



اجرا و مدیریت پروژه به روش اصول ناب (Lean Project Management)

فصل دوم: بکارگیری مفاهیم و اصول روش ناب در مدیریت پروژه
بخش پنجم: استفاده از سیستم Last Planner برای برنامه ریزی و کنترل پروژه

ارائه دهندگان:

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Introduction and research background



- With the advancement of technology and computer-based tools, the methods employed in planning and control of construction projects are becoming more potent.
- The main **driver** behind these methods, however, is the human knowledge through which the **interpretation** of the data and information at hand is of utmost importance in steering projects towards their **successful delivery**.
- The LPS system is founded on lean principles to improve **planning reliability** and **mitigate the detrimental effects of uncertainty** and variability in construction projects

Construction planning and project performance



- Project management encompasses various actions undertaken during the course of construction projects to **maximize the chances of success**.
- Conventional planning practices recognize the relationships between tasks using the **Critical Path Method (CPM)**.
- However, the main problem with these practices is the deficiency in acknowledging the workflow between tasks, whether it is the flow of trades, space, or resources.
- Similarly, conventional control systems, such as the commonly used Earned Value Management (EVM), have demonstrated several **limitations**, one of which is the inability to focus on work flow

The Last Planner® System



- Managing production flow is an essential process of construction planning and control on a project.
- Consequently, developing reliable and achievable plans is also a critical aspect of proper planning.
- The Last Planner® System emerged with the aim to enhance planning reliability and effectiveness.
- Early project stages undergo long-term perspective planning followed by short-term perspective planning as the project progresses forward and new information becomes available.

The Last Planner® System



- As such, major project milestones are set during the early stages and are then broken down into phases.
- Look ahead plans are generally based on a 6-week timeframe; these plans are then broken into Weekly Work Plans (WWP) (Ballard 2000).
- Therefore, planning is performed in greater detail the closer it gets to the start of an activity (Hamzeh and Langerud 2011).

The Last Planner® System



- LPS involves the following planning practices:
 - developing the work plan with those who are going to execute the work
 - identifying and removing work constraints ahead of time to make work ready and increase reliability of work plans
 - making reliable promises and driving work execution based on coordination and active negotiation with trade partners and project participants
 - learning from planning failures by detecting root causes and taking preventive measures

Combination of different planning methods



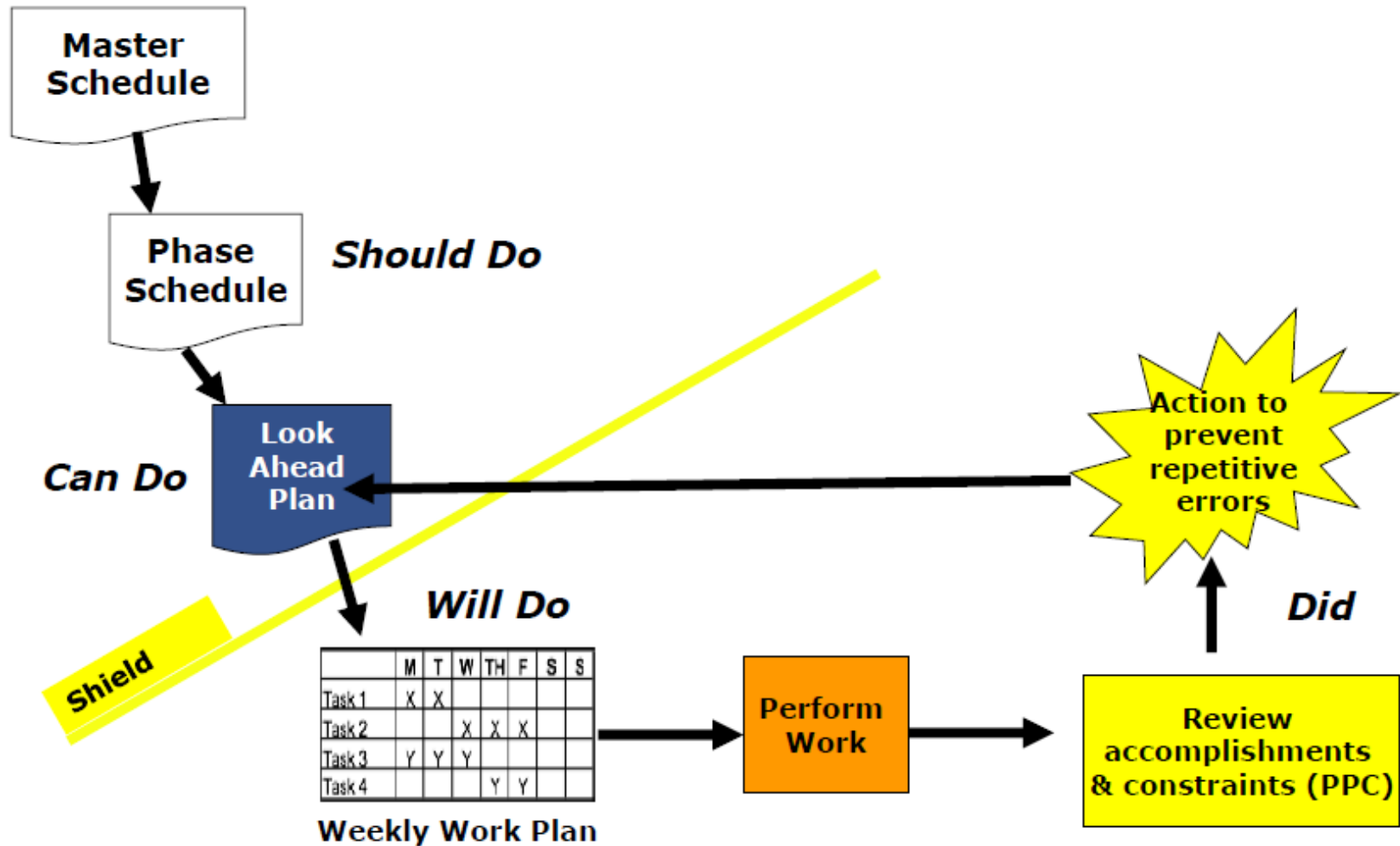
- Recently, there have been several attempts to combine two planning methodologies, the CPM and the LPS.
- CPM observes the big picture and focuses on delivering a master schedule that helps management maintain control over large and complex projects.
- However, even with such successful attempts at integrating several planning and control methods to improve the reliability of projects, a comprehensive approach for monitoring several aspects of construction planning is needed to present a holistic perspective for planners.
- In this regard, another aspect of planning that is often overlooked is capacity planning.

Capacity planning



- Planning should not only be concerned with achieving proper workflow and adhering to set plans but should also consider the proper assignment of activities and tasks (the workload) to the available labor, equipment, and other resources (the available capacity).
- **The balance** between the workload and capacity is known as **capacity planning**.
Workload is the quantity of work needed to be done in a specific time allotted by planners, and capacity is the quantity of work a crew can complete using their available resources

The Last Planner® System



Sample Sticky Notes

Company / Name	Duration	Delivery Date
My Promise (What I will deliver -- Be specific!)		
My Requests (What I need from others -- Be specific!)		
What	Needed from/ By When	

Design

Company / Name	Resources	Duration (5 days or less)
My Promise (What I will deliver -- Be specific!)		
My Requests (What I need from others -- Be specific!)		
What	Needed from/ By When	

Construction

Summary of available LPS metrics



Equation	Metric	Formula
1	Percent Planned Complete (PPC)	$\frac{Did}{Will}$
2	Tasks Made Ready (TMR)	$\frac{Did}{Can}$
3	Tasks Anticipated (TA)	$\frac{Anticipated\ Tasks}{Total\ Tasks\ on\ WWP}$
4	Planned Work Ready (PWR)	$\frac{Work\ Expected\ to\ be\ Performed\ in\ Lookahead}{Work\ that\ Should\ be\ Performed}$
5	Delta 1 ($\Delta 1$)	$\frac{Constraints\ Promised\ to\ be\ Removed}{Constraints\ Identified}$
6	Delta 2 ($\Delta 2$)	$\frac{Constraints\ Removed}{Constraints\ Promised\ to\ be\ Removed}$
7	Delta 3 ($\Delta 3$)	$\frac{New\ Constraints}{Constraints\ Identified}$
8	Percent Constraint Removal (PCR)	$\frac{Ready}{Can}$
9	Performance Factor (PF)	$\frac{Actual\ Labor\ Hours}{Earned\ Labor\ Hours}$

