTO AN ORGANIZATION

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I. Background

India is in the midst of immense and rapid infrastructure growth and the construction industry has yet to fully realize the impact of this. While business volumes will grow, other dynamics will enter like increased competition, reduced margins, shortage of labor etc.

The large and medium size stakeholders (Clients, PMC's, Contractors) in the Indian construction industry are fast realizing that the current project management practices are inadequate to contend with these shifting market dynamics, the rapid pace of works, and still operate profitably. As a result, everybody is on the look-out for systems that can give better control of the projects, improve operational efficiency and profitability so as to compete with (other key) global stakeholders.

This paper proposes an approach that an organization aspiring for such change can adapt and adopt for organizational lean transformation for improved operational efficiency.

II. Current conditions

- Although there are more than a few isolated attempts on embracing lean into organizations, we hypothesize that they are unable to see the transformative impact that they are expecting. This is because, we postulate that they could not formulate a corporate strategy or a holistic approach for organizational lean transformation.
- But, over the past few years people in Indian construction industry are exposed to lean construction. They understand and agree that lean construction would be a vital strategy to improve the performance of construction and create substantial improvements for firms that are adopting it. For that, they need a holistic approach for the organization transformation.

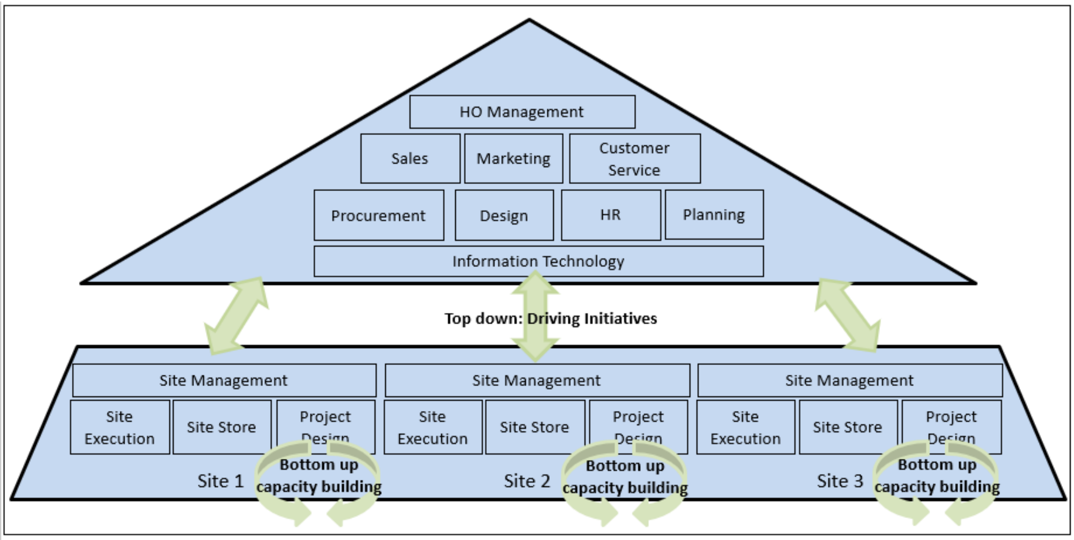
III. Working hypotheses

- The authors' hypothesis is that, isolated attempts can lead to sub-optimal results and probably question the efficacy or applicability of lean.
- What is needed is, a somewhat of holistic approach/strategy that is long term and comprehensive methodology for incorporating/inculcating lean tools, processes, and complementing technologies along with the culture into the organization; to make it sustainable and yield substantial benefits.
- There are references from literature that support this hypothesis. For instance, (Leonova, Ballard and Gehbauer, 2017) mentioned that if the success of lean adoption is sub-optimal, then we need a discussion about improved strategies.

IV. Research Method

Here, we are proposing a two-pronged approach to adopting lean at an organization level with complementary process and technology strategy. A Bottom-Up approach of implementing lean tools at the site to build capacity and collaboration between site teams that is complemented by a Top-Down approach that builds awareness to management drive continuous improvement initiatives.

The approach is explained with two independent case studies that are elaborated below. The first case study (**Bottom-Up Approach: Capacity Building**) is of an EPC contractor amongst the top ten contractors in India with operations pan India. The second case study (**Top-Down Approach: Driving Initiatives)** is of a real estate developer working on large residential projects in Mumbai region, India.



Lean Transformation Strategy

V. Research Findings

- The "Bottom-Up Approach: Capacity Building" was derived out of the authors' experience working with an EPC contractor to roll out LPS and VSM in a scalable and repeatable manner in several projects.
- The "Top-Down Approach: Driving Initiatives" was derived out of the authors' experience working with a real estate developer as a HR initiative to upskill their next generation leaders as the organization prepares itself for growth to the next level.
- The authors here, based on their experience and benefits that the two customers have realized, propose a simple and practical approach for an organization to adopt in its journey to lean transformation.
- The approach needs validation and further development and refinement, something that the authors hope to engage in with their next assignments and report on in the future.

VI. Conclusions

- An approach has been shown that organizations can adopt as a strategy to bring lean transformation to their organizations.
- The approach consists of building capability in the teams from the bottoms up that is complemented by having management drive continuous improvements from the top down. Each approach complements the other and together they help migrate the organization from its current state to a leaner organization that drives continuous improvement. It is prescriptive, yet adaptive to various organizations. The approach is generic enough for adoption both with Owners and Contractors.

COMBINED APPLICATION OF EARNED VALUE MANAGEMENT AND LAST PLANNER SYSTEM IN CONSTRUCTION PROJECTS

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I. Background

In many construction projects a missing project structure and the fact that project progress is not measured regarding the factors cost and time efficiency are major challenges. Due to lack of transparency for stakeholders, deviations from the planned process are not forecasted and measurement of deviations is often taken into account too late.

Earned Value Management (EVM) allows to measure project progress and project efficiency by specific key figures focusing on time and cost. With the Last Planner System (LPS) – a Lean Construction method – projects are planned and executed in collaboration with all participants and process reliability is measured with key figures like the PPC (Percent Plan Complete). The combined application of EVM and LPS in construction projects has not been analysed yet. Therefore, a model for the combined application of EVM and LPS has been developed.

II. Research Method

This research is based on a combination of three methods: firstly, a systematic literature review, which established the context of the current state-of-the-art regarding EVM and LPS in a combined application within the construction industry.
Secondly, a case study driven research took place. The case study project is the design phase of a new build pharmaceutical production plant with a project volume of 215 million € in which EVM and LPS were jointly implemented and analysed.
Thirdly, two rounds of semi structured interviews were conducted. The first round of interviews was conducted to provide a more fundamental understanding of the combined use of EVM and LPS. In the second round the developed model was validated and further developed.

III. Research Findings

Based on the first findings of the research, an abstract model for the combined application of EVM and LPS was developed as shown in Figure 1. The model consists of four workshops equal to the four planning levels of the LPS.

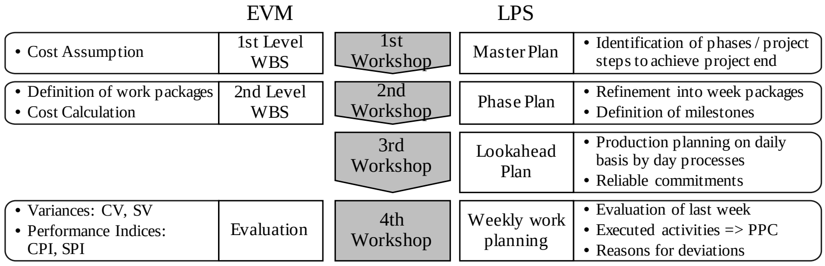

Figure 1: Abstract model of the combination of EVM and LPS

A concept was derived from the model to implement both methods in a project. In collaboration with all stakeholders a project structure is developed in the four workshops (Master Plan, Phase Plan, Lookahead Plan and Weekly work planning). The project structure is broken down into daily processes (Figure 2) and each process is budgeted. By means of this structure the EVM figures (Figure 3), schedule variance (SV) and cost variance (CV), respectively cost performance index (CPI) and schedule performance index (SPI), are measured.

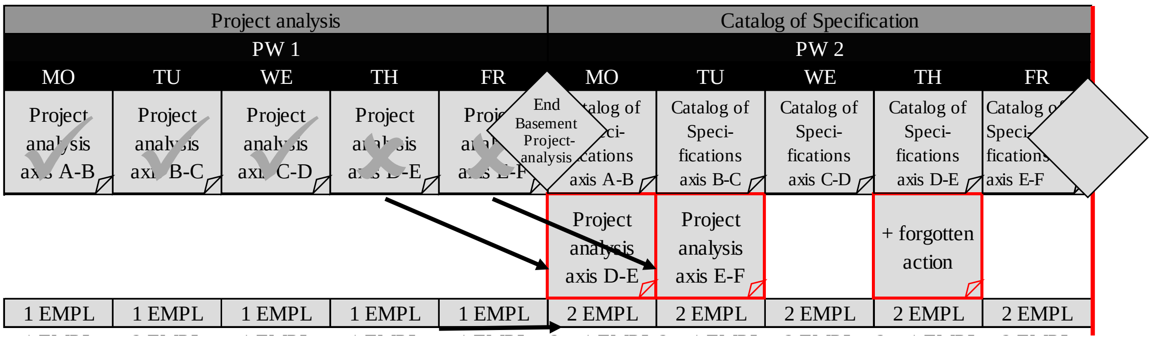

Figure 2: Production planning of the 2nd project week after the evaluation with rescheduling of the not fulfilled commitments

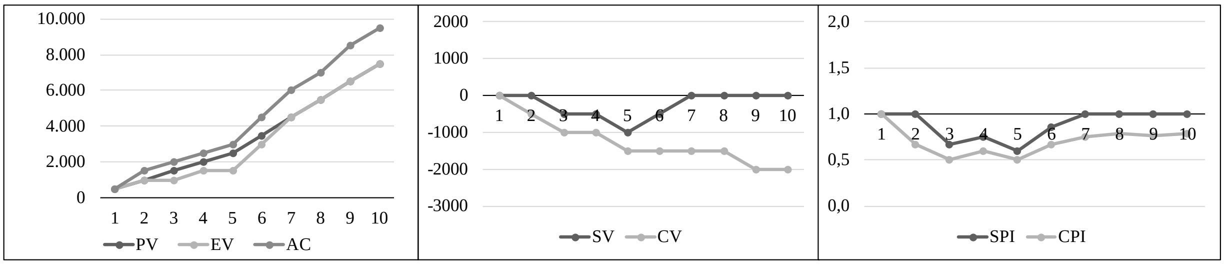

Figure 3: The measures of the EVM after the second project week, planned value (PV), earned value (EV) and actual costs (AC)

IV. Conclusions

Both EVM and LPS are project control systems, but both systems focus on distinct aspects. LPS focuses on the measurement and optimization of workflow. With LPS the reasons for deficiencies are becoming more transparent. But cost or schedule performance in particular are not directly measured. Nevertheless, both factors are of great interest for the customer to have an idea of the current status of the project. Therefore EVM could complement LPS since it focuses on measuring and controlling project progress with regard to schedule and especially costs. Consequently, the joint application of EVM and LPS could lead to a holistic progress measurement of a project considering both quantifiable metrics like schedule and costs but also factors like quality of work flow and collaboration. Analyses have shown that the combination of both systems offers indeed high potential to improve performance of construction projects.

A concept for implementing a combined control system of LPS and EVM was devolved in a design phase of a project – Based on the survey there is no limitation for the implementation in the construction phase of a project as well. Key aspects of both methods were combined, and the concept was developed and finalized on basis of a case study and expert interviews. The case study revealed that a long pre-planning phase is required to implement the suggested concept. Companies, which decide to implement both EVM and LPS, need to establish a strong standard that supports the application of this concept. To achieve this, not only commitment of the project participants (so-called Last Planners) is required, but also commitment of the management is essential for the successful implementation.

If standards are properly set and processes are controlled regularly, the joint application of EVM and LPS can lead to better project performance. Since the concept was developed and validated within the design phase, a further case study or action research within projects with both design and construction phase would be beneficial. All in all, the developed concept offers a sound basis in order to initiate the next steps.

Integration Enabled by Virtual Design & Construction as a Lean Implementation Strategy

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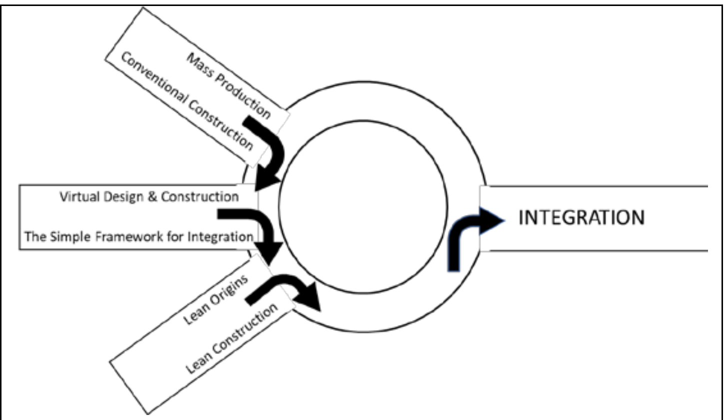
Introduction

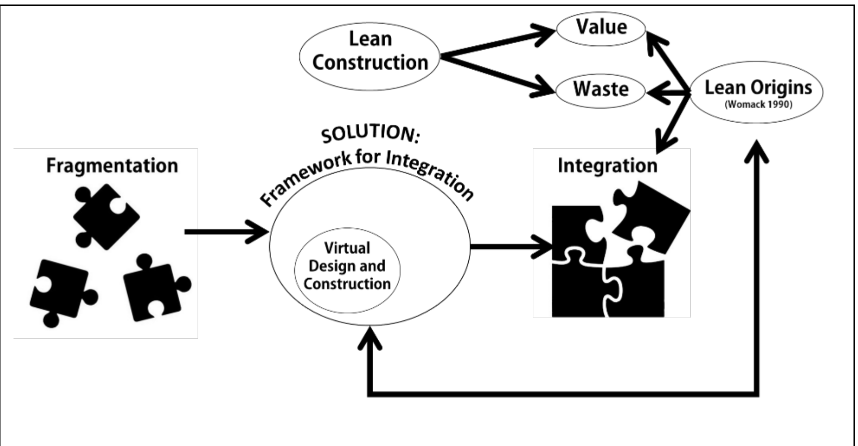
This theory paper probes the intersections of:

- Lean origins
- Mass Production and conventional Construction
- Lean Construction,
- the Simple Framework for Integrating Project Delivery model,
- and Virtual Design and Construction (VDC).



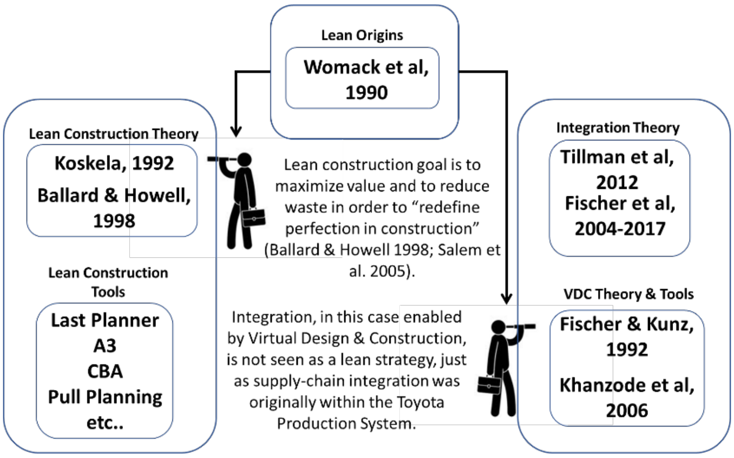
Background

In addition to the lean construction goal to maximize value and to reduce, integration, in this case enabled by Virtual Design & Construction, should be seen as a lean strategy, just as supply-chain integration was originally within the Toyota Production System.



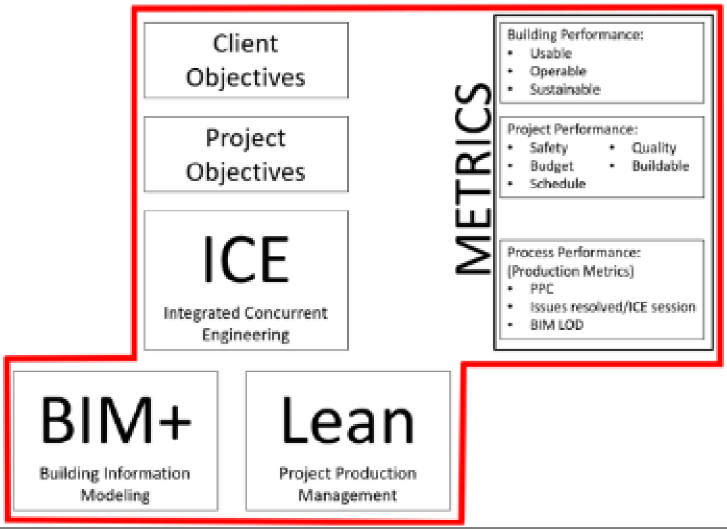
Current Conditions

Lean construction goal to maximize value and to reduce waste in order to “redefine perfection in construction” (Ballard & Howell 1998; Salem et al. 2005), does not consider explicitly integration as a lean strategy.



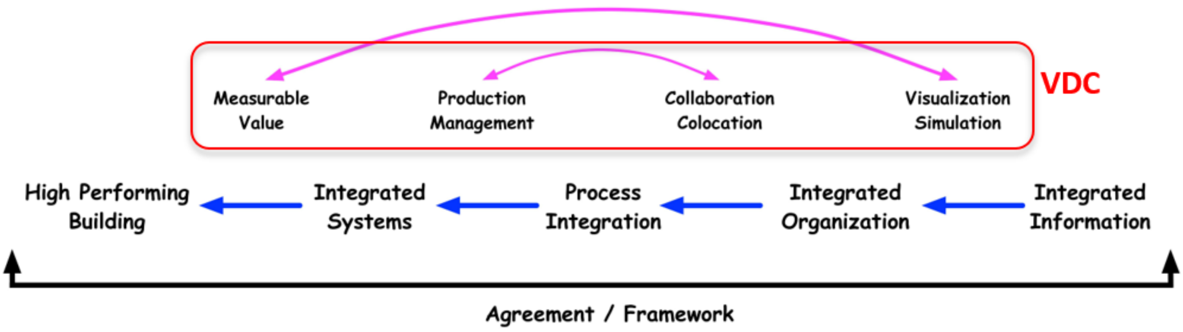
Lean Construction Theory and Integration Theory

Proposal

VDC occurs when its components are part of an integrated approach rather than being used in isolation. It is not enough to adopt each of its components in an isolated way.	VDC: 

VDC is the enabling upper tier of the Simple Framework. VDC functions as a subsystem enabling the integration of knowledge, organization and information required to produce the highly integrated system making-up a high-performing building. Everything people do within the VDC framework allows them to integrate systems, processes, their organization and information so they can deliver high-performing buildings.

Simple Framework for Integration:



Why visual management?

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I. Background

Visual management (VM) has been developed through practitioner efforts rather than being propelled by theoretical insights. However, recently, scholars have started to create a theoretical knowledge base for VM. One reason for the attention to theory has been the insight that design guidelines for visual devices are badly needed, and theoretical knowledge is necessary for creating such guidelines.

II. Current conditions

The only major attempt to theorise on VM is the suggestion of Beynon-Davies and Lederman (2017) to use the affordance theory as an explanatory lens. According to them "an affordance is an opportunity for action made possible both by the effectivities of the actor and by structures in the environment". Based on their theoretical work, they present five prescriptions for developing VM – unfortunately a short summary cannot convey the full depth of these: (1) Visual devices should be thought as multimodal, thus utilizing all senses; (2) Visual devices should be thought of in terms of facilitating action-taking; (3) Physical structures such as whiteboards should be thought as performative structures (how to communicate and what work would result from such communication; (4) The designer of VM should not consider an individual device but should consider the whole physical environment; (5) Patterns of action should be thought of either *as-is, as-if* or *to-be* (current status, targeted status and change).

III. Working hypotheses

The affordance theory is a valuable advance in understanding VM. Unfortunately, it falls short in several respects. For example, the discussion is centred around collaborative devices of VM; these are important but leave the similarly important types of visual devices addressing individual work aside.

Our hypothesis is that VM requires a multi-faceted and multi-level theoretical explanation.

IV. Research Method

We do not attempt to present a fully developed theoretical framework of visual management here but rather provide ingredients for further consolidation of such a theory.

V. Research Findings

We posit that the following viewpoints and domains are relevant in the further consolidation of the theory of VM:

- **Direct and rapid access to information:** According to a well-known theory**,** there are two systems of the mind: System 1 operates automatically and quickly, with little or no effort and no sense of voluntary control, while System 2 allocates attention to the effortful mental activities that demand it, including complex computations. It is posited that that visual information is captured by System 1 and comprehension of written information is handled by System 2. Accordingly, VM shows sheer superiority in terms of the speed of the capture of a conveyed message in comparison to arrangements where messages are written (or oral).

- **Reliability in comprehension:** Capturing the meaning of an image is more direct in comparison to a written or oral message, which as such reduces the potential for mistakes. Thus, there is reason to believe that VM leads to higher reliability.
- **Projection of internal mental models: spraction:** According to Tversky (2011), when thought overwhelms the mind, the mind puts it into the world, in diagrams or gestures; a thought is projected into the world. Thus, human actions organise space to convey abstractions; she calls this *spraction*. Physical action is thus seen as a direct extension of thinking. Some types of visual devices can be explained through this theory.
- **Matching visual devices with different cognitive/action capabilities:** The SRK taxonomy, developed by Rasmussen, refers to skill, rule and knowledge based response of operatives in a work situation. A skill based response is automatic, triggered by the perception of a need for action. A rule based response requires a selection of a rule compatible with the situation, and its implementation. A knowledge based response is needed in a surprising/rare situation, where the background knowledge of the operative on the process needs to be mobilised for problem solving. In the practice of VM systems, it has been possible to create support to all three types of responses.
- **Common ground, situational awareness and shared understanding:** Methods of VM seem often to be geared towards the creation of common ground, situational awareness and shared understanding, which have recently been found to be fundamental for collaboration. Especially, the practice of the Big Room (*obeya*) seems to be a paramount means towards creating a broad and solid common ground in product development or facility design.
- **Avoiding visual overburdening:** The method of 5S is considered part of visual controls. This method achieves organisation of the workplace through cleanliness, rejection of unneeded items, and order. Cognitive and neurological evidence suggests that absence of irrelevant visual detail, resulting from the application of 5S, facilitates the direct capture of relevant visual information and reasoning involving visual data.
- **Creating adherence:** In VM, the abstract concept of discipline is transformed into directly observable concrete practices. In view of this, VM can be seen as visual rhetoric, targeting adherence by the audience**.** This connection offers the opportunity of making the rich legacy of rhetoric to bear on understanding and designing VM.
- **Why is visual management preferred in some managerial approaches and not in others?** In lean production, elimination of waste requires reduction of cycle times and variability. Mental operations, such as communication and decision-making are strictly seen waste in production; they are not adding value to the customer. Through VM, communication and decision-making can be sped up. On the other hand, the higher reliability of VM translates into lower variability. Thus, VM has emerged as an intrinsic part of lean production as it is compatible with its first principles. In the mainstream approach to management and organization, such operational benefits of VM remain invisible.

VI. Conclusions

VM is at a fascinating crossroads of different phenomena, and of disciplines, old and new, addressing them. Several angles and levels will probably be needed for creating a practically complete theoretical account of VM.

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Determining Benefit - Understanding Buildings as Production System Assets?

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I. Background

Maximizing the client value delivered from construction projects is to large degree a matter of maximizing the benefit in use of the built asset. To do so, we must be able to accurately assess the benefits of a proposed solution at the time of design. While some authors have looked at simulation solutions for examining this issue, we believe that this research is putting the proverbial cart before the horse. A more fundamental understanding of what answers we seek is needed before considering how this technically speaking could be done

II. Current conditions

- The role of buildings is to serve as production infrastructure
- There exist no theoretical frameworks for explaining what this entails

III. Working hypotheses

- Fundamental production theory can be used as a basis for describing and optimizing buildings as production system infrastructure

IV. Research Method

- Anchored in the pragmatic research paradigm
- Abductive reasoning based on Scoping study to identify relevant literature

V. Research Findings

Production Systems Theory

- Two fundamental activity types in production systems
  - Transformation – Value adding processing of product or service
  - Flow – All non non-value adding activities (e.g. waiting, moving, inspection)
- All productions systems contain variability
  - Variability must be buffered
  - If variability is not buffered ad-hoc buffers will appear

Production system model

- To determine if a proposed building design can support the production system that will be housed in the building, a model of the production system is needed.
- We refer to such as model as a Building Activity Model (BAM)

Evaluation methods

- Two fundamental evaluation methods:
    - Analytical
        - Verification – Showing that all system trajectories satisfy the desired property. Yields binary yes/no answers
        - Calculation – Doing mathematical operations on system variables. Yields numeric values
    - Simulation - techniques for using computers to imitate the operations of various kinds of real-world facilities or processes
- Models can be either:
    - Deterministic – all the input variables are known
    - Stochastic – One or more of the input variables are uncertain

BAM evaluation

- Can the activities be done?
    - Verification suffices to determine if an activity can be performed at all
    - Calculation or simulation is required to determine if the building has sufficient capacity
        - Calculation can suffice for simpler scenarios
        - Simulation is required for complex scenarios such and for systems with high variability
- Can the activities be done well?
    - Activities can underperform due to flow issues or due to process issues.
        - Flow issues – Those that cause an activity to be starved of some material or input. For example, staff spending a disproportionate time waiting in line or hunting for bathrooms if the capacity is too low.
        - Process issues – Do not cause non-performance but rather degrade performance. Could be related to the characteristics of the building, e.g. suboptimal lighting, or caused by other activities in the system, e.g. noise in an office landscape.
    - Some aspects could be considered using simple calculation.
    - The interdependencies in production systems entails that simulation is required to fully determine how well an activity can be done in a building.

VI. Conclusions

- Evaluating the benefits of a building at design time requires an analysis of its ability to support the production system that it will house.
- To do so there are two fundamental questions that we must be able to answer:
    - Can the activities of the production system be performed?
    - How well can they be performed?
- To fully determine to which extent a proposed design will support the activities that will take place in it, computer simulation is required.

Stakeholder Value Evolution, Capture and Assessment in AEC Project Design

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I. Background

As per the Transformation Flow Value (TFV) theory, it is imperative that AEC project design be viewed through the lens of value in addition to transformation and flow (Ballard and Koskela 1998). Studies have shown that the strategies and the durations of the design of a particular organization was dependent on its design objectives (Joe et al. 2017). Understanding client value in construction is challenging owing to the extended time taken for completion of projects and the presence of stakeholders with conflicting objectives. Due to the multidimensional, subjective and dynamic nature of value, arriving at an agreement on a set of values for an AEC project is a challenge. It can be stated that, the success of a design lies in its ability to fulfil client values. However, the ambiguity in the identification of values by clients renders the task complex.

II. Current conditions

Despite ongoing efforts by researchers to develop a theory of value in the construction industry, a common definition has not materialized. Traditionally, values in an AEC project have been related to time, cost, quality, safety, environment, function, etc. However, studies show that investment in a good design produces economic and social returns as well (MORI 2002). Although, literature reports a number of tools and techniques for design value capture, stakeholder requirements in AEC projects are pluralistic and complex in nature. Moreover, the iterative, explorative and reflective nature of design suggest limitations in effective applications of the existing tools in managing design requirements

III. Working hypotheses

- *There exists a set of stakeholder values for the design of Institutional Buildings which can be captured using qualitative methods*
- *These design values can be quantified using stakeholder preferences*

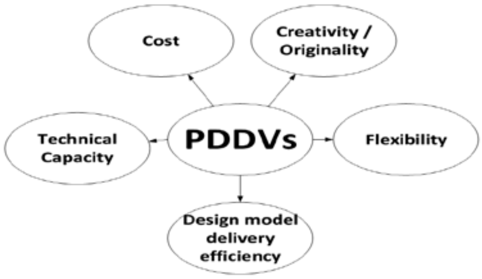
IV. Research Method

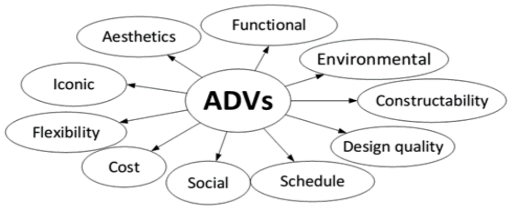
This work explores the process of client value generation and evolution which are based on ethnographic study of the architect selection process of two institutional buildings. The ethnographic study consisted of participant and non-participant observations of the project conceptualization and architect selection process. The first author was a part of the team involved in the drafting of design brief for the project, studying and analysing the proposal documents submitted by the architects. The second author was a member of the committee involved in design evaluation. In addition, semi-structured in-depth interviews of nine key informants and document analysis were conducted.

V. Research Findings

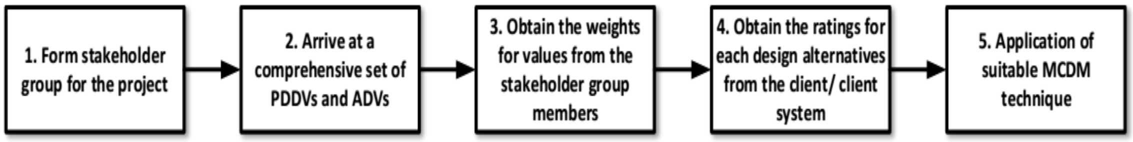
The main outcomes of the exploratory study were:

- The identification of two types of design values: Project Design Delivery Values (PDDVs) and Architectural Design Values (ADVs)
- PDDVs provide indications of the delivery performance of an architectural team, whereas ADVs are reflected in the architectural plans and features of the design.





- Framework for evaluation of value in design using Multi Criteria Decision Making technique



VI. Conclusions

The paper initially provides an account of the study that was conducted to understand the process of expressing the design values of two institutional buildings through an ethnographic study. The study reveals the significance of the presence of diverse experts and their involvement in defining the design brief. The study gives accounts of the capture and evolution of a comprehensive set of design values through iterative dialogues between stakeholders. Two categories of design values, viz. PDDVs and ADVs, for construction project designs were identified. Further, the study witnessed the evolution of PDDVs and ADVs into objective detailed design requirements.

The outcomes of the study provide a foundation for a new framework for assessing a design based on these values. The framework mainly considers stakeholder group preferences for evaluating and ranking design alternatives using appropriate MCDM technique.

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IMPLEMENTATION OF MASS CUSTOMIZATION FOR MEP LAYOUT DESIGN TO REDUCE MANUFACTURING COST IN ONE-OFF PROJECTS

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I. Background

Mechanical, Electrical and Plumbing (MEP) are complex systems representing a considerable portion of commercial and industrial projects, comprising 25%-40% of the total project cost and covering more than 50% of the total duration of the project.

MEP system is composed of the numerous components with different sizes and shapes having complex logic structure among them. Designing MEP systems involves defining the location and routing for different components of building systems to comply with diverse design and operation criteria.

II. Current conditions

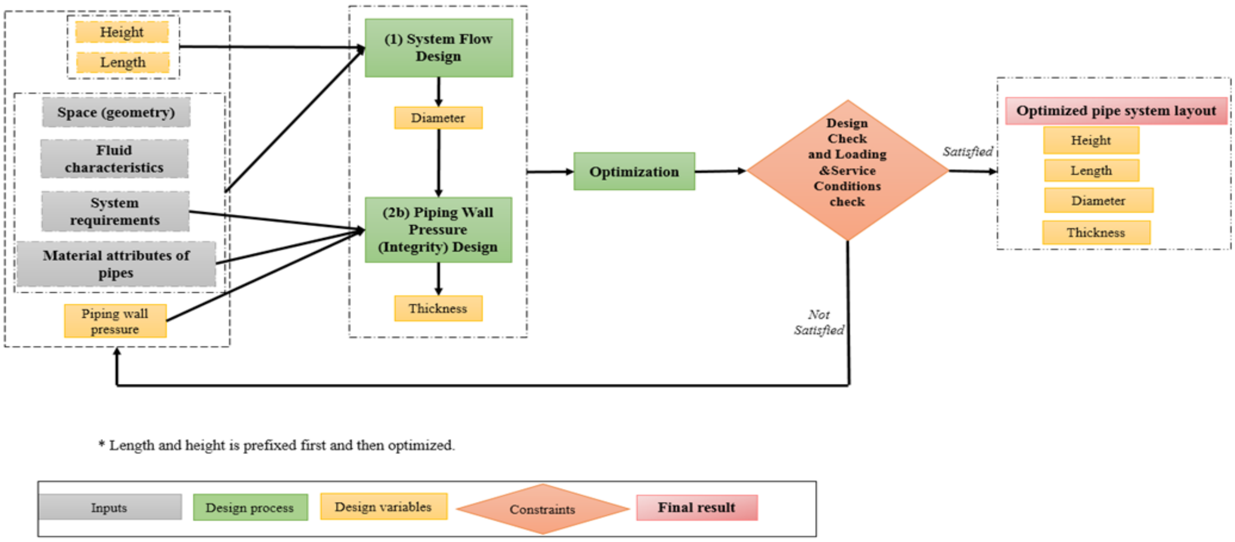
- The layout design of MEP system is generally based on client and system requirements, space limitations, interference within the system as well as with other trades. Not much importance is given to the design optimization as per fabrication and constructability perspective, thereby often increasing cost and time to a project in term of its component manufacturing.
- Most visible parts of MEP design only focus on geometry and functionality of the building systems. Thus, there is an increased need to focus on how the manufacturing cost of various MEP components can be curtailed keeping their performance and operation at their best.
- There is a need to automate the process of MEP design layout with the use of mass customized components to reduce the manufacturing cost of the components.

III. Research Objectives

- This paper introduces Design for Manufacturing approach into MEP system design to reduce the manufacturing cost of different MEP components using mass customized components.
- This study proposes a framework to automatically develop the layout of the piping system using mass customized components. The framework can be further applied to other MEP aspects such as Mechanical & Electrical with relevant changes.
- This study hypothesizes that using mass customized MEP components will increase the efficiency and reduce the cost for manufacturing of the MEP components. The presented theoretical framework is the basis for further research.

IV. Framework on piping system layout design using mass customized components

- Determination of pipe size and route is one of the most important and critical activities for any piping project. The selection of the optimal pipe route (length), diameter, wall thickness, material and equipment location is typically the result of economic scrutiny and investment evaluation of the most reasonable structure developed through the design phase.
- Calculation of Pipe size refers to the completion of two independent design functions: the fluid flow design and the pressure-integrity design.
- After calculation of minimum size requirement of the components, there is a need to determine what can be the best layout and optimum dimensions for a particular piping component, which can be used repetitively in order to mass customize the whole piping layout on the basis of the above two designs. Therefore, a fast and reliable optimization technique is required to get the best fitted standard dimensions of a component for mass customization of the piping layout.
- The figure below shows proposed framework to obtain pipe system layout having standardized components:



V. Conclusion and Discussions

- Current MEP system design focus only on the geometry and functionality requirement of the building systems.
- However, none of the previous study considered the importance of manufacturing cost associated with variety of MEP components and ease of the manufacturing of these components, during design stage.
- The manufacture of diverse components in MEP system constitutes huge cost and time, thereby often increasing cost and duration to a project. Thus, there is requisite on how the manufacturing cost of various MEP components can be curtailed keeping their performance and operation at their best.
- The benefits mass customization aims to offer increased product flexibility by standardizing components without increasing manufacturing costs is comprehended in this research.
- The developed framework also focuses on manufacturing aspects of MEP components in addition to operational requirements, which will solve many of the current MEP design problems such as not accounting constructability issues, low level of standardization etc.

Choosing by Advantages; Benefits Analysis and Implementation in a Case Study, Colombia

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I. Background

Decision-making may be one of the most common processes that faces professionals in the day-to-day work, but this practice could be very complex, especially when several objectives, factors, criteria and alternatives must be considered. These processes involves multiple objectives that use different methods of multicriteria decision-analysis (MCDA). Choosing by advantages (CBA) is one of the methods that takes into account the comparisons of the advantages of alternatives in order to construct the preferences of the decision-makers. Due to the importance of this process, this research analyses and compare the traditional methods used actually in the Colombian Industry with CBA method in the selection process of the structural contractor in a new University's facility construction.

