PennState College of Engineering | ARCHITECTURAL ENGINEERING

Lean Construction Institute
Transforming Design and Construction

Empower Your Team: How Lean Methods Drive Collaboration

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Objectives

An understanding of how methods and behavior work together to create lean teams

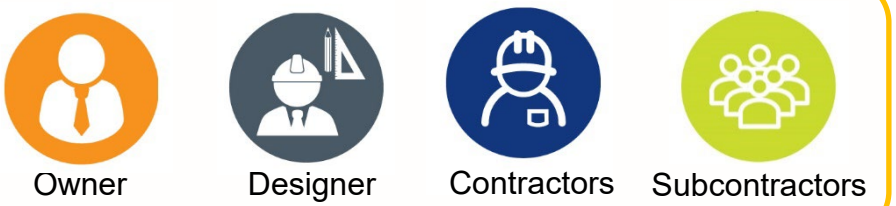
Case study examples demonstrating the impact of different levels of LPS maturity on team health and project planning success

Access to a maturity model to assess and improve your LPS implementation

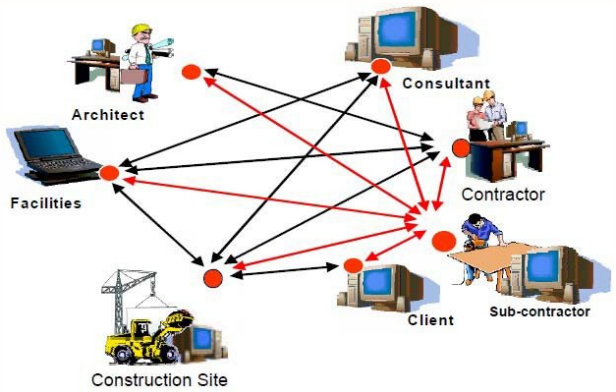
Construction Teams

If any industry should appreciate the importance of teamwork, that is the **construction** industry (Spatz, 2000).

Construction Team



Fragmentation



Fragmented nature of the construction industry (Al-Qazzaz, 2010)

Temporary Nature

https://www.flexjobs.com/blog/post/smart-tips-furloughed federal-workers-find-temp-project-work/

Lack of Shared Objective

Poor performance of project delivery

Lean Production

A philosophy of guiding principles and overarching goals through a strategic/philosophical lens

A set of management practices, tools, and techniques

"An integrated **socio-technical** system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability." (Shah and Ward, 2007)

High emphasis on LC practices and methods

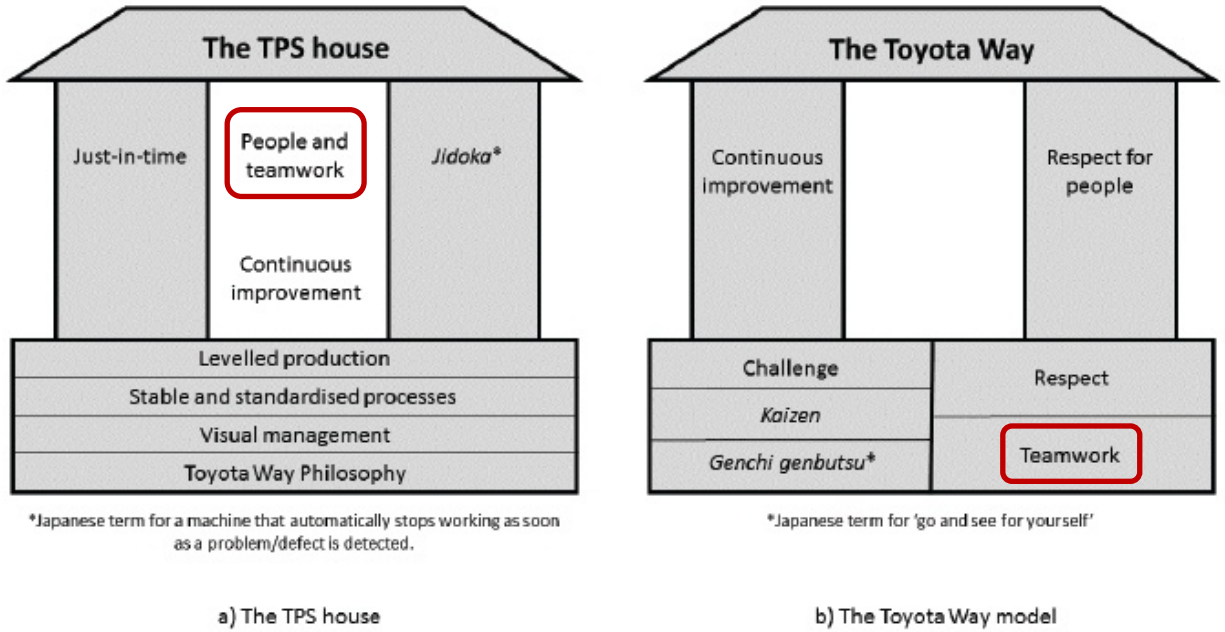
Low concentration on human dimensions

Lean Production

The reason lean adoption has proven to be a challenge outside of Toyota seems to be embedded in the **human dimension**