Summary of available LPS metrics



Equation	Metric	Formula
10	Labor Utilization Factor (LUF)	$\frac{EffectiveWork + \frac{1}{4}Essential\ work}{Effective + Essential + Not\ useful}$
11	Project Productivity Index (PPI)	$\frac{\sum(Activity\ Pr\ activity\ Indexes)}{N} \times 100$
12	Planning Reliability Index (PRI)	$\frac{Actual\ progress}{Planning\ progress} \times 100$
13	Construction Flow Index (CFI)	$10 \sum_{i=1}^7 W_i P_i^{x_i}$
14	Commitment Level (CL)	$\frac{Required\ Will}{Should}$
15	Percent Required Complete and Ongoing (PRCO)	$\frac{Required\ Completed + Required\ Ongoing\ on\ Track}{Required\ Will}$
16	Capacity to Load Ratio (CLR)	$\frac{Total\ Completed}{WWP}$
17	Required Capacity Ratio (RCR)	$\frac{Required\ Completed}{Total\ Completed}$
18	Required Percent Complete (RPC)	$\frac{Required\ Completed}{Total\ Required}$

The need for new metrics

- Several issues and gaps in connection with the available metrics, namely:
 1. Capacity planning is not properly emphasized, and no clear measurement frameworks are found to assess capacity planning jointly with the LPS.
 2. Studies employing the integration of metrics are scarce because most studies focus on certain aspects of planning rather than assembling and reflecting a holistic picture.
 3. Research correlating the available metrics to overall schedule performance has been both challenging and time consuming; collecting the required data was found to be overwhelming. Additionally, metrics were found to be inconsistently used.
 4. Few metrics consider activity status: whether the activity is critical/required, a backlog activity, or a newly emerging activity.

The need for new metrics

- The research methodology adopted in this research is Design Science Research (DSR). DSR is a multi-step process employed when there is a need to create and evaluate an innovative artefact intended to solve a certain identified problem.



Description of new metrics and sample calculation



- The metrics identified in this research aim at complementing the existing LPS metrics to have a more comprehensive planning exercise. The new metrics assess the performance of the weekly work planning efforts.
- The first problem addressed here is concerned with the drawback of the PPC metric and other metrics that ignore activity characteristics and consider them of equal importance.
- Consequently, the suggested metrics differentiate between activities and consider their status as being either Critical/Required, Not Critical/Not Required, Backlog, or New.

Description of new metrics and sample calculation



- Required activities are critical activities that have a priority over other activities since their delay will lead to delaying the whole schedule or the phase milestone. Backlog activities are excess activities that are ready for execution but are Not Critical/Not Required.

Advanced metrics developed



$$1. \quad RL = \frac{\text{Required Will}}{\text{Will}}$$

- Required Level (RL) helps planners in identifying the criticality level of the committed activities; a high RL indicates that most of the activities on the WWP are critical. Therefore, calculating RL before the start of the week of execution is important for planners to understand the seriousness of the situation. A high RL shall be accompanied with serious attempts by planners to complete all activities and to achieve a high PPC.

Advanced metrics developed



$$2. \quad CU = \frac{\text{Total completed} - \text{Completed from will}}{\text{Total completed}} \quad (\text{Completed Uncommitted})$$

$$3. \quad CU = \frac{\text{Completed from backlog}}{\text{Total completed}}$$

- Notably, a high CU indicates that teams are completing uncommitted work. An increase in CU thus reflects a tendency to complete activities that were not committed to by teams, a matter that needs to be addressed to understand the reasons behind it.

Advanced metrics developed



$$4. PCN = \frac{\text{Completed New}}{\text{Committed New}} \quad (\text{Percent Complete New})$$

- PCN helps teams in recording completed New tasks. These tasks, unexpected yet important, could be a burden on planning reliability. A high PCN indicates a high ability to complete New tasks on time. A low PCN, in contrast, reflects the inability of teams to complete the New emerged activities which can delay the schedule if these activities are critical, which is usually the case..

Advanced metrics developed



Parameter	Description
WWP	Represents all the activities on the weekly work plan that have been committed to be completed for the given week
WWP Completed	Represents all activities on the weekly work plan that have been completed for the given week
Total Completed	Represents all the activities from the WWP, New, and Backlog Clusters that were actually Completed on the given week
Total Required	Represents all the critical activities that are in the WWP, the Backlog, and the New Clusters for the given week
Required Completed	Represents all the critical activities that were Completed on the given week (indicated by all red pebbles in the Total Completed)

Advanced metrics developed



1. Capacity to Load Ratio (CLR) The CLR metric measures the total tasks that were completed representing the actual capacity (Total Completed cluster) to the tasks committed to on a given week (WWP cluster) representing the chosen load.

- $$CLR = \frac{\text{Total Completed}}{WWP}$$

2. Required Capacity Ratio (RCR) The RCR metric measures the Required activities, or otherwise the critical activities, out of the total completed activities.

- $$RCR = \frac{\text{Required Completed}}{\text{Total Completed}}$$

Advanced metrics developed



3. Required Percent Complete (RPC) The RPC, which is the third primary metric developed, focuses on the Required activities or critical ones. RPC measures the total number of Required activities completed out of the total Required activities during a given week.

- $$RPC = \frac{\text{Required Completed}}{\text{Total Required}}$$

4. Weekly Deviation (WD) From its name, the Weekly Deviation (WD) metric assess the team deviation from the WWP they prepared. WD is calculated by subtracting the total number of committed activities (WWP cluster) from the number of total Completed activities.

- $$WD = \text{Total completed} - \text{WWP} \Rightarrow < 0 \text{ ??}$$

5. Glut The RCR metric described earlier is concerned with critical activities completed out of the total completed; 1-RCR thus represents the non-critical activities that are completed in that given week. Glut measures the number of non-critical activities completed and consequently taking available resources from critical tasks.

- $Glut = Total\ Completed - Required\ Completed$

6. Starvation Likewise, if RPC represents the fraction of critical activities that have been Completed, then 1-RPC represents the fraction of required (critical) activities that have been missed or not completed. As such, the Starvation metrics actually represents the critical activities that are starving for resources.

- $Starvation = Total\ Required - Required\ Completed$

7. Misallocation Factor (MF) The Misallocation Factor (MF) is the sum of the Glut and the Starvation metrics.

- $MF = Glut + Starvation$

Planner's role in project planning



- Project performance with respect to time, cost, and quality is often affected by external and internal factors that occur during the course of construction. Usually, external factors are beyond the control of the management team. However, internal factors, related to the design and performance of the product, can be controlled and should be properly managed to improve the ultimate performance of the project.
- A simulation model was developed based on nine different project profiles, and variability was embedded with different intensities.



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فصل دوم: بکارگیری مفاهیم و اصول روش ناب در مدیریت پروژه
بخش ششم: مطالعه موردی استفاده و پیاده سازی روش ناب در پروژه ها توسط شرکتهای متفاوت

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- **Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)**
 - Kinetic Construction Ltd. is a mid-sized General Contractor – Construction Manager operating out of Victoria, British Columbia (BC) since 1984. Kinetic has three branches on the west coast of British Columbia; One in the greater Vancouver area and two on Vancouver Island, with their head office located in Victoria.