II. Current conditions

- The structural contractor on a project was selected by a traditional method, according to the law 80 of 1993, taking into account the technical and economic criteria contained in the specifications.
- The tendering with the cheapest bid was the most favourable.
- In order to support these decisions, the project manager provided all the project information needed for the process: a) the contract specifications where specify the factors and the criterions, b) the four alternatives proposals and c) the tendering evaluation used to take the decision.

III. Working hypotheses

- *The application of CBA method allows to consider more factors that affects the alternatives in comparison with the traditional method.*
- *The cost bias the selection to the cheapest offer if it is considered as a factor in the traditional methods of contractor selection.*

IV. Research Method

The focus of this study is the comparison of the CBA with the traditional method in the Colombian AEC Industry. With the goal of establishing if the CBA method provides significant advantages and add value over the other method, first, a background literature study of MCDA was made in order to deepen about the CBA application and its relation with similar methods used for contractor selection. In addition, from the case study, it was possible to compare the results of CBA with the results obtained based on the selection and hiring processes through the law 80 of 1993 of Colombia. Finally, the paper analyses the impacts of the decision taken on the project develop.

The selected project is an University's facility construction conformed by 8,555m2 constructed in irregular five stories and three basement building located in the middle of the campus of the Universidad de Los Andes (see Figure 1), located along the slope of the eastern range of the Andes Mountains.

Figure 1: Revit model of Case Study

V. Research Findings

- The best option applying the traditional method is the worst by applying CBA (see Figure 2).
- CBA considers that the best alternative is the one that provides more value to the project.

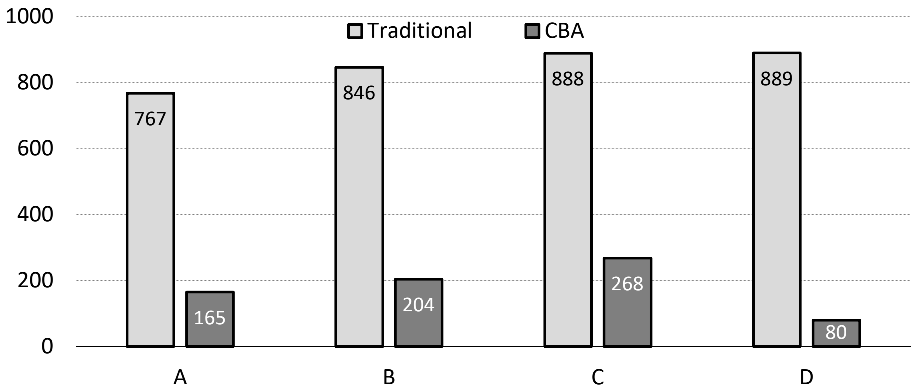

Figure 2: Comparison of results Traditional vs. CBA

VI. Conclusions

- The comparison of the traditional method and CBA allows analyzing the decision in two different perspectives of the construction management: the management in the world of the cost and the management in the world of the value.
- The difference of the results among alternatives varies among methods; partly, as a consequence of not considering the cost as the main criterion
- In CBA, the results of alternatives are easy to analyse, identifying the advantages, the factors in which is the difference and offer clearness to the criteria.

Simulation Exercise for Collaborative Planning System / Last Planner System™ (COLPLASSE)

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I. Background

Though the Last Planner System™ is becoming quite popular, in some regions where robust planning exercises are not commonly practised or background planning experience is not that strong, it is found difficult to develop the various structured templates, etc for the LPS. A simulation exercise, COLPLASSE (COLlaborative PLAnning System Simulation Exercise), has been developed to cater to this felt need.

II. Current conditions

- There are a few simulations and games available for LPS but these ae generally complex, require many players or need to be bought or subscribed to.
- Also, since these simulations are closed systems, it is not possible to adapt them to one's own requirements or contexts.

III. Working hypotheses

- *This open system simulation employs the well-known and popular Microsoft Excel spreadsheets as the base.*
- *It unfolds the Lean planning systems and concepts such as Look Ahead Plan, PPC Analysis, Root Cause Analysis, etc over the construction duration in a series of connected spreadsheets.*
- *It can help in teaching initial planning as well as planning updates to remediate production losses due to various factors.*
- *It has been kept simple, by design, to enable easy adaptations to a variety of problems, for training as well as for real-life cases.*
- *It has built-in automated graphics for depicting PPC trends as well as Root Cause Analysis.*
- *Further developments are ongoing mainly by deploying more Excel macros to infuse greater flexibility for tackling larger real-life cases.*
- *With its open domain architecture, users can freely make adaptations for varying contexts*

IV. Research Method

An *Initial Sheet* lists out the various basic data required for the simulation, including list of activities, quantities of work, number of crews available, average productivities, etc. One can introduce a Period of Inclement Conditions (such as monsoon) for specific weeks when such conditions prevail, which reduce the productivity of all activities performed in such periods. Also, probabilistically-evolved Productivity Modification Factors can be introduced individually for each activity for each work week, which increase or decrease the quantity of work performed during that week for the specified activities.

The simulation has as many intermediate spreadsheets as the number of work weeks, for the work plans (Fig. 1). The Final Sheet, at the end of the various work weeks, contains the results of analysis of the execution parameters, compiled automatically during the play-out of the various weeks.

V. Research Findings

No of Buildings = 50

PPC Check

S No	Work Item	Qty / Bldg			Total Qty	Productivity			No of Cre	No of day	Typ Qty/ wee	Qty Complet ed till	Qty Balan ce	Quantity planned each week				Likely Constrai nts	Action Plan	Expect ed Quaniti	PMF	MF	Modifi ed Qty	Actu al Qty	PPC 1 / 0	Root Caus e
		Nos	Vol	UoM		UoM	Qty	UOM		(8 hr day)	(6 days)/			3	4	5	6			Week NO:						
	No of Running Week													3	4	5	6			3						
1	Excavation	8	20	CuM	400	Nos	2.5	hrs/Ftg/crew	6	21	115	0	170	115	115	115	55			115	1.2	1	138	138	1	A
2	Foundations	8	3	CuM	400	Nos	3	hrs/Ftg/crew	7	21	112	0	0		112	112	112			0				0	NA	
3	Precast Columns	8	3	CuM	400	Nos	1	hr/no/crew	2	25	96	0	0			96	96			0				0	NA	
4	Precasting	8	1.5	CuM	400	Nos	1	hr/no/crew	2	25	96	0	0				96			0				0	NA	
5	Precasting HCS	4	1	CuM	200	Nos	1	hr/no/crew	2	13	96	0	0							0				0	NA	
6	Plinth Beams	8	0.4	CuM	400	Nos	1.5	hr/no/crew	3	25	96	0	0							0				0	NA	
7	Erecting Columns	8	8	Nos	400	Nos	1	hr/no/crew	2	25	96	0	0							0				0	NA	
8	Erecting Beams	8	8	Nos	400	Nos	1	hr/no/crew	2	25	96	0	0							0				0	NA	
9	Erecting HCS	4	4	Nos	200	Nos	1	hr/no/crew	1	25	48	0	0							0				0	NA	
10	Screed concrete		20	SqM	1000	SqM	5	sqm/hr/crew	1	25	240	0	0							0				0	NA	
11	Blockwork walls		72	SqM	3600	SqM	10	sqm/hr/crew	2	23	960	0	0							0				0	NA	
12	Plastering walls		120	SqM	6000	SqM	15	sqm/hr/crew	2	25	1440	0	0							0				0	NA	
13	Waterproofing		20	SqM	1000	SqM	10	sqm/hr/crew	1	13	480	0	0							0				0	NA	
14	Floor Tiling		20	SqM	1000	SqM	8	sqm/hr/crew	1	16	384	0	0							0				0	NA	
15	Painting walls		120	SqM	6000	SqM	8	sqm/hr/crew	5	19	1920	0	0							0				0	NA	
16	Electricals		1	LS	50	LS	4	hr/no/crew	2	13	24	0	0							0				0	NA	
17	Plumbing		1	LS	50	LS	4	hr/no/crew	2	13	24	0	0							0				0	NA	
18	Finishing		1	LS	50	LS	2	hr/no/crew	1	13	24	0	0							0				0	NA	

Create Next LAP

... Project Data | Basic Data Sheet | Phase Schedule | LAP 1 | LAP 2 | LAP 3

Fig. 1 Screen shot of typical Running Sheet for an example problem

- The LAP is typically 4 weeks for the example simulation. For each current week, the balance quantities are automatically brought forward from the previous week. Depending on the number of crews available, productivities and the modification factors, the current week’s quantities are worked out and compared with that required from Milestone and Phase schedules. PPC is then calculated and automatically plotted cumulatively. Depending on Productivity Modification Factors used, Root Causes are identified from a standard Library and a Root Cause occurrence pie chart is also automatically developed cumulatively.

VI. Conclusions

- There are different ways of using COLPLASSE: As a simple planning tool which can be used to trach the early students in the LPS templates; as a group exercise involving 8 to 9 people simulating various responsibilities; running COLPLASSE by an entire class independently and comparing “efficiencies” of various players, as the random number generation system used for Productivity Modification Factors will ensure different results for each player; using COLPLASSE for actual problems at site week after week.
- Limitations: the inherent designed simplicity precludes complex planning exercises. The Excel macros currently built-in are not very advanced but the user can always develop them further in view of the open architecture.
- Further research is proposed to be done using this simulation with various groups to evaluate its capabilities for helping nascent practitioners to use LPS.

The evolution of Lean Construction education (PART 1 of 2): at US-based universities

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I. Background

Effectively transferring lean knowledge and skills to owners, architects, engineers, and constructors (OAEC) requires behavioral changes within an industry that has been legitimately criticized for entrenched practices and low productivity. Documenting how successful that knowledge transfer is taking place can be helpful to those wishing to efficiently introduce lean into their own OAEC organizations. Lean educational efforts within academic settings have been brought to light through earlier publications. This research identifies the content of lean construction courses from five US-based universities to add to the seven previously documented.

II. Current conditions

The content of seven (7) lean construction course curricula had been previously published in Tsao, C., Azambuja, M., Hamzeh, F., Menches, C. and Rybkowski, Z. K. (2013). "Teaching lean construction: perspectives on theory and practice," *IGLC-21 Proceedings*, Fortaleza, Brazil. This paper represents an expansion of this prior work by adding five (5) universities to the list, with the intent to understand how lean construction education content is evolving at US universities.

III. Research methods

The researchers contacted five university faculty members who teach lean construction. Faculty completed and returned an e-mailed excel spreadsheet and responded to follow-up questions by telephone for clarification when needed.

IV. Research Findings

Some examples of reported lean course frameworks include:

- *Factory Physics* and its application to construction (Hopp and Spearman 2001);
- Eleven (11) principles from *Technical Report #72* (Koskela 1992);
- Fourteen (14) principles from *The Toyota Way* (Liker 2003; Figure 2);
- *Lean history and theory* from manufacturing to construction (Taylor 1947; Spriegel & Myers 1953; Gilbreth & Gilbreth 1963; Ohno 1988; Deming [Dawson-Pick 2004]; Liker 2003; Koskela 1992; Ballard 2000; etc.
- *Modern Construction* text (Forbes and Ahmed 2011); and
- Course modules from the Associated General Contractors (AGC 2017).

Of the 12 university lean construction curricula tabulated, we found the following:

- The most frequently played simulations include the *Parade of Trades* (all 12); the *Lego®Airplane Game* (or its lower cost variants—the Cup Game, Light Fixture Game, or Make-A-Card) (all 12); and Silent Squares (7 out of 12).
- The standard required reading diet of most lean construction courses in academia include IGLC papers (9 out of 12), published journal papers (7 out of 12), Koskela's *Technical Report #72* (1992; 6 out of 12), and Liker's *The Toyota Way* (2003; 6 out of 12).

IV. Research Findings *(cont'd)*

OVERVIEW	U. Cincinnati	Arizona State	San Diego St.	S. Illinois U.	Amer. U. Beir.	Ill. Inst. Tech.	Texas A&M	N Carolina St	Virginia Tech	Colorado St	Michigan St	Pittsburg St
Instructor	Tsao	Mitropoulos	Alves	Azambuja	Hamzeh	Menches	Rybkowski	Liu	Muir	Senior	Abdelhamid	Levens
Undergrad/Grad	Both	Graduate	Graduate	Undergrad	Both	Grad	Both	Grad	Undergrad	Grad	Grad	Both
Required/Elective	Both	Required	Required	Elective	Elective	Required	Elective	Elective	Elective	Elective	Elective	Elective
Enrollment	10-26	8 to 24	8 to 23	10 to 25	20 to 22	40	10 to 25	20 to 30	10 to 25	8	10	10 to 15
Semester/Quarter	Quarter	Semester	Semester	Semester	Semester	Semester	Semester	Semester	Semester	Semester	Semester	Semester
Weeks	10 of 10	8 of 16	15 of 15	16 of 16	16 of 16	16 of 16	16 of 16	15	15	16	15	16 of 16
Started	2005	2004	2009	2010	2011	2012	2011	2008	2018 (antic.)	1999	2001	2016
Ended	2008	2010	Continuing	Continuing	Continuing	Continuing	Continuing	Continuing	New	Continuing	Continuing	Continuing
Night/Day	Day	Night	Night	Day	Day	Night	Day	Day	Day	Evening	Evening	Day
Guest lectures	1 to 2	0	5	0	1 to 2	0	2-3	1	2-3	3-4	1-2	None
GRADING												
Assignments	X	X	X	X	X	X	X	X	X	X	X	X
Contribution	X	X	X	X	X	X	X	NA	X	X	X	X
Discussion forums					X			NA			X	
Exams	X	X	X	X	X	X	X	X	X	X	X	
Field trip	Toyota						Toyota	X	X		X	LCI Kansas Cty
Reflection papers	X				X			X	X	X	X	
Simulations	X	X	X	X	X		X	X	X	X	X	X
Team projects	X	X	X	X	X	X	X	X	X	X	X	X
Additional:												
Video presentation										X		
READINGS												
Ballard 2000							Required	Required	Required	Required	Optional	
Factory Physics			Recommend								Optional	
Gilbreths 1963							Required				Optional	
Goldratt 1992	Required	Required					Ch 13 req'd	Required		Required	Optional	
IGLC papers		Required	Required	Required	Required		Required	Required	Required	Required	Required	
Journal papers				Required	Required		Required	Required	Required	Required	Required	
Koskela 1992	Required	Required	Required				Required	Required		Required	Optional	
LCI white papers			Required					Required	Required		Optional	
Liker 2003	Required	Required	Recommend	Required	Required	Required	Required				Optional	
Oglesby 1989		Required						Required		Required	Required	
Taylor 1947							Required			Required	Optional	
Womack at al.1990	Required	Required				Recommend		Required			Optional	
Additional:												
AGC Textbook											Optional	Required
Aker, 2nd ed.											Optional	Optional
Forbes & Ahmed 2010											Required	
Martinez 1996											Required	
Schmaltz 2017											Required	
SIMULATIONS												
5S Game							X				X	
Airplane Game	X		X	X	X		X	X	X		X	
Cocktail Napkin							X					
Cups Game		X				X						
Delta Design	X										X	
Deming's Red-Bead							X			X	X	
Helium Stick	X				X			X				
Leapcon				X		X					X	
Magic Tarp	X											
Maroon-White					variant		X				X	
Origami Game	X											
Parade Game	X	X	X	X	X	X	X	X	X	X	X	X
Radioactive Popcorn				X								
Silent Squares			X	X	X	X		X	X		X	
TVD Game							X				X	
Win As Much As…	X				X	X				X	X	
Additional:												
Ball Game											X	X
DPR Block Tower									X			X
Gemba Walk									X			
Last Planner (AGC)											X	
Leadership Styles											X	X
Lego Hotel/Tower											X	X
Light Fixtures										X	X	
Make-a-Card											variant	X
Marshmallow Challng											X	
NASA Survive/ Moon											variant	X
No./Task Switching											X	
Oops								X				
Original Dice Game											X	
Prison Door Case											X	
Repairman												
Villego								X			X	X

V. Conclusions

Tabulated results revealed that: (a) the content of lean curricula is evolving *as grading formats, types of readings, and numbers and types of simulations have grown*; and (b) *lean curricula as defined by the Associated General Contractors (AGC) lean certification program is starting to permeate academic coursework*. This may be a testament that AGC lean certification is providing some advantage in career placement for students.

Investigation of the evolution of lean education within academia helps us better understand a driver of change as students enter the OAEC industry following graduation. The intent of this paper is to document this moment in time, as well as to raise a question about the potential impact of curriculum standardization on future continuous improvement initiatives with respect to lean construction philosophy, methods, and tools, in the OAEC industry.

The evolution of Lean Construction education (PART 2 of 2): at US-based companies.

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I. Background

The benefits of lean projects are well documented; yet many owners, architects, engineers, and constructors (OAEC) often have relatively little knowledge of the lean methodology due to its relative newness. Many participants in the lean movement such as members of the Lean Construction Institute (LCI) attribute project success to the lean training that is typically conducted to prepare participants and align the team with the priorities of the project. While lean education has been studied in the academic arena, less attention has been directed to researching education at the company and project levels. This study represents a starting point for an understanding of lean education at these levels.

II. Current conditions

Major challenges to implementing lean on a job site include: (1) lack of lean knowledge, (2) lack of sufficient support, (3) perception that lean is too complex, (4) employee resistance, and (5) lack of industry support. The content of seven academic lean construction course curricula had been previously published in Tsao, C., Azambuja, M., Hamzeh, F., Menches, C. and Rybkowski, Z. K. (2013). “Teaching lean construction: perspectives on theory and practice," IGLC-21 Proceedings, Fortaleza, No comparable study has been noted for the non-academic and project environments.

III. Research methods

A modified Delphi approach was utilized to interview executives, lean champions and trainers from several OAEC organizations that are known for their leadership in lean construction projects. A cross-section of established construction firms, design firms, and consultants were surveyed to identify current best practices. These organizations are all members of LCI or the Associated General Contractors (AGC). Fourteen (14) individuals were contacted (as subject matter experts) both by email and/or conference calls to identify the strategies used by OAEC stakeholder companies to impart lean practices to employees.

IV. Research Findings

There is a rapid increase in the demand for lean training of OAEC members, and it is provided through a variety of venues. LCI provides educational resources to 31 Communities of Practice throughout the US. and publishes and distributes educational books and lean simulations. They include the Make-a-Card-Game, the Parade of Trades (Tommelein et al. 1999), and Silent Squares (LCI 2017b). LCI’s “Introduction to Lean” class, presented at conferences, also includes the Lego® Airplane Game, a Big Room simulation and a Target Value Delivery (TVD) module. LCI also publishes the *Lean Construction Journal* (LCJ).

The AGC’s “CM-Lean” certification course comprises seven units and is taught by over 100 specialists throughout the US in a bricks-and-mortar setting. Each instructor aligns the course with specialized AGC textbooks and also presents the same simulations. The topics include Variation in production systems, Pull in Production, Lean Work structuring, The Last Planner System, Lean Supply Chain and Assembly, Lean Design and Pre-Construction, problem solving principles and tools. Other topics include root cause analysis, the lean triangle, co-location, kanban, Choosing by Advantages (CBA; Suhr 1999), Plan-Do-Study-Act, etc.

Leading contractors such as DPR, JE Dunn and Linbeck have developed in-house training programs. DPR's lean training includes the Lego® Airplane Game, Silent Squares, and the DPR Pull-Planning Game. Dean Reed of DPR reports a reduced focus on tools, more emphasis on leadership, and a "respect for people" culture through a nine-week program called "Lean Leadership".

JE Dunn Construction: With the help of VP Rebecca Snelling and their in-house training program, there have been substantial savings on several projects. The training includes the Lego™Airplane Game, the Parade of Trades, and Silent Squares

Linbeck Construction: Training includes pull planning and Lean board tracking. All Linbeck projects are pull-planned and involve posting a master (milestone) schedule, phase schedule, two week-look ahead plan, and weekly work plan.

Several architects have been applying lean construction methods to design thinking. At Boulder Associates Romano Nickerson and Todd Henderson have led the process; they are also discovering that Agile and Scrum, which are heavily practiced by the software design industry, may be a better fit for architectural design than the Last Planner® System

Lean consultants: Hal Macomber, as a lean construction pioneer has made critical contributions to many lean practices including: Study Action Teams (SATs), Reliable Promises, and the "5 Big Ideas". His recent work the "Pocket Sensei" continues his lean advocacy.

Large owners; Sutter Healthcare has developed an in-house training program with Digby Christian as director of Lean Integrated Project Delivery. Training is provided through a combination of in-house and external resources; the curriculum includes Last Planner and Target Value Design as well as the DPR Block Game, Parade of Trades, and Villego.

V. Conclusions

The results of this new study with lean construction leaders in the U.S. provide valuable lessons for the industry. The findings suggest that many OAEC stakeholders view a knowledge of lean as providing a competitive advantage, and they are trying to deploy lean training as rapidly as possible. Interest in lean construction and IPD has accelerated especially with the training that is provided at LCI conferences. Construction professionals have been actively seeking the AGC's CM-Lean credential. Designers are exploring alternatives to the LPS for optimizing lean projects. Construction companies have been developing customized training programs for their staff as well as trade partners on projects. Large owners have also developed in-house capabilities to derive the greatest benefit from lean projects. The "internal lean consultant" approach used by DPR, JE Dunn, and Linbeck Construction is reportedly an effective approach to lean deployment for contractors. DPR's leadership emphasis is also claimed to be highly effective.

VI. Follow up

This study provides an important reference point for future research on a standardized lean curriculum for the industry. Given the wide variety of training approaches used by companies, a number of questions arrive: How do individual methods stack up against a cost/benefit analysis? How should the training be adjusted to match the needs of a specific project? How does "just in time" training compare in effectiveness with routine training?

Lean Construction and Sustainability through IGLC Community: A Critical Systematic Review of 25 Years of Experience

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Christine Pasquire, Professor of Lean Project Management, Nottingham Trent University, UK

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I.Backgorund

It has been argued that Lean Construction (LC) offers the conceptual basis and the appropriate methods and tools needed for helping the construction industry meet the challenges of sustainable development. Since 1998, a growing body of knowledge has been emerging from the IGLC community, in relation to synergies between LC and Sustainability. The authors of this study therefore reviewed the progress made in understanding the linkages and inconsistencies between the two initiatives, through conducting a critical systematic literature review (SLR) and synthesising the findings of 'LC and Sustainability' studies published in IGLC conferences over the past 25 years.

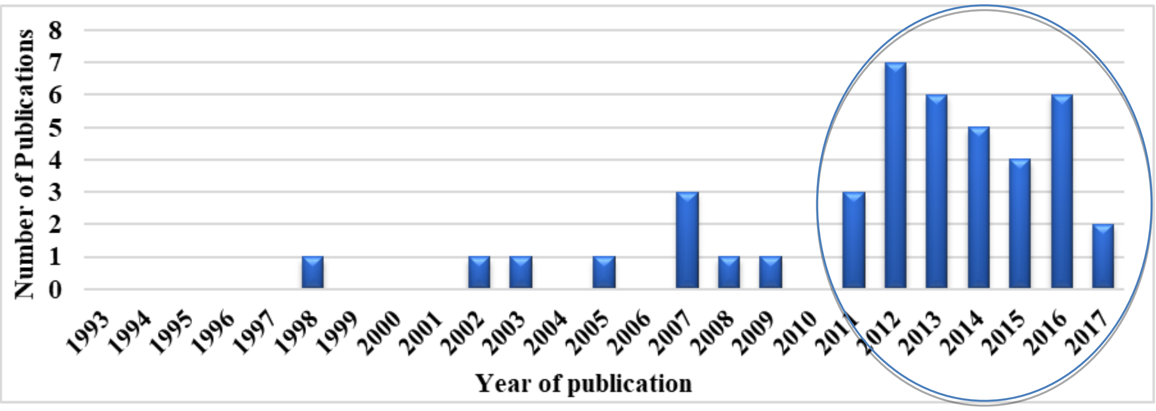
II. Research methodology

- This study adopted a Systematic Literature Review (SLR) and a qualitative approach to research synthesis
- The study adopted a deductive-inductive approach for data analysis, utilising QSR NVivo 11 software, and following a "*lean coding*" procedure

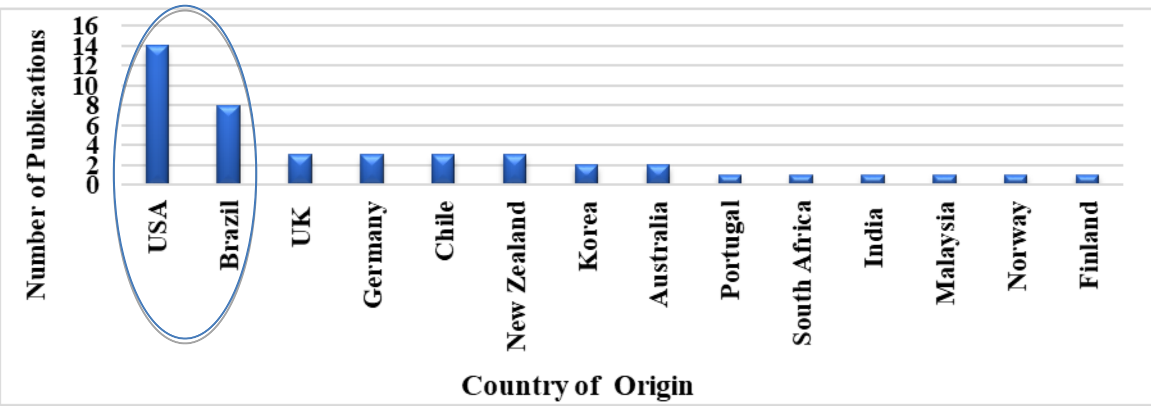
Search queries and outcomes

Keywords	No. of papers matching search queries
Sustainability	43
Sustainable	43
Sustainable + Development	6
Green	31
Environmental	42
Energy	23

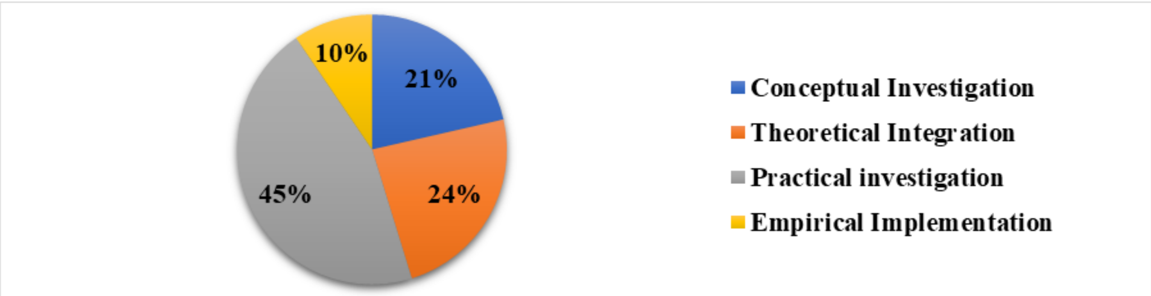
III. Sample analysis



Frequency of LC-Sustainability studies per year between 1993 and 2017



Geographical distribution of LC-Sustainability studies between 1993 and 2017



Research purposes and approaches

III. Research Findings

MAJOR LIMITATIONS IN APPROACHES TO LC RESEARCH AND PRACTICE	MAJOR LIMITATIONS IN APPROACHES TO SUSTAINABLE CONSTRUCTION (SC)
- Predominance of a 'limited' customer-focused perspective of 'Value'; - Little focus and attention paid to the management of the project life cycle requirements (e.g. facilities, operations and maintenance) - The prevailing conceptualisation of 'Waste', which does not account for environmental and social impacts	- The over-reliance on formal 'Green Performance Certifications' (e.g. BREEAM and LEED), which limits opportunities for sustainability improvement; - Much of the approaches to sustainability in architecture and construction are based on the assumption, in the economic theory of production, of 'fixed input-output relations'.

VI. Conclusions

- The findings of this study revealed the slow up-take and limited amount of existing research on the topic of LC and sustainability within the IGLC community (only started in 1998 with a total of 41 studies to date).
- SLRs are valuable for their ability to synthesise and uncover connections between separate studies, describe directions for future research, and provide implications for practice and policy.
- Tackling the identified flaws in approaches to LC and SC, and exploiting the opportunities for future research collated by this study could certainly help to move the research agenda forward and potentially lead to sustainable improvements in practice.

Believing is Seeing: Paradigms as a Focal Point in the Lean Discourse

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I. Obstacles to the Take-up of Lean

Failure to educate the youth in new concepts and principles before they become habituated to the old

Not understanding how industries, organizations and individuals change

Resistance by those who live off the waste

Paradigms

- Assumptions about reality; the filter through which one sees the world – facts only have meaning through the lens of paradigms.
- In traditional paradigms, Lean's claims are impossible.

Table 1: Kuhn's five phases of paradigm development

Phase	Description
1	Pre-Paradigm
2	Normal Science
3	Crisis
4	Paradigm Shift
5	Post-Revolution (return to Normal Science)

II. Examples of Traditional Construction Management Paradigms

Table 2: Paradigms in traditional construction management (Ballard et al. 2011)

Paradigm
Trust is for suckers.
Win-win is an illusion. What counts is that I win.
You can manage projects by managing contracts.
Risk is managed when transferred to someone else.
If you pay least price for each part of a project, you pay least price for the project.
Management by results yields the best results.
Variation in work flow is from external causes.
Resource utilization trumps project flow.
Control starts with identifying a negative variance between DID and SHOULD.
Social factors are interesting, but don't really matter.

III. Why are Paradigms a Problem for Lean Construction?

How widespread are the paradigms in the above table?

- Very. Construction professionals in the traditional paradigm default to behaving in accordance with them when under pressure, believing them to be true.

To what extent are they true?

- On every point, counter examples or at least counter arguments can be brought to disprove them.

This is confirmation bias and paradigm paralysis at work

- Confirmation bias is the tendency to search for, favor, interpret and recall information in a way that confirms one's preexisting beliefs.
- Paradigm paralysis is the inability or refusal to see beyond the current models of thinking.

IV. What Can Be Done?

Use Research as a Weapon

Educate the Next Generation

Create Market Pressure

V. Research

Accumulate evidence against the assumed truth of paradigms.

Capture and develop knowledge about how industries and organizations change

VI. Educate the Next Generation

"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." – Max Planck

Focus on AEC professionals of the future (students)

- Increase Lean Construction content in university courses
- Get them to Gemba

VII. Create Market Pressure

Some people and companies are less captive by paradigms than others. Work with 'early adopters' to make them ferocious competitors and informed/demanding buyers.

LCI conference growth is an encouraging sign

- 15% growth year-over-year

Some of the new people were likely influenced by competitor actions or owner demands.

VIII. Conclusions

- Call to action for Lean Construction community:
  - Raise awareness of paradigms and how they impact our advocacy
  - Work to change the prevailing winds of the industry
- Don't lose patience or hope – wide-spread paradigm shift takes time

Demonstrating the Value of an Effective Collaborative Decision-Making Process in the Design Phase

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I. Background

Decisions are the foundation for creating value in a project. Particularly in the early design phases, decisions form and restrict the value creation processes throughout the project's life cycle Therefore, project teams should pay attention to the decision-making process, and design it to secure maximum value creation, to meet budget constraints, and to secure a clear documentation.

II. Current conditions

The decision-making process is important in the design phase. Nevertheless, there is little research about the value creation through decision-making processes in the design phase. We argue that how the project team decides on design alternatives is crucial for the project's success. The decision-making process makes the foundation for the creation of value for the client and sets the standard for how efficiently the supply chain will be able to deliver.

III. Research Questions

- What creates value in the decision-making process?
- What is needed to make decisions effectively?
- How should the decision-making process be designed?

IV. Research Method

To explore the research questions the research consists of a literature review and a cross-case analysis of four projects. Case study research and action research as strategy was used in dependence of the project status. The following table shows which strategy and methods were used to collect and analyze the data based on the four characteristics: (1) decision-making method, (2) structure of the decision-making process, (3) governance process, and (4) documentation process.

Case	Location	Status	Research strategy	Data collection	Data analysis
UCSF Mission Hall	San Francisco	completed	Case study	documents, open-ended interviews	Qualitative content analysis
UCSF Medical Centre	San Francisco	completed	Case study	documents, open-ended interviews	Qualitative content analysis
Lower Thames Crossing	London	ongoing	Action research	Surveys, meeting evaluations	Grounded Theory
IT Campus Project	San Francisco	ongoing	Action research	observation, documentation, interviews	Grounded Theory

V. Research Findings

- The four characteristics (1) decision-making method, (2) structure of the decision-making process, (3) governance process, and (4) documentation process are essential and need to be considered when designing the decision-making process.
- Making decisions collaboratively will lead to value adding opportunities.
- Define a clear structured decision-making and governance process, and define responsibilities for every hierarchical level.
- Use an integrated bottom-up process for decision approval.
- Use CBA as a method to choose between alternatives.
- Connect the timing of the decisions with the LPS.
- Document and share decisions among the team using a clear defined template such as A3s.
- Test the value of the alternatives against TVD identified by the project team.

VI. Conclusions

- Value is created when decisions are made within targets and constraints.
- Collaborative decision-making creates value, because group decisions increase the quality and the acceptance of the decision, interdependence and effects on certain team members are discussed, resulting in an easier implementation process.
- It is essential to address the decision-making process.
- For effective decision making, coordination, a clear structure, and a governance process that fully utilizes the team's resources, using an integrated bottom-up approach, are necessary.
- A transparent decision-making method such as CBA supports the involvement and the collaborative discussion about alternatives.
- Linking CBA with SBD, LPS and TVD provides effectiveness and reduces waste in the design process.

Visual Planning for Supply Chain Management of Prefabricated Components in Construction

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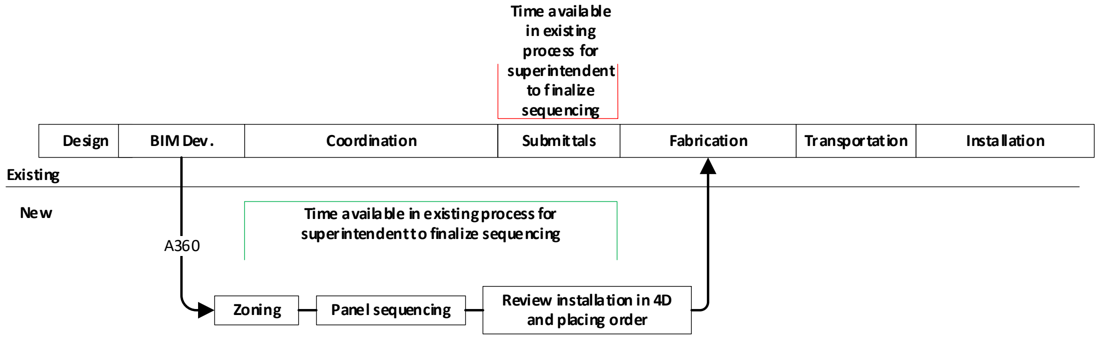
I. Introduction

One of the challenges in the supply chain management of prefabricated components is the communication gap between the jobsite and the fabrication shop to coordinate on the deliveries. The context is the supply chain of light gauge metal stud panels that are digitally fabricated using BIM and CNC Robots in the US construction industry.

The issues addressed in this paper, in the context of supply chain dynamics, are demand variability, material re-handling, coordination challenges with other trades, inefficient planning and design change creep into the submittal/shop drawings and procurement phase thereby either reducing the lead time for fabrication or wastage. In this case study, Building information model (BIM) enabled mobile application (iPad app) called 'Flow' has been used as a primary mechanism for solving the issues.

II. Current conditions

Fabricators have been facing challenges like bulk ordering, multiple orders, less correspondence, miscommunication, schedule delays. The orders are placed in bulk which leads to higher inventory cost. This gap between site and subcontractor is a common problem in construction. Furthermore, miscommunication between site and fabricator results in overproduction, wastage of material, delay in delivering panels on site, logistics problem like re-handling and thereby, causing overall delay.



III. Research Hypothesis

- By implementing VDC enabled app based integrated workflow, we are able to eliminate inefficiencies inherent in manual 2D based disjoined processes.

IV. Research Methodology

The research methodology that we adopted was practical application of developing VDC enabled iPad App that integrated the visual and quantity attributes of BIM with planning process of sequencing the panels.

- Cloud based data hosting: information of sequencing, priority locations, installation dates is provided by Site team via "Flow".