(Magnani et al., 2019)

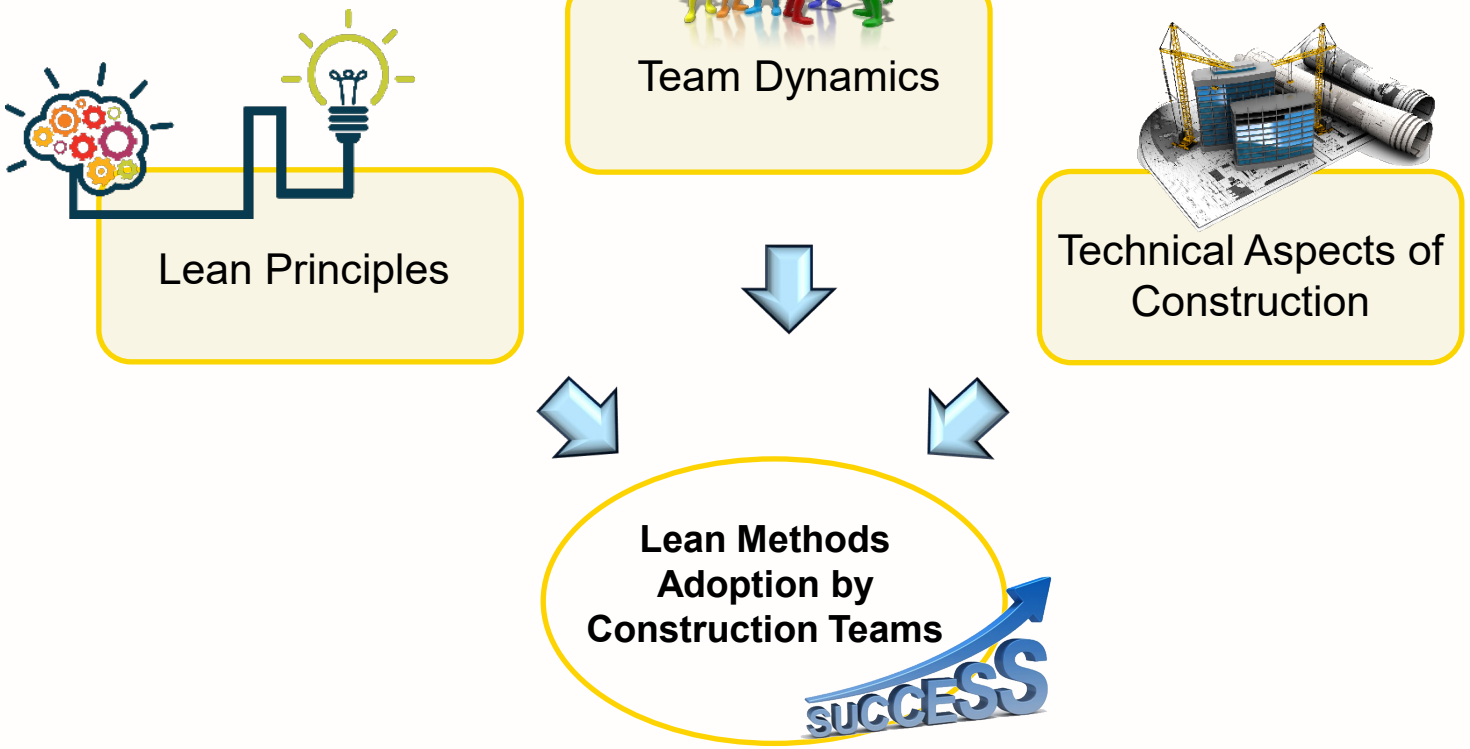
‘We do not just build cars, we build people.’



a) The TPS house

b) The Toyota Way model

Research Framework



Research Goal

Illuminate the social-technical underpinnings of lean implementation within construction project teams.

Last Planner System (LPS)

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Research Framework

How variation in LPS implementation would affect social interactions and team dynamics within construction teams?

LPS Technical Procedures → Lead to →  **Social Interactions** → Translate to →  **Team Dynamics** → Enhance → **Team Planning Outcomes**