- **Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)**
- **A CEO's revelation:**
 - Tom received an invitation to the LCI-C's 2016 Inaugural conference through the local construction association. During the first day he was introduced to the philosophy of Lean and participated in a Lego airplane simulation. The simulation had a profound impact on Tom and over the three days he was there, the metric that stood out the most was the steady increase in participant satisfaction as they learned basic pull, one-piece flow and just-in-time concepts and continually improved through collaboration and PDCA during the simulations and games.

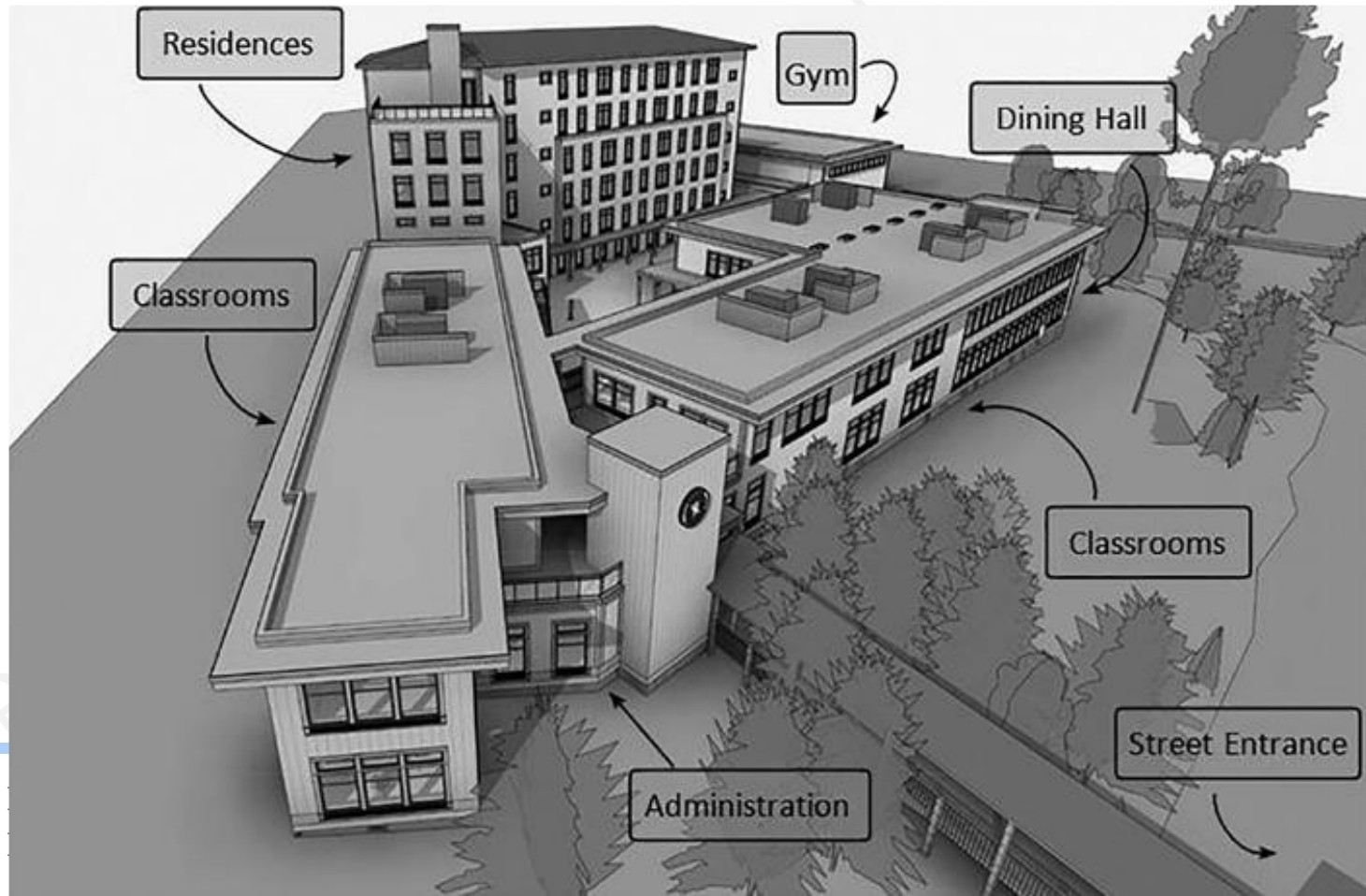
- **Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)**
- **The lean journey:**
 - One of Kinetic's early Lean Initiatives was to use The Last Planner® System on a \$40M, 16-story high-rise located in Victoria, Canada.
 - The contractor acquired the help of a Lean consulting firm to hold a two-day LPS (Villego) Bootcamp prior to implementing LPS on the project. During the bootcamp the project team identified their Conditions of Satisfaction – This was a very important step for the group and was often reflected on although not always adhered to.
 - The results obtained from this early foray into lean construction were mixed. But important lessons were learned about the lean methodology and the logistics of implementing it. It is generally accepted within Kinetic that this project experiment was a positive endeavor.

- **Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)**
- **The Brookes project:**
 - In late 2016 Kinetic Construction was approached by a prospective client that was considering them for a new location of an international private school campus.
 - The project started with a collaborative workshop to allow the trades to assist with final design inputs – a modified version of Target Value Design (TVD), The Last Planner® System (LPS) for onsite production control, just-in- time (JIT) material supply and both on and off-site prefabrication methods for the wooden wall and floor assemblies.
 - The use of lean techniques enabled the project team to complete what was expected to be a seventeen month project in just thirteen months.

- **Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)**
- **Project description:**
 - **Location:** Vancouver Island BC, on a 2.9-acre
 - **Scope:** comprised of three large structures; A six-story – 93 Unit/40,000 square foot Student Dorm Facility; A two story 24,000 Ft² Academic Classroom and Cafeteria facility and 5,300 square foot gym and fitness facility. The site straddled an environmentally sensitive Streamside Protection and Enhancement area (SPEA). The SPEA supports fish and wildlife habitat for several months of the year and is heavily regulated by the Canadian Federal Fisheries Act.

Case Studies

- Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)
- Project description:



- **Case 1: The Kinetic Construction Ltd. Story (Contributed by Trevor Coyle, CM-Lean, Lean Implementation Manager)**

- **Project description:**

- The proposal was to evaluate whether the project could be completed within 13 months, and be partially operational for the September 2018 school year. The complexity of the scope and timeline, and the unique challenges of the site, compounded by current market conditions that were starving projects of skilled labor, would traditionally have led to a discussion with the client about setting more realistic expectations. Perhaps to allow for an additional four-month construction period after the design was complete. Although Kinetic had limited exposure to Lean as a project delivery model, their past experience had validated enough of the concepts to give them the confidence to agree to the project. This was a historical turning point for the company

- **Case 1: The Kinetic Construction Ltd. Story**

- **Initial Goals:**

- A finite budget
- Academic wing and gym available for use during 2018/2019 school year
- Residential wing to follow early spring 2019
- Incorporate as much green space as possible
- Minimize design time and construction time challenges identified
- Budget – not negotiable
- Timeline
 - reduced design period (not nearly enough time to do TVD properly)
 - to start in June and be handed over for occupancy early August 2018

- **Case 1: The Kinetic Construction Ltd. Story**

- **Initial Goals:**

- Multiple permits required
- Multiple occupancies
- Completion of residence building on occupied site
- RAR zone
- Extremely tight space on site
- Market conditions/resources

- **Case 1: The Kinetic Construction Ltd. Story**

- **Design:**

- Target value design – design to specific budgets
- Contractor input on a more frequent basis – initially civil, structural, mechanical, electrical with other team members added as needed
- Eliminate the need for redesign
- Maximize innovative solutions

- **Case 1: The Kinetic Construction Ltd. Story**

- **Construction:**

- Eliminate waste in all processes
- Create workflow to avoid workers waiting for work and work waiting for workers
- Use of pull planning and last planner scheduling-all trades
- Targeted – measurable production levels
- Reduce the need for excessive design input during the construction phase
- A happy – collaborative site

- **Case 1: The Kinetic Construction Ltd. Story**

- A select group of 6 contractors that would represent the core team was invited to a two-day Lean workshop. The group was asked to participate at their own cost with the intention that those who were serious about the project would see the value of the Lean approach and eventually enter a contract to assist with completion of the design and build the project.
- One attendee was heard commenting that the idea of slowing down to go faster was long over-due in our industry and that the conversation was finally making sense to them.