- 2D drawings do not provide readily available quantitative information. It does not automatically tell the planner how long the sequenced panels will take to install. The information generated through ‘Flow’ is used to analyze the production scale.
- Factory doesn’t have to wait for final panel install layout drawing. The Site team starts inputting installation requirement during coordination.
- The proposed system supports process transparency through visual management by making it easy for all involved to see and order parts (panels), cycle time reduction due to the streamlined process, potential elimination or reduction of other types of waste such as rework, waiting, re-handling and excessive transportation.

IV. Research Findings

Table below describes the comparison between the new state after applying the research methodology (By building the App “Flow”) with the existing production process

Construction process	**Existing Production Process**	**New Process using App 'Flow'**
Planning the installation of building elements and sequencing	Sequence of installation is defined by the superintendent only when all the submittals are ready.	The process using the app gives the project team the ability to plan the installation sequence from design phase. The app user can define the categories of panels, E.g. priority panels and leave-out panels (Reduced cycle time due to streamlined process)
Location based planning	The superintendent provides markup of installation plan on the panel install 2D layout drawings. Sequencing across floor is not possible.	Areas can be easily marked on 2d sheets. Panels can be added/removed from a zone hence sequencing across floor is made possible. (Reduces the share of non-value adding activities)
Communication between the Superintendent and the factory	Information flow in this process may lead to misunderstanding and waste due to rework	Sequence report generated through the "flow" application gives a clearer picture of fabrication requirement. (Elimination of waste such as rework, waiting, re-handling and excessive transportation)
Quantitative planning	Existing process doesn’t give the idea of overall production levels from different projects	Integration of BIM and IT will help to understand the forecast. (Increased process transparency through visual management)
Review of installation	Review of orders cannot be done.	4D of panel installation will be used as a review by the superintendent (Increased visualization of the process)

V. Future Scope, Limitations and Conclusion

- The future version of app ‘Flow’ will include functionalities for tracking status of material delivery (using IoT) and progress tracking of installation on site.
- Quantitative comparison between existing and proposed processes is yet to be measured as the app is in beta testing phase.
- There are some limitations and challenges to the app implementation. For the app to work properly the models and the sheets must be uploaded with predefined nomenclature.
- It is also planned to include the other trade models to improve the overall installation sequence.

NEW APPROACH TO DEVELOPING INTEGRATED MILESTONES FOR PLANNING AND PRODUCTION CONTROL

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I. Background

This paper examines the issue of bringing improved structure with integrated milestones into the project and production management process to handle progress and strategic coordination in complex AEC-projects. We address the phases between front-end planning and project execution. In terms of theory, we base our project on a concept of strategic milestone planning and we find inspiration in ideas from the practical world.

The present study fills a gap in project management literature, which appears to address milestones in a superficial manner; this is partly the case for Last Planner System for production control. Our study contributes to theory and practice regarding development of milestones.

II. Current conditions

Milestones are an important part of project planning and management, whether traditionally oriented or based on the concepts of Lean Construction (LC). Last Planner System® (LPS) for production management (Ballard, 2000) is a key component of LC and is built up of several elements of which the overarching one is the master plan.

A traditional way to establish milestones for construction is to split the building period into phases, usually with a milestone for the transition between phases. The phases may be installation, groundwork, foundation, framework superstructure, roofing, interior work, outdoor work and handover. Depending on the provisions and type of contract, the assignment may also entail pre-design and detailed design. What characterizes this approach is a breaking down of the project based on WBS logic (Work Breakdown Structure).

III. Working hypotheses

An alternative option that we have observed being used in practice is process-oriented milestone planning in an early phase of projects. A salient example we know well and that has been a source of inspiration for this article is the construction of a new art institute, Bergen Academy of Art & Design (Statsbygg & KHiB team, 2017). KHiB relied on guidance from Porsche Consulting when they initiated the project budgeted at approximately NOK 1 billion (start-up sitework in 2014 – handover late 2017). We have found no references to any publication pertaining to process-oriented milestone planning from Porsche Consulting, and we conclude that progress in practice has surpassed that of academia. Our research question, then, is **how to identify a method for development of process-oriented milestones in an early stage of project management**.

IV. Research Method

The design research approach is applied, and our artefact is a proposed method by which to develop a network of pull-based integrated milestones. The proposal is verified by documentation of the application in a construction project.

V. Research Findings

This study's artefact based on theory and practice is how to conduct a milestone-driven planning process in collaboration with the project's key actors (e.g. the owner, designers, engineers, main contractor, subcontractors). The method is summarized below:

a. Identify all core processes (and dedicate one owner per process)
b. Identify maximum 15-20 milestones per core process
c. Find the logical sequence for the minor milestones in each core process by pull scheduling
d. Identify the network and logical sequence between the minor milestones in all core processes, confer Figure 1
e. Establish basic process information (input/activity/output/due date) for each minor milestone where the Output information should satisfy predefined Conditions of Satisfaction (CoS) such as acceptance, confer Table 1

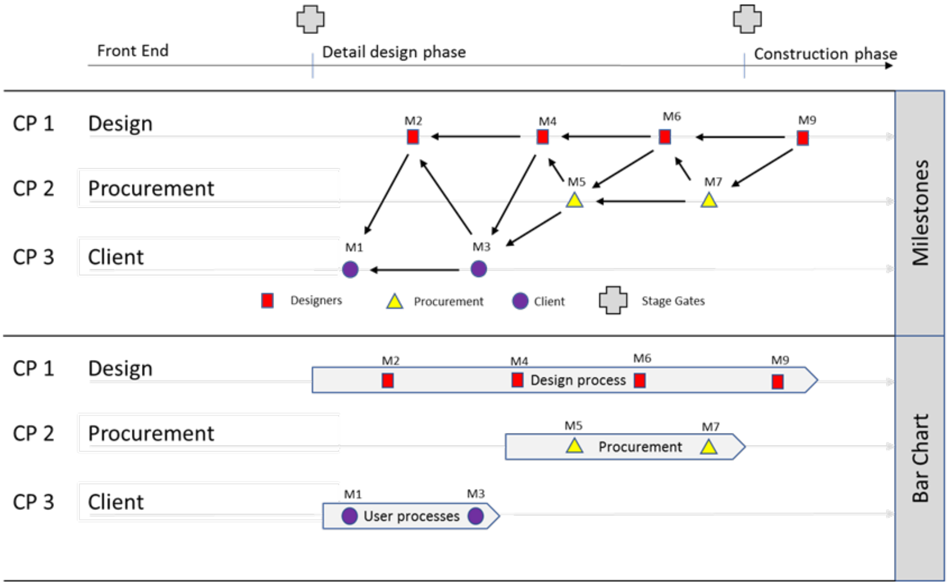

Figure 1 - Illustration of a network developed process-oriented milestone plan

Table 1- Milestones – an example, confer Figure 1

#	Milestone	Input	Activity	Output * (CoS)	Due date
M1	Floor plans approved	Floor plans, Requirements	Assessment meetings	Approved plans	[Date]
M2	Freeze Floor Plans	Approval of plans	Finalize Floor Plans	Frozen Floor Plans	[Date]
M3	Furniture & Equipment approved	Approved Floor plans, Requirements	Assessment of products	Approved furniture & equipment	[Date]
M4	Freeze BIM	All related information	The design process in general	A complete model ready for tendering	[Date]
M5	Tender announced	Approval from client	Announce the coming tender	Tender announced for contractors	[Date]
M6	Tender material	All previous information	Finalize design into tender material	All design related material for tender ready	[Date]
M7	Tender material published	All design material for tender	Establish all documents for tendering	Tender material ready for bidding	[Date]
M8	Contracts established	Contractors bids	Evaluation and selection	Contracts with contractors established	[Date]
M9	Shop drawings finished	Info from contractors	Producing drawings, Quality work	Complete and approved shop drawings	[Date]

VI. Conclusions

A basic idea in this study is to apply a process approach to creating milestones at the front-end of a construction project, whereas the conventional approach starts up with WBS. The master plan in Last Planner is also based on a conventional approach to milestones, but ideas are present for development in which the pull-concept is included.

Our proposed method for developing what we define as integrated milestones is verified based on experiences from a relatively large and complicated building project. There is nevertheless a need for further verification and testing. The theory concerning use of pull-oriented network planning as a backdrop for process-oriented milestone planning appears promising.

Employing Simulation to Study the Role of Design Structure Matrix in Reducing Waste in Design

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I. Overview

The design process is a complex and dynamic system owing to the interdependencies of tasks which need to be coordinated between different involved parties. As the design process continues to grow in complexity with the progress of design, and since the early stages are the most complex to manage, this paper proposes the use of the design structure matrix (DSM) to overcome the encountered challenges within the design management process. This study is based on the implementation of the DSM method to manage information flow in the preliminary design of a building project following a traditional design approach. Based on interviews with multidiscipline practitioners, tasks are identified and presented in a Base DSM. To better manage dependencies and improve performance, tasks are re-sequenced in a Partitioned DSM. Accordingly, two simulation models were developed for the Base DSM and the Partitioned DSM. Results show that the flow of tasks in traditional design leads to an increase in the design duration due to negative iterations representing rework in tasks receiving modified input from subsequent activities. Results also show the cyclic dependency between considered tasks and the effect of information change on work progress. This paper concludes by suggesting the application of an integrated design approach to manage the current planning system of the design process at early stages, where intensive coordination is required.

II. Objectives

- Our aim in this paper is to reflect on the current practices in traditional design. This paper introduces simulation to help in numerically realizing the need to enhance the design process and minimize the duration of the design phase by adopting efficient tools such as the design structure matrix. Additionally, our objective is to emphasize the need for an integrated design along with the necessary tools to improve the whole process.
- This research contributes to the body of knowledge in further proving the importance of better planning the early design phases to work efficiently and reduce waste.

III. Methodology

In order to achieve the aforementioned objectives, the planning and control of the design process for a typical building project at its early stages is assessed. The study consists of four major stages as indicated in Figure 1.

Figure 1. The methodology followed in this research

IV. Partitioned DSM

Preliminary Design Tasks		A1	A4	S2	S1	ME1	M2	M4	E1	A2	A3	M3	A7	A6	S3	E2	A5
Plans	A1				H	H			M								
Finishing	A4	M															
Layout & Sizing of Slabs/Beams	S2	H	H														
Layout &Sizing of Vertical Elem.	S1	H	H	H					M								
MEP Shafts	ME1	H					M										
Routing & Sizing HVAC	M2	H		H													
List of Power Req. to Electrical	M4						H										
Transformer Rooms	E1	H						M									
Sections	A2	H		H							M						
Elevations	A3	H								M							
Plumbing	M3	H				H											
Fire Zoning layouts	A7	H															
False Ceiling layouts	A6	H					H			H			M				
Location & Sizing of Footings	S3			H	H												
Earth Pits location	E2	H													M		
Doors & Windows Schedules	A5	H									H		M				

Major Coupled loop

- A major coupled loop was found which includes 8 activities. Those activities are related to all four disciplines which indicate the need of upfront coordination across functional teams at the beginning of the design process. Coupled loops help create value through aiding integrated teams spur innovation. Set-based design can be implemented in the coupled loops where coordination and collaboration between the involved parties, within the coupled loop, facilitate building consensus for the considered alternatives.

V. Simulation results

- Based on results from 1000 runs of the two models representing the Base and Partitioned DSM, the average number of workdays of the preliminary design phase was equal to 93 days for the Base DSM, and 66.4 days for the Partitioned DSM, compared with duration of the value adding activities, equal to 51 days.

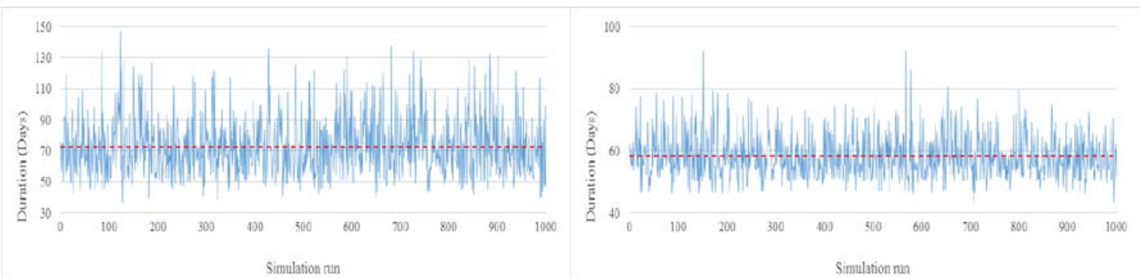

Figure 2. Simulation results of Base DSM vs. Partitioned DSM

VI. Conclusions

The study reveals the importance of planning design tasks based on the design structure matrix to minimize loops and reduce negative iterations which cause waste in design. The main idea of this study is to depart from the practitioners' traditional practices of executing tasks without involving downstream players and to promote a restructured design management process allowing for more coordination. The simulation results highlighted a 45.2% of waste in the design phase due to rework. This percentage can be decreased to 23.2% when using the DSM. However, waste in design may still occur. This creates a sense of urgency to adopt an integrated design process due to the intensive exchange level of information during the early phases of the design process.

USING TAKT PLANNING ANS TAKT CONTROL IN PRODUCTION PROJECTS – COMPARSION OF CONSTRUCTION AND EQUIPMENT PHASES

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I. Background

Takt Planning and Takt Control (TPTC) as a method for construction processes shows the potential for improving time aspects of construction sites in many practical examples. A first example of using the method of TPTC not only in construction but also in following processes such as equipment installation (production projects) indicates equal improvements. By analyzing 10 construction and seven equipment installation case studies, this paper gives an overview of similarities and differences in construction and equipment projects.

II. Current conditions

While TPTC is a well-known and well-established method for steadily planning and executing construction projects in the meantime, it is practically not used in equipment ventures, yet. Although a timely finish of equipment projects is crucial for the start of production and therefore decides over considerable losses of profits for principals, research rather focuses on savings through maintenance strategies instead of plannable and steady installation processes. The Takt Plan is the central scheduling tool for successful application of the Lean Construction methods of Takt Planning and Takt Control. Compared to others such as the Gantt-Chart, the Takt Plan shows more information while using less space and giving greater oversight.

III. Working hypotheses

The stages of construction projects have many interfaces to preceding and successive stages. For example, after completing a building for industrial production, assembly of the equipment needed for the building’s end-use will begin. Thereby construction projects aim at assembling the structure of the building itself, while consecutively assembly lines and production equipment is installed in an equipment installation projects.

This paper will use data from real case study projects to show differences and particular characteristics differentiating both stages and provide a resource for preparing a common Takt Plan for both project stages.

IV. Research Method

Comparison of 17 case study projects – 10 construction projects and seven equipment assembly projects – shows the differences between the two project types due to their own specific values. In some cases, equipment assembly projects are projects which followed directly after construction projects which are also part of this study. This allows comparison in terms of identical conditions in terms of surface area as well as in terms of cultural and climatic factors.

There is a large difference between the project categories in terms of costs. For example the cost of production facilities in automobile plants is many times more expensive than the cost of the building.

V. Research Findings

Underlying Projects are all realized by an industrial principal in several different countries in Europe, North- and South-America, as well as Africa. While some of them were already terminated, others were in the process of construction or not yet started by the time of data acquisition.

A Takt Plan which is able to provide a common overview of the different project stages must be able to show these both in terms of time as well as in relation to value creation from different parts of the plan. Figure 1 gives an example of such a Takt Plan. Due to dependencies, the two project stages cannot work on the same parts of the project area at the same time. For this reason, it is possible to modify the time scale of the y-axis between the two project stages. However, this is not recommended as this compromises readability and simplicity. From the example in Figure 1 it is immediately recognizable that the Takt Time of equipment assembly is exactly half that of the Takt Time for construction. This connection is easily visible, but as per the data collected, it is not the norm. Other relationships to the Takt Time are more difficult to show. Using uniform horizontal sizing of Takts despite different Takt Times must be avoided, so as not to distort the time dimension of the Takt Plan.

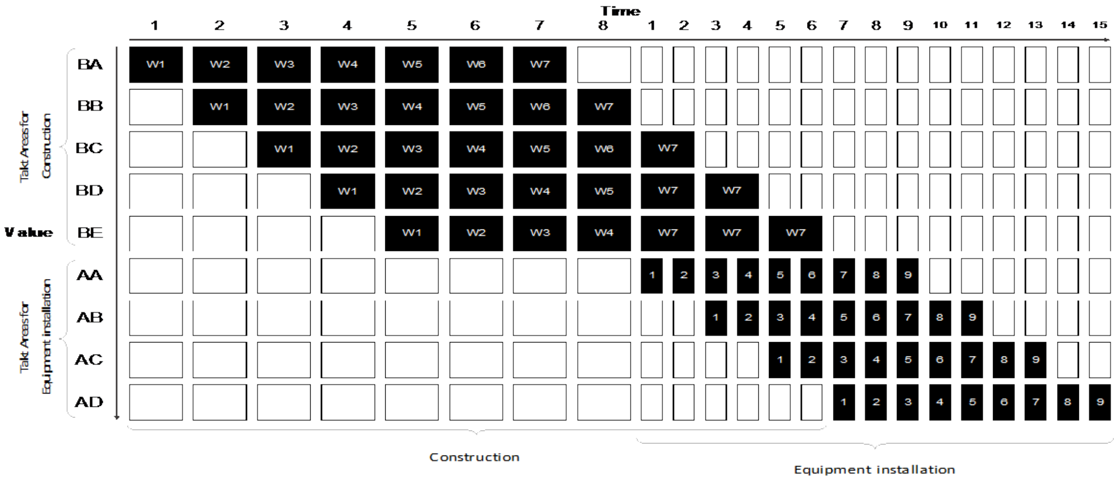

Figure 1: Uniform representation of the two project stages in a higher level Takt Plan.

Planning of both construction and equipment assembly projects can be completed individually for each stage. Additionally, the two Takt Plans can be joined to give an overview of the entire project and possible conflicts can be resolved.

VI. Conclusions

Investigation of the 10 construction projects and seven equipment assembly projects has shown the similarities and differences between the two project types. However, due to the small sample size no generalizations can be made. Despite this, the investigation shows that while joint planning of construction and equipment assembly works does not require synchronization of Takt Areas and Takt Time, it strongly simplifies planning and execution. Dialog between planners from both project stages is important to provide a common understanding of the sequence of works, and to guarantee measures with positive effects on the overall project such as earlier access to prioritized Takt Areas will occur. Apart from this, the knowledge gained could be used to prepare a new method for visualizing project information. Its use is considered a combined approach for Takt Planning and Takt Control in project planning to enable the project stages of construction and machine assembly to be shown together. As the companies involved are usually not active in both areas, this form of planning is mainly interesting for customers and their designers.

Enablers for Sustainable Lean Construction in India

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I. Background

Lean Construction and Sustainability are two concepts that have garnered enormous interest among researchers. Making construction sustainable is of prime relevance in India owing to damage that construction processes have caused to multiple dimensions including environment, economy and society. However, the urgency has not translated into action and when it comes to practical application; Lean implementation is supported by the top management of construction organizations owing to the immediate financial benefits that Lean can potentially bring in. While researchers have demonstrated that Lean benefits can be gained by adopting Sustainable practices, the discussion has remained at a 'concept demonstration' level. In order to promote 'Sustainable Lean Construction' (SLC) there is a need to identify enablers that can automatically bring in the perceived advantages of SLC.

II. Current conditions

- Lean construction concepts have a greater acceptability amongst the top management of construction organizations, especially contractor group.
- Construction practices in Indian have taken a toll on environment, workforce, supply chain, community, governance, quality issues (Piercy and Rich 2015) and contractual arrangement.
- The urgency and the need to make construction sustainable has not translated into actions that can make construction practices sustainable whereas Lean implementation is gaining ground owing to its immediate financial benefits

III. Working hypotheses

- *Top management of construction organizations are open to Lean implementation owing to the immediate financial benefits that Lean implementation can usher in.*
- *Lean and Sustainability concepts are mutually reinforcing and sustainability can find a greater acceptance amongst the top management of construction organizations in India if it is possible to demonstrate the link by identifying 'enablers'.*

IV. Research Method

The current status of Lean and Sustainability practices implementation in Indian construction has been established through a review of relevant literature. The need for making Indian construction sustainable is then analyzed conceptually through an existing framework that takes into account seven dimensions of sustainability. The enablers of Sustainable Lean Construction (SLC) have finally been identified in this paper based on the combined experience of the authors in the construction domain.

V. Research Findings

- The identified enablers are Owner Commitment, Designability and Constructability, Government Policy, Long-term Partnership, High Market Penetration and Compatibility with existing Contractual Frameworks. It is expected that the identified enablers enable the implementation of SLC aiding the industry to address the urgent needs of sustainability as well as reap the benefits of Lean construction.

VI. Conclusions

- Lean implementation finds greater acceptance amongst top management of Indian construction organizations, mainly because of the possible financial advantages.
- There is an urgent need to implement sustainable practices in Indian construction industry.
- While SLC has been discussed extensively in the literature, there is a need for identification of enablers in the Indian context that would help address the dual needs of urgency as well as financial benefits. The summary of paper is described in figure 1 and 2.
- Limitation: Enablers for SLC identified in this paper are having the need to be validated through a survey or case based research.

Figure 1: When Lean and Sustainability is viewed as independent concepts

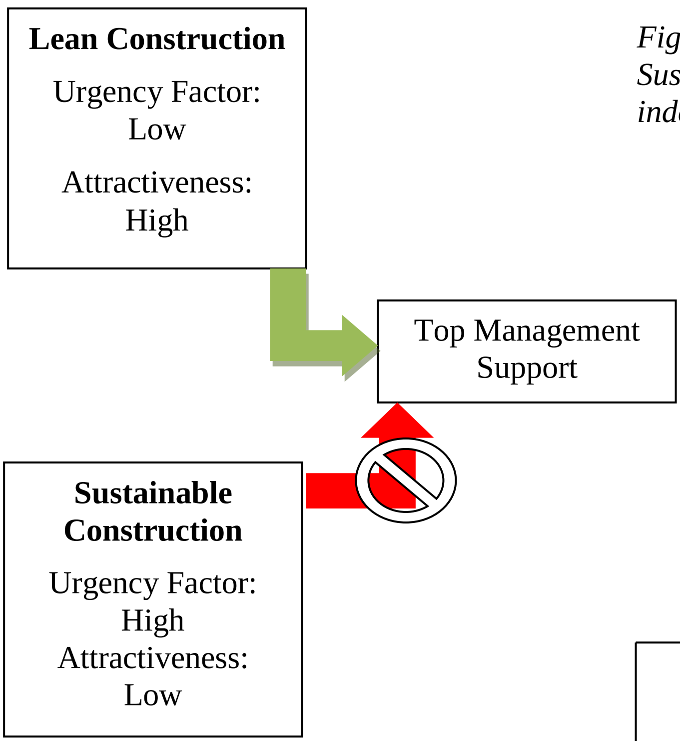
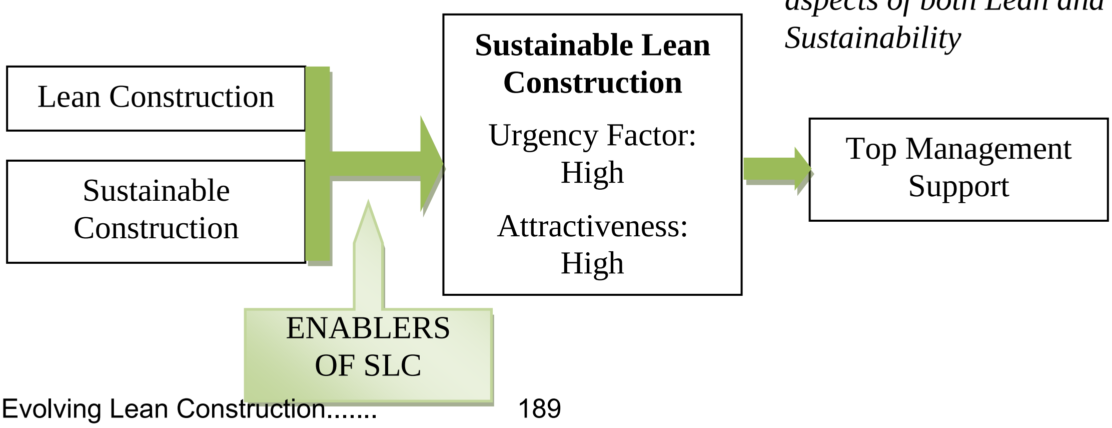


Figure 2: Enablers help in synthesizing the most crucial aspects of both Lean and Sustainability



Innovative Quality Management in a Lean World

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I. Background

Appraisal of quality is technically a waste, but a necessary waste. It consumes resources, but doesn't add value. However, it tells us what the actual value or work is, and in many cases why the work might not have met the expected value. Without the appraisal of quality, we don't know whether or not the work meets requirements before it is accepted and incorporated into the project. It also adds value to our confidence about the quality of the work, which is often necessary to be paid for the work, to warranty the work, to insure the work, or to even allow public occupancy of the work.

II. Current conditions

- Traditional quality management theory is usually described as either Quality Control (QC) or Quality Assurance (QA). These terms are often used loosely. A person performing a role described as QC may not be able to explain exactly what they control, if anything. A person performing a role described as QA may not be able to explain exactly what they assure, if anything. Even worse is the term "QA/QC" which is casually used for any suspect issue on the project where the work didn't turn out as expected. However, this is often used as a term of blame, not a term of root cause.
- Traditional quality management practices evolved out of the paper form, which was the only way to collect information prior to the "digital revolution". However, even though data can now be collected directly from processes without writing numbers on a paper form, the use of paper (or PDF) forms is still mandated by most organizational policies and contract documents.
- Emerging technologies are often thrown at project delivery in the hopes that quality and/or efficiency will improve. However, technologies without the application of a good, sound theory of practice not only will not improve quality and efficiency, but will often make them worse.

III. Working hypotheses

- *The terms of "QA" and "QC" are obsolete and no longer accurately describe the flow of quality through a project. An improved set of terms is "Prevention" which is the actual process control, "Appraisal" which is measuring the work after it's done, "Internal Failure" which is the discovery of defective work requiring removal and replacement, and "External Failure" with is defective work that remains undiscovered and fails in service. Each category is an order of magnitude more expensive to the project*
- *Innovations in production will hit a limit of improvement unless the quality management methods that oversee production are also improved. Otherwise quality management, whether it be the actual control, the appraisal, or response to failure will continue to be the bottleneck.*

- *Innovations in quality management are more difficult because they often cross organizational boundaries, as opposed to production that can often be contained within a controlled organization. If legacy quality management processes have to be retained for a single stakeholder that has difficulty modernizing, there will be limited savings in time and cost, in not an increase.*

IV. Research Method

- The methods described in this paper were either observed firsthand or personally implemented by licensed Professional Engineers practicing on large, innovative delivery transportation projects.
- The actual identification of the projects and clients are not disclosed due to the requirements for confidentiality in the engineering practice laws and rules.
- These observations were organized into a taxonomy of project requirements, design process control, design appraisal, construction process control, and construction appraisal.
- Current knowledge from the American Society for Quality and the International Council for Systems Engineering were heavily relied upon for insight.

V. Research Findings

- New, innovative methods of quality management that take advantage of enabling technologies are being prototyped on innovative delivery projects, such as design-build, where the design engineer, and construction engineer, and the contractor are all partnered within the same contract.
- These innovative methods are often developed by trial and error, or by synthesis from other industries such as systems engineering, information management, or GIS.
- A framework to guide the development and implementation of innovative quality will improve our ability to predict what will work on project better than trial and error. It will also help lead to the development of a general theory of quality management for project delivery in a digital world.

VI. Conclusions

- The appraisal of quality doesn't necessarily need to be categorized as a waste.
- Innovative quality management needs a taxonomy within which to organize actual and proposed improvements, to avoid random trial and error.
- Innovative quality management must be integrated into engineering accountability. The protection of public health, safety, and welfare demands that the quality of the constructed project is verified by a publicly accountable professional, not just the liability of the constructor based on contract law
- <u>The ultimate goal is where the appraisal of work is integrated into the actual production of work, so that independent appraisal after the fact is rarely required. Immediate appraisal of work during the production process also helps to prevent both internal and external failure, transforming appraisal into something that will actually reduce the cost of the constructed project, as opposed to the traditional view that it's a necessary but non-value adding cost</u>.

Behavior-Based Quality, Case Study of Closing the Knowing-Doing Gap

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I. Background

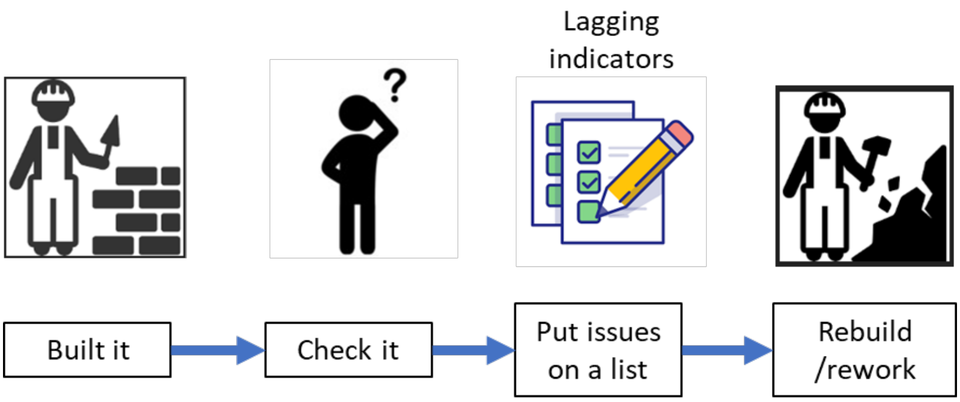
This paper presents a case study depicting a large US general contractor's effort to rethink and implement a new behavior-based approach to quality aimed at achieving zero errors, zero defects, zero rework, and zero surprises.

Quality Mission

Being so skilled at **understanding** project stakeholder **expectations** and developing **measurable acceptance criteria** that our projects experience **zero rework.**

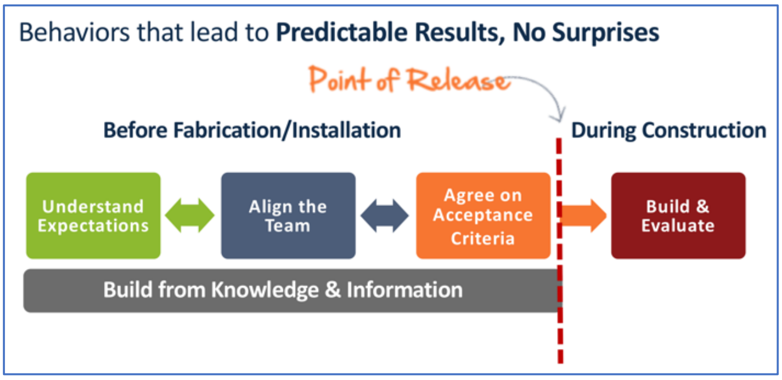
II. Current Conditions

Quality is discussed after fabricated or installed work resulting in a built it, check it, put issues on a list and rebuild it approach to quality, which doesn't help the industry prevent rework. Rework plagues the construction industry. The industry focuses on lagging indicators.



III. Goals/Targets

Zero surprises that the project experiences rework for fabricated and/or installed work.

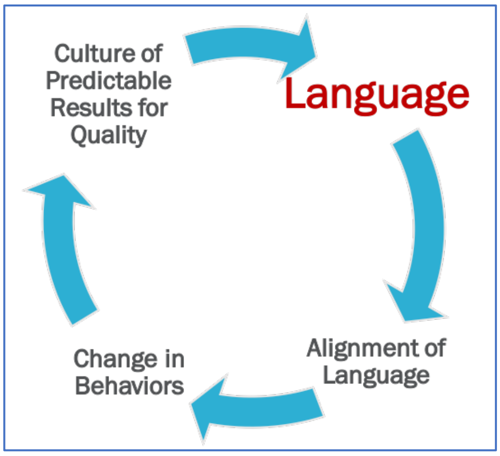


IV. Analysis

Following an industry standard approach to quality, this GC:

- Sometimes delivered work right the first time to very satisfied customers.
- Sometimes achieved Zero Defects at substantial completion but spent extra time and money in doing so.
- Sometimes experienced warranty call backs.
- Sometimes delivered work in accordance with the plans and specifications only to have the owner or architect view the work and say, “that wasn’t what I was expecting, tear it out.”

V. Proposed Countermeasures

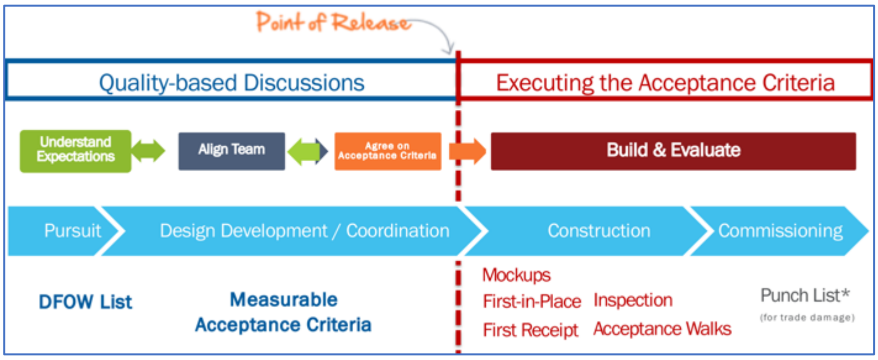


First change the language around quality. Describe quality in terms of Understanding Stakeholder Expectations around Distinguishing Features of Work, and aligning on measurable acceptance criteria, instead of describing quality as mock-ups, first-in-place, inspections, rolling completion lists, failed inspections and non-conformances.

Grow leaders and teams who understand the zero rework mindset, have changed their language and behaviors and have processes in place that give transparency to this change in behaviors.

Peer-to-peer training between projects and across regions describing the team’s engagement, implementation strategy & results.

VI. Plan



1. Educate the company, workgroups, regional groups and project teams: why this is important and how we need to approach work to achieve zero rework.

2. Have project teams share their successes, challenges and opportunities for improvement.

3. Change quality measurements for success. Instead of only measuring lagging indicators, how many issues have been identified, measure whether teams have identified and aligned on DFOW & acceptance criteria before starting work on key deliverables from design through installation.

VI. Follow-up

Measure the behaviors across projects:

1. Have teams identified Distinguishing Features of Work?
2. Do teams have documented measurable acceptance criteria for each DFOW before each point of release?
3. Do teams have DFOW and measurable acceptance criteria posted on-site?
4. How many DFOW are signed-off the first time with no rework?

SOURCES OF WASTE ON CONSTRUCTION SITE: A COMPARISON TO THE MANUFACTURING INDUSTRY

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I. Research Purpose

The key behaviour underpinning successful lean management involves the exploration of waste hidden in a production system. The performance of a production system will be strengthen by eliminating wastes through kaizen. This paper investigates, from a lean viewpoint, the source of waste occurring on construction worksite. As the starting point, two perspectives are adapted to discuss the issue:

1) The sources of wastes in operations at construction worksites

2) The sources of organizational wastes caused by the constraints of place and time

II. Sources of wastes in operations at construction worksites

Table 1 indicate that it is difficult to directly apply lean methods from the manufacturing industry to the construction industry, and that it is necessary to develop the theory of lean construction though studying construction worksites' operations.

Table 1: Difference of the attributes of a production system between manufacturing and construction, with reference to construction peculiarities

Attributes of production system		**Manufacturing industry**	**Construction industry**	**Peculiarities of construction worksite (Koskela 2013)**
Operations	Repeated operations	Mass products	Same structures built in one product	Specific customer
Product and supply chain	Flow of martials and finished product	Supplier-Factory -Market	Supplier-Construction site	Specific customer
	Places of production and utilization of finished product	Different	Same	Site production
Management resources (Physical and temporal scales)	Size of managed objects (martials, machines/equipment/facilities)	Small	Large	Site production
	Production lead-time	Short (Daily, In minutes or, Seconds)	Long (Yearly or Monthly)	Site production
	Participants	Same members	Different specialists	Temporary organization

Koskela, L. , Bølviken, T. & Rooke, J. (2013). "Which Are the Wastes of Construction?", *Proceedings of 21th Annual Conference of the International Group for Lean Construction*, 3-12., Fortaleza, Brazil.