Help follow them correctly

LPS Technical Procedures

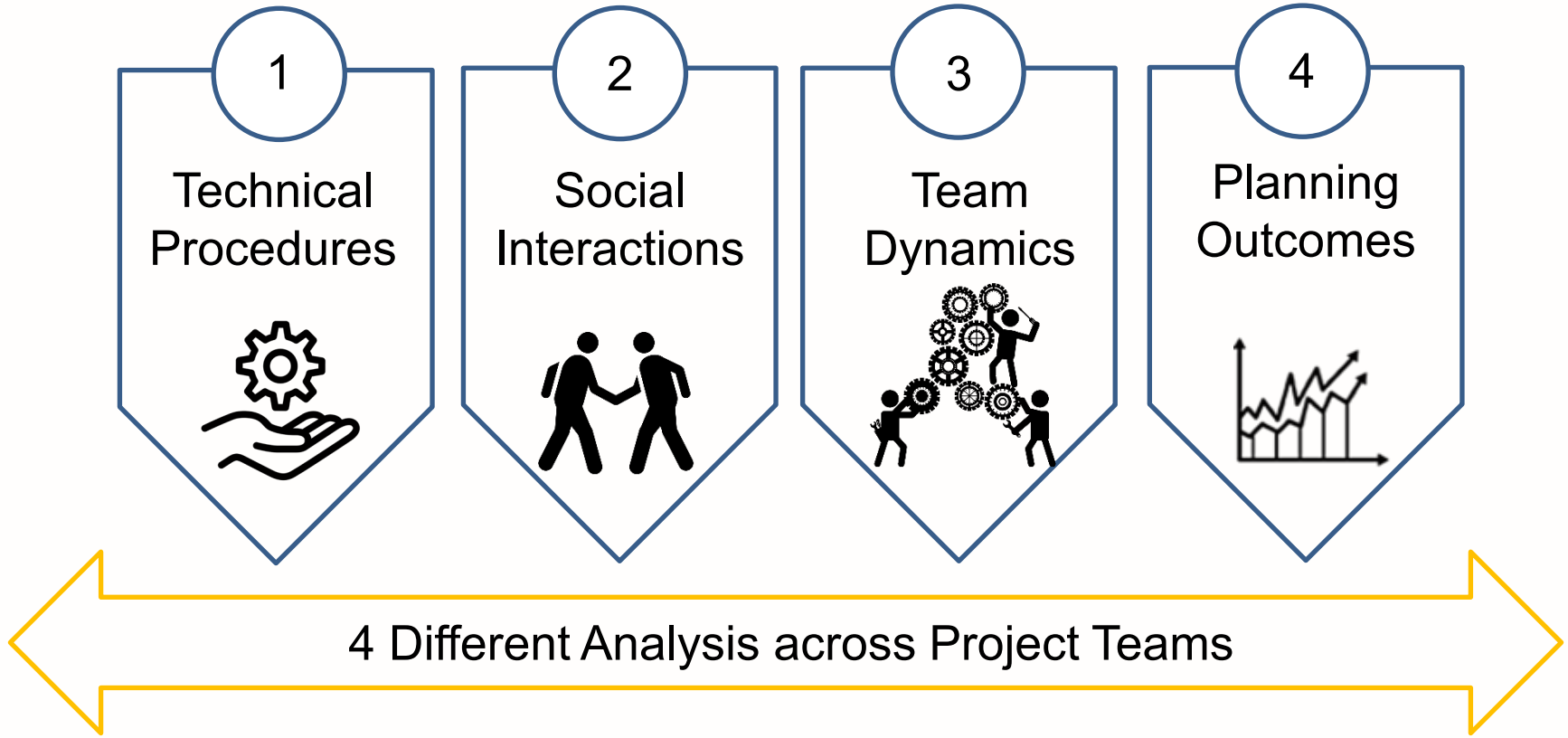
- Collaborative planning process
- LPS Training
- Constraint Analysis