- **Case 1: The Kinetic Construction Ltd. Story**

- The owner's representative presented the group with the intent for the project and communicated the background and prestige surrounding their investment. He defined his idea of value for the project and was open-book about the funds that were available and the restrictions surrounding them.
- **Primary concerns:**
 - Market Escalation
 - Regulatory Approvals
 - Site Access
 - Environmental regulations
 - Financial Limitations and budget

- **Case 1: The Kinetic Construction Ltd. Story**

- **Conditions of Satisfaction:**

- Zero injuries
- Transparency in all project activity
- Deliver what we promise
- Act with integrity
- As a team, we will not allow scope gaps
- Act respectfully to everyone
- On budget, on/ahead of schedule/meet owner value
- Commit to lean culture
- No rework of Design and Construction
- Environment

- **Case 1: The Kinetic Construction Ltd. Story**

- At the time of the workshop, the design drawings were at 30% and the budget had been developed to a class D estimate.
- **Workshop team discussion highlights**
 - **Phasing the project**
 - **Initiate critical path early –Start a project with the largest building – the Dorm, to ensure that trade presence is on-site and continues to the other building rather than having smaller crews onsite and ramping up the operation at the end – it will be more difficult to get manpower commitments later, because of labor market shortages.**
 - **Imperative to coordinate exterior works and plot to accommodate continuous access for siders.**

- **Case 1: The Kinetic Construction Ltd. Story**
- **Workshop team discussion highlights**
 - **Framing**
 - **Framer – Will prefabricate walls offsite and floor assemblies onsite; install with a crane.**
 - **Virtual mock-up of framing required to solve all prefabrication issues.**
 - **Extend walls to the underside of sheathing along parallel walls to reduce assembly components and install time.**
 - **Fire Blocking/FRR alternatives to be considered to reduce assembly components and install time.**
 - **Resolution of mechanical exhaust in the dorm – it is key to resolve and accommodate framing.**
 - **Discuss logistics surrounding joist direction – Shorter lengths and faster, easier assembly: Will work with mechanical crafts.**
 - **The building does not have large windows or decks typically used to load material – Proposed solution: Frame in extra structural headers each floor to allow wide, temporary access doors. Structural engineer to confirm location with Framing contractor.**

- **Case 1: The Kinetic Construction Ltd. Story**
- **Workshop team discussion highlights:**
 - **Sequencing of building construction**
 - Gym structure 'last' and erected quickly. To allow for truck turnaround and lay down during construction.
 - Start dorm first to get envelope in fall before weather impacts and this will increase trades onsite early.
 - Importance of framer "flow" efficiencies to allow subsequent trades to follow.

- **Case 1: The Kinetic Construction Ltd. Story**
- **Workshop team discussion highlights:**
 - **Basement (eliminate)**
 - Is it possible to relocate sub-level basement mechanical area to expedite critical path activities?
 - Mechanical could be at penthouse-structural spans accommodate.
 - Eliminating the basement will avoid pumping issues and cost.
 - Code implications of a “seven- story” design with mechanical systems on the roof should be reviewed.
 - Will eliminate tanking and floodplain issues.
 - High impact solution – Team to investigate and confirm asap.
 - **Main Access Foot-Bridge**
 - Sequencing to access SPEA window (8 weeks in summer).
 - Divide Substructure (2017) and Superstructure 2018.
 - Environmental access to be confirmed asap.

- **Case 1: The Kinetic Construction Ltd. Story**
- **Workshop team discussion highlights:**
 - **Wall Cladding**
 - Will select a system that is fast and can be installed during wet months.
 - A system that is less impacted by weather **MUST BE** durable (owner requirements).
 - Building skin to apply vertical and complete “Finish to Finish” with roof framing.
 - **M&E Distribution (Dorm)**
 - Provide dropped ceilings at water closets and corridors.
 - Set up distribution to leverage horizontal plenums/shafts.
 - Centralized panels and comm. Each floor for simple distribution (shorter runs).
 - Main electrical room and ground floor.

- **Case 1: The Kinetic Construction Ltd. Story**

- The discussion among the groups was focused on finding efficiencies and cost savings around the current design proposal. The team identified at an early stage that the sequencing of the site would lead to the greatest cost savings given its constraints. The Last Planner® System was already intended to be used but it was communicated to the group – who had no prior knowledge of it, that this would be the mechanism to combat the perceived challenges and constraints. Kinetic would be responsible for training and supporting team members on the program. The remaining discussion was opened to the trades to offer their ideas on product substitutions that they had the experience and the most certainty with. They were evaluated for compatibility with the associated assemblies as well as availability and simplicity of installation without decreasing the value of the final product.

• Case 1: The Kinetic Construction Ltd. Story

• Design document handling process:

- Conversations to reduce the waste of passing documents back and forth to clarify intent resulted in the agreement that shop drawings would be produced based on thorough discussions around intent and the shop drawings would ultimately influence and in some cases become the IFC document of record. Given the time constraints, the team also agreed that the use of The Last Planner® System would enable them to produce Just-in-Time drawings.

• Risk management

<u>RISK MATRIX</u>			IMPACT				
LIKELIHOOD			Negligible	Minor	Significant	Major	Severe
			1	2	3	4	5
	Very Likely	5	Low	Medium	High	Extreme	Extreme
	Likely	4	Very Low	Low	Medium	High	Extreme
	Possible	3	Very Low	Low	Medium	High	High
	Unlikely	2	Very Low	Low	Low	Medium	High
	Very Unlikely	1	Very Low	Very Low	Low	Medium	Medium

- Case 1: The Kinetic Construction Ltd. Story
- Risk management

RISK REGISTER SCORE SHEET

Rank each item in each of the 4 columns. First 3 col'ms are based on IMPACT of Cost, Schedule, and Quality. The 4th column is PROBABILITY of this risk occurring.
Rank from 1-5. 1 being very low, 5 being very high

IMPACT					PROB'LY	DESCRIPTION
COST	RISK	SCHED	RISK	QUAL		
5	EXTREME	5	EXTREME	1	VERY LOW	3.5 Won't achieve complete project schedule of August 2018 completion
5	MEDIUM	5	MEDIUM	3	LOW	1 Owner's FF&E requirements unclear
3	MEDIUM	5	EXTREME	1	VERY LOW	4 Not being granted permits when required
3	LOW	3	LOW	1	VERY LOW	2 Scope creep due to unclear Municipal Development expectations
4	MEDIUM	3	LOW	2	VERY LOW	1 Lack of fully documented design approaches & cost could result in missed scope, exceeding expected costs &/or legal disputes
4	MEDIUM	4	MEDIUM	3	LOW	1 Misalignment of subtrade scopes of work
4	MEDIUM	3	LOW	3	LOW	1 Insufficient detailing
2	VERY LOW	5	MEDIUM	2	VERY LOW	1 Timely submittals/shop drawings/reviews/RFIs/etc.
5	MEDIUM	5	MEDIUM	5	MEDIUM	1 Risk of using unknown trades with potentially inadequate performance
5	HIGH	5	HIGH	2	LOW	3 Material delivery and installation not on time
3	MEDIUM	2	LOW	1	VERY LOW	2 Site congestion
5	MEDIUM	5	MEDIUM	5	MEDIUM	1 Risk of ineffective communication, insufficient communication, or lack of collaborative communication impacting project coordination/schedule/reputation
5	HIGH	5	HIGH	1	VERY LOW	2 Team members don't cooperate to meet the schedule
5	MEDIUM	5	MEDIUM	1	VERY LOW	1 Crane access and logistics tight

- **Case 1: The Kinetic Construction Ltd. Story**

- **Risk register highlights:**

1. The achievement of the schedule was known to be the most challenging aspect of the project since it is, in fact, the effect of the subsequently listed causes. Interestingly, the team did not associate the risk to the quality of an expedited schedule to the degree that it transpired. The speed of the project ultimately affected the quality outcomes to a considerable degree and lead to significant re-work for the trades.
2. Lack of fully documented design approaches and cost – Exceeding expected costs and leading to disputes, was identified but ranked very low in probability. In actuality, this did become a problem for the project team and the probability was underestimated. There were some scope gaps and escalations that occasionally lead to fractured team performance. Both in managing the deviations from what was expected and in production.
3. The risk of ineffective, insufficient or collaborative communication and the impact on the project coordination, schedule, and reputations of the contractors was identified as high risk to cost, schedule, and quality and given a low probability of occurring. These challenges did occur on the project, as they do with many projects – schedule, cost, and quality were also affected.