III. Sources of organizational wastes

A construction site including the structure, which disturbs communication among project members, is shown in Figure 1. The structure consists of the following four sub-boundaries of the two-boundary structure, that are prone to lead to a communication loss in Table 2:

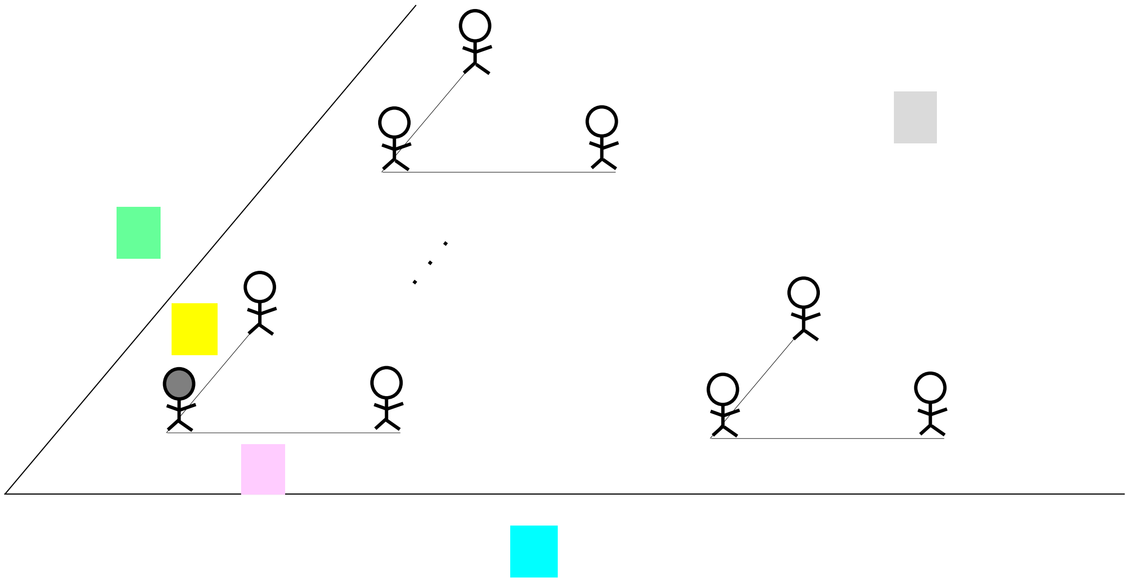

Figure 1: Nested structure model of communication in the construction industry

Table 2: Classification of boundaries by the nested structure model

	Boundary	Bad impact of a boundary
Geographical boundary	A. Between headquarter	Not smoothly communicating
	B. Among other sites	Not transferring technology & knowledge
Temporal boundary	C. By lead time	Not continuously keeping a quality of work
	D. By temporary organization	Not finishing a job together
Both boundaries	E. For many achievements	Not reviewing footprints of our job

VI. Conclusions

It is a finding of this paper that there are two kinds of waste in construction:

- Operational wastes, hidden in construction production systems
- Organizational waste due to lack of connection due to temporal and geographical boundaries

The cause of the first waste is associated with management of resources and operations on worksites. The cause of the second waste is associated with communication among different specialists. In other words, the former is about the contents of communication and the latter is the issue of the design of communication scheme. Lumping them together can possibly be misleading, because the core object of waste reduction in traditional lean management is the first one. This means that it is necessary to establish a scheme to overcome the second one, before eliminating the first one.

A Conceptual Model for Value Chain Management in Construction Contractor Organisations

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I. Background

Waste is commonly interpreted as waste of material even though, waste in construction industry also relates to activities such as defects, movement, waiting time and processing. Such waste can be minimised through an in-depth understanding of the organisation. Herein, Value Chain Management (VCM) can be used to facilitate organisations to categorise the activities in terms of their value addition.

The generic value chain model developed by Porter in 1985 focuses on the manufacturing industry thus, a framework is required for contractor organisations based on which Value Adding Activities (VAAs) and non-VAAs can be identified. This paper is aimed at proposing a conceptual model for VCM in contractor organisations.

II. Literature Review

VC in an organisation is identified as the "activities" that are undertaken in order to deliver a valuable product or a service to the end user. The underlying principle behind VC is that, value creation of a company cannot be recognised as a whole and hence, needs to be broken down into activities. Each activity that creates value in the aforementioned process is identified as a VAA. While VC of a firm is recognised as the activities, VCM is simply identified as managing the VC of the organisation.

Generic VC Model developed by Porter in 1985 is adopted as the foundation for identification of a firm's VC, as the model shows the manner in which a product adds value while it moves along the production process. Thus, it can be used as a template to identify the strategic improvements or opportunities within a firm in order to eliminate waste. However, the model is for identifying value creating activities of firms in manufacturing industry. Direct application of the model to the construction industry has come under question due to the significant differences that the construction industry possesses compared to the manufacturing industry.

III. Research Method

Three case studies were conducted in large-scale contractor organisations to investigate the VAAs of contractor organisations. Altogether, 15 interviews were conducted within the 03 cases. The interview findings were analysed using content analysis with QSR NVivo (version 11) software programme to identify VAAs within the contractor organisation.

IV. Research Findings

Case study findings revealed that the VAAs of contractor organisations can be mainly categorised into two categories as primary VAAs and secondary VAAs. The primary activities of a construction organisation can be classified under four phases namely; the pre-tendering stage, the tendering stage, the construction stage and the post construction stage. Furthermore, six categories of secondary VAAs were also identified as finance and auditing, human resource management, legal, procurement, technology and development, and other. The VAAs that were not specific for the first five categories of secondary activities were grouped under the 'other' category. The 'margin' towards which the activities are pointed implies the difference between the costs that are incurred and the price that the customer is willing to pay. The proposed VC model for contractor organisations developed using the aforementioned findings along the identified VAAs is shown Figure 1.

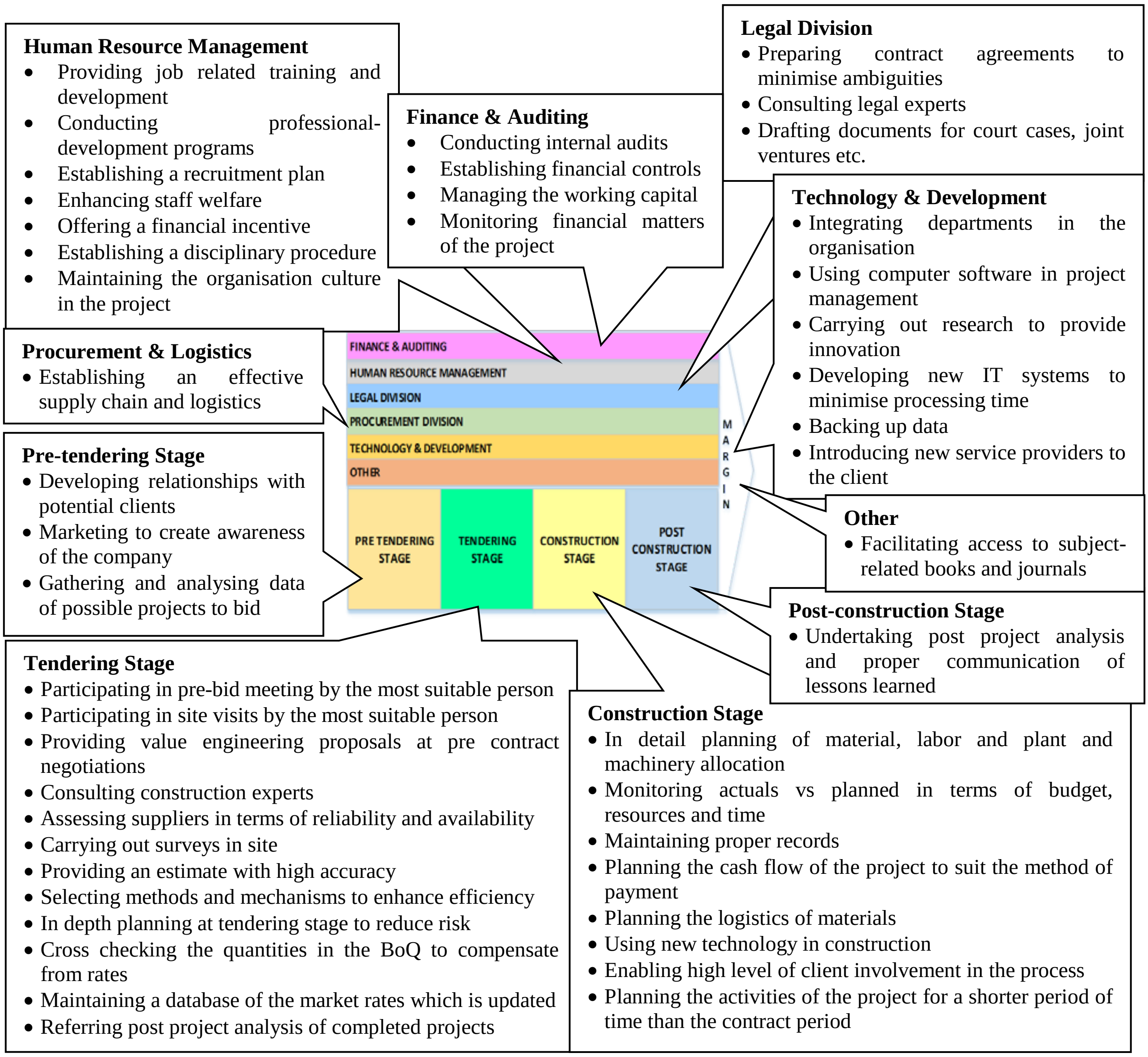

Figure 1: Proposed VC Model for Contractor Organisations and VAAs Identified

V. Conclusions

Altogether 24 VAAs were identified under the primary functions where the highest number of VAAs were found under the 'tendering' phase. Similarly, secondary activities were classified under six sectors; i.e. finance and auditing, human resource management, legal, procurement, technology and development, and other. Altogether, 22 VAAs were identified under secondary functions, out of which the highest were from the HRM category.

The findings of this research can be used by contractor organisations in undertaking VCM in their organisations to gain an in depth understanding in terms of the value addition of the activities, ultimately leading to enhanced value for construction clients.

Kaizen – Analysis of the implementation of the A3 Reporting tool in a steel structure company

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I. Background

The implementation of the PDCA management method can be incorporated to companies by making use of techniques and methodologies that facilitate its development. The A3 report is one of these tools. It regularizes and systematizes the collected data, presenting the main causes, the actions taken and the proposed solution to eliminate problems and defects in both products and services on one side of an A3 sheet (42x29.7cm). The results presented by this report enable not only the detailed analysis of causes, actions and solutions, but also a record of the occurrences and measures adopted on each A3, forming a history of data for future reference, accelerating decision making (Durward et al, 2010). The concepts of the A3 report have been deployed in the automotive sector, improving and facilitating the implementation of the Kaizen philosophy, which stimulated the present research to analyze the impacts on the implementation of the Kaizen philosophy of the use of the A3 tool in a steel structure prefabrication and assembly company in Brazil.

II. Current conditions

A case study was applied to a construction company that implemented the Kaizen philosophy, seeking results through the commitment of all involved in all areas and processes of the company. The Kaizen deployment process used the A3 reporting tool to support improvements. As such, a standard was created for the report, which can be seen in Figure 1.

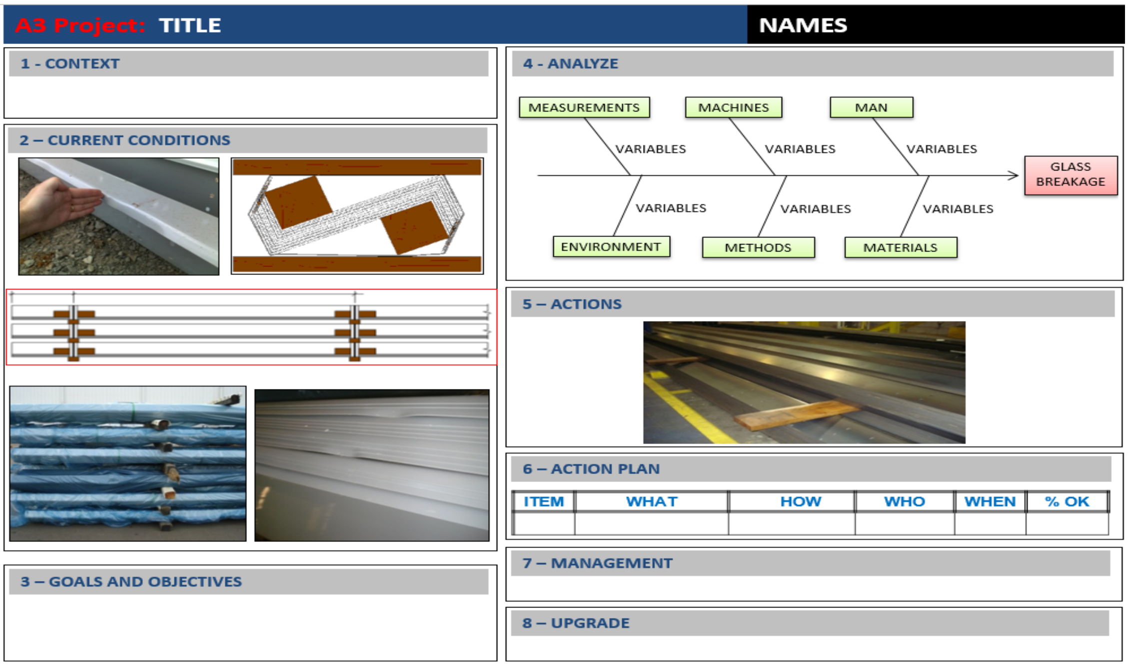

Figure 1: A3 standard developed by the company

III. Research Method

The plan and sequence of the employed research can be observed in Figure 2.

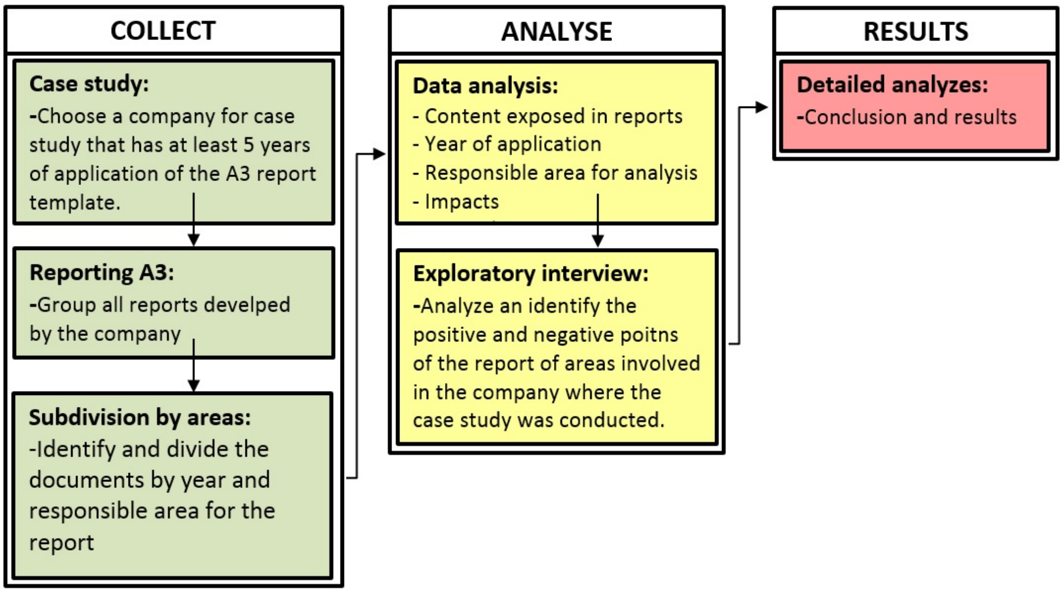

Figure 2: Research steps

IV. Research Findings

With the application of A3 report in the machine setup and layout processes, according to Figure 3, satisfactory lead time gains for the company were identified when compared to the previous scenario, in some cases cutting these times by a third of the previous time.

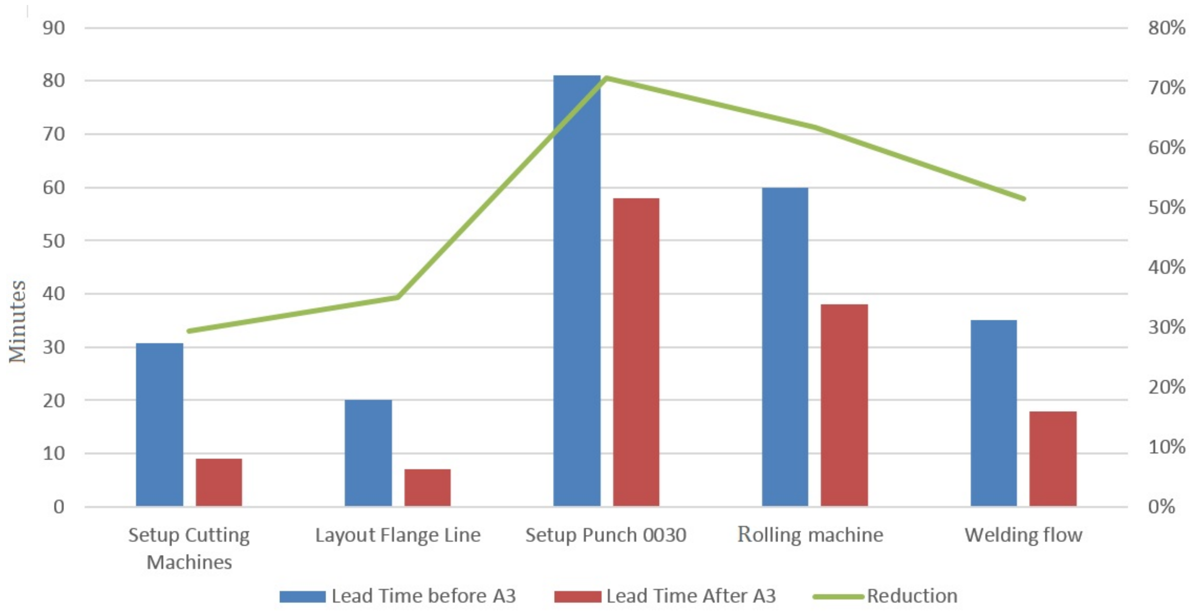

Figure 3: Result of the A3 tool in processes

V. Conclusions

After applying the A3 report, the reduction in lead time resulted in such gains as the synchronization of the production process, with a capacity to calculate the productive capacity of the work center and consequently schedule production, reducing buffers or inventories of raw material. The record of the situations addressed and treated by the A3 tool tends to result in an acceleration of decision making in future recurrences, since a database is created with the scenarios of the application of each improvement.

Impact of Gender Bias on Career Development & Work Engagement in the OAEC Industry & Lean Practice

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I. Background

A bias by definition is a deviation from what is normal, where "normal" is defined according to social norms. Bias can be conscious or unconscious, and it may manifest in subtle or obvious ways (d'Orgeville et al. 2014). The term "gender bias" is a preference toward or prejudice against one gender over the other.

II. Current conditions

Multiple studies document gender bias in STEM education (e.g., PCAST 2012; Menches and Abraham 2007; del Puerto et al. 2011) and workplaces (e.g., Slaughter 2012; Sandberg 2013). This paper focuses on the OAEC industry, where relatively less work has been done. The OAEC industry is male-dominated; men occupy most of the top positions in OAEC organizations. According to Chun et al. (2009), women are reluctant to join the OAEC workforce as they experience discrimination when they apply for a job or when they join the workforce.

III. Research Questions and Method

This paper seeks to address the following questions: Does gender bias exist in the OAEC industry? How does gender bias impact recruitment and promotion? How does gender bias impact work engagement? and Do lean principles translate into more equitable experiences in career development and work engagement via lean construction practice? The authors used a survey as the research method to answer these questions, distributed the survey over professional networks. The 153 survey respondents comprised of women (53%) and men (47%) representing 22 countries, and about half of the respondents implement lean in some form with varying degrees of intensity. The data was analysed using quantitative content analysis, which is a method frequently used in Social Science (e.g., Mayring 2014).

V. Research Findings

General perception: The results show that 75% of women vs. 62% of men feel positively affected by their gender, but only 13% of women vs. 27% of men frequently or very frequently feel positively affected by their gender. In contrast, 89% of women vs. 21% of men feel negatively affected by their gender, and 32% of women vs. 0% of men frequently or very frequently feel negatively affected by their gender.

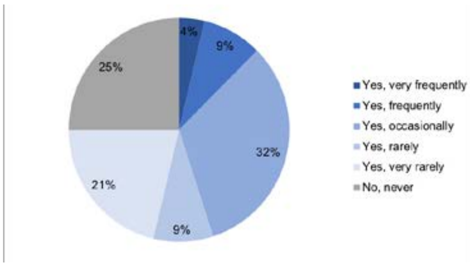

Figure 1: % of women who feel positively affected by their gender

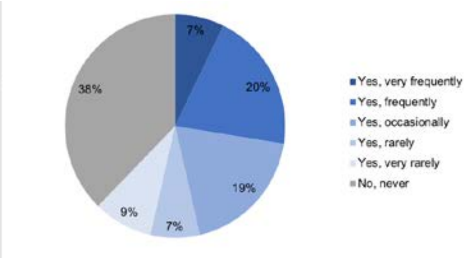

Figure 2: % of men who feel positively affected by their gender

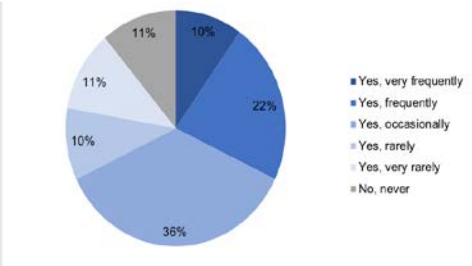

Figure 3: % of women who feel negatively affected by their gender

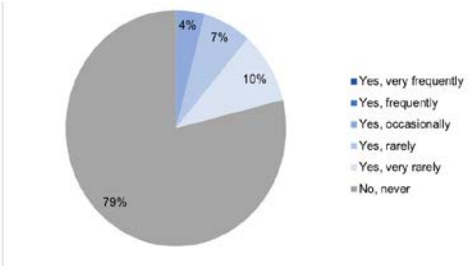

Figure 4: % of men who feel negatively affected by their gender

Recruitment process: When broken down by gender, 26% of women vs. 4% of men reported experiencing rejection in a recruitment process because of gender bias. Female recruitment rejection examples ranged from directly receiving inappropriate comments, to more subtle questions (or micro-aggressions) about plans to have children.

Promotion process: 32% of women vs. 0% of men reported being delayed in a promotion due to gender bias. Specific promotion delay examples include: seeing less qualified male colleagues get promotions before them, differences in salary found by chance, reluctance to give titles/positions of power to women doing the same job as men, and some women who are not sure they have experienced promotion delays due to a hidden evaluation process.

Ideas not taken seriously: 62% of women feel that their contributions are not taken seriously and this value increases to 71% for women involved in intense lean practice.

Ideas not taken seriously	All	Women	Men	Intense Lean	Non-Intense Lean	Women + Intense Lean	Women + Non-Intense	Men + Intense Lean	Men + Non-Intense Lean
Yes	54	51	3	29	25	27	24	2	1
No	98	30	68	46	52	11	19	35	33

VI. Conclusions

- Women and men perceive gender bias in the OAEC industry.
- Women perceive their gender as a reason to not be recruited or be delayed in promotion; women report, with alarming frequency, experiencing gender bias when sharing ideas.
- Regardless of lean implementation, women perceive that their ideas are not heard.
- Female respondents present more negative perceptions about gender bias and how this affects their work lives. Negative perceptions influence what women in the OAEC Industry think is possible or not in terms of career advancement and the pursuit of their ideas.
- Most male respondents recognize or observe gender bias in the OAEC Industry. Paradoxically, a larger portion of men compared to women think that gender bias is not an issue, and no programs or strategies are necessary for correction.
- The majority of men and women explicitly wish to have better programs or deliberate actions to overcome gender bias in the OAEC Industry.

IPD in Norway

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I. Background

Studies show various problems, such as adversarial relationships, low productivity rates and frequent failure to meet the owner's expectations in the AEC industry. IPD is a delivery model that accommodates the construction industry´s need for more efficient collaboration between project participants. There is limited documentation related to IPD in the Norwegian construction industry. By collecting data from Norway's first IPD project, named The Tønsberg Project, this research seeks to fill this gap of knowledge.

II. Current conditions

- Fragmented teams, disputes within the project organization and problems related to the interface between design and construction.
- Project parties tend to work in isolated siloes focusing on their own interests.
- Project parties have a low degree of common understanding and a high degree of individual interests in the project, which often results in inefficient project delivery.

III. Working hypotheses

- Identify which theoretical IPD elements that are being used in The Tønsberg Project.
- Present the experienced effects and challenges related to the individual elements.
- Provide a framework with respect to which of the theoretical IPD elements future projects should implement.

IV. Research Method

This study is based on a qualitative research method, with multiple sources of data. The theoretical IPD elements were identified in a literature study. The research presented in this article is established through a comprehensive single-case study. The Tønsberg Project was selected as case seeing that it is the first IPD project in Norway. The project is a complex building project within the Norwegian health care sector, consisting of a 31,000 m^2 somatic building and a 12,000 m^2 psychiatry building, with an estimated cost of approx. 370 million USD and is set to be completed in 2021. The Lead Contract and Procurement manager in The Tønsberg Project is co-author of this article, which provides a unique insight into the project´s delivery.

The case study is based on a review of the project´s IPD agreement, a pre-project report, powerpoint-series previously used by the project participants, and 9 semi-structured in-depth interviews with representatives from all major project participants.

V. Identified IPD elements

- **Contract:** *Multiparty contract, shared risk and reward, early involvement of key participants, intensified planning, collaborative decision making, collaborative goal definition, liability waivers* and *financial transparency*.
- **Technology and processes:** *Lean, BIM* and *integrated information.*
- **Culture:** *Mutual respect and trust, willingness to collaborative, open communication* and *co-location.*

VI. Research Findings

- The Tønsberg Project has implemented all the theoretical IPD elements presented.
- However, the desired degree of intensified planning was not achieved, the general performance goals were not defined collaboratively, and participants are not co-located "full-time" but rather 3-4 days a week.
- Several interviewees describe a culture where decisions are being made based on what is considered best for the project, which results in optimal solutions based on a high degree of common understanding and communication between the project participants.
- The project has nevertheless experienced some challenges, and the findings indicate that it is possible to learn from the project´s experiences to deliver future IPD projects more efficiently.

VII. Conclusions

- The Tønsberg Project has embraced the IPD methodology and to a certain extent implemented all the theoretical IPD-elements.
- The collected data indicates an efficient project delivery, where most of the desired effects of IPD are achieved.
- All the theoretical IPD elements are recommended for future IPD projects.

Empirical Study on the Influence of Procurement Methods on Last Planner® System Implementation

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I. Background

Previous studies have examined various factors that influence the implementation of the Last Planner System (LPS) in construction projects. However, there is limited documented evidence on the influence of procurement methods on the implementation of the LPS. The aim of this study, therefore; is to understand the influence of some selected procurement methods on the implementation of the LPS using case study approach.

II. Current conditions

- There is an increase in the rate of implementation of the LPS in construction projects across the world.
- Additionally, it has also been observed that contextual factors (such as procurement method, contract and culture) within the project environment could influence LPS implementation on a construction project.
- However, there is limited documented evidence on the influence of procurement methods on the implementation of the LPS. Our study aims at filling this knowledge gap.

III. Working hypotheses

- *What is the influence of procurement methods on the implementation of the LPS in construction projects?*

IV. Research Method

An interpretive case study approach was adopted for the study. The case study was designed using the approach suggested in Yin (2014). Table 1 presents the attributes of the case study projects.

Table 1: Project Attributes

Project Attributes	CSP01	CSP02	CSP03
Nature of project	Highways and Infrastructure	Highways and Infrastructure	Building construction project
Proposed project duration	30 months	24 months	30 months
Procurement Method	D&B,	Traditional DBB	D&B

The three case study projects were selected from top 10 UK construction companies. Purposive sampling was used in selecting the case projects; this was done to enable the study answer the questions sufficiently. The case studies were conducted over a 12 months period. On each of the project, data were collected using three major approaches: observations, documents analysis and a semi-structured interview. Senior manager (SM), middle manager (MM), operational managers (OP), and subcontractors (SC) were interviewed. A total of 28 interviews were conducted, in addition to observation and document analysis. The interviews were transcribed verbatim and cross-checked with findings from documents analysis and observation for triangulation. A summary of the findings is presented below.

V. Research Findings

- The investigation shows that the prevailing traditional mindset exhibited by the designer in the traditional DBB influences the quality of promises and commitments that could be made during the lookahead and make-ready planning

- The study found that it seems no single procurement method is a sure way to the full application of the LPS process on a project.

- The study observes that irrespective of the procurement route used, a mindset change towards collaboration among the different stakeholders on the project is fundamental to successful LPS implementation.

VI. Conclusions

- The study concludes that the procurement approach to be used on LPS project should not be too static, but agile enough to integrate collaborative working among the different stakeholders on the project for a smooth workflow.

- Additionally, the study suggests that the LPS should be included in the contract clause in DBB procurement method to encourage the full commitment of all stakeholders on the project especially the design team.

- This study exposes how the traditional DBB and the D&B procurement methods influenced the implementation of the LPS in a real-life project context which provides some empirical evidence for future applications of project production planning principles in the construction industry. This would benefit both lean construction practitioners and scholars.

Continuous Improvement Cells in the Highways Sector

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I. Background

The highways sector in the UK has been actively engaged in Lean Construction (LC) since the late 2000s. Alongside the Last Planner System and Visual Management, utilising Continuous Improvement (CI) cells has been a subject of interest for the sector since then. Following the first CI cells in the supply chain, which were started at some construction service providers around 2009, the main client also initiated CI cells among its internal teams in 2014. The paper presents the initial findings of a research project on those cells.

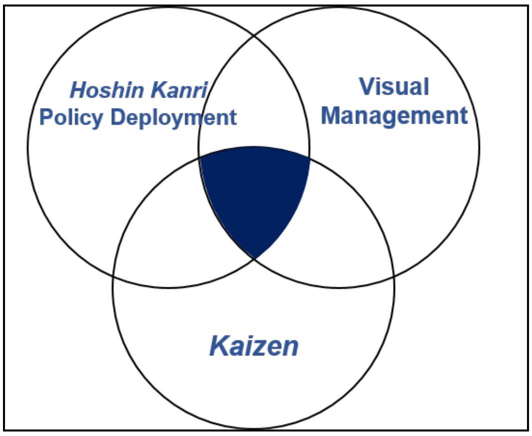
II. Current conditions

The CI cell is a small-group task coordination and work improvement technique developed from Quality Circles (QCs), a form of employee involvement mainly used for gradual quality improvement. The intrinsic CI cell aim of problem solving and gradual work improvement through group effort links the concept to the continues improvement or *kaizen* principle of lean thinking.

III. Working hypotheses

As a CI cell regularly exposes the team to the information associated with their work in the form of team performance metrics, team-member availability, work-related issues, the continuous improvement process or work coordination/follow-up, CI cells can also be included in efforts toward increasing process transparency within Visual Management.

Additionally, the importance of having structured team coordination meetings and two-way communication channels from the operational level to the strategic management level and vice versa has been underlined in disseminating organisational strategic goals as part of *hoshin kanri.*



IV. Research Method

12 internal CI cells of the highways supply chain's main client were studied using interviews, participant observation in CI cell meetings, CI cell board observations and discussions with the team members. A CI cell board can be seen below.

V. Research Findings

- Two types of CI cells were identified, Of the two types of cells, Type I cells are more focused on work coordination and planning with minimal or ad-hoc work improvement.
- Alongside work coordination, the systematic execution of continuous improvement efforts in Type II cells is more conspicuous than Type I cells.
- The following CI cell benefits and challenges were recorded:

Benefits (+):

- enables having structured and succinct team meeting,
- supports coordination of team work,
- increases team engagement and morale,
- discloses related information to employees,
- increases transparency,
- helps with team building,
- facilitates task ownership,
- prompts team members to make more reliable promises (peer pressure)
- helps teams allocate and level their resources (work balancing/ prioritising)
- serves as a training mechanism for junior and new team members,
- supports task delegation, empowerment and employee autonomy,
- simplifies progress reporting and creating meeting minutes,
- helps save team resources.

Challenges (-):

- ad-hoc and unstandardized data recording,
- not understanding what to measure and how to measure with respect to CI cell benefits,
- hardships faced in identifying root causes of problems,
- ad-hoc problem solving,
- insufficient standardisation among the teams in their CI cell executions (i.e. the frequency of meetings, the content and design of the CI cell boards, the governance of the CI meetings, some teams' ignoring the continuous improvement function),
- providing the team with only basic training as to the CI cell execution and systematic problem solving techniques,
- root problem causes not being systematically recorded, classified and visualised,
- the lack of senior management engagement,
- the lack of systematic incentivisation practices for the CI cells,
- the limited authority of the teams to make work improvements as they are mostly restricted with their work domains.

- The captured transparency increasing benefit of CI cells further justifies its role in increasing process transparency and supporting Visual Management.
- However, some issues in the continuous improvement (*kaizen*) function of the cells were found in practice.
- Also, due to the fact that senior management do not have their CI cells at the moment, there are issues regarding the two-way flow of information over the CI cells from the strategic level to operational level, and vice versa for the execution of *hoshin kanri*.

VI. Conclusions

CI cell research in construction has remained scarce. Alongside *kaizen*, CI cells also can be positioned within other important lean concepts like Visual Management and *hoshin kanri*. The identified benefits can be tested and prioritised in the future with data from different organisations and quantitative methods (i.e. design of experiments and action research). The identified challenges are also deemed important in improving the current CI cell practice. Deploying CI cells in construction supply chains and linking them with other Lean Construction techniques like the Last Planner or Visual Management systems can be also an option for future investigations.

OPTIMIZING FLOW PROCESS THROUGH SYNCHRONISATION OF CYCLE TIME

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I. Background

The theoretical understanding of construction project has evolved from transformations model (i.e. Project Management) to 'Lean Construction' based on TFV theory of production. The 'Lean' approach assumes construction as combination of transformation and flow activities which progressively add value to meet customers need. Researchers highlighted the need to eliminate/ optimize flow activities which consumed almost 70% of the time and resource. However, despite waste reduction, variability in construction flow process remains due to variation in cycle time (C/T) of its components. This variability leads to penalties and sub optimal resource utilization.

II. Current conditions

Most of the construction project are still based on conversation model and broken into work packages (WPs) for their management. Often, these WPs involve varying degree of mechanization in view of competing needs of different process heads, special conditions of contract for quality assurance, etc. The true benefits of mechanization remain unrealized due to weak theoretical foundation and the lack of holistic approach while introducing mechanization. Even if 'Lean' approach is adopted, all project components cannot be structured in continuous flow processes due to associated complexities. Hence, a framework is needed for systematic analysis to identify the extent of adjustment is needed in C/T for rhythmic continuous production.

III. Working hypotheses

- *Synchronization of C/T of interconnected sub process/ operation in process will enhance the process productivity by minimizing construction bottlenecks.*
- *The use of charts and tables may be adequate for simple processes. However, discrete event simulation will be needed for complex projects. A flow diagram for to clear the bottlenecks and synchronization of C/T is as shown in Figure 1.*

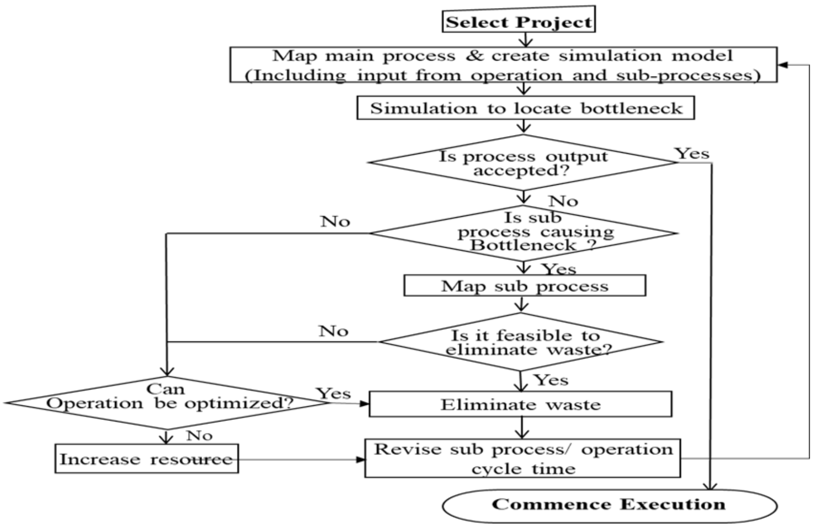

Figure 1 Flow diagram to clear bottlenecks and synchronization of C/T

IV. Research Method

In the present research 'Case Study' approach was used. The data was collected from ongoing railway track laying project. In order to speedup track laying, automated New Track Construction (NTC) machine was introduced. However, daily progress of 1.15 km (i.e. 30 km per month with 26 day) could be achieved against NTC capability of 1.5 km/day with 10 hrs shift in 24 hrs cycle.