Team Dynamics

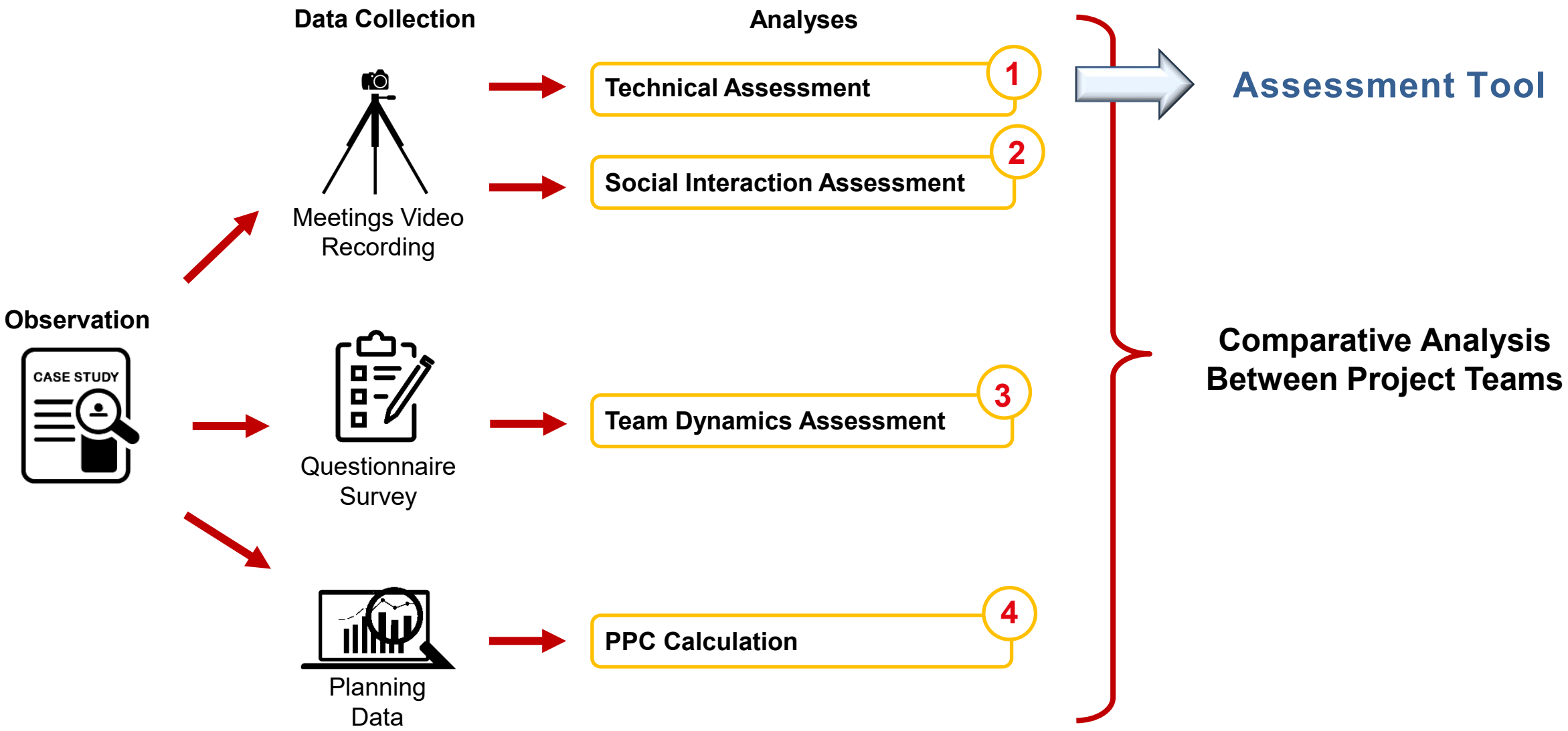
- Effective Communication
- Respect for team members
- Open information sharing