- **Case 1: The Kinetic Construction Ltd. Story**

- **Summary of outcomes from the project Kick-off:**

- A commitment to complete 100% of the project within 13 months – A new, expedited master schedule would be developed using collaborative methods.
- The concrete basement would be deleted, and the mechanical moved to a rooftop penthouse – This solved many challenges brought up by the contractors and allowed site production to commence while the design is being completed.
- The framing contractor would produce design schematics and initiate prefabrication of wall panels and engineered floor systems. Pre-manufactured panels were to be built in Vancouver and brought to Vancouver-Island across the strait of Georgia (70miles) by way of Ferry or Barges. – An unprecedented strategy that had never been done or even considered by Kinetic before.
- Several options for material alternatives that would be reviewed for conformance.

- **Case 1: The Kinetic Construction Ltd. Story**
- **Summary of outcomes from the project Kick-off:**
 - Clarity by all of owner value.
 - Understanding and buy-in of the lean approach.
 - General confidence and excitement from the team to take on the challenge.



- **Case 1: The Kinetic Construction Ltd. Story**

- The project mobilized, and a 40-foot, temporary site office was set up as the new boards were installed using standard closet door hardware and the new Last Planners were oriented on the system. During the first pull plan in Kinetics' boardroom, it was mostly the Project Managers in attendance to represent their respective firms. When the site space was set up, the Foremen were invited to participate for the first time. The concepts were new to them, but the same approach was taken as the first session – Learn by doing.

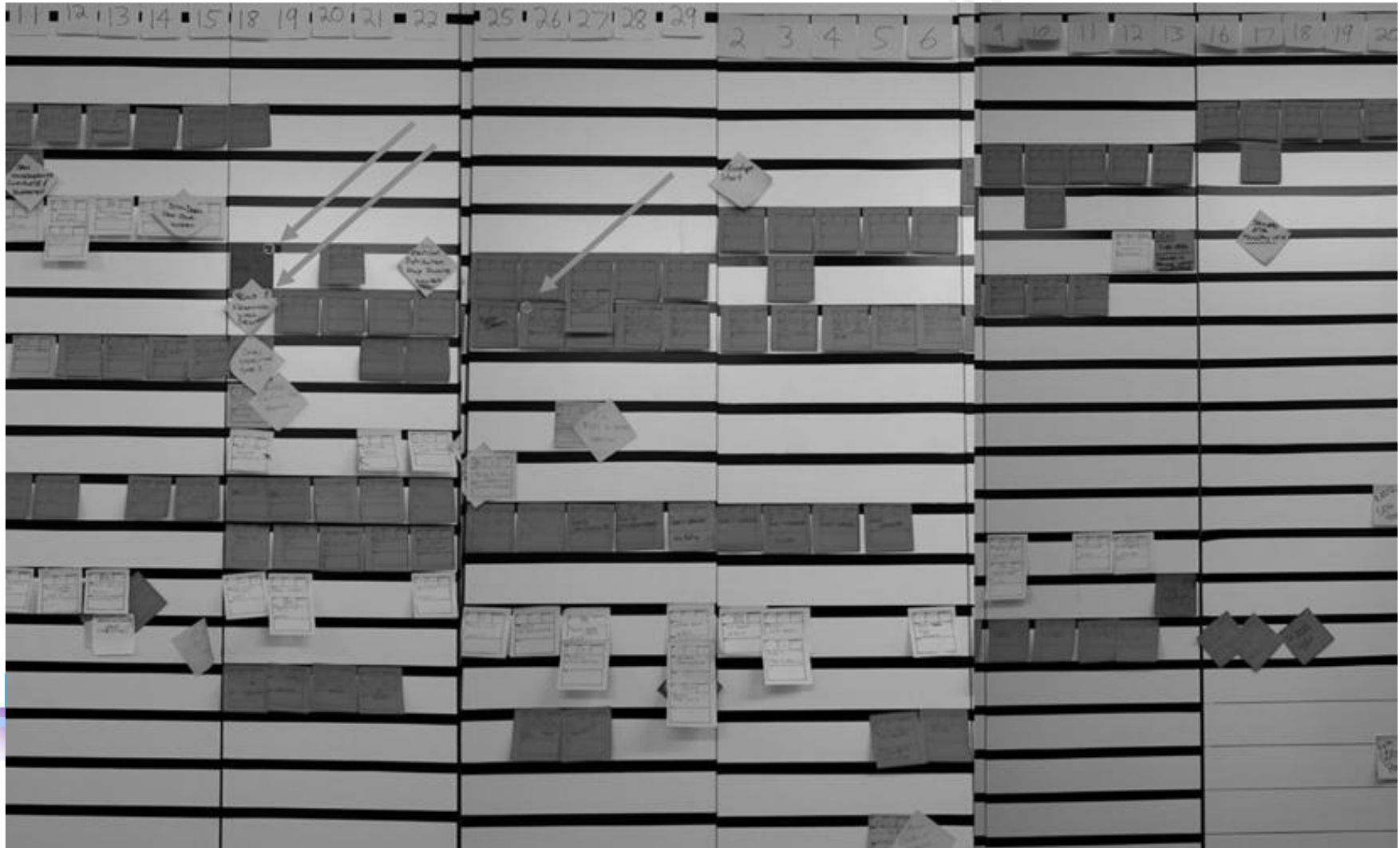
Case Studies

- Case 1: The Kinetic Construction Ltd. Story
- Prioritizing information constraints: (Kanban Board)