The research methodology to enhance process productivity has been elaborated in Figure 2.

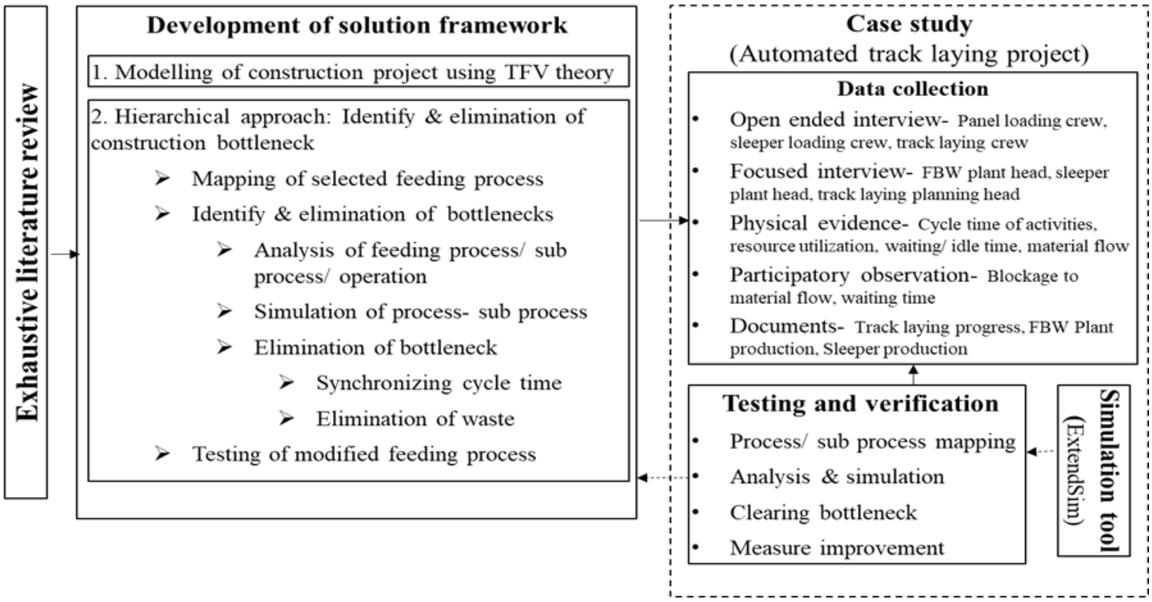

Figure 2 Research methodology

V. Research Findings

- Mapping of the construction flow processes can reveal mismatch in C/T of interconnected processes/ sub processes/ operations. However, in case of complex sub processes/ sub processes, discrete event simulation will be required.
- Initially, track laying was a bottleneck activity. The introduction of NTC for track laying shifted bottleneck to other sub processes.
- The analysis of data revealed new location of bottlenecks and requirement of additional resources for synchronization of C/T.
- The use of additional resources (i.e. double rack transportation system, 9 bed sleeper production, etc.) increased the rate of track laying from 30 km per month to 72 km per month.

VI. Conclusions

- The lack of synchronization in a flow process create construction bottlenecks and restrict continuous flow of input material to the pull activities.
- Mechanization and waste reduction does reduce the C/T but may not enhance the overall rate of progress if the flow is not balanced, rather shift the location of bottlenecks.
- The proposed framework, offers systematic approach to identify the bottlenecks and progressively synchronize the C/T till required rate of progress is achieved.

Last Planner Implementation in Building Projects

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Lean Methods to Improve End User Satisfaction in Higher Education Buildings

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I. Background

End user satisfaction is one of the major indices that attest to the success of a project in terms of adding value to the client. In order to rate the overall functions of a facility, the fulfilment of end users' needs is to be taken into consideration during the whole project phase (i.e. design through operation). Many clients believe that allocating more resources and higher budgets to a project automatically guarantees the project’s success. What they fail to realize is that in most cases, success, which can be translated in end user satisfaction, relies more on how the project was thought of, planned, constructed and delivered. This paper highlights the ongoing problem through studying the case of a high-budget engineering complex at the American University of Beirut. Despite the owner’s optimistically high satisfaction with the complex, end users are disappointed. The paper also aimed to suggest lean methods and tools to be used instead of traditional methods to improve the design and delivery of such facilities and establish a higher end user satisfaction rate.

II. Case Study

The building considered in this research is the Irany Oxy Engineering Complex (IOEC). Main insights include:

- six floors and two basements
- more than 60 highly equipped teaching and research laboratories, six state-of-the-art classrooms including an e-classroom and data center, and 85 cubicles for doctoral students
- first building to register for LEED-NC certification, the gold standard of ‘green design’ in Lebanon

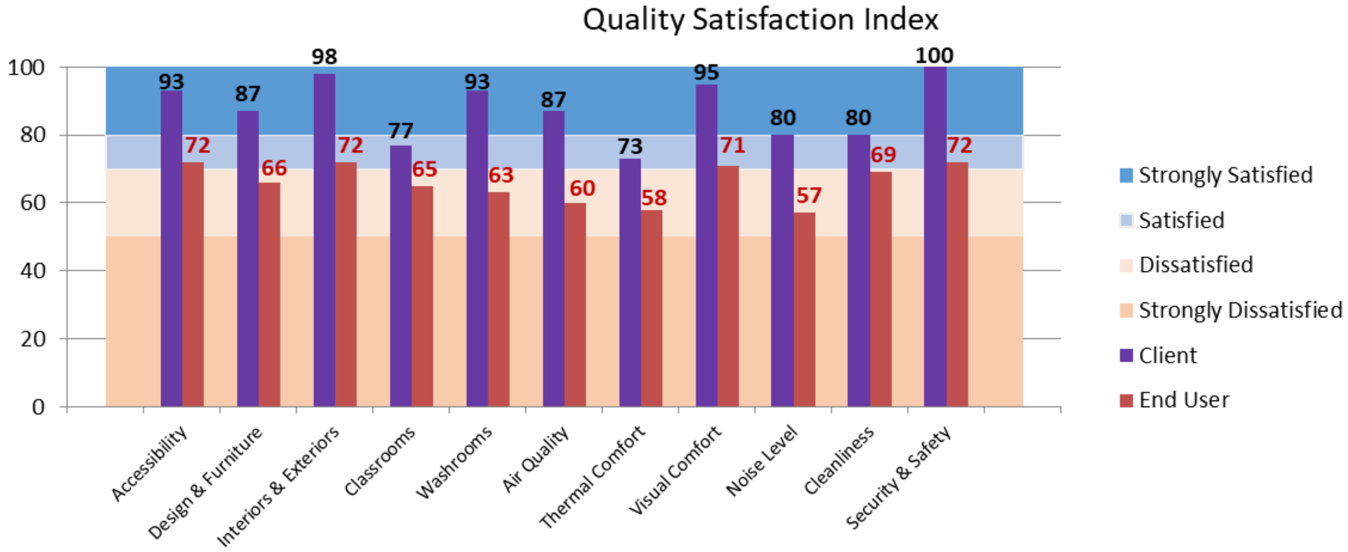
The complex was subjected to a post occupancy evaluation exercise to measure the end-users satisfaction and suggest implementing Lean approaches during the early lifecycle of design and construction that could have enhanced the process.

III. Methodology

- An end-user satisfaction survey was designed, tested and distributed to different end users who use IOEC (population included engineering students of different majors, staff working inside IOEC and professors); the survey was also filled by AUB’s Facility Design and Planning Unit (FPDU) representing the owner of the complex
- The satisfaction level with the complex as filled by both parties was compared and analyzed were compared and analyzed; For further data analysis, two interviews were set with the operation manager of IOEC, a major end user of the complex, and a senior project manager representing the FPDU
- The importance and relevance of the results were evaluated, and Lean solutions were suggested by the authors to help improve the end user satisfaction for future projects

IV. Results & Analysis

The results of the detailed section of the survey (represented in the graph below) show a clear gap between the satisfaction of the end users and that of the owner; end users were mostly dissatisfied with the studied aspects while the owner was mostly strongly satisfied with them.



Upon conducting an interview with every party for further analysis, the following was noted:

- The design of the building took an unusual duration of two years and costed around $700,000 due to the hindered communication between the different entities. As for the construction, it started three years after the design phase finished.
- The delay between the design and construction phase incurred unnecessary costs due to the fluctuation of raw materials prices. New majors were also added to the engineering faculty during the delay that required more space and lead to changes in design and construction. The cost of the complex increased from an estimated $10 million to more than $24 million.
- Traditional minded planners refused the idea of adopting new concepts such as lean and avoided large collaborative meetings with the faculty members. Tradition stakeholders also objected the idea of modern class designs and furniture.

V. Conclusions

In order to narrow down such conflicts in future projects, and fulfill a better end user satisfaction rate, a shift in planning perspective is needed and a number of lean management processes are to be implemented. Design and planning units in educational facilities such as the FPDU in AUB are encouraged to find lean innovative measures to improve design without impacting an increase in cost (e.g., Target Value Design, Target Costing, and LPS) and eliminate non-value adding activities and design concepts in order to reduce time and cost and increase overall value of the facility. They are also encouraged to command proper sharing of information and data (less tedious RFIs, enhanced communications) between the different stakeholders in order to help achieve value, explore different alternatives to come up with the most suitable in order to avoid rework or maintenance problems and apply global instead of local optimization. Most importantly, the design and planning team should align the client's needs with that of the end user and involve the latter as heavily as possible during the entire project phases to guarantee project satisfaction. Applying all the above is the first step towards Lean Project Delivery to increase the delivered value to the end user in terms of safety, quality and value fulfillment.

Supply chain management in construction from a production theory perspective

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I. Background

Despite the successful examples of Supply Chain Management (SCM) initiatives at the higher tiers of the construction supply chain, relationships at the lower tiers seem to remain traditional and the SC Maturity of construction firms continues to be low (Broft et al., 2016). The quality of a main contractor-supplier relationship affects the main contractors' ability to perform on projects (Kale & Arditi, 2001). The increasing percentage of project turnover which is spent on buying goods and services provides opportunities for contractor-supplier collaboration, and emphasises the importance and significance of managing suppliers (Bemelmans et al., 2012). Main contractors are willing to develop closer relationships, but implementing SCM seems a long-term, complex process and requires a certain level of understanding and therefore learning throughout the supply chain (Broft et al., 2016). In the last decades, various supply chain concepts have emerged in parallel in generic theory and manufacturing practice – all highly related, leading to a high ambiguity between the definitions of the different concepts and reflecting the cross-functional nature of SCM (Ellram & Cooper, 2014).

II. Current conditions

The construction industry, both theoretically and in practice, has been dominated by the transformation concept (Koskela, 2000). This conventional model was criticised for its centralised and formal management, as this does not recognise the uncertainty of and interdependence between the operations of the construction process (Tavistock Institute, 1966). The correctives to the conventional model have been explicitly or implicitly based on flow and value principles. One of these correctives, SCM, can be seen as an alternative for realising efficient construction management.

In construction, SCM is often seen as a project-specific approach (Green et al., 2005). Main contractors have a central position in the management of supply chains (Pryke, 2009) – it is believed that main contractors have more influence on the organisation of the project and on the performance and quality of the work of its suppliers. However, implementation of SCM by main contractors is relatively slow (Green et al., 2005).

III. Research aim

This paper takes a closer look at SCM as an alternative for efficient management of construction production. An analysis from the production perspective might help to create a better understanding of the concept – discussion exists whether SCM is based on flow or value principles.

IV. Research analysis & findings

SCM is considered a way of thinking about management and processes, which includes improved relationships, integrated processes and increased customer focus (Pryke, 2009). Integration (or interdependency) and value creation – important aspects of the F- and V-conceptualisations of the production theory – seem to be essential in SCM. The Table represents the characteristics of SCM in construction from each production perspective, following from the analysis in the paper. The table is descriptive – it decomposes SCM to its constituents and presents them as key principles.

Table: The characteristics of SCM in construction from a TFV-perspective

View on production	Conceptualisation of SCM	Key principles
Common to all views	Long-term collaborations between supply chain actors to ensure a project-exceeding focus and to create a more permanent organisation.	▪ Long-term collaboration with suppliers.
Transformation	Managing all subprocesses, subcontracted to different suppliers, and logistics needed to perform a production process. Relationships between subprocesses are acknowledged, but remain transactional.	▪ Clusters of related transactions that are managed as chains; ▪ Non-temporary organisation; ▪ Alternative ways for the minimisation of transaction costs.
Flow	A supply chain, encompassing all the subprocesses is conceptualised as a production flow. Coordination between subprocesses is important in order to boost total process efficiency and effectiveness across members of the supply chain. This involves the acknowledgement of interdependencies between subprocesses, and includes integration. This integration between subprocesses focuses on the overall efficiency of the entire supply chain.	▪ Focus on overall efficiency; ▪ Lead time reduction through the elimination of waste and the reduction of variability; ▪ Product-focus (including the subprocesses organised around this product).
Value	Ensuring that the client’s needs are fulfilled and that value creation is maximised – all supply chain actors need to be able to make a full contribution. This implies a collaborative customer focus and a higher quality of each delivered subprocess.	▪ Fulfilment of customer requirements for the product regarding time, cost and quality; ▪ A higher quality of each delivered sub-product; ▪ Collaborative customer focus; ▪ Common product development; ▪ Supplier prequalification and early supplier involvement; ▪ Mutual competitive advantage.

V. Conclusions

Production management in construction is moving away from conventional construction management. SCM is often presented as suitable for efficient management of construction production. Its successful implementation in the industry, however, remains limited to the improvement of logistics and inventory, whereas in some industries SCM has become a central strategy, dealing with total business excellence.

Important aspects of the F- and V-conceptualisations of the production theory have already been implicitly acknowledged in SCM, however, this paper provides the reader with a more descriptive and explicit conceptualisation of SCM from each production perspective and reflects the difference between each view on these conceptualisations.

Despite that all three SCM conceptualisations include long-term collaborations with suppliers, clustering subprocesses around a supply chain, each view on production emphasises a different aspect of SCM. Where transformation focuses on the transactional relationship between subprocesses (or in other words, suppliers) and focuses on cost minimisation accordingly, flow acknowledges the interdependency through the integration of processes and the creation of relationships, and value acknowledges the delivery of quality as a result of each subprocess. The differences have been presented in the paper. In this way, the paper creates a better understanding of the SCM concept and suggests that for SCM to succeed in the best possible manner, all three views need to be considered and promoted. This understanding could be used prescriptively in the further development of SCM in construction, and added clarity of the concept might subsequently offer opportunities for successful implementation of SCM at the lower tiers of the construction supply chain.

COMPLEX PRODUCTION SYSTEMS: NON-LINEAR AND NON-REPETITIVE PROJECTS

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I. Background

In most residential building construction, the production system design relies on the assumption of linearity per zone and per story, thus, takt-time schedules and flowlines are produced accordingly. However, in practice, such smoothness is difficult to achieve due to non-linear and non-repetitive projects (complex production systems). Contractually, these projects are managed with Critical Path Method (CPM) master schedules with multiple sectional completion dates. Production teams who apply TTP or flowlines in linear and repetitive project face problems in non-linear projects due to unequal workload between zones and discrete activities.

Project/Location >	Size	Operations	Resources	Flow	Outputs
Repetitive Linear	Equal	Equal	Equal	Smooth	Equal
Repetitive Non-linear	Not uniform	Equal	Not uniform	Moderate	Not uniform
Non-repetitive	Unequal	Unequal	Not uniform	Turbulent	Unequal

II. Research method

The aim of this research is to (1) develop a framework for complex production systems, and (2) identify the main challenges of production system design in non-linear and non-repetitive projects. First, a framework for complex production systems is drawn from the literature. Second, data was collected from two existing construction projects (drawings, takt-time and CPM schedules, division of locations, trade contractors' production rates, interviews). Third, projects were modelled using BIM software. Results were contrasted with the complex production system framework. Finally, the findings are discussed, and directions for further empirical validation are presented.

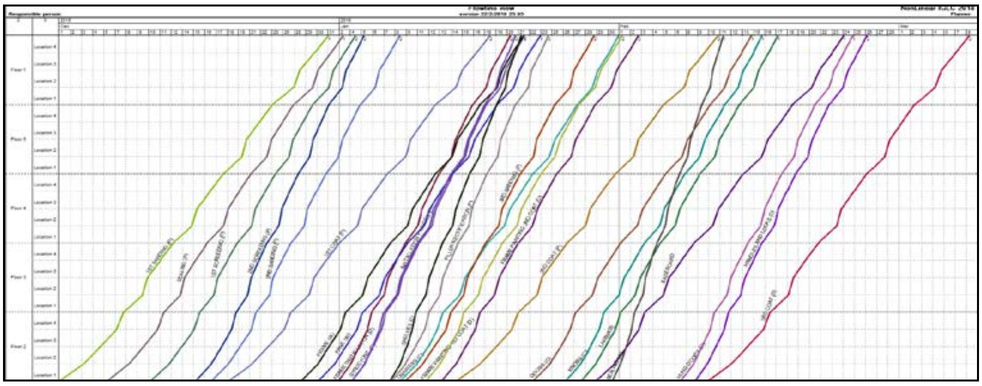
III. Framework

Gidado (1996) found that the components of complexity in the production processes of construction can be categorized as (a) complexity in components that are inherent in the operation of individual tasks, and (b) complexity when bringing together different parts to form a workflow. Williams (1999), contended that complexity in construction projects can be regarded as: (a) variety of tasks, and (b) degree of interdependencies of tasks.

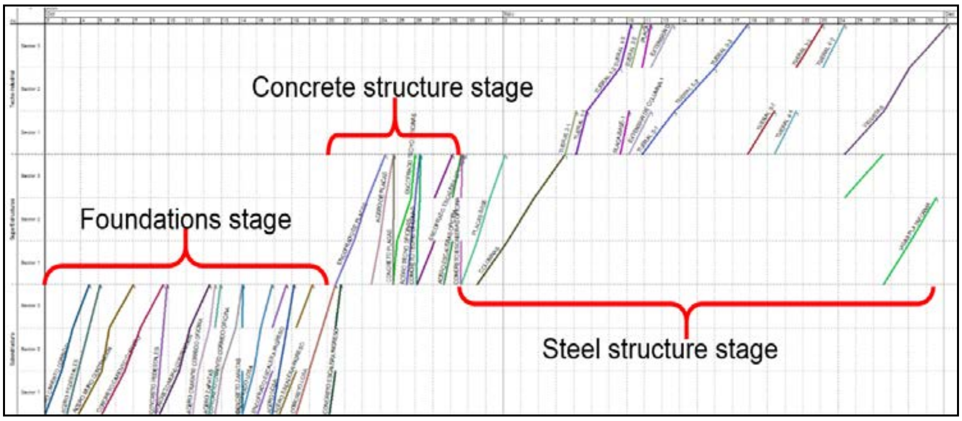
Complex production system	Description
Variety of tasks	This includes the variety of sub-systems in the project, variety of tasks per location, and one-off products.
Task interdependence	Network of activities at the operational level are pooled, sequential, or reciprocal.
Supply chain interdependence	Variety of trade contractors and their involvement with pre-fabrication, design changes, or incomplete designs.
Work density disparity	Depends on the scope of work per area, the number of crews and their capabilities, and trade's means and methods

IV. Research Findings

In the first simulation (non-linear), high levels of ***sequential*** and ***reciprocal*** interdependence were observed. One of the main challenges of a non-linear system is the crew design due to the ***work density*** disparity between zones. If the number of crews is fixed, there will be high productivity in the bigger locations and low productivity in the smaller locations. Crews might not be able to deal with cycles of random work shifts. Thus, LBMS seems to be a strategy for the production system design as it allows constant resources across locations. Finally, the ***supply chain interdependence*** could be minimised if pre-fabrication of components is allowed in the system.



The second simulation (non-repetitive work) is produced based on contractual stipulations. Thus, the project is divided into several independent stages depending on the ***variety of sub-systems*** in which each trade contractor works independently from others. This becomes critical when one-off products are to be installed. As a result, the more sub-systems, the more stages in the master schedule. Structural steel assembly exhibits ***sequential*** interdependence. However, activities at the operational level have high levels of uncertainty, negotiation, and ***supply chain interdependence***. Crew design also becomes a challenge as it is not economical nor productive to allocate crews for each component type or unique task



VII. Conclusions

A crucial step is to identify the reciprocal interdependences between trade contractors as this interaction becomes critical in the field. The work density disparity is a key factor in the production system design as it causes high and low productivities in different locations as well as crew's periods of downtime. The simulations suggest that flowlines scheduling method is more suitable when a planning team faces a non-linear project. A non-repetitive project can be handled as a repetitive non-linear one although quantities and distribution of locations change across stages. However, each location exhibits high levels of variability due to the supply chain interdependence and the difficulty in the prediction of production rates.

RESPECT FOR PEOPLE'S WELL-BEING: MEDITATION FOR CONSTRUCTION WORKERS

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I. Introduction

Work stress is recognised world-wide as a major challenge to workers' health and the healthiness of their organizations (Leka et al. 2004). The practice of meditation appears to be beneficial in environments where people have high levels of stress, such as the workplace (Cramer et al. 2016; Elder 2014). The aim of the study was to understand the perceptions of construction workers who had participation of a meditation-training program as emotion-focused coping. The objectives were to discover if they would be willing to practice meditation, and its preparation stretching, respiratory exercise and relaxation.

II. Background

- Some life habits, such as smoking, alcoholism and other drugs, increased their occurrence after some employees started to work with construction (Haupt et al. 2016).
- Studies indicate that the mechanisms to face stressful events, adopted by construction workers, lead to worse feelings of psychological suffering (Langdon and Sawang 2017).
- Meditation improvement in psychological symptoms and perceived stress, suggest that the improvements result from regular practice and are related to the significant reductions in psychological distress and perceived stress (Carmody and Baer 2008).
- The psychological and organizational literature suggests that full attention meditation can have a meaningful influence in the well-being of the employees (Good et al. 2016).
- The results of respect for people will be beneficial to all, because in showing respect for the workforce, it earns both the respect of the workforce and the public in general (Movement for Innovation 2000).

III. Research Method

Qualitative method was used. The action research method is adopted as a strategy. The action research method approaches scientific research from an interventionist's viewpoint, and researchers both observe and participate in the phenomena under study (Baskerville 1997). A corporate meditation program was developed and took four weeks long. Guided Meditation technique was applied and included: Preparation with Stretching, Respiratory Exercise and Relaxation. Qualitative data-collection techniques were combined: interviews, direct observation and filming. Construction workers participated voluntarily in order to demonstrate them point of view, without pretensions of generalization. This work followed the logic of replication (Yin 2001, 2013).

IV. Research Findings

- Based on analysis of filming realized it was possible to observe that construction workers did not have great difficulties to put in to carry out the practice of conscious breathing and relaxation;
- All participants followed teacher's instructions with seriousness and attention and performed the exercises of conscious breathing and relaxation, which had purpose of preparing for meditation moment;

Source: The authors, *Shots of conscious breathing and relaxation techniques in the job site*

- Majority of the interviewees that practiced meditation in the job site totally agreed there are demands to implement this activity in the job site;
- Majority of interviewees agreed meditation in construction values the workers, contributing more for good attitudes that intend to offer higher satisfaction levels to the workers of the approached company.

Source: The authors, *Construction workers during meditation practice*

- The barriers against meditation could be overcome with good planning along time, in a way it does not mess the employees' work routine and their work pace.

V. Conclusions

- This research shows there is viability for meditation in construction
- Participants construction workers consider that meditation values them, they also recommend its implementation;
- It is viable to introduce a meditation routine, as a emotion-focused coping, within the weeky activities at a construction site;
- Meditation is an opportunity to express respect for the workforce and obtain benefits out of this important principle. It is believed that, through these actions, the company is "building" people before "building" houses.
- The research findings provide insights on how the construction industry could improve the quality of life of it is most important resource: people.

Literature Review on Visual Construction Progress Monitoring using Unmanned Aerial Vehicles

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I. Background and Current conditions

- The most common practices for construction progress monitoring are still based on individual observations and often still rely on text-based documentation (Teizer, 2015).
- Studies highlight the use of visual data technologies in construction, such as photographs, videos, 3D and 4D models, as solutions that improve and optimize the progress monitoring, making it more transparent and collaborative and reducing non-value adding, costly and time-consuming activities associated with this manage process (Teizer, 2015; Han and Golparvar-Fard, 2017; Lin and Golparvar-Fard, 2017; Tezel and Aziz, 2017).
- By enabling fast and efficient construction site images capture, the potential of Unmanned Aerial Vehicles (UAVs) with integrated cameras to monitor and document construction progress has been explored in recent studies (Lin *et al*., 2015; McCabe *et al*., 2017).

II. Objectives

In view of the large number of publications that address the use of visual data for construction progress monitoring and the growing use of UAVs for recording the work status, the main goal of this study is to present a systematic literature review aiming to discuss the use of UAVs and visual data to aid construction progress monitoring.

III. Research Method

Two systematic literature reviews were carried out using Scopus database:

1) Literature review 1: Use of visual data for construction progress monitoring.
2) Literature review 2: Use of UAVs to aid construction progress monitoring

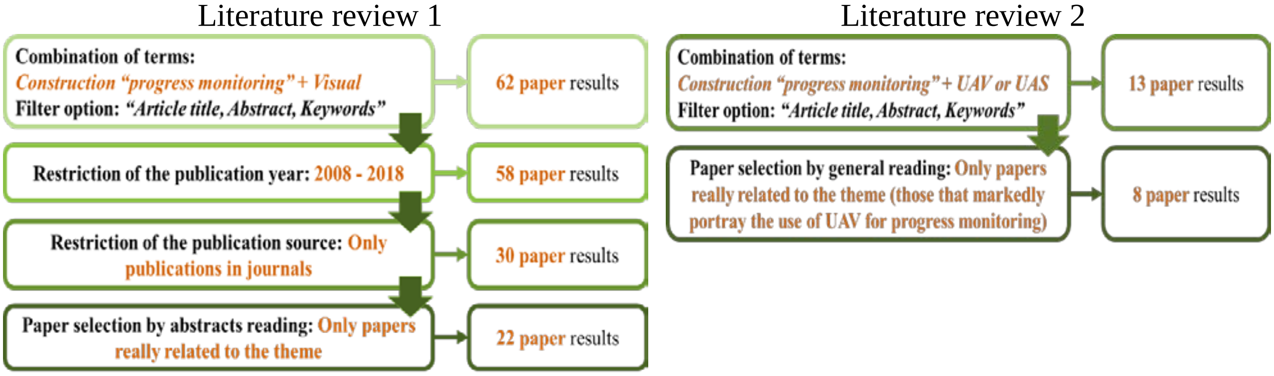

Figure 1: Step-by-step of the literature reviews

From the papers selected in the literature reviews, the following analyses were carried out:

- Quantitative distributions: publications per source and per year;
- Identification and analyse of specific frequent or relevant issues classified according to: (a) visual data recording technologies, (b) other associated technologies, and (c) other topics/themes addressed;
- Discussions on how the papers address the specific use of UAVs.

IV. Research Findings

- **Use of visual data for construction progress monitoring:**

The most frequent or relevant subjects among the papers identified in this literature review included:

a) The acquisition of images by hand-held digital cameras as the most used technology for visual work status recording in sites, presented in 15 of the 22 papers;
b) The noteworthy use of automated systems technologies, appearing in 19 of the 22 papers, and the also relative frequency of using 3D as-built by point cloud technologies (present in 14 of the 22 papers) and as-planned Building Information Modelling (BIM) (in 11 of the 22 papers);
c) The topic of the integration of visual progress monitoring to the construction management system presented very low frequency, addressed directly by only two of the 22 papers.

- **Use of UAVs to aid construction progress monitoring:**

Table 1 presents the main recurrent or relevant specific subjects addressed by the eight papers selected in literature review 2.

Table 1 – Most frequent or relevant subjects covered by the papers

Most frequent or relevant subjects in the 8 selected papers			Subjects of each paper								Total
			A1	A2	A3	A4	A5	A6	A7	A8	
Other technologies for recording visual data		Images by hand-held digital cameras	x	x			x				3
		Laser scanner	x	x			x				3
		Video recorder					x	x			2
		Satellite imagery									0
Other associated technologies		Point cloud (digital photogrammetry)	x	x	x		x		x	x	6
		Building Information Modeling (BIM)	x	x	x	x	x			x	6
		Geographic Information System (GIS)									0
		Computer-Aided Design (CAD)									0
		Feature/pattern recognition techniques	x				x		x	x	4
		Automated systems technologies	x	x	x	x	x		x	x	7
		Web Systems				x	x				2
Other themes	Typology	Building constructions	x	x	x		x	x		x	6
		Infrastructure constructions									0
		Integration with construction management	x				x				2
		Cost of technologies adopting						x			1
		Literature review papers				x	x				2

Most discussed subjects; Less discussed subjects; Subjects not covered

A1: Han *et al.* (2018); **A2:** Tuttas *et al.* (2017); **A3:** Qu *et al.* (2017); **A4:** McCabe *et al.* (2017); **A5:** Han and Golparvar-Fard (2017); **A6:** Irizarry e Costa (2016); **A7:** Fang *et al.* (2016); **A8:** Lin *et al.* (2015).

- **The UAV as a tool for Construction Progress Monitoring:**

The specific approach of the UAV technology for progress monitoring varied slightly among the eight selected papers: (1) five studies approach the UAV as a tool for continuous acquisition of site images used for point cloud model generation; (2) one paper present UAVs as an alternative for recording images used in the continuous 3D tracking of construction elements; (3) one paper identify progress monitoring as a potential managerial application for UAVs' visual assets of the site; and (4) one paper provide a literature review of the potential of UAVs for internal building monitoring.

V. Conclusions

- The literature review indicates the use and development of automated system technologies as the subject most overly addressed in the studies related to visual progress monitoring.
- The use of point cloud models for as-built 3D representation and BIM for as-planned are presented as the main visual technologies to aid construction progress monitoring.
- A gap was identified regarding the lack of studies that effectively integrate the visual monitoring with the construction management systems.
- It is necessary that new studies about visual progress monitoring, especially with the support of UAVs, address the impact of this new visual technologies in construction management systems, considering aspects associated with Lean principals, such as improvement of visual management, increased communication and collaboration in construction progress management and increased process transparency.

Last Planner System: Implementation and Evaluation with Focus on the Phase Schedule

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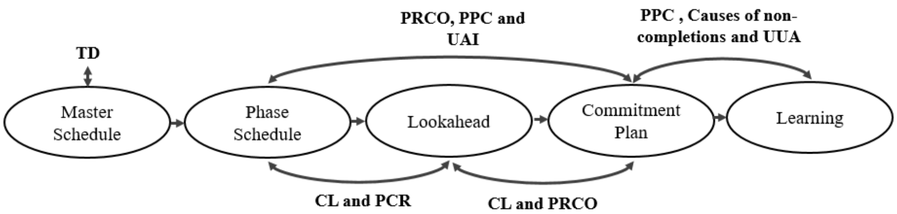
I. Background

The development of the Last Planner System (LPS) established several changes in the way construction projects were planned and controlled. The LPS is divided into different planning levels (Ballard and Tommelein, 2016): master scheduling; phase scheduling; lookahead planning; commitment planning; and learning. A set of the metrics identified in the literature may support the adherence and integration between planning levels, such as: Time Deviation (TD); Commitment Level (CL); Percentage of Constraint Removal (PCR); Percent Required Completed or Ongoing (PRCO); Percent Planned Complete (PPC) and Cause of non-completion plan; Unplanned Activities Included in the commitment planning (UAI); and Unplanned and Unfinished Activities in the commitment planning (UUA).



II. Current conditions

Despite some studies about the use of the Phase Schedule practices, there is still a need to understand how to implement and evaluate the LPS performance, focusing on the Phase Schedule, aiming to integrate the hierarchical planning levels

III. Research Method

Two in-depth case studies were carried out in Salvador-Brazil to implement and evaluate the LPS focusing on the Phase Schedule practices. The Phase Schedule cycle was carried in the Case Studies, through the following steps: (a) preparation; (b) meetings; and (c) monitoring of the activities and constraints planned.

Stages of the implementation cycle	**Techniques or tools**	**People involved in the Case Study A**	**People involved in the Case Study B**
Phase Schedule preparation	Construction projects Master planning in the MSProject tool	1 Production Engineer 2 interns 2 foremen 5 supervisors of the subcontractors	1 Production Engineer 3 interns 1 foreman and 3 supervisors 5 supervisors of the subcontractors
	Excel sheets		
Phase Schedule meetings	Board and Post its Reverse plan Construction projects Excel sheets		
Monitoring of the planned activities and constraints	Excel sheets for the monitoring of what was planned in the meetings		
Process evaluation	Structured Questionnaire		

A set of constructs and variables were proposed for data analysis: collaboration, transparency, adherence between planning levels, reliability of plans and commitment to the deadlines.

IV. Research Findings

The effectiveness of the Phase Schedule practices, which are the techniques used (reverse planning, board, post-it) are concerned to collaboration and transparency and the effectiveness of the processes of the LPS, which are the procedures the team will perform to achieve the defined goals (monitoring of the activities and constraints, use of metrics), are related to adherence between planning levels, reliability of plans and commitment to the deadlines. The main findings in relation to the proposed constructs are summarized in the table below.

Constructs	Strengths
Collaboration	Joint decision making and shared knowledge
	Previous discussions between the team involved
	Self-reorganization and better interaction between the production team
	Joint identification of constraints
Transparency	Verification of activities that would be performed simultaneously through visual tools
	Simplification of the information
	Better visualization of all activities in the phase schedule, facilitating the reorganization
	Reorganization more efficient
Adherence between Planning Levels	CL and PCR indicators: relation between Phase Schedule and lookahead planning. Evaluation of whether what was planned concerning the start dates of the activities and the due date for removal of the constraints was achieved
	CL and PRCO indicators: relation between the lookahead planning and the commitment planning. Evaluation of whether the activities that were ready to be executed were actually planned and executed within the duration stipulated in the Phase Schedule
	PRCO and PPC indicators: relation between Phase Schedule and commitment planning. The activities taken into account in the PRCO are part of the activities in PPC
	UAI and UUA indicators: complement the PRCO and PPC indicators. Provide information about the activities not planned in the Phase Schedule cycles.
Reliability of Plans	The team that participated in the Phase Schedule meetings was also the one that monitored the constraints and activities planned
	Case Study A: constraints were not removed until the due date (PCR average 66%), however, there was a greater effort to remove the constraints at the last moment (CL average 88%). Case Study B: constraints were removed at the due dates (PCR average 78%) and the activities were ready to be executed on time (CL average 72%).
Commitment to the Deadlines	Two commitments: (1) start the activity on the planned date - evaluated by the CL (2) end the activity on the planned date - evaluated by the PRCO
	Analysis of the master plan – evaluated by the Time Deviation (TD) indicator

V. Conclusions

- The constraints analysis, the collaboration between those involved and the transparency in the planning processes were improved in both Case Studies.
- The metrics selected improved the adherence between planning levels, reliability of plans and commitment to the deadlines.
- Two main commitments are made between those involved in the Phase Schedule cycle: to make the activities ready to be executed and to complete the activity within the deadline.
- The activities which were not analyzed as critical for planning in the Phase Schedule had strong influence on the performance of the PPC.