Research Approach

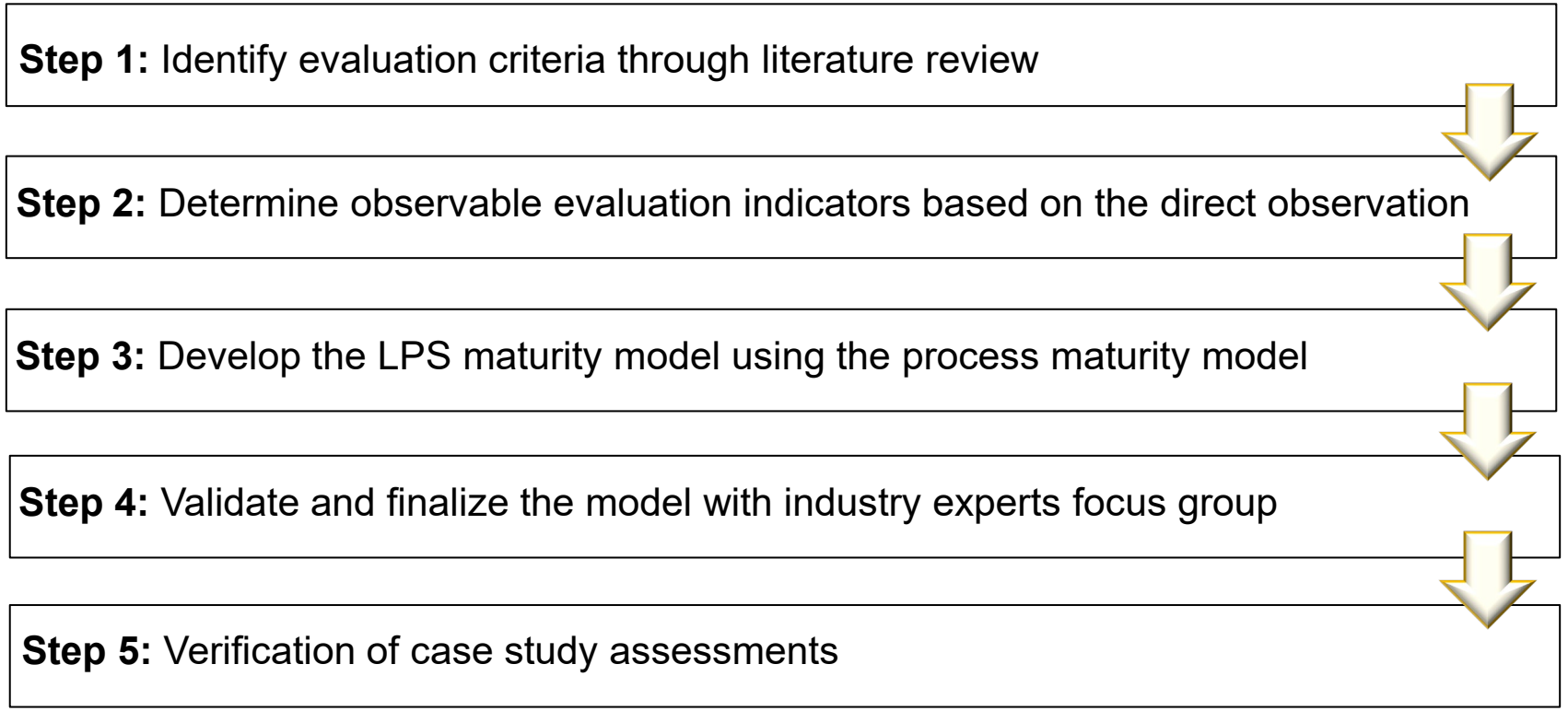
Comparative Analysis



Research Process

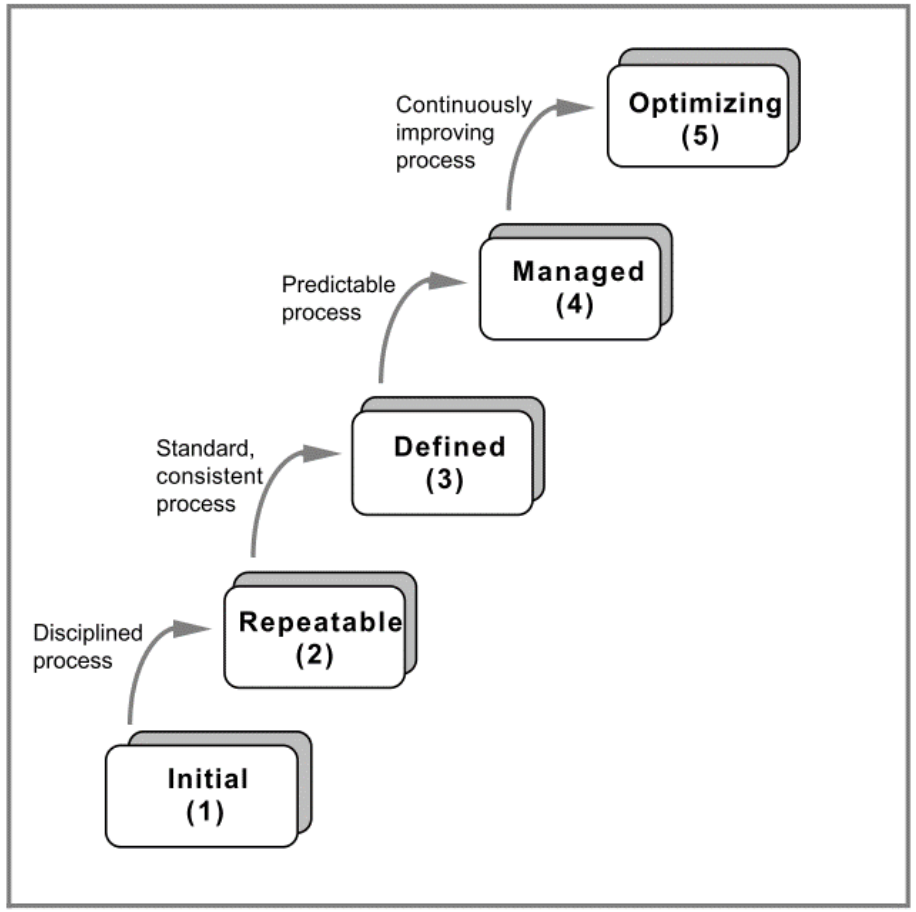


LPS Maturity Model



Process of Developing the LPS Maturity Model

Process Maturity Model



The Five Levels of Software Process Maturity (Pualk et al., 1993)

Assessment Categories

Team Training and Coaching

- C1. Team Technical Training
- C2. Team Cultural Training
- C3. Project Team Coaching

In-Meeting Interactions

- C4. Preparation
- C5. Participation
- C6. Project Team Commitment
- C7. Project Team Collaboration

Sharing/ Tracking Information

- C8. Manage Constraints
- C9. Using Visual Management of the Project Information
- C10. Analyzing the trends