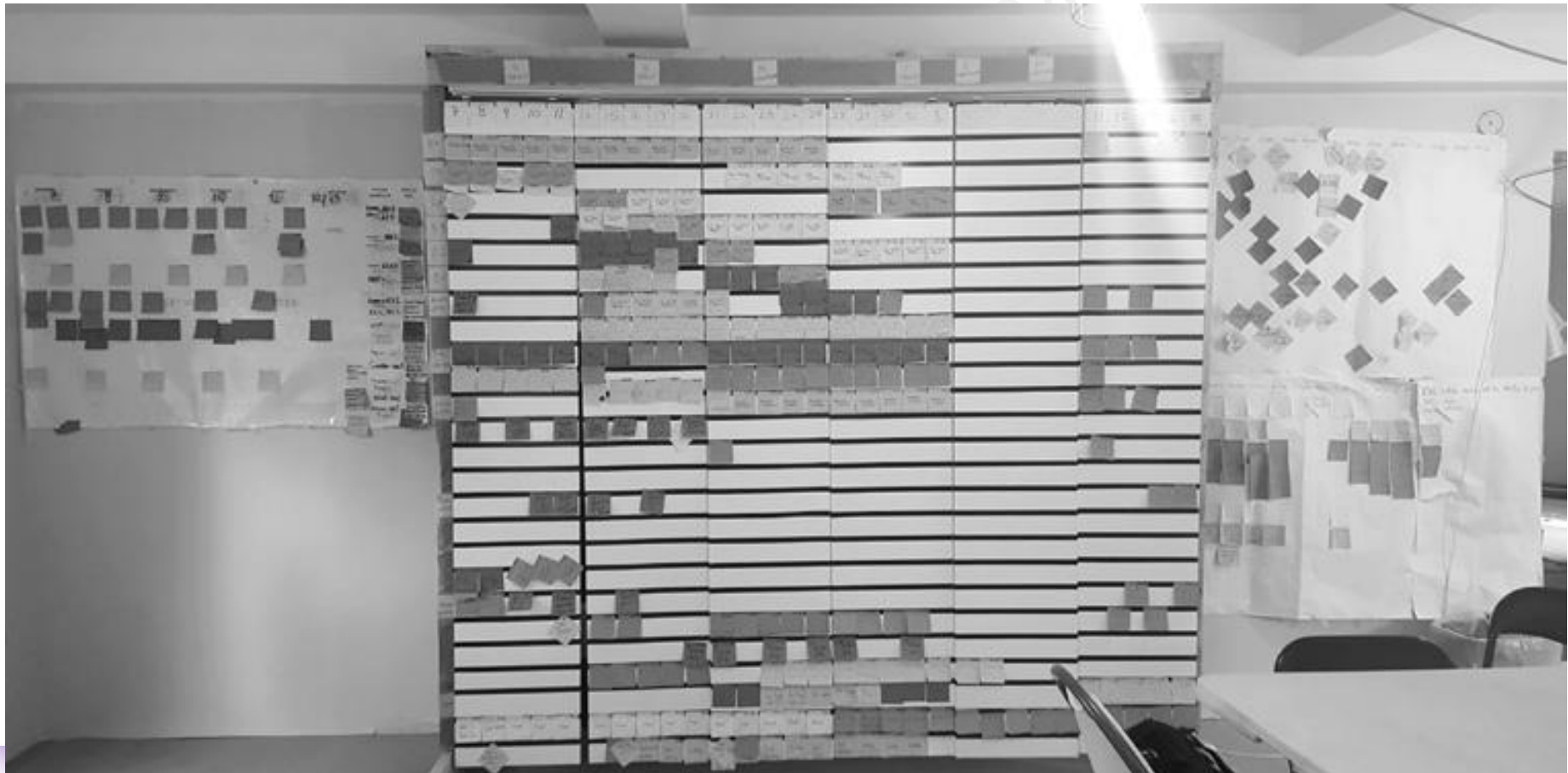
INFORMATION CONSTRAINTS	DATE REQUIRED	NEXT IN CUE			FOCUS		COMPLETED	REVIEWED
		COLD	WARM	HOT	SECONDARY	PRIMARY		
1 RFI #117 Hydro B32A Box Location					7	13		
✓ 2 Kitchen Exhaust/Kitchen Drawing H200								
✓ 3 Heat ACAD								
✓ 4 BC Hydro								
5 Shaw/Telus Service Providers					2	6		
6 FIRE PROT ACAD DESIGN			15	17		1		
7 ACAD ceiling heights/bulkheads								
8 Concrete ACAD mech room		9			8	3		
9 FLOW STANDPIPE DOOR								
10 Washer/dryer delivery Apr 9/18						11		
11 NVT WASH Mockup			12	10	5	4		
12 Kitchen equip delivery Apr 30/18								
13 CANOPY (COOR) FOR GYM								
14								

Case Studies

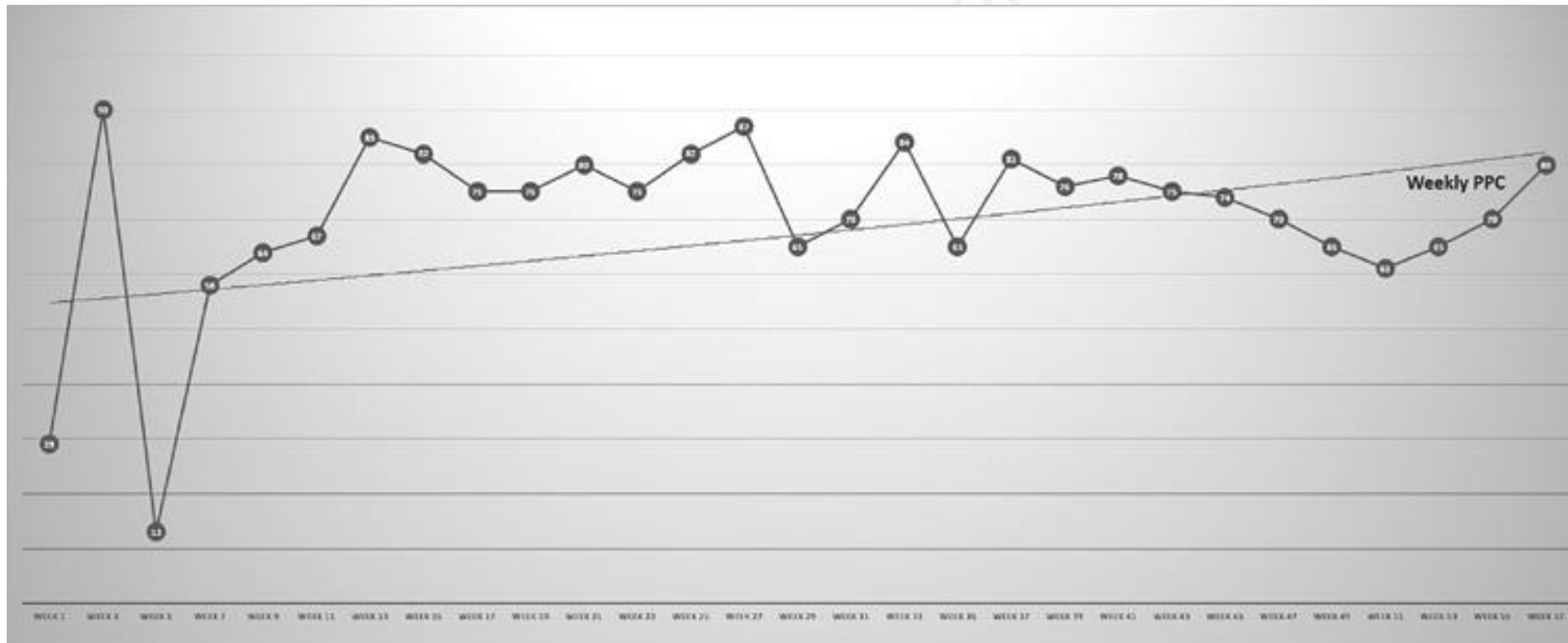
- Case 1: The Kinetic Construction Ltd. Story
- Prioritizing information constraints: (6 Week lookahead board)