PAPERS CONVERTED TO POSTERS

Towards a Lean-led Cost Management framework for Public sectors projects: Identification of Lean Opportunities

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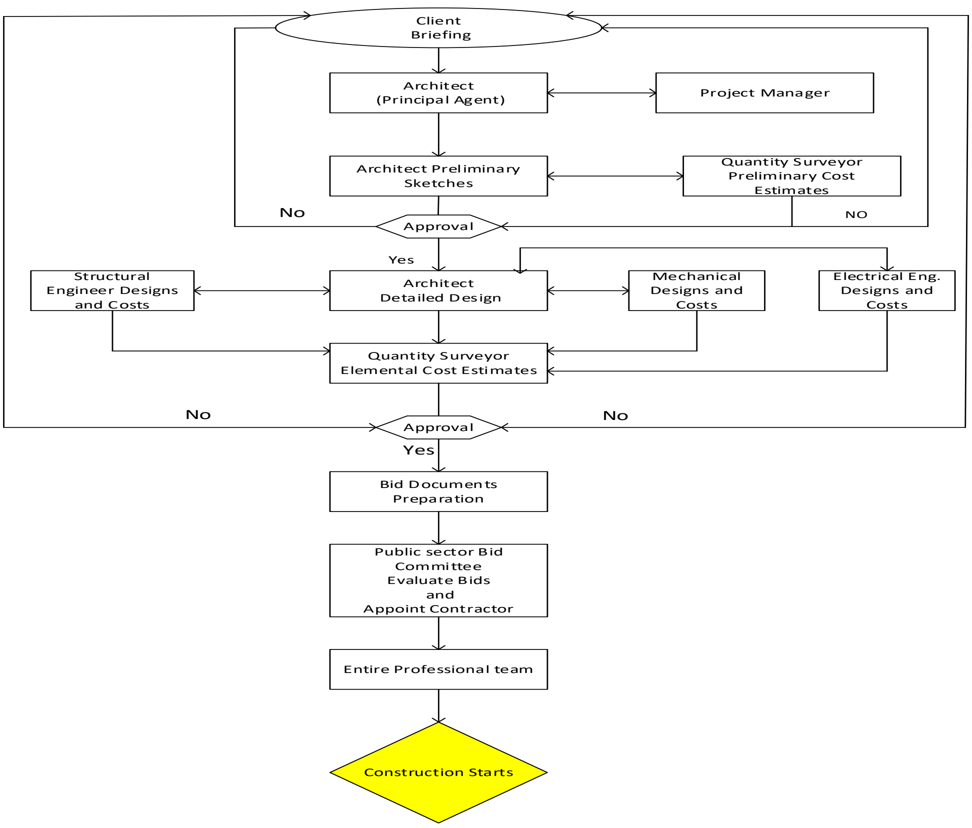
Gerrit Crafford, Associate Professor, Nelson Mandela University, RSA

I. Background

Prior studies by the authors of this study reported on the status quo of projects cost management; study identified the challenges hindering effective project cost management in the delivery of projects in South Africa. Four case study projects were evaluated and validated by interviews with project participants to strengthen the comprehension of the status quo of cost management approaches used in the South African construction industry. The objective of this study is to provide a vignette of lean-led cost management framework applied to these projects. Various stages and activities by the project planning teams are revealed from inception until project construction completion. The vignette displays lean opportunities to add value by eliminating waste, reduction of lead times, cost optimization.

II. Current conditions

- The pre-contract cost management in South Arica involves an advisory service provided by consultants to a client on the price to design and construct a project
- The tasks are isolated and driven solely by the cost manager with little regard to collaborative costing by all project participants. Fragmentation is reported as major cause of overruns experienced on projects

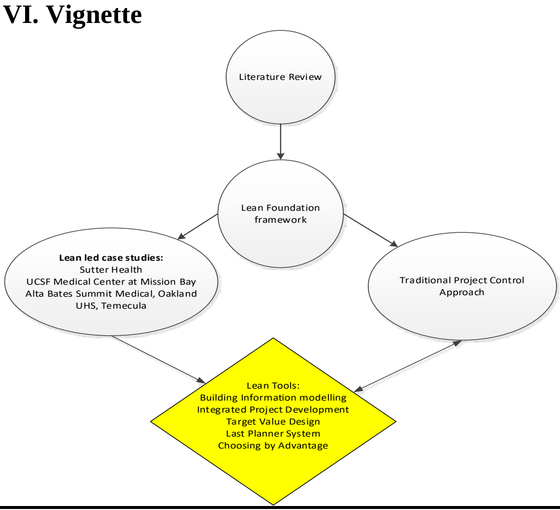


III. Working hypotheses

- *Target value design may definitely assist with reducing first cost, but constructing to target may pose challenges. Secondly lean culture needs to embraced before even tools such as TVD may be applied, hence a lean-led cost management framework specific for South African context is a necessity.*

IV. Research Method

A qualitative research design from a coterie of recently completed cases from the public sector. In addition, interviews were conducted with project participants to triangulate findings from document analysis.

<table>
<tr><td>I. Background
The culture of traditional project delivery still dominates the South African construction market in recent times.</td><td>V. Proposed countermeasures
The industry is embracing BIM due to client demands and obviously remaining relevant to new ways required for business survival. BIM is already the buzz word in the industry ad it also requires all stakeholders to really collaborate not just come together for the sake of a project.</td></tr>
<tr><td>II. Current conditions
The same old ways of delivering projects are expected to bring out different outcomes of projects
- figure above displays the management of cost from the inception stage of projects until handover of asset to project owner.</td><td rowspan="2">VI. Vignette

</td></tr>
<tr><td>III. Goals/Targets
To develop a lean led cost management framework from a South African perspective from a combination of known lean tools.</td></tr>
<tr><td>IV. Analysis
The construction stakeholders believe that the traditional way of doing things just needs a different approach to attain the different outcome.
- Comparison of lean led projects were compared with traditional ones to convince all stakeholders of the needs to change.
Cost management is still a fragmented process without any consideration to collaborative costing</td><td>VII. Follow up
The new roadmap for BIM implementation should really begin at the bottom and built its way up to have a real collaboration from project participants.
- Ensure the cost manager is the center of the model as costs are requires an expert to take charge and get everyone's buy-in.
- Lean culture needs to be instilled and training is a necessity to overcome barriers</td></tr>
</table>

Source: Shook, J. (2008). *Managing to Learn: Using the A3 Management Process to Solve Problems, Gain Agreement, Mentor, and Lead, Lean Enterprise Institute, Cambridge, MA, 138 pp.*

V. Research Findings

Multiple lean tools are a necessity to be applied in different situations to achieve efficiency and effectiveness in delivering projects. Lean-led cost management framework from an SA context will assist practitioners to embrace lean construction implementation in the country.

VI. Conclusions

- To really obtain optimum efficiency in project delivery, lean culture is pertinent.

A LEAN E-GOVERNANCE APPROACH TO MITIGATE CORRUPTION WITHIN OFFICIAL PROCESSES IN THE CONSTRUCTION INDUSTRY

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I. Background

Lebanon is a country that has been plagued by corruption; official processes run at suboptimal levels and delay the day-to-day activities of citizens and projects across all industries. The concept of applying lean methods to mitigate this corruption is promising; as this is the first study in Lebanon to address this issue by employing a lean perspective. The aim of this paper is to analyze, assess, and formulate frameworks of official processes based on interviews conducted with professionals in the field who have experienced unexplained delays in their construction documents. The study develops a tailored e-governance strategy that would effectively lead to a lean revamp in the public sector in terms of service quality, transparency, and reliability. This study serves as the theoretical foundation for the transformative shift in the official processes in the Lebanese official processes.

II. Current conditions

Residential permits must be issued to register apartments for the owners. The official time for this permit is stated as ten days, where it passes through five stages to check that the constructed facility coincides with the designs and that prices are adequate.

The process is vulnerable to manipulation by the employees performing it; especially when supervision is absent. And a great proof of that is the fact that a process can be performed within one day if a bribe is offered.

F.H. is a document tracker who has been in field for over 30 years. He believes that bribery has become the guaranteed path to perform any service in a much shorter time, and that employees in public sectors manipulate their positions for personal interests. He stated that sometimes they might fabricate illegal intentions or even claim that a document is missing just to provoke the owner to offer a bribe for him.

III. Working hypotheses

The first step in solving the problems stated above is to establish clear simple guidelines that cannot be manipulated. Second, processes must be digitized to enable the control over them and the introduction of lean principles to make them more efficient.

In order to develop an effective strategy to mitigate the effect of government corruption, two strategies must be followed to illustrate the methods in which an impactful change can be achieved.

IV. Research Method

- Exploratory research about corruption within official processes in Lebanon
- Short interviews to determine the current process steps and the impact of document delays on the construction projects
- Interviews with construction engineers and a document tracker that has been working in the field for more than 30 years

V. Research Findings

- LEAN IT STRATEGY: This foundation is in the form of an Enterprise Resource Planning (ERP) System that breaks down barriers in terms of information silos and enables the swift and real-time transfer of information between different governmental entities involved. Lebanese ministries always have interdisciplinary work among them that requires them to connect with each other in an efficient manner, so an ERP system would be essential to maintain a proper flow of information among them.
- PHASES OF LEAN IT:

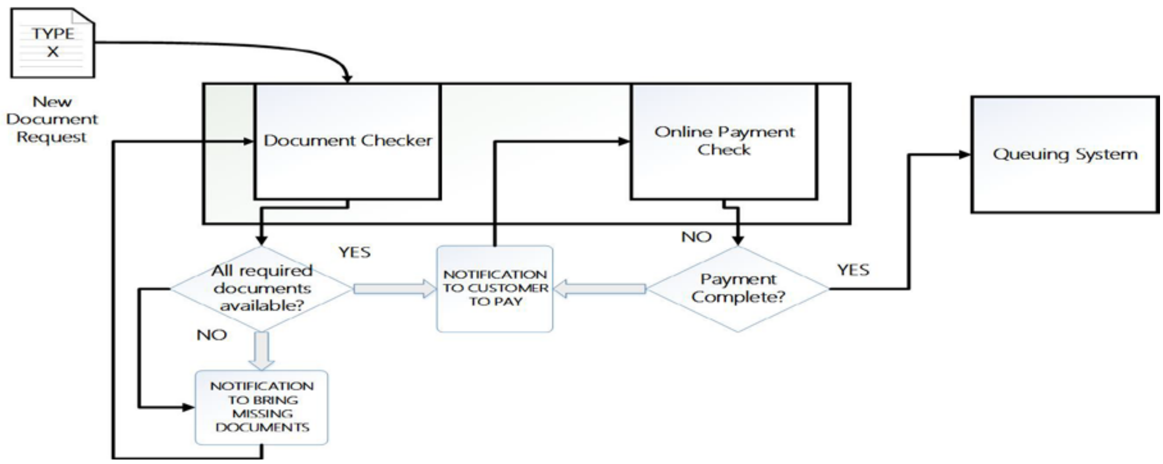

Figure 1 Phase I

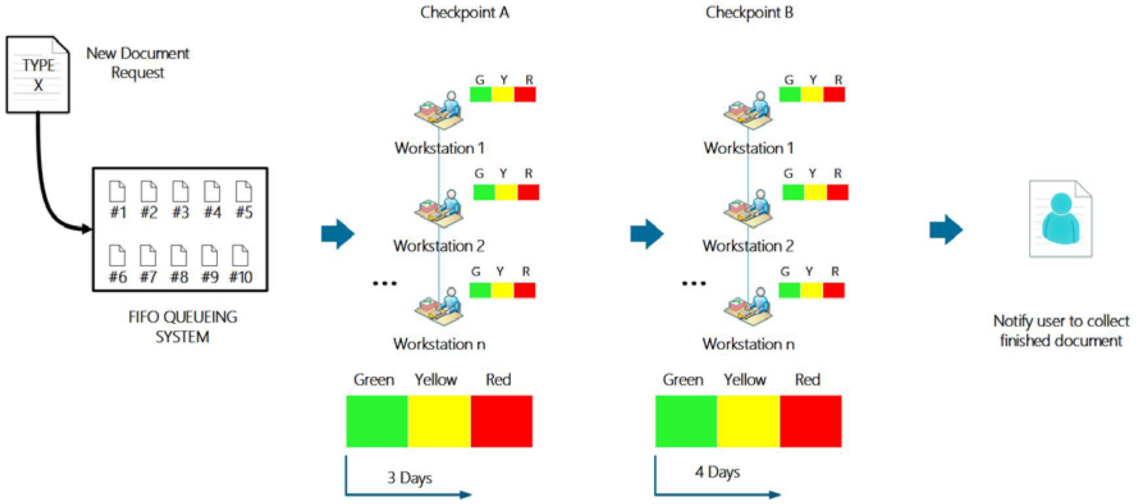

Figure 2 Phase II

VI. Conclusions

These strategies will start by removing inefficiencies of current procedures to end with improved processes that would keep improving with time. By that, we would elevate the standards and transparency within the Lebanese Construction Industry in a way that would motivate other industries to adopt such a lean mentality, and in return, advance at both a personal level as well as a country-wide level through promoting a sense of reliability and authenticity of work.

Lean Formwork

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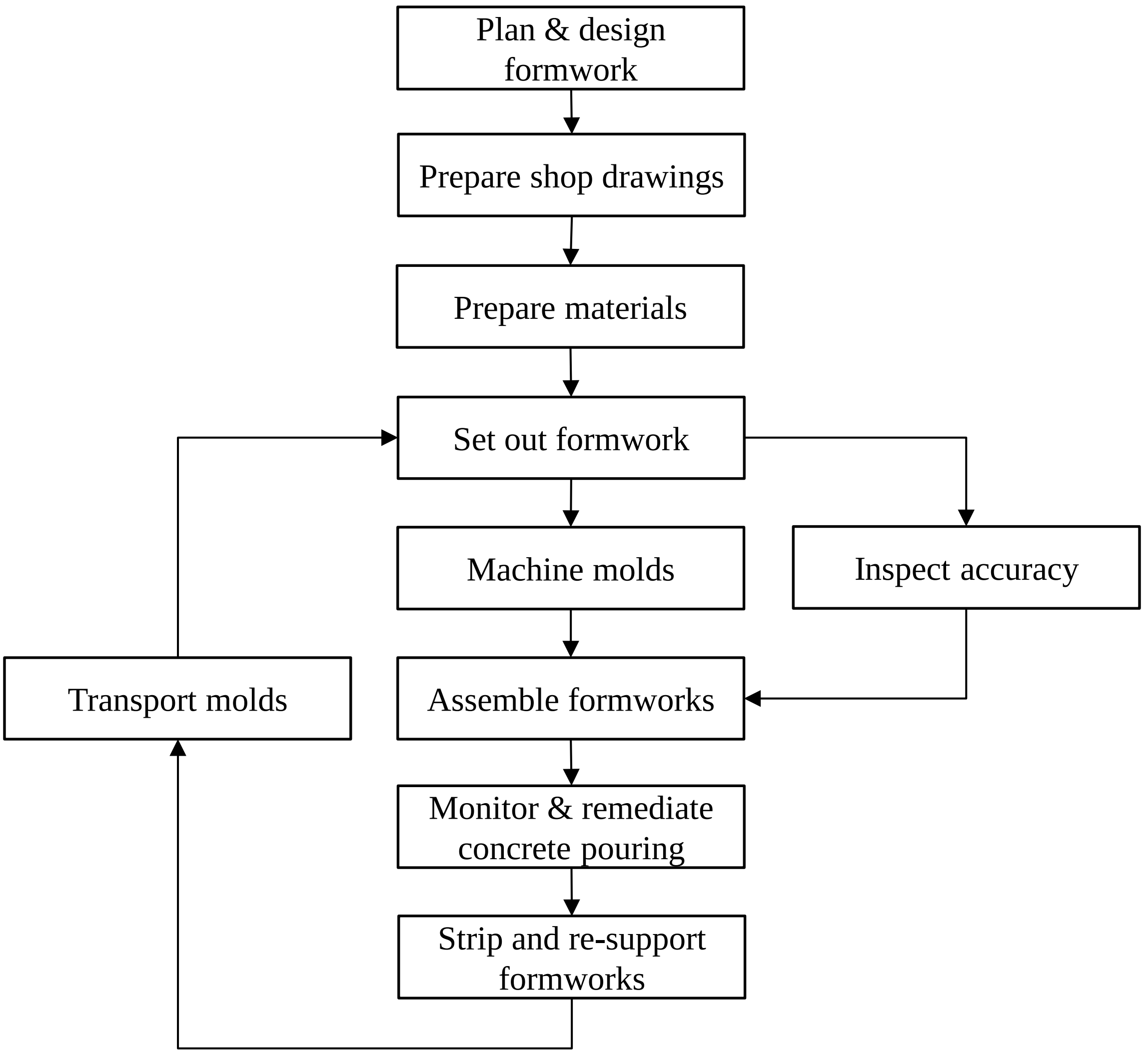
Jiun-De Kuo MS, National Pingtung University of Science and Technology, Taiwan

I. Background

Formwork material and worker payments are one of the main costs in the reinforced concrete structures. Therefore, formwork engineering is one of the key factors affecting project success. Traditional formwork construction involving non-value-adding activities result waste.

II. Current conditions

- The general contractor designs the formwork system.
- Subcontractor then prepares the shop drawing and materials according to the formwork system.
- Mold inventory and hardware fittings are also enquired by the formwork subcontractor.
- If the inventory is insufficient, the subcontractor re-orders the required materials from material suppliers.
- Mold positions are set out before assembly.



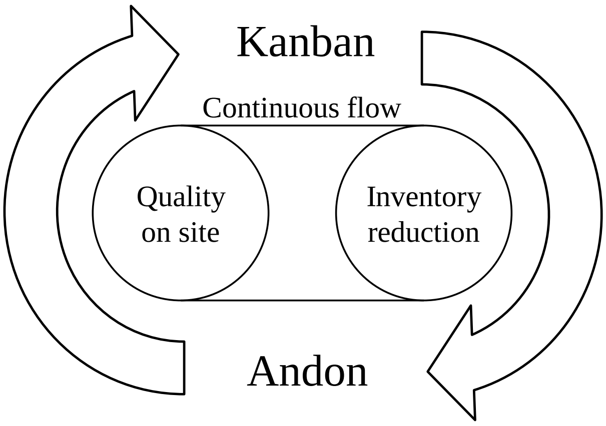
III. Working hypotheses

Kaban, originates from the stamping production line of the Toyota manufacturing site, could be used to reduce formwork inventory in the formwork engineering.

Andon, originates from the automatic loom invented by Sakichi Toyoda, could be used to improve quality in the formwork engineering.

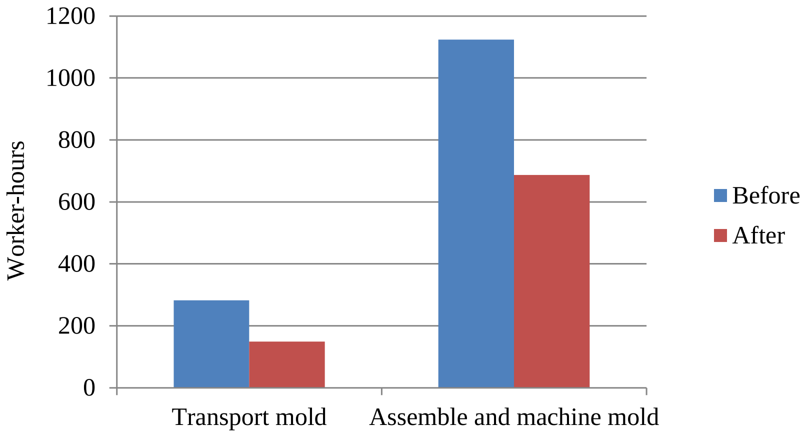
IV. Research Method

- Andon is mainly used for establishing the quality control culture, and the Kanban system is used for reducing material inventory.



V. Research Findings

In assembling and machining formwork, motions i.e. measure, pull, cut, pass, nail, and mend are value-adding activities whereas walk, search, and wait are waste. The move motion in the transporting mold produces value, however, waiting to be transported is the waste. An appropriate site layout can reduce the non-value-adding motions, such as the walk and wait in assembling and machining formwork and the wait in transporting molds. As a result, work efficiency can be enhanced.



VI. Conclusions

Improving formwork quality depends on continuously learning and improvement attitude. The Andon culture and Kanban system can then be used to eliminate the non-adding-value waste. However, when transforming lean into formwork construction process, foreman and superintendent also should take the resistance of change into consideration. Lean education is necessary when implementing the lean formwork construction model. Since managerial philosophy between the lean formwork construction model and the current practice is different, workers may resist changing.

The Role of Slack in Standardized Work in Construction: An Exploratory Study

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***Tarcísio A. Saurin**, Associate Professor, Industrial Engineering and Transportation Department, Federal University of Rio Grande do Sul, Brazil*

***Carlos T. Formoso**, Professor, Industrial Engineering and Transportation Department Federal University of Rio Grande do Sul, Brazil*

I. Background

Standardized work (SW) is a type of action-oriented procedure that sets a basis for continuous improvement in the Toyota Production System. However, the usefulness and applicability of this practice to construction is still unclear. Furthermore, while some studies have addressed the key elements of SW, the role played by the concept of slack as a fundamental element of operations design is rarely discussed in an explicit way. This is a drawback since slack resources allow for the system to cope with variability from different sources.

II. Current conditions

- Although SW is commonly applied in the manufacturing industry, existing literature indicates that the same does not happen in construction.
- In construction, buffer and contingencies are terms more commonly used than slack, these usually refer to specific resources such as material, capacity, time, backlog of made-ready work packages, money or even work in process.
- Saurin and Werle (2017) identified five strategies for the deployment of slack in complex socio-technical systems, such as construction, which are not limited to specific types of slack resources (Table 1).

III. Goals/Target

- *To highlight the role of slack as a basic element of SW in construction*
- *To identify which slack strategies play a key role to coping with variability arising from the precondition of a construction task.*

IV. Research Method

This study carries out an exploratory investigation of the role played by slack in SW. This analysis is mostly based on a review of literature and on a matrix that checks strategies for the deployment of slack resources against sources of variability in construction (Table 2).

VI. Results and Conclusions

- Results indicate that SW, in construction, should account for a broader range of slack resources than manufacturing.
- The matrix (Table 2) indicates that, although the strategy of using WIP may be the most known, it needs to be jointly applied with other strategies to support SW in construction.
- This matrix also makes it possible to identify that two slack strategies (i.e margin of maneuver and redundancy) play a key role to coping with variability arising from the preconditions of a construction task. Thus, these two strategies of slack should probably be explicitly incorporated into the list of basic elements of SW in construction.

Table 1- Strategies for the deployment of slack in construction (adapted from Saurin and Werle 2017)

Strategy	Definition	Examples of application
Redundancy	It is divided into four sub-categories: (i) standby redundancy; (ii) active redundancy; (iii) duplication of functions; and (iv) redundant procedures or redundant inspections across process stages.	1.Redundant equipment/tools 2.Creating formal or even informal leadership redundancy to distributed authority when necessary
Work in Progress	Refers to stocks of raw materials, partially finished products and finished products.	1.Several simultaneous work zones 2.Stock of materials
Margins of maneuver	It is characterized by autonomous or coordinated strategies that create margins through reorganization of resources.	1.Multifunctional workers 2.Capacity and time buffer
Cognitive diversity	Refers to divergence in analytical perspectives among members of an organization	1.Short-term meetings involving different team leaders to identify and solve problems of previous week 2. Cross-training
Control slack	Refers to individual degrees of freedom in organizational activity, with some range of individual action unconstrained by formal coordination or command.	1.Supervisors allow for experienced subordinates to improvise when the action adopted is consistent with the overall goals of the process

Table 2 Interaction matrix between strategies for deploying slack and sources of variability in construction

	Variability of preconditions for a construction task							
Strategies	Construction Design	Components and materials	Workers	Equipment/ Tools	Space	Connecting Works	External conditions	Work Infrastructure
Redundancy	X	x	X	X	X			X
Work in progress		x				X		
Margins of maneuver	X	x	X	X	X	X	X	X
Cognitive diversity	X		X					
Control slack		x		X	X	X		X

V. References

Saurin, T.A.; Werle, N.B. (2017). A framework for the analysis of slack in socio-technical systems. *Reliability Engineering and Systems Safety* ,167, 439-451.

How Making-Do crates ineffective refurbishment projects

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I. Background

The aim of this research has been to identify Making-Do in refurbishment projects and the reasons behind it. A case study research approach has been used to collect data by actively participating in weekly Last Planner System meetings, observing work in progress on-site on three projects and conducting work sampling studies on six trades. The research showed that Making-Do is highly likely to be both the prevailing and lead waste form in all of the three cases, and that insufficient management of production was the main cause. This was found by firstly identifying an overlap between known impacts of Making-Do from literature and the most occurring negative impacts observed in the cases. Secondly, finding that talking generally contained the biggest potential for being reduced and that this potential had an apparent correlation with Making-Do.

II. Current conditions

The current conditions for refurbishment production systems is presented in V. Research Findings.

III. Working hypotheses

The working hypothesis is that a huge potential for optimization is hidden in refurbishment projects.

IV. Research Method

Three social housing refurbishment projects were followed for 12, 8 and 8 weeks respectively.

The methods applied: 1) interviews and observations and 2) work-sampling (WS)

<u>Case facts:</u>

- Case 1: 297 apartments, basement to 2
- Case 2: 291 apartments, basement to 2
- Case 3: 601 apartments, basement to 3

<u>The methods applied: 1) interviews and observations and 2) work-sampling (WS)</u>

Categories for the Work-Sampling Study is displayed below:

Direct Work	Indirect Work			Waste		
Production	Talking	Preparation	Transport	Walking	Gone	Waiting

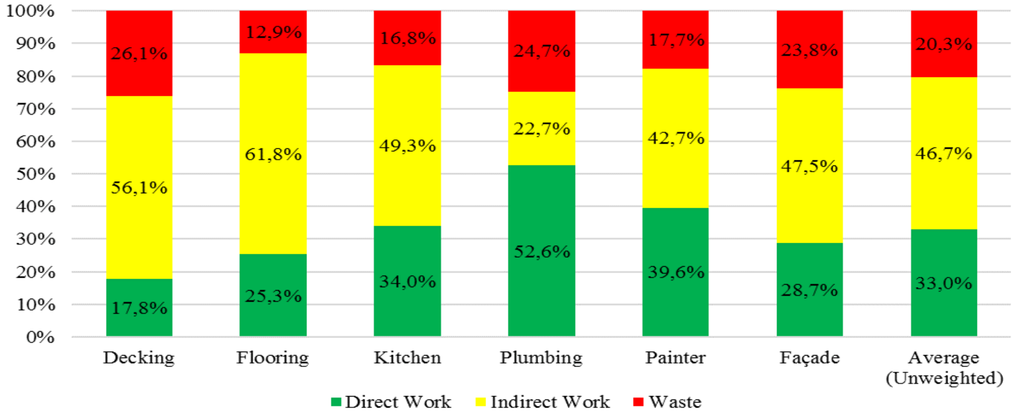
V. Research Findings

The results from this case study consist of interviews and observations including PPC measurements and a WS-study of six different trades consisting of 6324 observations.

<u>Results from interviews and observations:</u>

- Insufficient planning leads to talking
- High frequency in Making-Do events
- PPC: case1: 54%, case2: 46% & case3: 60%

The below diagram presents the WS findings for the six trades presented in 3 main categories:



Identified Causality in refurbishment projects:

↓ WS-study, Interviews and observation

↓ Identify potential

↓ Insufficient Control and Planning

↓ Starting of activities missing at least one flow

↓ Making-Do events occurs

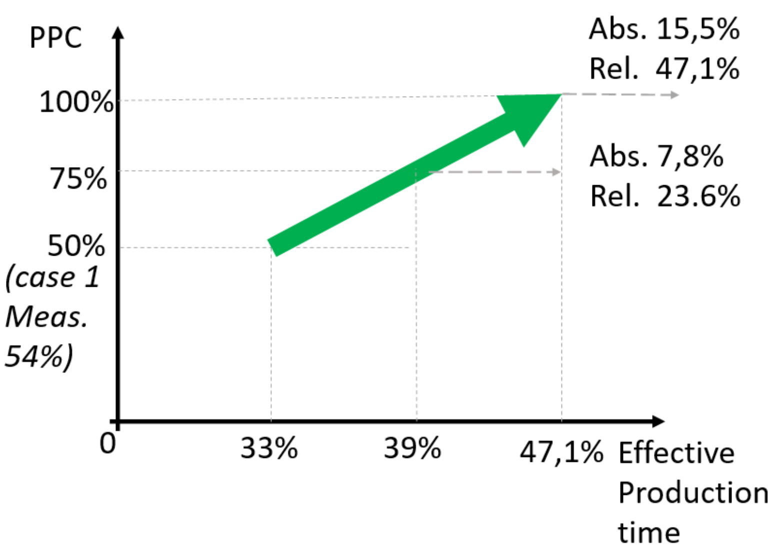
↓ Unnecessary talking among trades

↓ Talking contains the apparent largest optimization potential

↓ Making-Do is highly likely to be the prevailing and lead waste in refurbishment projects.

VI. Conclusions

The conclusion presents a theoretical optimization prognoses based on feedback from each trade observed in WS-study and PPC levels from literature. Feedback from trades were obtained by asking each trade to assess how much time each category required if PPC were stabilized on 100% and site logistics enhanced. To identify a realistic achievable PPC level 10 studies were analyzed finding that a PPC level on 75% is realistic if lean tools as LPS are used. The numbers are plotted in figure 4 with production (Direct-Work) on the x-axis and PPC on the y-axis.



Cat	Talk.	Prep.	Trans.	Walk.	Gone	Wait.
Abs.	7,4%	0,0%	2,9%	1,4%	3,4%	0,3%
Rel.	52,4%	0,0%	31,6%	19,4%	19,4%	10,0%

SyncLean: An Application for Improved Lean Construction Practice

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I. Background

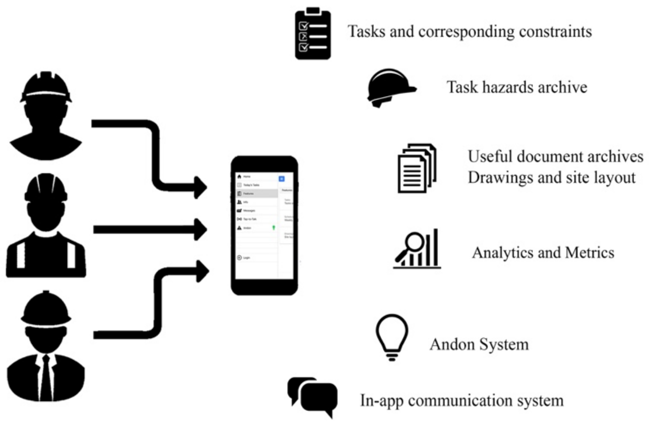
Visual management (VM) is instrumental in implementing lean construction philosophy and principles. The lack of communication and sharing of information among construction professionals in construction projects hinders workflow. This A3 introduces a mobile application, Synclean, inspired by the virtual Obeya room of Toyota Production Systems (TPS) to ease the transfer of information between site personnel. SyncLean's features will ensure the application is relevant to the very last planner on construction sites and will support collaborative value-adding, waste-minimizing work. The application prototype mobile interface was tested by users and the impact of this application will be later tested by surveying site personnel of various positions for the application's impact.

II. Current conditions

Keeping up with the pace of technology, many software applications have been proposed/developed in the field, each aiming at improving the workplace from a different perspective. These applications will ensure better construction practice, from the standpoint of lean theory and practice.

However, what these applications/programs offer is only one of many features that describe a lean execution. Safety in particular, is not tackled by any of the applications or programs mentioned despite being a crucial goal in the Toyota Production System.

III. Proposed Application/Features



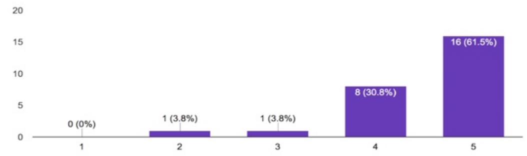
IV. Research Method

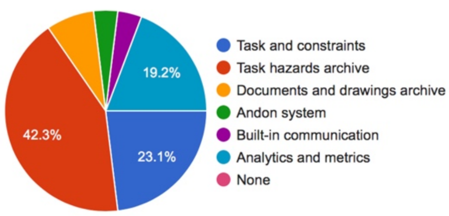
The research process will consist of assessing the need for such an application through the review of literature, developing the application interphase and testing of the application features and effectiveness on a small student community and some accessible site personnel.

V. Research Findings

For the application itself, Alarcon et al. (2013) state that managing information is critical for organizational performance, and that information networks are vital for value generation (Alarcon et al., 2013). SyncLean, being the center of construction site information sharing will make way for value generation through accessibility to the Last Planner. Not only will the mobile application provide easy accessibility, but also shorter communication time between the site personnel and decision-making entities through its communication features and virtual Andon system. Hamzeh et. al (2012) state that an agile response to unexpected problems is ensured through shortening the previously mentioned communication time. By achieving a more reliable workflow on site, through SyncLean, schedule performance will be significantly affected.

The application usage was tested by a small student community at the American University of Beirut and the results turned to be mostly positive. Users praised several aspects, mainly the task hazards tab, the Andon/notification system, and the analytical features that automatically generate metrics. The users also reported the ease of use of SyncLean, and the simple design that ensures a fast learning/adaptation process.





The figures above show the results of the usage survey, where the first figure shows the ratings for the ease of use of the application, and the second shows which features were voted most relevant.

VI. Conclusions

To conclude, the theoretical analysis for the need of SyncLean is but a step in the course of fully implementing this application in a construction project. Much work is yet to be done however, in terms of fully developing this application and testing it on real ongoing projects. Next steps would be to release a final build of the application that would then be implemented into a construction site for study. Full implementation would serve as a case study that would uncover the weaknesses of SyncLean and show through quantitative analysis whether it would benefit a project.

VALUE-ADDING ACTIVITIES LEVEL IN BRAZILIAN INFRAESTRUCTURE CONSTRUCTION COMPANIES – 9 CASES STUDY

Bernardo Martim Beck da Silva Etges, Federal University of Rio Grande do Sul, Brazil

I. Background

This work presents an approach to answer the question of what is the level of value-adding activities that infrastructure projects usually operates. Considering the Lean Construction concepts, waste definitions and Value Stream Mapping, added to an Operational Excellence perspective, it brings the result of nine infrastructure projects conducted by a consultancy company in seven Brazilian Construction Companies.

II. Current conditions

Given the premise of understanding the operational level of value-adding activities as a basis or kaizen implementations and productivity improvement, construction groups, focused on infrastructure in the public and private sector in Brazil are investing in improvement processes and implementation of operational excellence programs. To understand the level of value-adding activities on site, the process diagnostic step is conducted integrated three main concepts:

- Waste identification,
- Value Stream Mapping (VSM)

  Gemba routines and observations of the shop floor.

III. Goals and Targets

- To illustrate the value-adding status in infrastructure projects in the public and private sector.
- To demonstrate the use of production analysis tools that allow us to understand the zero line for the implementation of productivity kaizens the analyzed works

IV. Research Method

The data collection comprises two phases of the Workshops: (a) Analysis/Diagnosis and (b) Kaizen Workshop.

Analysis/Diagnosis:

In this phase is mapped the VSM for the main activity and the Gemba and waste analysis is conduced: the 7 wastes defined by Ohno are used as references. In order to identify wastes and their impacts, the following tools are used:

(a) Gemba-Walk, which consists of observing and finding evidence of the aforementioned wastes;

(b) Multi Moment Analysis (MMA), a count of people who add value or for some of the types of the seven wastes, an analysis of several consecutive intervals of time;

Kaizen Workshop:

7-phase Workshop, where in the third step the project team go deeper in the VSM analyses and after the process has been mapped and the value stream has been clarified, the Workshop team engages on field-work in order to identify and quantify failures and wastes. The team is split up to cover some formats of analysis that include: Identifying the seven wastes; a spaghetti diagram; a MMA for periods of at least 30 minutes of observation.

V. Research Findings

The results were analysed in three criteria's: (a) type of construction operation under execution during the observation; (b) level of value-adding activity in each project; and (c) level of value-adding activity in each type of operation observed.

The consultants developed over 1090 observations in a total period of 72 observation hours and more than 890 manhour considering the total of frontline workers on-site in each observation. Considering the critical path identified in the VSM the main operations observed that Steel assembly, frames and concrete represent the highest amount of observation time (representing 67% of the total time). The level of value-adding activities is shown in Figure 1.