LPS Maturity Model

LPS Technical Process Assessment

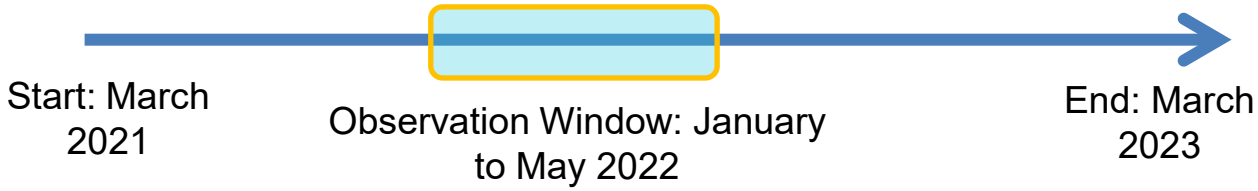
Assessment Categories		Description	Level 1 Initial	Level 2 Repeatable	Level 3 Defined	Level 4 Managed	Level 5 Optimizing
C1	Project Team Technical Training	Training on technical aspects of LPS before and during planning sessions is provided.	There is no training provided for the project team. The team relies on their previous experience to know the LPS principles and planning process without any guidance.	Basic training is provided to the team before planning sessions, but it is not consistent across team members. Participants are given a general overview of LPS principles and the planning process, but there is little support in terms of explanation or hands-on training.	Formal, well-documented and consistent training is provided before planning sessions for all team members. Participants receive detailed explanations of LPS principles, the planning process, and visual management tools. Hands-on training is provided to ensure participants understand how to use the tools and follow the planning process.	In addition to formal training offered in level 3, the effectiveness of their training is measured and tracked, and additional training is offered as needed to manage the training process.	The team is continuously improving the training process, leveraging feedback and data to drive innovation and value. The facilitator encourages the team to provide feedback on the training and planning process to help identify areas for improvement. The team collaborates with other members to optimize the LPS process and training, incorporating new technology or techniques, as necessary.
C2	Project Team Cultural Training	Training on cultural aspects of LPS and lean principles before and during planning sessions is provided.	There is no training provided for the project team. The team relies on their previous knowledge of lean and its principles.	Basic training is provided to the team before planning sessions, but it is not consistent across team members. Participants are given a general overview of lean principles, but there is little support in terms of explanation or hands-on training.	Formal, well-documented and consistent training is provided before planning sessions for all team members. Participants receive detailed explanations of lean principles and the cultural aspects of LPS implementation. Hands-on training is provided to ensure participants understand the lean mindset.	In addition to formal training offered in level 3, the effectiveness of their training is measured and tracked, and additional training is offered as needed to manage the training process.	The team is continuously improving the training process, leveraging feedback and data to drive innovation and value. The facilitator encourages the team to provide feedback on the training to help identify areas for improvement. The team collaborates with other members to optimize the training, incorporating new technology or techniques as necessary.
C3	Project Team Coaching	Effective coaching during planning sessions is provided for all participants.	There is little to no coaching provided before and during planning sessions.	Coaching is provided before and during planning sessions, but it is not consistent. The facilitator may also serve as a coach.	Coaching is provided before and during planning sessions. It is consistent and the coach is actively supporting Last planner to understand and engage resource and constrains to plan their work.	Coaching is consistently provided to all Last Planners and the facilitator before and during planning sessions. The coach actively offers constructive feedback and support, using a personalized approach considering the strengths and weaknesses of each team member. Coaching is also available for the facilitator on how to improve the facilitation process.	The team encourages providing feedback on the coaching process to help identify areas for improvement. The coaching is integrated into the planning process and is provided in a way that encompasses all aspects of LPS, such as collaboration, teamwork, and commitment. The goal is to help each team member becomes a coach for less-experienced members.
C4	Participation	All key players participate in the actual LPS sessions.	Team members attend LPS meetings sporadically, and participation is passive or non-existent.	Team members attend LPS meetings more regularly. Participation is passive, with little engagement or discussion by last planners. Meetings are sporadically cancelled.	Meetings are consistently held, and team members attend LPS meetings regularly. Participation is active, with engagement and discussion among team members. Few team members initiate the discussions, but most participants respond to questions/ requests.	Meetings are consistently held, and team members attend LPS meetings regularly. Participation is active, with engagement and discussion among team members. Initiation of the topics for discussions is balanced across the team.	Meetings are consistently held, and team members attend LPS meetings regularly. Participation is active, with engagement and discussion among team members. Initiation of the topics for discussion is balanced across the team.There is clear participation and discussion how to imporve the process by the team members.
C5	Preparation	Stakeholders come to the meeting prepared with meaningful inputs to discuss the project schedule to develop a reliable and achievable work plan.	Team members attend meetings with little to no prior preparation, and their inputs are incomplete or missing.	Some participants come to the meeting with some preparation done beforehand, but it is inconsistent across team members.	There is consistent preparati… come prepared with their not… They are ready to engage in… achievable work plan.		…ared for the meeting with a clear understanding of …ct for the next few weeks, including their resources …tinuously help each other to get better prepared in … needs to negotiate their work plans. They …is preparation process to get better at planning so …e reliable and achievable for everyone.