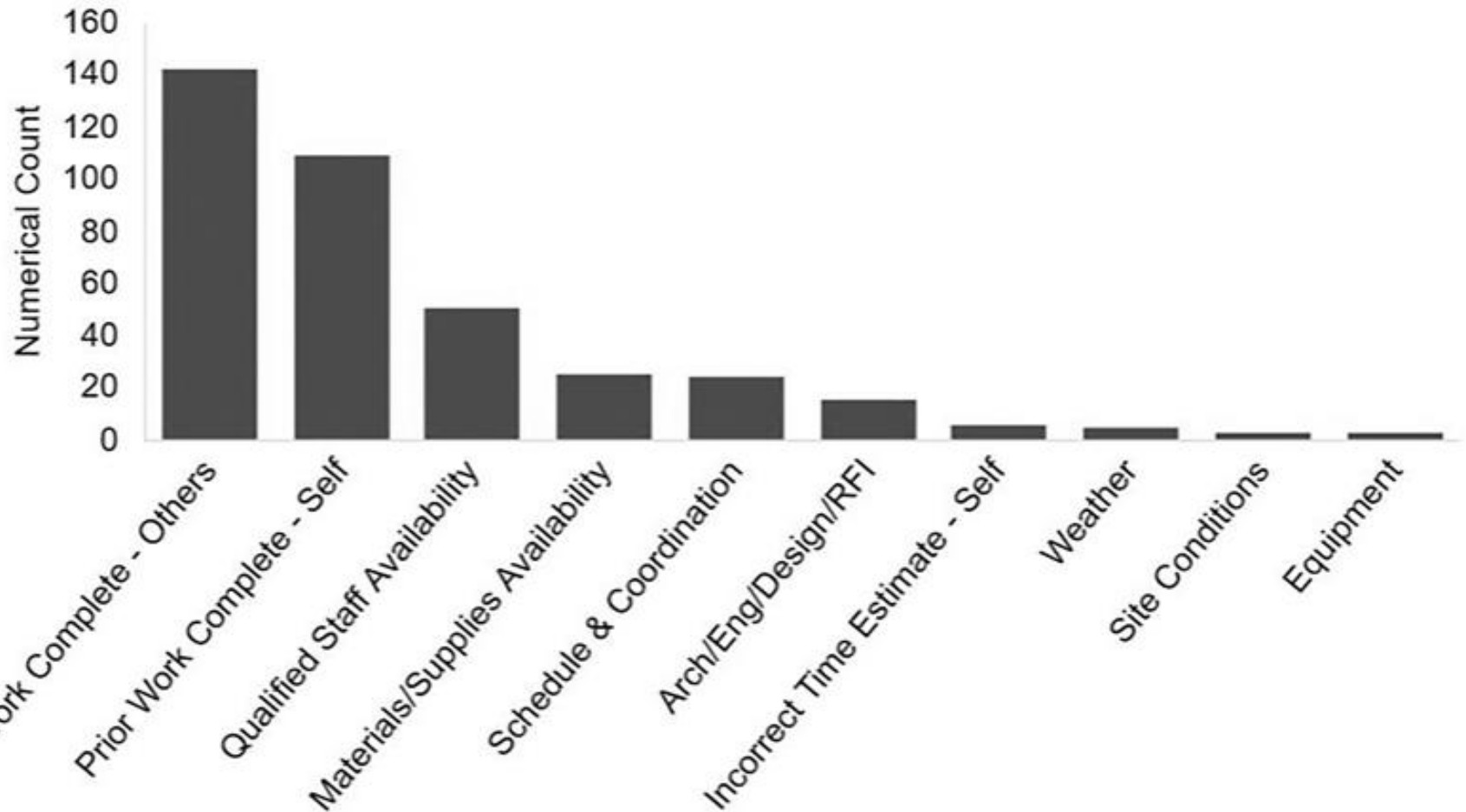
- Case 1: The Kinetic Construction Ltd. Story
- Prioritizing information constraints: (Rolling boards)



- Case 1: The Kinetic Construction Ltd. Story
- Prioritizing information constraints: (PPC Chart – including a trend line)



- **Case 1: The Kinetic Construction Ltd. Story**
- **Prioritizing information constraints: (Reasons for Variance)**



Case 1: The Kinetic Construction Ltd. Story

- **Last Planner® System**
– **self evaluation:**

Very satisfied	The LPS has created a team environment that that delivers a safety and overall trade performance on this project consistently reliable flow of work, reduces stress and improves The LPS has created a team environment that that delivers a consistently reliable flow of work reduces stress and improves safety and overall trade performance on this project The LPS is our preferred method of production management and we rely on it completely to deliver this project My trade partners regularly deliver on their promises and consistently have all the resources and information available to perform their work
Mostly satisfied	I regularly deliver on my promises and have all the resources and information available to perform my work. I have a high and accurate PPC and am able to predict the work of other trades. I always participate in daily and weekly meetings as well as phase planning (Pull) sessions. My phase planning is accurate and feeds into the SWLA. I use the SWLA to identify constraints and make my work ready by screening my promises I have a good understanding of the five stages of the LPS and their respective functions and how they benefit me and the project team
Somewhat satisfied	I always participate in the regular planning sessions and rely on the LPS to schedule my work. I maintain a predictable workflow and clearly understand the WWP, PPC, and SWLA All of my work is organized on the six week look ahead and it has helped me to reduce constraints and improve my predictability. I see the value in this process I participate in all weekly planning sessions and understand the importance of my attendance to the team and am starting to experience some improvements to my daily workflow
Mostly unsatisfied	I participate in all weekly planning sessions and understand the importance of my attendance to the team but am not getting much value yet I attend weekly planning sessions when I can and understand the potential benefits but am not seeing much of the value I attend planning sessions when I am available but have not seen any returns on my investment of time
Completely unsatisfied	I do not see the value for my company's participation in the last planner system and do not wish to attend the planning sessions

Case Studies

- **Case 1: The Kinetic Construction Ltd. Story**
- **The Last Planner® System at closeout (The closeout Big Room)**



Case Studies

- Case 1: The Kinetic Construction Ltd. Story
- The Last Planner® System at closeout (Example of closeout document pull plan)



- **Case 1: The Kinetic Construction Ltd. Story**

- **Manager's reflection on the use of LPS:**

- Although Kinetic and the project team underestimated the support required to manage the Last Planner® System at different times during the project, it is clear that it's deployment and the collaboration efforts it supports were the most fundamental reason for the success of the project. The regular communication of the daily huddle and designer, owner, contractor collaboration paid the most dividends to the team.
- Although Kinetic and the project team underestimated the support required to manage the Last Planner® System at different times during the project, it is clear that it's deployment and the collaboration efforts it supports were the most fundamental reason for the success of the project. The regular communication of the daily huddle and designer, owner, contractor collaboration paid the most dividends to the team.

- **Case 1: The Kinetic Construction Ltd. Story**

- **Project post mortem:**

- After the completion of the project – 35 members of the project team were invited to a one day, Value Innovation Kaizen to analyze the performance of the project and narrow in on opportunities for being more successful in the future.
- The team broke the project down by phase and broke into four key focus groups to review the plus/delta's and develop themes for opportunity by doing an affinity analysis. Each focus group was facilitated by a greenbelt-certified member of Kinetics' internal Lean committee and the themes were laid out using value stream mapping techniques. Root causes were identified, and countermeasures were developed among the groups and then reviewed on a Kano graph to illustrate the value achieved through the post-mortem effort.
- Each team was given time to present their findings to the group and have an open discussion at the end of the session.

- **Case 1: The Kinetic Construction Ltd. Story**
- **Project post mortem: (Plus/Delta Highlights)**

Plus	Delta
Solution oriented team worked well	Conflicting service layouts caused re-work
Speed of construction	Supply chain coordination – Late equipment
Trade to trade communication – best ever	Unclear instructions on changes caused re-work
Good selection of systems – quick install	Just in time design was challenging
Scheduling and Last Planner Coordination	Some trades just doing what's best for them

- **Case 1: The Kinetic Construction Ltd. Story**
- **Project post mortem: (Issues and Solutions highlights)**

Issue	Root Cause	Countermeasures
Lack of clarity on the scope, project priorities and expectations.	Decision-making protocol was not defined well or early enough.	• Incorporate “Key-Decision” cover sheet into meeting minutes template and review bi-weekly. • Define decision and contractual hierarchy • Use Last Planner® System to identify major impact decisions pre-project.
Poor understanding of Lean processes by most.	Team underestimated the complexity of the project – Did not acquire enough experienced help.	• More comprehensive boot camp to kick off the project – All trades. • Hold smaller boot camps at key milestones and mid-project onboarding. • Use the same team on another project.
Multiple iterations of design and revisions took too much time – caused rework.	Time constraints led to moving forward on assumptions – an inadequate process in place.	• Establish stop gates and validation steps in the process early. • Use LPS to connect design processes to field execution dates.

- **Case 1: The Kinetic Construction Ltd. Story**

- **Project outcome:**

- The outcome for the project was that the school was able to open in time for fall classes due to a 25% reduction in delivery time. This gained the client an additional year of revenue and the total cost of construction by the time it was complete, represented a savings of \$30 per square foot below current market value.
- The Lean approach was a major opportunity for all of those involved and the high-profile nature and visibility served a catalyst for new ways of thinking about how we do construction locally. The project also gained the attention of Award magazine who published the story of this highly ambitious and collaborative achievement.
- Site clearing for the school started in July 2017 and critical construction was completed on schedule in August 2018, just in time for the new school year. “The structural systems for the school were conventional.