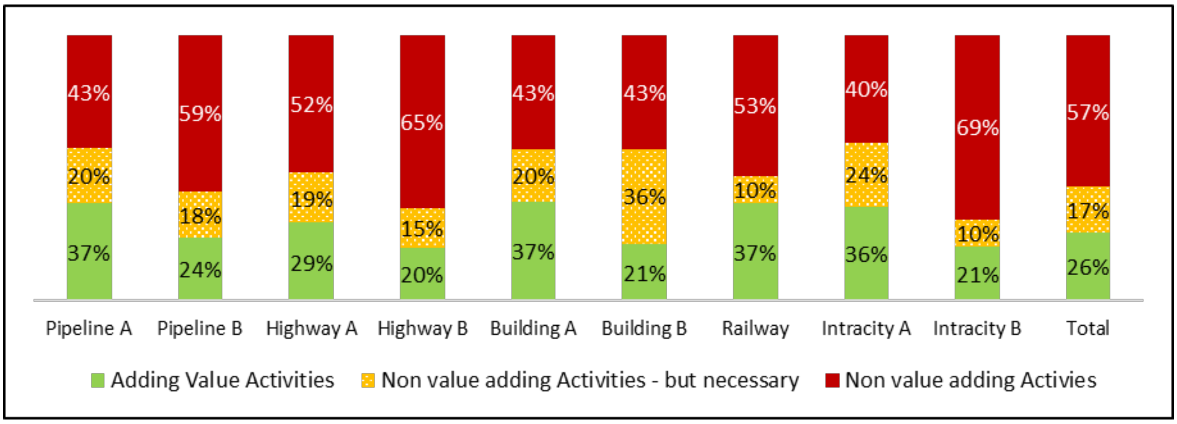
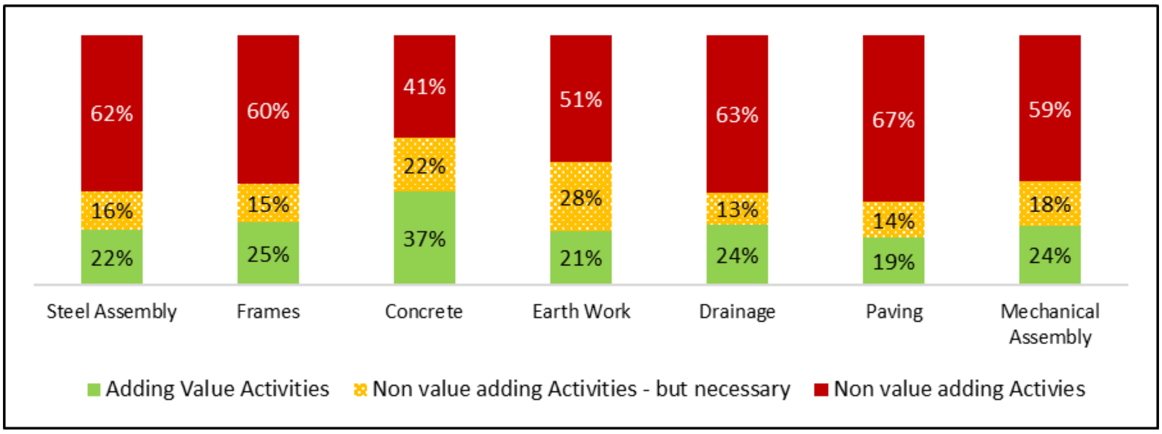


Figure 2 illustrates the analysis of the value stream critical operations.



VI. Conclusions

- The results show that 57% the construction activities observed did not add value (69% and 65% on Intracity B and Highway B respectively). Being able to understand this level of waste, promote critical change actions is a fundamental stage in the performance improvement process, cost savings and a leaner construction management.
- The perception, identification and presentation of the level of wastes and non-value-adding activities to the Construction Companies managers brought a new managing attitude toward planning, control and understand their on-site activities.
- By implementing the described methodology even companies with high technical level and management team with extensive experience in infrastructure works, are unaware of a high level of non-value-adding activities. It is also clear to conclude that as more organized, prepared, planned, and controlled the activity is, better level of value-adding may be found.

Mapping of BIM Process for Teaching Lean

Shobha Ramalingam, Assistant Professor, NCMAR, Pune, India

I. Background

Value Stream Mapping (VSM) and Building Information Modelling (BIM) are two contemporary approaches that aim to reduce waste and enhance collaboration in the realization of construction projects. However, there are limited studies that elucidate their synergies and demonstrate the value for teaching lean in construction management programs. While VSM visually maps a process and identifies areas for possible improvement, it is more applicable for assembly line operations, in manufacturing industries, an environment which the civil engineering students may not be familiar with, and therefore require experiential learning.

II. Current conditions

- Lean educators adopt different methods to facilitate learning for university students including: lectures, tests, assignments, discussions, case-studies, simulations, activity-oriented games and field trips (Tsao et al., 2012).
- Yet, construction engineering and management students, find it difficult to grasp the abstract concepts of ‘waste’, ‘value’, ‘process’, ‘conversion’ and ‘flow’ of activities that are analogous to Lean manufacturing (Nofera et al., 2015; Pellicer and Ponz-Tienda, 2014; Hirota and Formsa, 1998).

III. Working hypotheses

- *VSM is process oriented and unless students are part of the process, they may not be able to apply the technique in actual practice, as also opined by Lobaugh (2008). Therefore, I posit:*
- *How does VSM enhance the production of 3D building information model from 2D design drawings and enable the students to learn by doing?*

IV. Research Method

To address this concern, a synthetic experiment was conducted, wherein, 4 teams of post graduate students from a leading Construction Management Institute in India participated in the task of conversion of 2D design drawings to a 3D BIM for a multi-storey residential building project comprising of G + 6 floors using Revit® Architecture and MEP. Each floor typically consisted of 5 dwelling units with 2 staircases and a lift shaft. VSM implementation followed a structured process as suggested by Tapping et al. (2002). The teams created the *current state map* using universal symbols. *Lean metrics* (including Takt time, cycle time, process time, lead time, defective rate and total value added time) and *value parameters* (process efficiency and quality) were determined. The *future state map* was generated through kaizen efforts and brainstorming sessions, by minimizing wastes due to inefficiencies, non-value added activities, defects, rework, errors and omissions. The entire methodology was action-based learning (Stringer, 1999), wherein, each team was involved in the process of solving a practical problem and using a feedback system, they evaluated alternatives and implemented an action for future process improvement.

V. Research Findings

The overall production time was initially 17.95 hours. Takt time was 13.33 hours. Increase in time was 34.6%. Figure 1 shows the current state map, figure 2 shows the BIM models generated. Figure 3 shows the cycle time for various tasks and sub-tasks for each team and the areas with clashes requiring rework. Figure 4 shows the future state map of VSM.

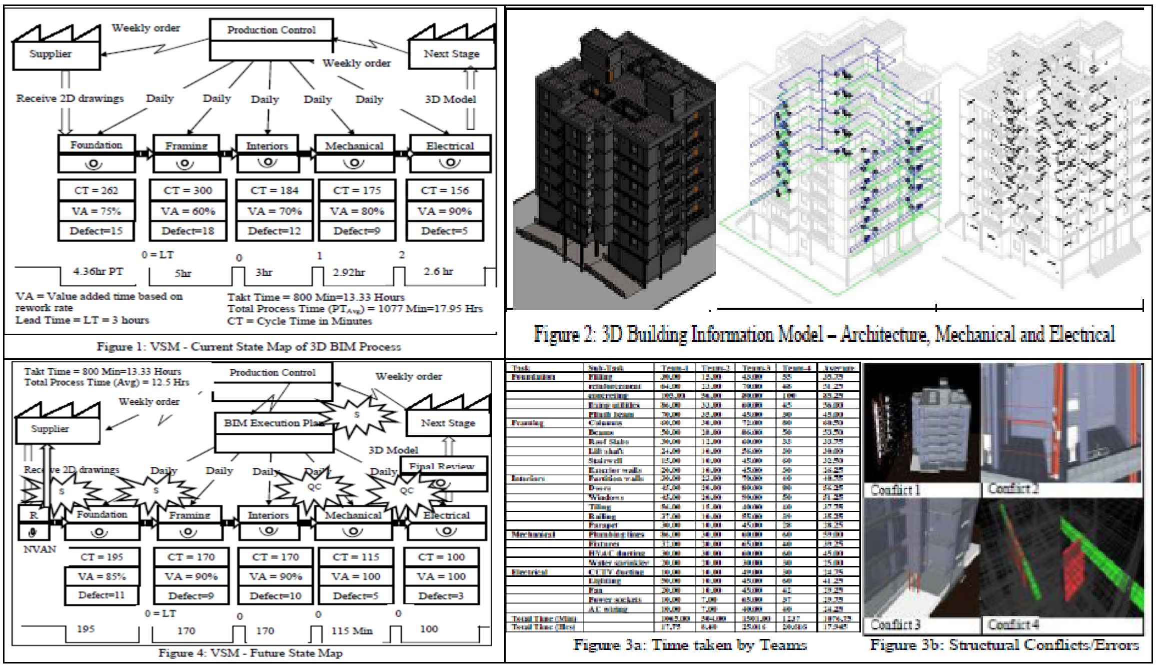


Figure 1: VSM - Current State Map of 3D BIM Process

Figure 2: 3D Building Information Model – Architecture, Mechanical and Electrical

Figure 4: VSM - Future State Map

Figure 3a: Time taken by Teams

Figure 3b: Structural Conflicts/Errors

- Kaizen efforts included: Synchronizing the output with the Takt demand time to reach an ideal state in future; Standardizing work procedures to avoid rework such as level of details and types of handrail, staircase; Restructuring work where needed to improve flow and reduce variability and finally, Quality control efforts such as through self-checks/checklists. For instance, during kaizen workshop, members created a checklist on constructability parameters to self-validate their model before handing it over to the subsequent modeler. Such efforts reduced variability and non-value added activities such as waiting for information.
- Interventions included: developing method statement on modelling sequence for stairwells, beams and plumbing ducts, developing a BIM execution plan to act as guiding reference, introducing coordinators at the beginning and end of the sequence to review the inputs/outputs, generating checklists.

The final production time after kaizen efforts reduced to 12.5 hours.

VI. Conclusions

This study has attempted to demonstrate the value of VSM in BIM process in the design development phase of a construction project through an experimental study. The findings were two-fold: First, it reinforced the value of the lean tool in identifying and eliminating waste in the BIM process. Second, it helped the members to develop their team building skills.

In specific, mapping the information in the BIM process showed variability in production. Some of the improvement measures included developing method statements, standardizing the process and ensuring quality checks at intermittent levels to minimize rework and waste. Further, enhanced communication such as through a BIM execution plan, aided in establishing pull systems for information and enabled a more efficient flow within the process. Indirect benefits included increased commitment, transparency and coordination amongst the actors apart from learning the VSM technique.

What is *Lean Construction*? Another look – 2018

Alan Mossman, The Change Business Ltd, UK;

I. Findings

- Many in our community have a definition of Lean Construction that they use
- There is no shared or agreed definition
- It may be more helpful to think about the purpose of Lean Construction

II. Background

Many have complained about the lack of an agreed definition, some suggesting that it cannot be researched without a definition. [Note: There is no definition of traditional construction either.]

This study reports a simple survey to collect 'definitions in use' within the Lean Construction Community. It includes a brief chronological review of some of definitions used in the formal and informal lean construction literature.

III. Current conditions

- A definition is "*An exact statement or description of the nature, scope, or meaning of something*". An operational definition makes the measurement criteria unambiguous.
- There is no shared or agreed definition
- There is no agreement that there should be a definition of lean construction – some suggest that a definition could be divisive and would reduce innovation in the field
- It is suggested that a definition of lean construction should:
    - **Differentiate** — and so exclude those who practice traditionally
    - **be operational**
    - **be concise —** *as simple as possible and no simpler*
    - **reduce communication problems**
    - **simplify education** on the subject
    - **make research easier**
    - **make it easier to define overall goals of the concept**

IV. Method

- To find the favourite answers used by members of this community to the question "What is lean construction?" I asked the community via a number of overlapping channels:
    - **LinkedIn article**. That article was "reposted" 3 times by others;
    - **Posting a 'discussion'** on 2 lean construction groups on LinkedIn;
    - **Email to the IGLC yahoo group**, copied to selected individuals;
    - I also took definitions from the first 20 results from Googling the question.
- In six weeks I received 42 unique 'definitions' via email or via comments on LinkedIn from 39 authors – yes, some people submitted 2 or more definitions. In addition, I have considered 26 definitions retrieved via Google search on the term '*what is lean construction?*'. (The paper also reports some definitions from the formal & informal literature).

V. Limitations

- This is not a systematic review of the literature.
- It did not involve the whole lean construction community – and I have no sense how representative of the community those who responded are.

VI. Things to think about

Chauncey Bell suggested that lean is not definable. He put his thoughts on the subject into the *Forward* he wrote for Hal Macomber's recent book *The Pocket Sensei*:

"Most of those who employ this word [lean] today think that they are pointing intelligibly to coherent, valuable practices, tools, and methods – whether originally derived from the Toyota experiences or not – that will move people and organizations toward some cohesive path of improved action. However, the word lean *itself does not reliably indicate any particularly organized direction of thinking for improving a difficult situation, despite what we might guess from reflecting on old jargon such as* lean and mean*. There is no stable method or approach called* lean *…. …. Unfortunately, what the word lean points to today is little more than what the word* modern *indicates.* (*Macomber 2017, xiv*)*"*

Sven Bertelsen wrote (Sven's emphasis):

This seemingly simple four-word question is hard to answer, not least because our understanding has changed over the years and is still changing. …. The most important thing is that Lean Construction is based on theories about the project's nature. Originally the Transformation-Flow-Value theory [Koskela 2000], …. In practical terms, this implies that the client and his satisfaction is the guiding light and the schedule is more important than the budget in the day to day management. …. A later theory … is complexity theory ... This makes Lean Construction accept and deal with the construction projects' natural complexity and dynamics, and treat it as an adaptive system existing on the edge of chaos. …. Finally, Lean Construction stimulates and improves cooperation between trades in the daily operations, and thereby further stimulates the learning process. [Thus] Lean Construction is:

1. "A new way of managing projects based on two theories, The Value-Flow-Operations [=TFV] *theory that puts schedule & logistics before budget & work, and chaos theory that introduces pull logistics through Last Planner. Sven Bertelsen, email*

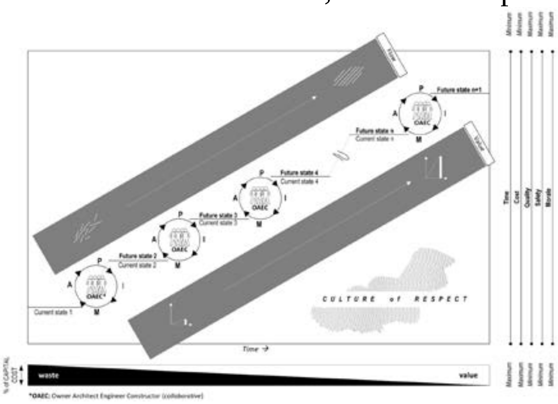
2. "A management principle that stimulates continuous learning and improvement and supports cooperation. Sven Bertelsen, email

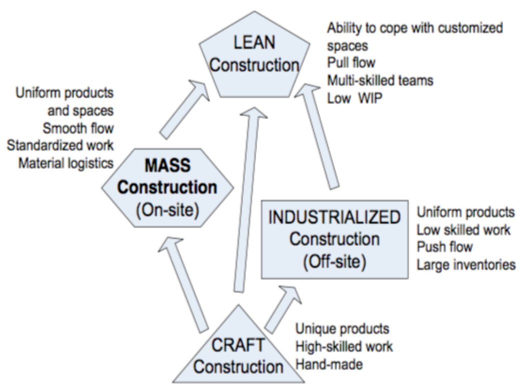
Christine Pasquire offered: "*synchronised harmony*"

Howard Ashcraft wrote (email)*:*

I think that you need at least 2 definitions. One to illustrate how Lean differs from traditional practice (gatekeeper definition) and one that illuminates its essence (philosophical definition).

My own conclusion from this study is that "lean" is *a practical collection of theories, principles, axioms, techniques and ways of thinking that together and severally can help individuals and teams improve the processes and systems within which they work.* I don't believe that this meets the Howell criterion – it doesn't differentiate, nor is it an operational definition. It does speak about purpose.





Illustrations from the paper (Rybkowski et al 2012; Sacks et al 2017)

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Laminated timber versus on-site cast concrete: a comparative study

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Sigbjørn Faanes, Project Developer/ Design Manager, Veidekke Entreprenør Trøndelag, Trondheim, Norway

Ola Lædre, Associate Professor, Dr. Ing., Norwegian University of Science and Technology, Trondheim, Norway,

I. Background

Veidekke AS, one of the largest contractors in Scandinavia, has a strategy to acquire knowledge on and gain a competitive advantage by building environmentally friendly buildings. Veidekke was using both Cross Laminated Timber (CLT) and on-site cast concrete to construct two apartment buildings at the same building site in Trondheim, Norway, in a comparable setting. The contractor used the Lean method Collaborative Planning (CP), a Last Planner adaption, during design and construction. They also used Takt Planning for the construction planning. This provided a unique opportunity to research both on Lean construction and buildings in CLT.

CLT-building **Concrete building**

II. Current conditions, Need for study

- The fifth assessment report of the Intergovernmental Panel on Climate Change confirms with 95% certainty that global warming is caused by anthropogenic greenhouse gas emissions. It is estimated that 18% of the global CO_2 emissions are directly or indirectly generated by the building sector and is projected to increase by 50-150% by mid-century.
- Builder experience with mass timber in general and CLT in particular is limited and not widely known.

III. Working hypotheses

The objective of this study was to investigate how Lean measures like Last Planner and Takt influence the construction process when new and green materials like CLT are introduced. To answer this objective, the following three research questions were formulated:

1. What are the differences between construction in cross laminated timber (CLT) and on-site cast concrete?

2. What pros and cons are associated with the use of CLT?
3. How can contractors improve construction with CLT?

IV. Research Method

An initial literature review was conducted on the topic “mass timber”. The aim was to map the state of the art from a project management point of view in relation to construction in mass timber.

This study used a case study approach, collecting data from three sources:

- Three direct observations were conducted in design meetings. A role as a participating, but passive, observer was used
- Five respondents from the main contractor and seven respondents from the sub-contractors, were interviewed.
- A document study was conducted based on the available and relevant documents in the online project hotel of the main contractor.

V. Research Findings

The most important findings:

- Acoustic, fire and structural challenges related to the use of CLT caused extra work during concept development and detailed design. The architect and the main contractor were the most influenced parties.
- The CLT-elements represent an advantageous construction method. Reduced construction time and the accuracy of the elements due to prefabrication are the most significant benefits.
- Reduced material waste at the building site, improved HSE and reduced CO_2 emissions are among the sustainability benefits for contractors.
- The main drawbacks with CLT in this case is the loss of work that can be carried out with in-house capacity and an increased design cost.
- Early involvement through CP may have lowered the perception of risk concerning the building in CLT and have been a key factor to provide a stabile framework in the design and production planning process

VI. Conclusions

- When it comes to how contractors can improve construction with CLT, Lean tools such as Last Planner and Takt proved advantageous in the studied pilot project.
- With higher uncertainty arises the need for increased planning for the unforeseen. Tools like Last Planner and Takt provided the stability needed for tackling the uncertainty that entailed the introduction of a new and green material as CLT.
- Early involvement through CP may have lowered the sub-contractor’s perception of risk concerning the building in CLT.
- To get a good flow through the design process, the main contractor depended on reliable consultants and sub-contractors. CP and Takt can be used to secure this reliability, and these tools may have influenced the outcome more than the respondents have realized so far.

Evaluating Why Quantity Surveyors Conflict with Collaborative Project Delivery System

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Christine Pasquire, Professor, Nottingham Trent University, UK

Emmanuel Manu, Senior Lecturer, Nottingham Trent University, UK.

I. Background

The UK construction industry has evolved a 'survivalist shape' set by certain commercial activities in reaction to the environment in which it operates (see fig 1). This is evident as the industry and its clients usually have non-aligned interest reinforced by the wasteful procurement protocols that have become part of the institution of the construction industry 'the way it does business'. Thus, this has triggered an industry wide demand for performance improvement and modernisation in the construction sector. But the lack of strategic framework in place to galvanize the required transition is still enormous.

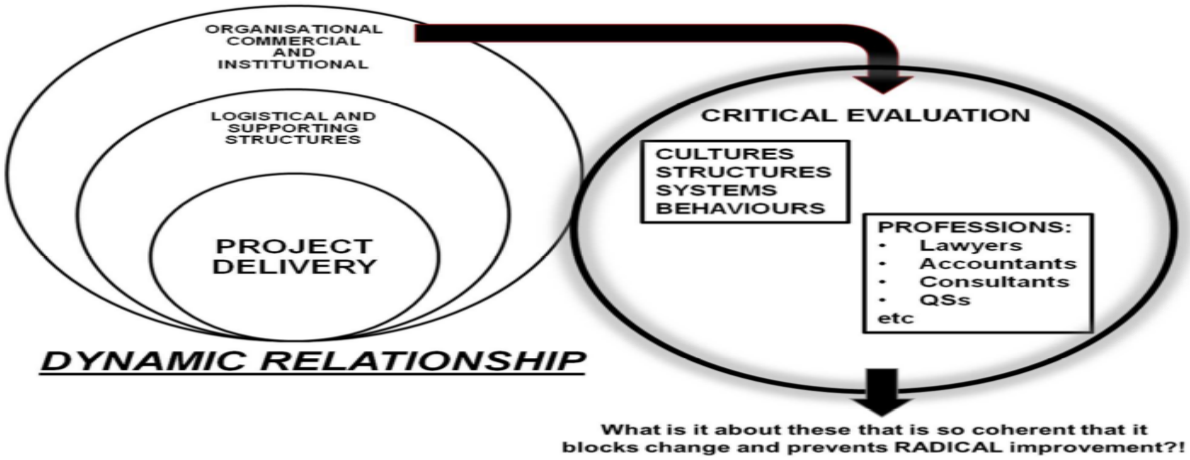

Figure 1. A roadmap guide for the study showing dynamics around construction model and the institutionalised structures surrounding it.

Quantity Surveyors (QSs) within the UK system are known for their commercial functions i.e., contract advice and cost related roles. But, the lack of evidence on collaborative practice across these commercial roles has somewhat eclipse the separation within the construction model. A position where QSs are formulated and outside the core project production team (client, designers, and constructors). This lingers with other practical implications like process waste, value loss, conflicts among others. In an attempt to examine why the conventional model is somewhat 'dualised' into production and contractual system, (see fig 2) this study looks at one aspect, the commercial roles of QSs outside the production stream. In particular, the study aims to evaluate why QSs functions in either the traditional or advanced system conflict with collaborative practice.

II. Current conditions

- Currently, within the model QSs are only involved when strategic decision is taken i.e. designers & engineers appointed, briefing conducted and technical drawings reaching completion if not completed.
- This is also similar in their traditional cost planning function, where they are involved late for input on 'after-the-fact-estimating' and in 'design-estimate-redesign' respectively.
- This separation shows a gap and disconnect that stifle collaborative practice, limit their value addition in process and allow more inefficiencies and wastes across the project spectrum.

III. Working hypotheses

From a production perspective, figure 1 further illustrates how the construction model is separated which gave rise to safeguarding practice that continue to deter collaborative agenda.

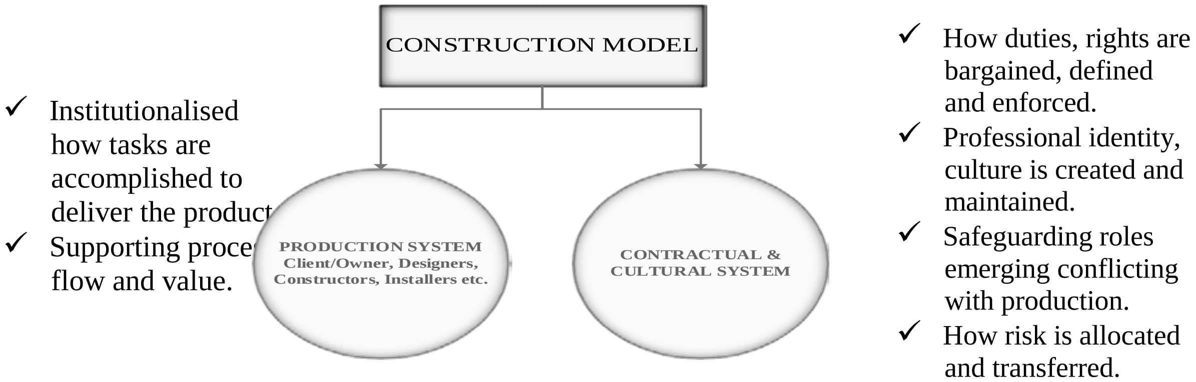

Figure2. Construction model showing the separation between production and contractual system [modified from Gottlieb & Kim Haugbølle, (2013)]

IV. Research Method

The research adopts a case study approach (Yin, 2009) to provide in-depth and real-life instances. Eighteen semi-structured interviews were conducted with industry expects in order to:

- Investigate collaborative practice from a multidisciplinary setting and understand how commercial teams are maintained.
- To also understand the commercial challenges affecting collaborative practice in projects and programmes.

V. Research Findings

- The study established some relational challenges associated with the QSs in both conventional and multidisciplinary setting that inspire the current UK construction model, and how they affect collaborative practice.
- Chiefly among these factors are; excessive reporting & commercial governance, QSs background/training, customer practice and balancing standard with innovation.
- Other notable issued identified was on the standard form of contract deployed in practice, as it's contributing immensely to most of the problems acknowledged, and partly the 'wedging-stone' for professional QSs who are mostly concerned with protecting their commercial positions.

VI. Conclusions

- The study sheds light on how the construction model is separated, and how commercial teams, QSs are formulated outside the production system.
- The research study identified other commercial factors that continue to stifle collaborative practice drawn from major infrastructural sectors in the UK industry.
- The study recommends on establishing commercial teams/QSs and their associated roles into a relational contract arrangement to promote collaborative practice in the UK construction industry.

Teaching Choosing by Advantages: Learnings & Challenges

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Devanshu Pandit, Professor, Faculty of Technology, CEPT University, Ahmedabad, India

I. Background

The fundamental premise for improving workflow and processes in a construction project with lean philosophy hinges on collaborative efforts among stakeholders, value creation for the client and waste removal. There are different tools that have been devised for bringing in transformational changes in the design, construction and operation phases of a construction project. The application of lean tools and techniques in the construction phase has been more widespread than in its design phase. Among the different tools for lean design management, the Choosing by Advantage (CBA) method holds great potential owing to imbibing and/or forcing collaborative processes in the design process and value maximization process for the client. It is thus important to elucidate the benefits derived from lean philosophy to emerging construction managers such as students of construction engineering and management programme. This will provide an impetus to the propagation of lean ideals in the construction industry. In this context, this paper discusses the learnings and challenges in teaching CBA.

II. Current conditions

- Lack of collaboration between designer, contractor and client in the design process.
- Minimal inputs from contractors in selection of design options.
- Unstructured flow of communication among different disciplines during the design process
- Challenges in defining value to be delivered to the client

III. Working hypotheses

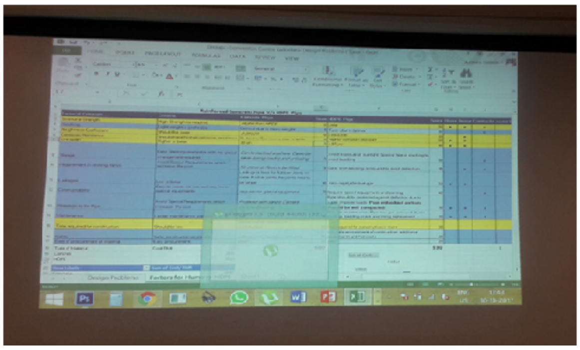
CBA is a collaborative, visual and transparent decision making system developed by Jim Suhr. There are specific terms: factor, criteria, attribute and advantages, known as CBA vocabulary. CBA is one of the lean methods / tools that can be applied in the design stage of a project. There are many such potential tools that are useful across lifecycle of construction project and it is very important to impart knowledge about these tools to novice construction professionals. The academicians must ensure integration of lean philosophy into the existing curriculum of civil engineering programs in India. The authors have performed an analysis of the curriculum of a master's programme in construction engineering and management in India, in terms of the incorporation of lean construction courses. The analysis showed that most academic institutions do not have courses or lessons on lean construction related topics. In this context this paper shows how lean tools can be included in the civil engineering curriculum in order to enhance learning in this area.

IV. Research Method

This participant observation method has been recognized as a most important core research method, with the strength of "collecting data first-hand". The instructors involved in this CBA exercise played multiple roles. Firstly, they played the role of "teacher" with the primary objective of teaching the application of CBA in the design process at hand. Further, they played the role of "facilitator" for the role play exercise wherein collaboration and communication was facilitated. The objective of the CBA exercise was to investigate the extent of learning in the areas of 1) benefits of early involvement of contractors in the design process, 2) collaboration between designer and contractor for delivering value to the client, 3) striking balance between value, cost and advantages related to design option. The instructor played the role of an "insider" and participated in the CBA exercise to guide the role play and entire process for maximizing the learnings in the mentioned areas. At the same time, the researcher became an "outsider" and observed the extent to which the learning actually occurred. The information pertaining to extent of learning was gathered with the help of questions that were asked to the students and observations during the CBA exercise.

Table 1. Design Options

Project	Design Problem	Design Options
Four laning of Mehsana Himatnagar Highway	- Choice of recycled material in sub base layer - Choice of street lights - Choice of crash barrier	- Reclaimed asphalt, steel slag, glass, plastic - Solar powered LED lamps, Sodium Vapour Lamps, Mercury Vapour Lamps -W-Beam Metallic, Concrete, Cable
Vadodara Exhibition and Convention Centre	-Choice of material for partition walls -Choice of sewer drains -Choice of pavement for parking	-Brick, precast hollow crete, gypsum board -Hume, HDPE, DI -Hot mix asphalt, precast paver blocks, concrete
Desalination plant for industrial water supply in Kutch region	-Choice of energy source for the desalination plant -Choice of pump technology -Choice of material used for pump manufacturing	-Non-renewable, photovoltaic, wing Membrane -Reverse osmosis, ultra filtration, nano filtration -Stainless steel, carbon steel, cast iron and copper nickel alloy
Redevelopment of Motera Stadium	-Selection of stadium roof material -Choice of parking alternatives	-PVC, PTFE (Teflon coated fibre glass) -Surface, Conventional multilevel, automated multilevel
Integrated solid waste management project for Vadodara	-Choice of roofing material -Choice of pavement of transfer station -Choice of liner system	-Steel roof, eco roof / vegetative roof, modified bituminous membrane, foam filled composite panels -RCC pavement, post tensioned RCC pavement, bituminous flexible pavement -Compacted Clay+geomembrane liner system, Geobentonite+geomembrane liner system
Maritime museum at Lothal	-Choice of cladding material -Choice of parking lights -Choice of flooring	-Metal, stone, glass fibre reinforced, glass -High pressure sodium vapour lamps, energy efficient fluorescent tabular lamps, LED lamps -Vitrified tile, ceramic tile and wooden



V. Research Findings

- Improved understanding on necessity of collaboration in design process
- Easing communication flows among designer, client and contractor
- Understanding of iterative and collaborative nature of value definition

VI. Conclusions

The CBA exercise discussed in this paper showed that students obtained enhanced understanding of collaboration and communication flow required between key stakeholders – client, contractor and designer during design process of construction project. These stakeholders principally strive to bring clarity on value to the client and its maximization. The students realized that the CBA offers structured approach for value maximization at the design stage without diluting the much required collaboration and communication among stakeholders. The lean philosophy has been gaining attention among construction professionals and academicians. The imparting of knowledge about lean construction along with classroom activities simulating real life environment of construction project for construction management students is important. In this context, this paper provides guidance on conducting CBA exercise in a classroom environment. There are a few limitation of this study. First, this study used the participant observation method, with the "instructor" roles of both participation and intervention. Therefore, there could be possibility of bias in observation and analysis. Secondly, the learnings reported in this study are influenced by various contextual variables like educational background of students, work experience, and prior knowledge of subject area.

MASTERING COMPLEXITY IN TAKT PLANNING AND TAKT CONTROL – USING THE THREE LEVEL MODEL TO INCREASE EFFICIENCY AND PERFORMANCE IN CONSTRUCTION PROJECTS

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I. Background

The approach of Takt Planning and Takt Control (TPTC) offers a possibility to dimension buffers and schedule them transparently. This approach is often seen as a rigid and complicated procedure. The planning has to be adapted with a huge effort to changes in the construction process and therefore often does not show the real image of the construction site. The three-level model tries to structure the method for all participants.

II. Current conditions

When scheduling a construction project, resource consumption, efficiency of the trades, external influences and the possible changes within the construction process must be taken into account. Hence, the complexity of the construction schedule and an exact planning is difficult. So often the time buffers are balancing the unexpected events. That’s the reason the full potentials of the construction project are often missed.

III. Working hypotheses

A quick and transparent reaction in order to change the schedule is prevented due to the detailed planning and post calculation. Therefore, a standardization of the product and an always similar process with as little disruptive factors, is often the main condition for Takt. In doing so, rigid requirements are given to the contributors of the construction project, in order to comply with the Takt Plan.

This paper aims to improve the simplicity of dimensioning value, time and activities in Takt Planning. Performance indicators can provide information about the dimensioning and its adaptation to the construction process. Thus, TPTC can be seen as a flexible method for controlling the complexity of construction planning and excellerate efficiency of the hole project.

IV. Research method

Takt is not an one-dimensional unit, but it is an interaction of different dimensions. By considering the components of Takt principles in figure 2, the following three dimensions of Takt become visible:

1. **Takt time** is the time dimension. For every Takt in a system is it the same or scalable. It creates a generally valid rhythm.
2. **Takt process** or Takt content represent the ongoing, which takes place in the Takt. This dimension is often combined with Takt time. (cf. Verband für Arbeitsstudien, 1985, p. 282).
3. **Takt location** describes the place, where the Takt process happens. It is not necessarily a physical place.

Due to the differentiation of the Takt into three dimensions, the complexity of an optimization becomes more difficult. Currently, for simplicity, often at least one of the dimensions; time, location or process, is held. If it is possible to influence, in a flexible way, the interaction between the three dimensions in a simple system and to analyze their effects, the Takt Planning could be essentially simplified.

The double packaging and double sequencing represents at the current status of research the first type of such a solution. The multiple packaging allows an itemization of the work steps whilst simultaneous overlapping level of detail. As shown in figure 3, the smallest work steps are single-origin allocated at first to the trades, whereby useful work packages are created. In step 2 those work packages are combined in a necessarily order, where a process sequence is build. Thereby sequenced work packages (trade sequence) are created out of the work steps.

V. Research Findings

In sum it can be said, that the micro level the data input of single trades in the planning serves. In the norm level the harmonization takes place. The macro level is used for the simplified representation and communication of the construction progress, from the perspective of the customer. The differentiation of the three levels in Takt Planning guides the planner from a variety highly detailed data and information to a holistic and simplified description (see figure 7). The same differentiation of the three levels within Takt Control gives the possibility to identify the cause-source and their effects in a fast way, caused by deviations.