C6	Project Team Commitment	Last Planners make promises that they are accountable to complete.	There is no clear ownership of tasks or responsibilities. There is little accountability for missed commitments. No discussion about the Last planners' constraints or resource needs occurs before agreeing to requests or making commitments.	There is some assumed ownership of tasks and responsibilities, but it is not clearly defined. There is a limited or inconsistent discussion of resources or constraints before agreeing to tasks during planning sessions. Last Planners make some reliable commitments, but there is inconsistent accountability for missed commitments.	There is clear ownership … members being held accoun… provide their input on what th… Last Planners to make comm… There is agreement and com… deliver assignments they are…		…of commitment and accountability among team …nderstanding that reliable commitments are …ss. The team uses data and feedback to …planning and commitment process. Based on … Last Planners consistently work at and improve …nts and outcomes.
C7	Manage Constraints	Constraint analysis of all activities is applied as a proactive approach to team problem-solving.	There is limited or no focus on identifying constraints. The team does not have a systematic approach to identifying and addressing constraints.	The team has a process for identifying constraints, but it is not consistently applied. There is a mechanism to track constraint analysis, but the deadline and responsibility are not clear.	The team has a process for i… team consistently applies thi… schedule and uses constrain… deadlines to support the reliability of the planning. The process is documented and communicated to all team members.	investigate noncompliance reasons and provide solutions to prevent recurrence.	…ity and continuous improvement in how they …o get better at removing constraints. The team might use cutting-edge methods for identifying and managing constraints, such as predictive analytics or machine learning algorithms.
C8	Project Team Collaboration	The team collaboratively plans how to achieve the project milestones in alignment with the trades' production systems.	The facilitator does not ask for input from the last planners, and their perspectives are not considered. The plan is developed without much consideration for the trades' production systems. The facilitator asks the trades to commit to completing tasks, without knowing their resource and capacity constraints.	The facilitator asks for input from the trade in an inconsistent manner. The plan is developed with some consideration for the trades' preference for sequence or resource needs. The facilitator asks the trades to commit to completing tasks without knowing their resource and capacity constraints.	The plan is built with consistent inputs from the trades' resource requirements to achieve the schedule. The facilitator helps engage discussion among team members when conflicts occur to build the plan by considering the trades' resources and capacities and pulling from milestones. The facilitator consistently asks for the Last Planners' opinions or constraints to understand how they can better align their production performance with project milestones.	The plan is developed in alignment with the trades' production systems and the project milestones. The facilitator helps team members collaboratively build the plan by considering the trades' resources and capacities and pulling from milestones. The facilitator consistently helps discuss and manage resources and constraints needs to ensure the plan is achievable and reliable across the team.	The team is committed to a culture of continuous improvement and sees planning and collaboration as key drivers of project success. The ability to engage in collaboration across the team is explicitly discussed. The team encourages everyone's collaboration in identifying and removing constraints. Team members voluntarily offer suggestions to change their plans to better enable others to do their work.
C9	Using Visual Management of the Project Information	BIM Model, design drawings, and layout of work area(s) are actively used by the team to ensure clear communication.	Little visual information about the project is provided during planning sessions and only occasional ad hocs use to support topics.	Drawings and models may be available, but they are not always used to communicate construction activities or support discussions. There might be sometimes misunderstandings or confusion in understanding the topic or clarifying segmentations of work.	Visual information about the project is consistently available, such as models and drawings. The team uses visual aids to raise questions and support discussions about segmentations of work. Drawings and models are consistently used to support understanding the plan and decision-making.	The team updates and manages visuals to support the current and future plannings as the project progresses. The visuals are consistently used. Visual extends beyond basic or common drawings or model images.	Visual management of project information is used to continuously improve project performance and exceed expectations. There is continuous improvement in how they use project visuals, and visual aids are used to identify and plan new opportunities.
C10	Analyzing the trends	The team measures and analyzes root causes for misses or failures to improve plan reliability.	The team does not review their performance from last week, and there is no analysis of trends. The team does not discuss disruptions or reasons for failure to complete planned work.	The team discusses whether they met their commitments, but there is no formal analysis of trends. The team discusses disruptions, but there is no consistent process to analyze the root causes.	There is a formal and consistent process to track and analyze the teams' commitments. The team discusses disruptions and identifies reasons for the failure to complete planned work.	The team measures PPC consistently and analyzes trends. The team discusses disruptions and consistently tracks reasons for the failure to complete planned work. The team focuses on analyzing the trends and investigating suggestions and opinions to improve the trends.	The team focuses on continuous process improvement through periodic reflection on their trends in separate meetings. Detailed analysis of the trends is provided to the team, and the team uses data to drive continuous improvement.