- **Case 1: The Kinetic Construction Ltd. Story**

- **Project outcome:**

- A better workflow approach for the envelope saved time as well, beginning when the structure was on the fourth floor rather than waiting until the roof was completed to start. Just-in-time delivery of the windows allowed the workflow to continue without waiting for a large inventory of windows to be stored on a site that had little storage space.
- Kinetic Construction was able to deliver a project that should have taken 17 months but was completed just 13 months instead, on time and on budget. “Staying on schedule is rarer these days and the project was able to do so by using a lean construction tool called the Last Planner® System to deliver value to your customers who are building owners, consultants, trade partners, and our own employees.” Adds Tom Plumb, president, and CEO of Kinetic Construction.
- This approach allowed the \$25M school to start providing exceptional educational opportunities for 300 local and international students without delaying the start of term-1

- **Case 2: The Grunau Company Inc's lean journey**

- The Grunau Company is headquartered in Oak Creek, Wisconsin, with offices in Indianapolis, Pittsburgh, Orlando, and Boardman, Ohio. Grunau designs, installs and services mechanical systems for HVAC, plumbing, fire protection and specialized electrical systems. The company is also active in specialty metal fabrication under the name Grunau Metals. Four generations have led the company, starting with Paul J. Grunau, the original founder in 1920. He was followed by Paul E. Grunau, Gary Grunau and Paul W. Grunau, who purchased the company in 1999.
- Since April 2003, Grunau Company has been developing business practices adopted from lean production theories. These theories seek to minimize waste and maximize value by creating better workflow, thereby increasing productivity. When used consistently, these philosophies, which were first implemented in the manufacturing industry, save time, materials and costs.
- According to Ted Angelo, lean practices are “the way they do business”. A company newsletter supports a recognition program by highlighting individual accomplishments.

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 1. Application of the Last Planner® System (LPS) technique:**
 - Grunau has used the Last Planner® System to identify the tasks that need to be completed each week. On simple projects, the foreman serves as the last planner and may keep the schedule by hand. The foreman is a working part of the crew. In Grunau's view pull planning gets the foreman involved in the field to assist other trades.
 - On big jobs, the foreman is the last planner, but Grunau has a project engineer who works closely with that person. The GC superintendent often leads the group. The project engineer attends the weekly meetings and provides input on where the trades are and what they WILL do (i.e., their work commitment) the following week. This approach helps Grunau to make reliable promises, on work they are scheduled to perform, to other parties that are involved in a given project. Such reliable promises are an essential component of lean construction. Grunau uses software to track their progress.

- **Case 2: The Grunau Company Inc's lean journey**

- **Lean initiative 2**

- a) Use of building information modeling (BIM)

- On big jobs, Grunau uses BIM to keep track of the routing of various systems to ensure there are no clashes between various lines such as pipes and ducts.
- Grunau gets a file on a CD in Navis Works from the A/E, and it is used to show various lines for building systems that they are scheduled to install. This enables Conflicts/clashes can be detected.

- **Case 2: The Grunau Company Inc's lean journey**

- **Lean initiative 2**

- b) Human Relations: Daily huddle

- The Daily Huddle is a Pre-Task planning exercise for discussing what is needed for each job for a given day. The Huddle helps to reduce accidents, eliminate waste and improve efficiency. It supports the
 - Lean Mission: To continually examine processes to provide greater value to customers without waste.

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 2**
- The team members write notes on 3x5 cards to promote discussion, and a volunteer is selected each time to read questions from the card.
- A typical list of questions for the huddle are as follows:
 1. What are our Productivity Goals for today?
 2. Do we have what we need?
 3. Are there any obstacles to achieving our goals?
 4. Does anyone see a Better Way?
 5. Were there any Near Misses Yesterday?
 6. What Safety Hazards should we be Aware of Today?

- **Case 2: The Grunau Company Inc's lean journey**

- **Lean initiative 2**

- Examples of answers to typical Daily Huddle Questions

- 1. What are our Productivity Goals for Today?**

- 300 Feet of pipe, boxes hung, fixtures set, heads roughed in.

- 2. Do we have what we need?**

- Yes, all materials, tools, information to get the job done TODAY.

- 3. Any Obstacles to Achieving our Goals?**

- Is another trade in our way? Is the area not completely open to us? Can we move around area?

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 2**
- Examples of answers to typical Daily Huddle Questions

4. Does anyone see a Better Way?

- Is the routing of piping/duct OK, or is there a better way? How about the material handling – any better way? Share a better way to complete a task.
- If a crew member develops a way to eliminate waste, inform a Lean Team Steering Committee member so we can share with others in the company through a future newsletter.

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 2**
- Examples of answers to typical Daily Huddle Questions

5. Were there any Near Misses Yesterday?

- This creates safety awareness for team members Someone else may be subject to same situation.

6. What Safety Hazards should we be Aware of Today?

- There is going to be a lot of crane activity on the west side of the building. The conditions out there are slippery. Pay special attention to where you are walking.

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 2**
- Observed benefits of Daily Huddles:
- The Daily Huddles have changed workers' behavior. Even though the work for a given week may have been already planned, workers increasingly go through a thought process before taking action on a project.

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 3**
 - a) Space reorganization
 - b) Electronic filing
 - c) Vendor supply team

- **Case 2: The Grunau Company Inc's lean journey**
- **Lean initiative 3**
 - a) Space reorganization
 - b) Electronic filing
 - c) Vendor supply team

a) Space reorganization

Grunau's Oak Creek facility was housed in a 22,00 sq. ft. building. Management recognized the need to prepare for expansion, yet they opted to optimize their existing space so they could use the available space more effectively.

The CEO directed the Grunau team to reorganize the existing space, using a 5S approach and leave unused space for up to 20% growth in staff and operations. The team was also directed not to touch the exterior walls of the facility, but rather to make changes to the use of the interior space only. The underlying purpose of the transformation was to “Reduce storage, increase efficiency, and eliminate waste”. This new requirement was very difficult to accept for many employees, especially for those who had worked with Grunau for several years and held supervisory positions and titles. Paul Grunau himself set the tone by announcing that he would not have a private office. Eight “quiet” rooms were to be established that would allow staff to hold meetings, etc. These were modeled after the “big room” (obeya) concept.

The work spaces make it easy for employees to collaborate on the planning of projects, as a CAD operator can talk with a foreman about the configuration of a piping layout and enable an estimator to price a job accurately at the same time. Also, space was allocated that would facilitate personal business such as family matters, medical appointments, etc.

b) Electronic filing

Previously, Grunau's service department had organized the storage of large numbers of three ring binders that contained Operating & Maintenance (O&M) manuals from completed jobs. These binders had been indexed with their respective storage locations in a large bookshelf system. More than 500 such binders were eventually stored in Service Department cubicles, with the overflow accommodated along a building wall.

Electronic filing was seen to represent a significant opportunity for space saving.

All the O&M manuals were scanned electronically and placed in computer files, with CDs as backup copies. The storage space that was occupied by the shelving system has been regained and modified to provide employee work space. Two small CD cabinets have replaced the extensive shelving system that monopolized a fairly large storage area.

Time savings: O&M data can now be retrieved through each employee's computer, using project reference information. There are considerable time savings in eliminating the need to physically walk to the storage cabinets and locate the respective binders. (Estimated \$ savings?)

c) Vendor supply team

Employees studied the supply chain for materials and took steps to improve it.

In the previous state, materials would be purchased from supply houses and stored at Grunau's facilities.

In the current state, they have a purchase agreement based on delivering materials when needed, where needed. It includes having a driver do the delivery for each trip, but it provides a major saving, estimated at \$70,000 annually.