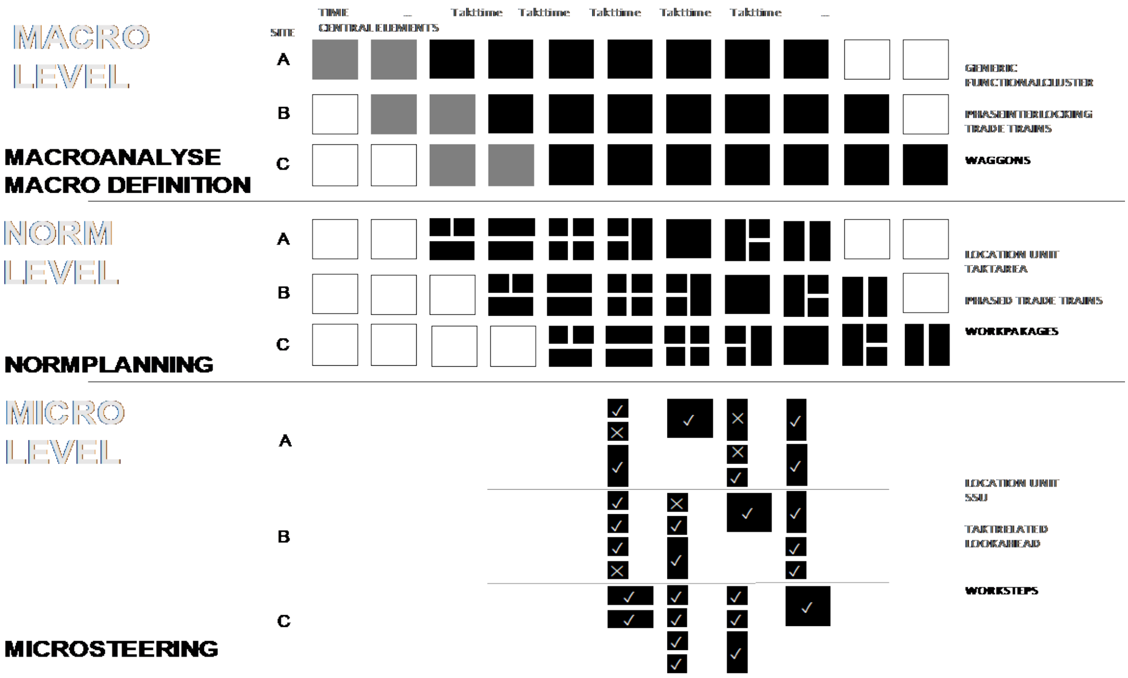

Figure 1: The three-level model

VI. Conclusion

Takt planning and Takt Control is seen in a lot of projects as a very complex and rigid procedure: The trades are individually optimized and, in each case, harmonized with the construction site flow by a complex buffer dimensioning. In case of changes of the plan, the updating of the Takt plan causes a lot of working steps. Due to this effect trades as forced to adhere to a rigid Takting. In another case the Takt plan doesn’t represent the real image of the construction due to variations. The complexity of Takting is mostly caused by mastering of the three dimensions. These are Takt time, Takt process an Takt location. To be able of simplifying and mastering all of the three dimensions, different abstraction and communication levels are needed. With the help of the Three-Level Method and by the double packaging and sequencing a possible solution can be created as shown in this paper. The dimensioning on the three levels is accommodated in different abstraction levels.

IMPROVING DESIGN COORDINATION WITH LEAN AND BIM, AN INDIAN CASE STUDY

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I. Background

Building Information Modeling (BIM) and Lean construction principles have been used independently as significant methods to construction process improvement. Their combination presents challenges and opportunities in implementation, especially when applied in the field.

This study explores two perspectives, firstly identifying factors and issues in design coordination of construction projects; secondly, applying lean and BIM functions simultaneously to overcome some of the problems in design coordination. Relative Importance Index (RII) method was adopted to identify major critical factors of design coordination and their effect on the three categories viz; design management, time management and cost management. Subsequently, BIM and lean functions such as 4D simulation integrated with Look ahead planning, Quantity take off, Clash detection during look-ahead and weekly work planning, to reduce change orders and RFIs for additional value to customer were applied in an integrated fashion. This improvised BIM-Lean process facilitates the design co-ordination during construction phase for all project stakeholders. Finally a matrix is drafted based on previous research that shows integration of Lean Principles and BIM functionalities adopted for the case study.

II. Current conditions

- Literature explains that the key sources of design error are connected to repetitive design cycles that results from unanticipated changes, poor management and communication (Arayici et.al, 2012, Hattab et.al, 2016) disrupt design workflow, subsequently creating waste such as increased cycle times, cost, rework, and errors.

- Design clashes involves positioning errors where building components intersect each other when the models are fused. To prevent costly rework, resolution of these clashes is important (J.Won et.al, 2016).

- Recent research conducted by Peansupap and Ly (2015) studied five categories of structural and MEP related design errors but the study was limited to schedule delays and omitted any discussion on how BIM can facilitate error mitigation at the design stages. Research that studied design clashes are grounded on limited scope of analysis.

III. Research Method

A case study project an IT park in Gurgaon (Haryana) India, was undertaken to study issues regarding design coordination, and apply Lean and BIM solution to try to solve them. The case study was carried over a 2 month period and the issues related to design coordination were studied. Total site area was 100,362 sq. There were total of 9 towers in the complex out of which 5 were already constructed and 4 were under construction. The scope for study was limited to Tower 9only.

The things that were worked upon:Quantity takeoff from BIM, Clash Detection,Cost saving by avoiding core cutting,one month lookahead schedule and constructability through 4D simulation.

IV. Research Findings

Quantification-Quantity Take-off from BIM: The variation in quantity and cost for the entire project was identified as: Blockwork (100 & 200 mm) -2,155 sq.m, Rs -28,17,800 (~$ -43,062.84) , Column concrete -175 cu.m , Rs -14,38,850 (~$ -21,983.70) and Slab concrete 350 cu.m , Rs 24,51,750 (~$ 37,511.78) .

Clash detection: If clash detection process would have not been followed, it would have caused an extra cost of Rs 61, 6400 (~$ 9,449.41) for the entire scope and 1 week instead of a day for detecting clashes manually contributing to waste. The RFI'S related to plumbing works reduced from 10 to 3 for a particular week i.e. almost 70% reduction.

One month look ahead Schedule and constructability through 4D Simulation: Look ahead schedule reduced the duration of activities from 358 days to 230 days with cost saving of Rs 5, 40,000 (~$ 8,278.20) in terms of shuttering material. So it acted as a step for 4D simulation and simultaneously for production planning. The 4D process helped in visualising the activities, their related issues for the coming month and prepare material, labor and drawings ready in advance that increased the production flow and value when executed.

V. Conclusions

The study highlighted that there are several design coordination issues that affect the efficiency of not only the design but also the construction process. The interaction matrix showing Pre and Post implementation achieved for design coordination.

Index	Explanation	
	Pre Implementation	**Post Implementation**
1.	Manual clash checking took 1 week for an area of 23791.11 sq.m with still having manual discrepancies.RFI'S related to plumbing were 10 for a particular week.	The incompletely detailed parts were easily observed in automated clash checking reducing efforts to a day simultaneously RFI'S reduction to 3, almost 70% reduction. This improved design quality reducing variations.
2	Manual quantification of elements for the entire scope of the project took 600 minutes including checking for variations, if any.	The BIM model data used in automated quantity takeoff taking just 75 minutes for the entire scope making work 88% faster. Quantity variations easily tracked with the variation amount tending to Rs 28,17,800 (~$ 43,062.84) for 100&200 mm blockwork reducing variability at the time of billing.
3	No verification/validation of designs before actual execution.	Verification and validation done in terms of clashes detected related to plumbing saving against rework cost of Rs.6,16,400 (~$ 9,449.41) for 500 core cuts for the entire scope.
4	No future thoughts for designing production system for flow, value and any generation of alternatives/visualization for reducing coordination issues.	4D and look ahead helped in reducing issues during production. The duration for the activities was reduced from 358 days to 230 days. Cost saving for the shuttering material due to zone wise planning came to Rs 5, 40,000 (~$ 8,278.20).

An exploratory study on lean teaching adoption rate among academia and industry in Indian scenario

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Prasanna K, Assistant Professor, Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, India.

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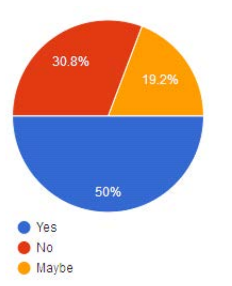
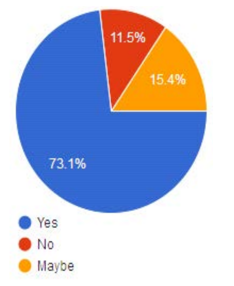
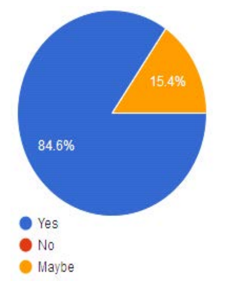
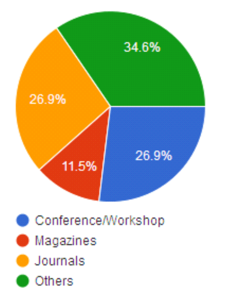
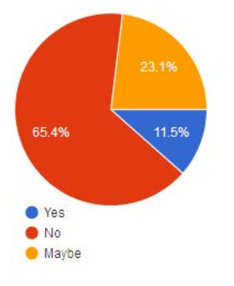
I. Background

Construction industry in India is one vital source of socio-economic growth. The workforce involves not only the professionals but also skilled, unskilled workers from various places, irrespective of gender. Construction industry offers more employment and contributes towards the national GDP. Lean teaching in the classrooms is to be considered only if there is a proper understanding, awareness, and knowledge towards Lean in construction. There are various other factors that influence productivity concerning it, adopting new technology and new concepts will increase productivity of engineers. There are differences in teaching approaches, experiences and lessons learned from course offered. In addition, the method of teaching Lean requires, combinations of reading, lectures, discussions, simulations, exercise and field trip and guest speakers. Online methods will be more useful in supporting classroom teaching.

II. Current conditions

- The need of the hour: Extensive research to explore the importance of Lean teaching and its subsequent implementation in academia and industry.
- Comparatively it's been observed very limited in practice in the real time construction industry projects.

Teaching/practicing Lean concepts	Lean construction concept relevance to Indian construction scenario	Awareness of Lean construction concept	Sources of Lean exposure	Lean concept in curriculum
				

II. Working hypotheses

- *To analysis/capture the awareness &demand of Lean construction in academia and industry respondents.*
- *To seek insights concerning Lean construction teaching from the prerogative of the teaching faculty and civil engineers in the south Indian scenario.*

IV. Research Method

I. Background Engineering education system in construction engineering management (CEM) and introducing Lean Teaching.	**V. Proposed countermeasures** This can be adapted by creating awareness among students and also Faculty teaching CEM. By including in syllabus into curriculum for civil engineering students for graduates & CEM for Post graduations.
II. Current conditions Current scenario is about Lean Teaching is very limited and not having much exposed to student's level both UG and PG level. Having higher demand in construction industry. **III. Goals/Targets** To know more about the demands and awareness about the Lean Teaching both in academia and industry. Target audiences are teaching fraternity and Construction professionals implementing Lean concepts.	**VI. Plan** While designing the curriculum for civil engineering and CEM, Lean theories should be included to learn. Qualifications, genders, experiences, designations all these demographics are indicates the clear insights about the Lean Teaching. Policies/ standard can be implemented in construction companies at the contractual period itself. Client driven and client awareness drive can be initiated
IV. Analysis Qualitative method approach, email base survey was done Statistical analysis were done using SPSS. Chi square test, Discriminant factor analysis, with respect to awareness and demand about Lean Teaching.	**VII. Follow up** By practicing and teaching the concept of Lean Theories can be have more insights Short term executive courses can be conducted by experts. International exposures should be showcased to civil engineers

V. Research Findings

- Based on the results, it can be seen that Lean construction awareness is high in the industry as Lean is considered as one of the effective Business model compared to the awareness in academia, where the premier institutes have relatively high exposure.
- Most of the colleges/universities does not offer Lean construction through their curriculum which directly impacts the development of the industry.
- When compared to senior faculties of the academia, younger professor's shows more interest in learning and teaching new concepts.

VI. Conclusions

- The amount of research, teaching and practices adopted in the area of Lean construction in India is comparatively low with respect to other countries. It is also realized that Lean Construction is in the infant stage of growth and the availability of Lean experts is limited.
- It is also observed during the study that certain SME's has practices that aligns with Lean concepts, but the group is not aware of the Lean philosophy, which is an evidence for low awareness. Hence, this study would give wide publicity to the users and make them more comfort exposure.

Large scale project using takt planning and takt control-Creating and sustaining multitasking flow

Janosch Dlouhy, Miguel Ricalde, Bernardo Cossio and Carlos Januncio. (2018). "Large scale project using takt planning and takt control. - Creating and sustaining multitasking flow." In: Proc. 26th Annual Conference of the International. Group for Lean Construction (IGLC), González, V.A. (ed.), Chennai, India, pp. xx–xx. DOI: https://doi.org/10.24928/2018/0503. Available at: <www.iglc.net>.

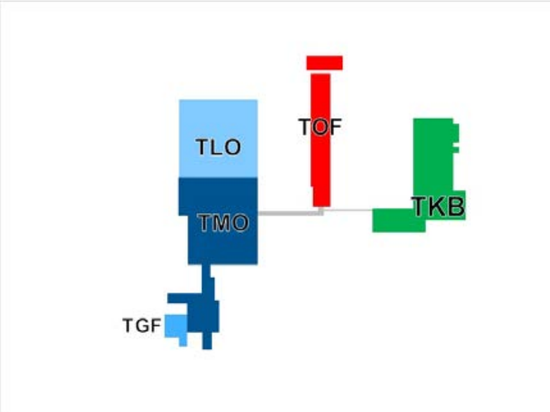
I. Background

Taktplanning and Taktcontrol (TPTC) is a production system approach that is most commonly used in individual construction projects. In case of the new construction of a complete, greenfield plant requires a huge effort in project management and administration. Facilitating information flow to all practitioners, controlling construction processes, planning and sustaining site logistics, while focusing on the client's values (and changes to their demands), as well as coordinating all buildings from different construction companies, while ensuring delivery in time by for connection to infrastructure are only some of the many requirements for a project's management system. As the main contribution from this paper, a system and its results for creating a Lean culture, collaboration, transparency, planning and overall project control within a multitasking flow is described and validated.

II. Current conditions

The plant was built in a greenfield, where all services and infrastructure had to be built entirely new. The project required several bid-packages (groups of buildings) to be tendered. An overview of the project is given in the list of expressive numbers, below:

- 3.000.000 m²
- 300.000 m² Building Area
- 5 Main Contractors
- Over 3.000 Workers Peak
- Over 10 different partial projects
- Over 20 client departments involved



III. Working hypotheses (Implementation)

The Taktplanning approach sought to help align the expectations with the execution of construction, synchronize and harmonize all different construction projects. The aim was to enable the entire project management of all stakeholders and external participants to pull requested information.

Understanding the client's requirements and value perception was fundamental to define the priorities for construction.

During the bid process, the realized that 95% stated having had little or no experience with Lean Construction, thus confirming the need to establish a formal strategy. The client's previous experiences in similar scenarios set the guideline to establish Lean as a contractual requirement. Furthermore, clear advice was given to the selected GCs to hire local Lean Construction consultants to accelerate the learning curve and sustain the implementation of Lean within their companies. Based at respect for people, one of lean principles, in this large-scale project, the training was extended to the systematic needs of a multi-contractor and multi-building project.

IV. Research Method (Operating system)

Following the implementation strategy mentioned earlier, a diverse Lean training program was developed to focus on individual target groups.

The planning workflow consisted of a 4-tier structure behaving transparently in a bottom-up and top-down information flow, involving weekly revisions on the Norm Level and daily adaptation on the Micro Level, informing each other of improvement opportunities and requirements.
Similar to the planning structure, the tools used for multi-level communication were broken down by levels and focused on target groups.

Working with the same structure and language to communicate the status of each building allowed a unique Lean Weekly Report to be processed collaboratively by the contractor and client, thus simplifying the visualization of critical interface challenges.

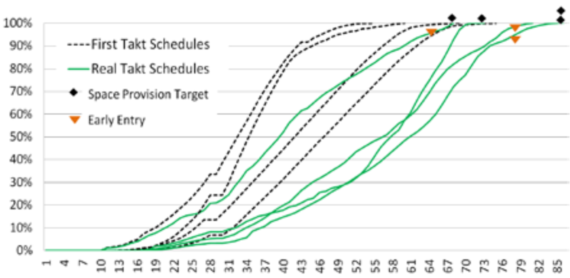
V. Research Findings

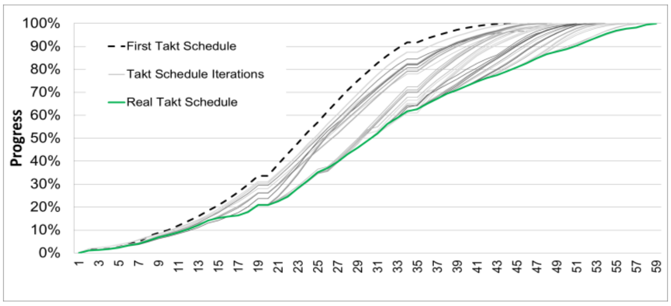
At one point there were over 20 different Takt schedules for both, buildings and infrastructure, allowing a comparative analysis between projects behavior.

The data herein shows the project control at 2 different levels: on the *Micro* the daily performance measured daily and averaged for any given week, and on the *Norm* progress curves (planned based on Takts complete).
Weekly goals were deployed to the micro level as daily quantifiable activities and the performance of the daily plan was recorded.

Less variance in the performance, endowed a higher reliability to daily planned activities, which in turn increased certainty on Takt Schedules and on Space Provision dates.

Towards the end of the construction sequence, the buffers were considerably reduced although always fulfilling the Space Provision commitments.





VI. Conclusions

The overall project transparency, with all single flows created by the large-scale Takt-approach in different construction sites, enabled multitasking adjustments in and at the same time. Quality issues and process instabilities could be detected at a very early stage. For every Takt time, information across the single flows were collected and used for the next Takt times over all projects and general contractors. At the micro-level planning, steering and optimizing flow of trades was possible. At norm-level the flow of the single buildings in Takts was visually made clear and understandable. At the macro-level, for the overall project flow of the whole plant, the customers' needs could be prioritized, maintaining flexibility relying on data and buffer transparency.

To improve future results for large-scale projects, it is necessary to include increased involvement from other project departments (such as design), change management, safety, quality and procurement, as well as integrating a software solution for hosting, processing and analyzing the huge amount of data points generated. Although there was a cultural barrier regarding Lean practices, it was mostly overcome by training, resulting in a common use of Lean language and buy-in from both the client and the general contractors.

Application of 4D Bridge Information Model as A Lean Tool for Bridge Infrastructure Projects: A Case Study

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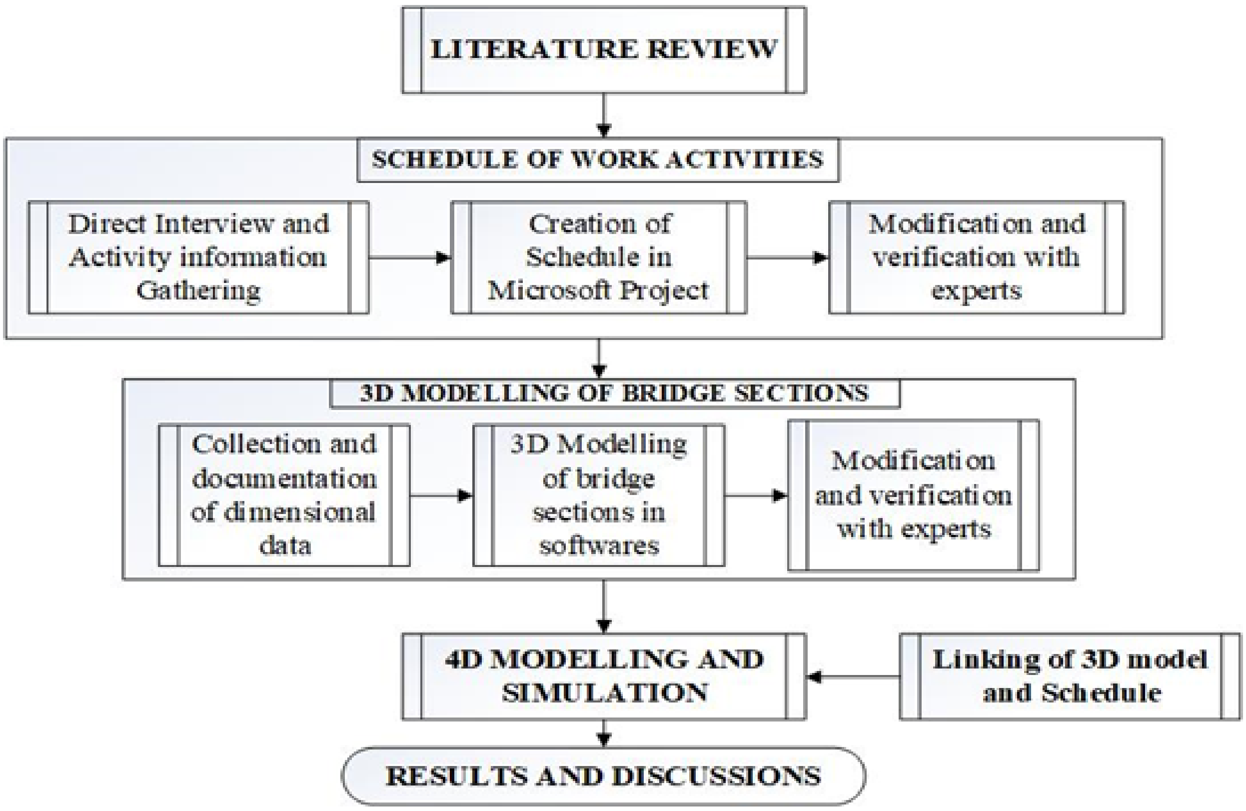
I. Background

This paper presents the effort made to use 4D Bridge Information models as a lean tool in construction practice for an ongoing flyover project in India. The developed 4D BrIM enables value addition through improved visualization, co-ordination and communication among project participants. This study provides a practical contribution by showing that project stakeholders can use 4D BrIM models as a lean tool to prevent undesirable situations and reduce the overruns and rework in Bridge construction projects.

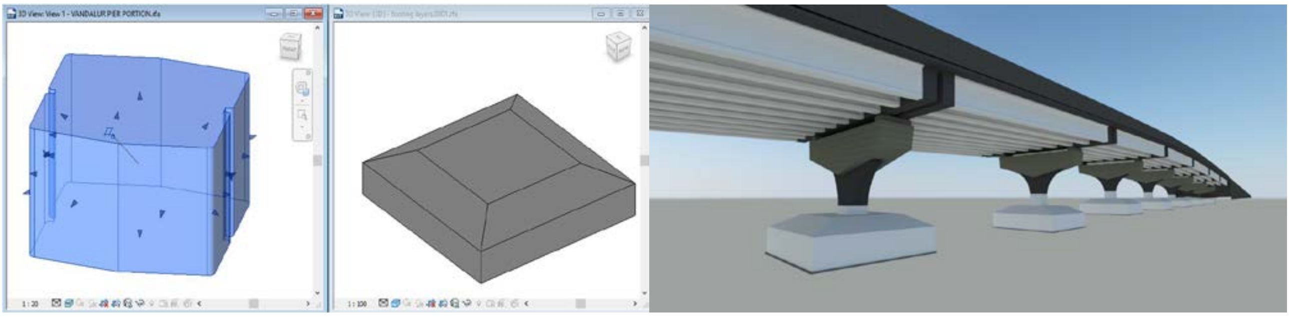
II. Research Method

A case study of an ongoing bridge construction project in Chennai, India was considered. Data was collected via direct interviews, onsite observation and through refereeing site documents.



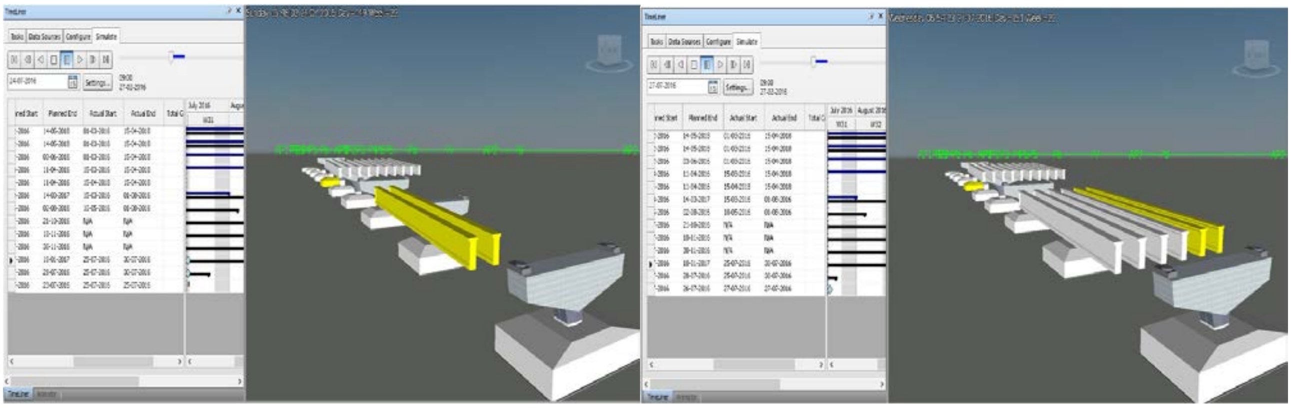
III. 3D Modelling

Use of Autodesk Revit is adopted to develop 3D models. A parametric model of individual structural elements is developed as separate family members. The elements are placed on respective levels as per the collected field data.



IV. 4D Modelling

The Autodesk Navisworks software is used to link the schedule information and the 3D model. A simulation of entire construction process is run over specific period of time. Further a comparison of planned vs actual construction sequence is simulated. The results of comprison are used by the project team to identify lags and take future plans to control the project.



V. Conclusions

- This study develops simulation of 4D BrIM models for an ongoing bridge construction project to enable visualization of entire construction process.
- The developed models were used for discussion by the project team to make effective decision to improve the further performance. The models and simulation enabled collaboration and coordination among the different labour crews in the construction process.
- Thus, the study concludes that application of BrIM as a lean tool enables value addition through improved visualization, co-ordination and communication among project participants.

THE REVIEW OF REWORK causes and costs in HOUSING CONSTRUCTION SUPPLY CHAIN

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I. Background

The UK housing supply chain has often been criticised for the poor quality and performance of its products and the inadequacy of its production process (Pan, et al., 2008). The Construction industry in 2014, contributed around £100 billion to the UK economy (equivalent to 7% of the GDP), from which the housing sector contribution was approximately 40%. Traditionally, the UK housing construction industry has not improved its productivity to deliver such value, and it has been one of the largest construction economic challenges encountering the UK construction industry.

II. Cost of rework in construction projects

Almost all the existing cost estimates for rework are expressed as a percentage of the total project cost (Taggart, et al., 2014). Recent studies by Love and Li (2000), Love, et al. (2004) and Hwang, et al. (2009) indicate that rework costs ranges from 2-6% during construction and an additional 3-5% during the maintenance.

III. Lean approach in housing supply chain

The housing construction industry has a large supply chain and is characterised by high levels of fragmentation. Harris (2013) has shown that for a typical large housing project (within a range of £20 to £25 million) the main contractor may be directly managing around 70 small enterprises as subcontracts. For a regional project, the subcontract size may be even smaller. This is clear evidence of the scale of fragmentation in the industry, which also confirms the extensive engagement of small medium size enterprises (SMEs) in the housing supply chain in the UK as subcontractors.

IV. Root causes of rework

Traditionally, the source and cause of construction rework have mostly been considered as the responsibility of the main contractors. However, this is a simplistic view of the complex problem. Some of the rework problems handed to the site operatives are beyond the contractors control. Project designer, product manufacturer, contractor and subcontractors, materials handling, procurement and site construction practices can all contribute to the reduction of construction rework.

The focus in most house construction practices is on fixing the problems (that is, the faults in the particular house) at the end of the construction and before handing over to the client. However, if the source of the problem is not examined and the cause is not identified, there is no guarantee that the problem will not to be repeated in the next project.

The outcome of a comprehensive literature review (Fayek, et al. 2004; Mossman, 2009; Love, et al., 2010; and Arashpour, et al., 2014) on the contributors and root causes of rework in construction projects is presented in Figure 1.

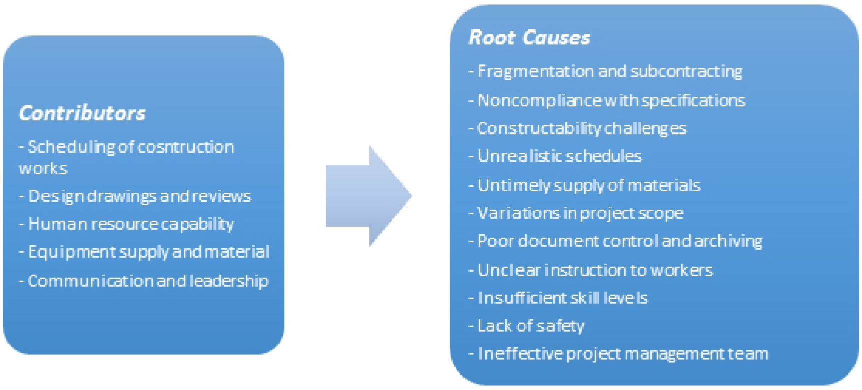

Figure 1. Cotributors and root causes of rework in construction project

V. Current practice for rework minimisation

Previous works on rework reduction and avoidance in construction projects have identified the following two key practices for construction organisations seeking to minimise rework:

- Rework reduction by using various measures at the early stages of the design process including standardisation and dimensional coordination, limitation of design modifications and provision of detailed designs (Poon, 2007).
- The use of prefabricated products to reduce rework generation on site, which consequently contributes to cost savings and higher quality (Love, et al., 2004; Zhang, et al., 2012).

Academic conversations indicate that many barriers to efficient rework minimisation revolve around underlying behavioural and structural characteristics of the construction supply chain in general and SMEs as subcontractors in particular

VI. Conclusions

This paper investigated the significant problem of rework generation in housing construction projects. The root causes of reworks were reviewed and it was concluded that the entire housing supply chain should be studied to accurately point the source of rework. This is necessary to avoid or minimise rework for future projects. Fragmentation and subcontracting was identified as one of the major causes of rework generation in the housing supply chain. An efficient lean-based framework to be used within the supply chain by embarking on the role of subcontractors and their engagement to rework minimisation needs to be established for an efficient lean housing supply chain.

MDM-based Buffer Estimation in Construction Projects

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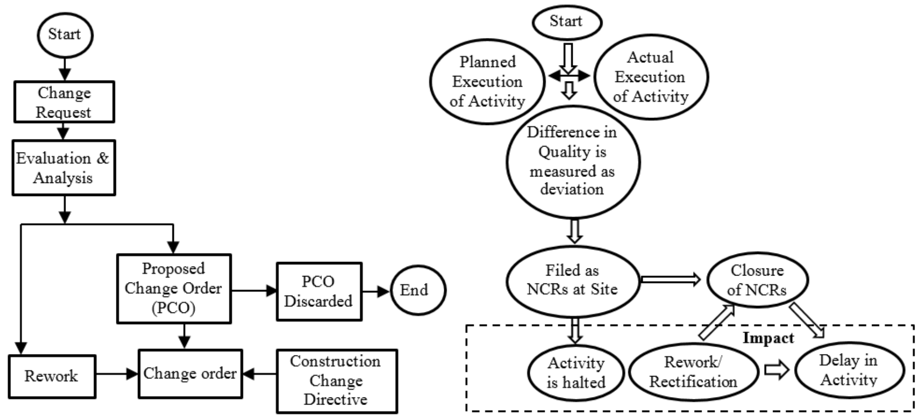
I. Background

Schedule delay and cost overrun are the two major challenges for the successful project delivery in construction. Rework is considered to be one of the major reasons for delay in construction projects. Two main causes for rework in construction projects are 'design changes' and 'non-conformances'. There is a need for the assessment of such delays due to rework in construction projects in order to estimate suitable buffers while planning for an upcoming project.

II. Current conditions

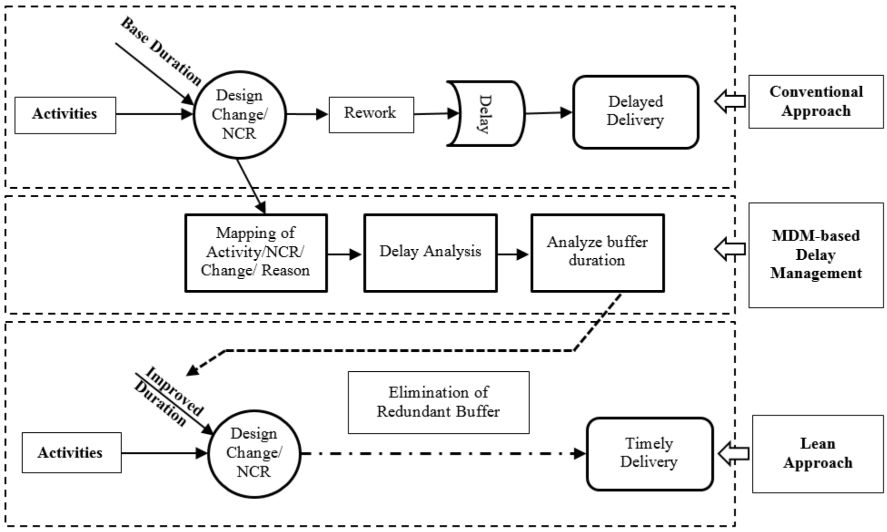


(a) (b)

(a) Flow diagram for Design Changes and Delay (based on (González *et al.* 2014))

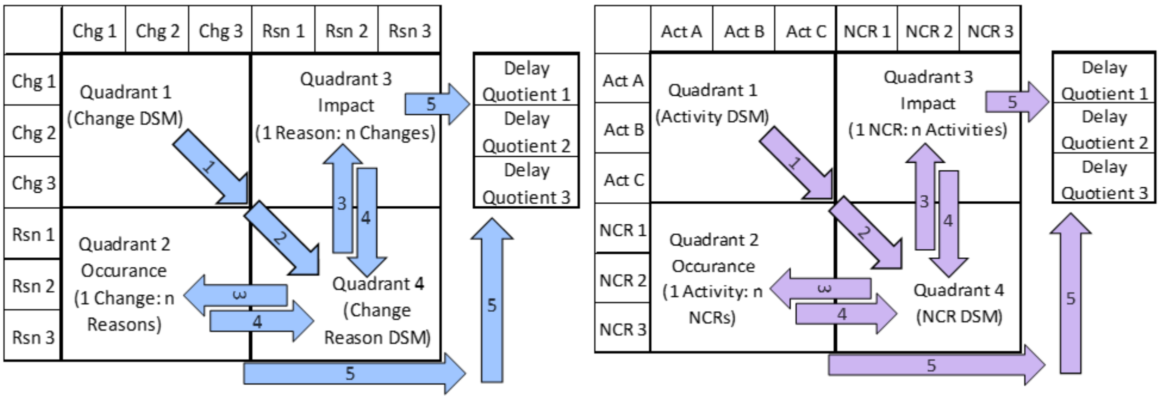
(b) Flow diagram for NCRs and Delay (based on (Kumar 2015))

III. Working hypotheses



IV. Research Method

The objective of the study is to propose a lean framework for delay assessment in construction projects due to design change and non-conformance. The scope of the study is limited to time overruns only. MDM is proposed to identify and assess the relationships among the delay, design change and the non-conformance. To illustrate the design changes and the non-conformances, a transmission line project and a mall construction project have been chosen respectively. Semi-structured interviews have been conducted with the project team members to support the information gathered from the project documentation.



(a) Case A: Design Change (b) Case B: Non-conformance

Workflow for MDM formation

V. Research Findings

	Act A	Act B	Act C	NCR1	NCR2	NCR3	NCR4	NCR5	NCR6	NCR7	NCR8	NCR9	
Act A	70.00			0.628	0.186								0.341
Act B	0.300	60.00	0.800			0.476	0.374						0.348
Act C		0.500	70.00					0.021	0.515	0.024	0.001	0.091	0.260
NCR1	0.444			49.80									
NCR2	0.333				19.70								
NCR3		0.475				61.10							
NCR4		0.325					70.10						
NCR5			0.034					17.00					
NCR6			0.483						30.50				
NCR7			0.034							20.00			
NCR8			0.034								1.00		
NCR9			0.103									25.00	

Legend:
Act A: Reinforcement
Act B: Shuttering
Act C: Concreting
NCR1: Bars not as per specification
NCR2: Rusted Bars
NCR3: Alignment
NCR4: Shuttering pieces inside
NCR5: Inspection
NCR6: Honeycombing
NCR7: Cracks in concrete
NCR8: Improper curing
NCR9: Concrete Testing

Activities	**Duration**	**Delay quotient**	**Delay in activity**	**Extended duration**
Reinforcement	70 days	0.341	23.87 days	93.87 (≈94 days)
Shuttering	60 days	0.348	20.88 days	80.88 (≈81 days)
Concreting	70 days	0.260	18.2 days	88.2 (≈88 days)

VI. Conclusions

- MDM models formed using the proposed framework for delay assessment have captured the relationship between change and its reasons as well as the dependencies among the activities and NCRs effectively.
- MDM models have been used to estimate the delay in an objective way for a meaningful time buffer estimation.
- This method has been found to be very useful in the application of lean principles of eliminating/minimising the time waste by managing construction delay.
- The reduction of time delay by way of managing the rework probability can be a future scope for intensive research.