The team has a process for identifying constraints, but it is not consistently applied. There is a mechanism to track constraint analysis, but the deadline and responsibility are not clear.

Projects Overview

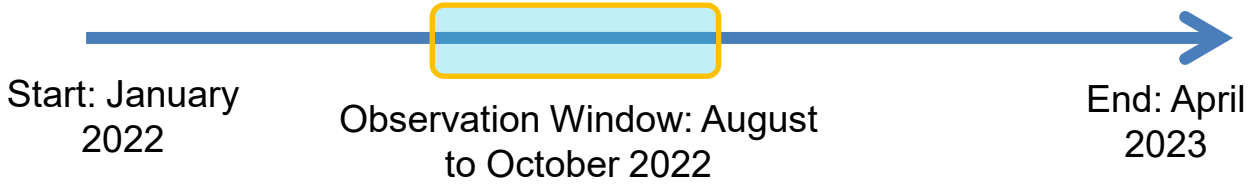
Project A

- Educational building
- Location: Mid-Atlantic region
- Area: 300,000 square feet
- Budget: $167 million



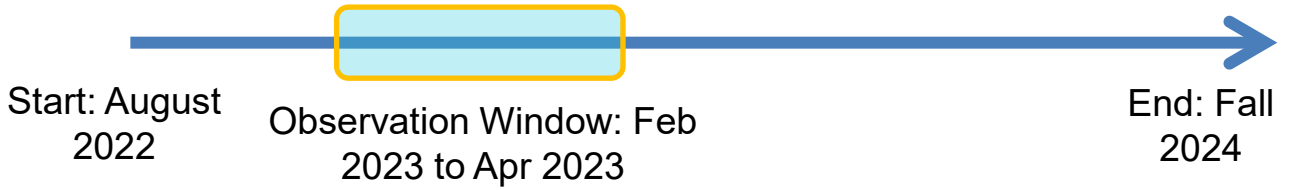
Project B

- High-rise building & a park landscape
- Location: Mid-Atlantic region
- Area: 2.1M square feet (Park Area:10,000 sq f)
- Budget: $790 million



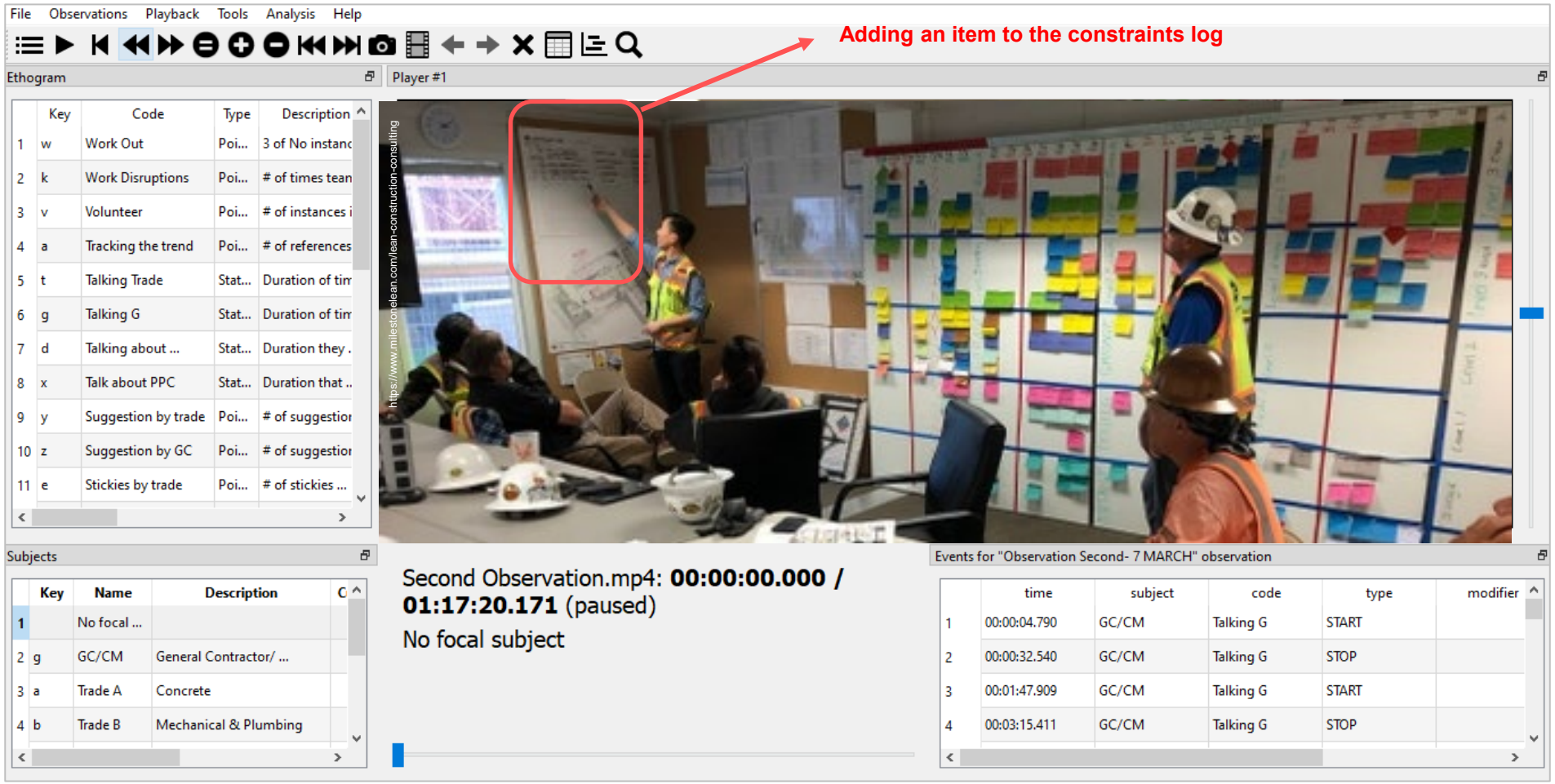
Project C

- Educational building
- Location: Mid-Atlantic region
- Area: 150,000 square feet
- Budget: $130 million



Coding Software

Behavioral Observation Research Interactive Software (BORIS)

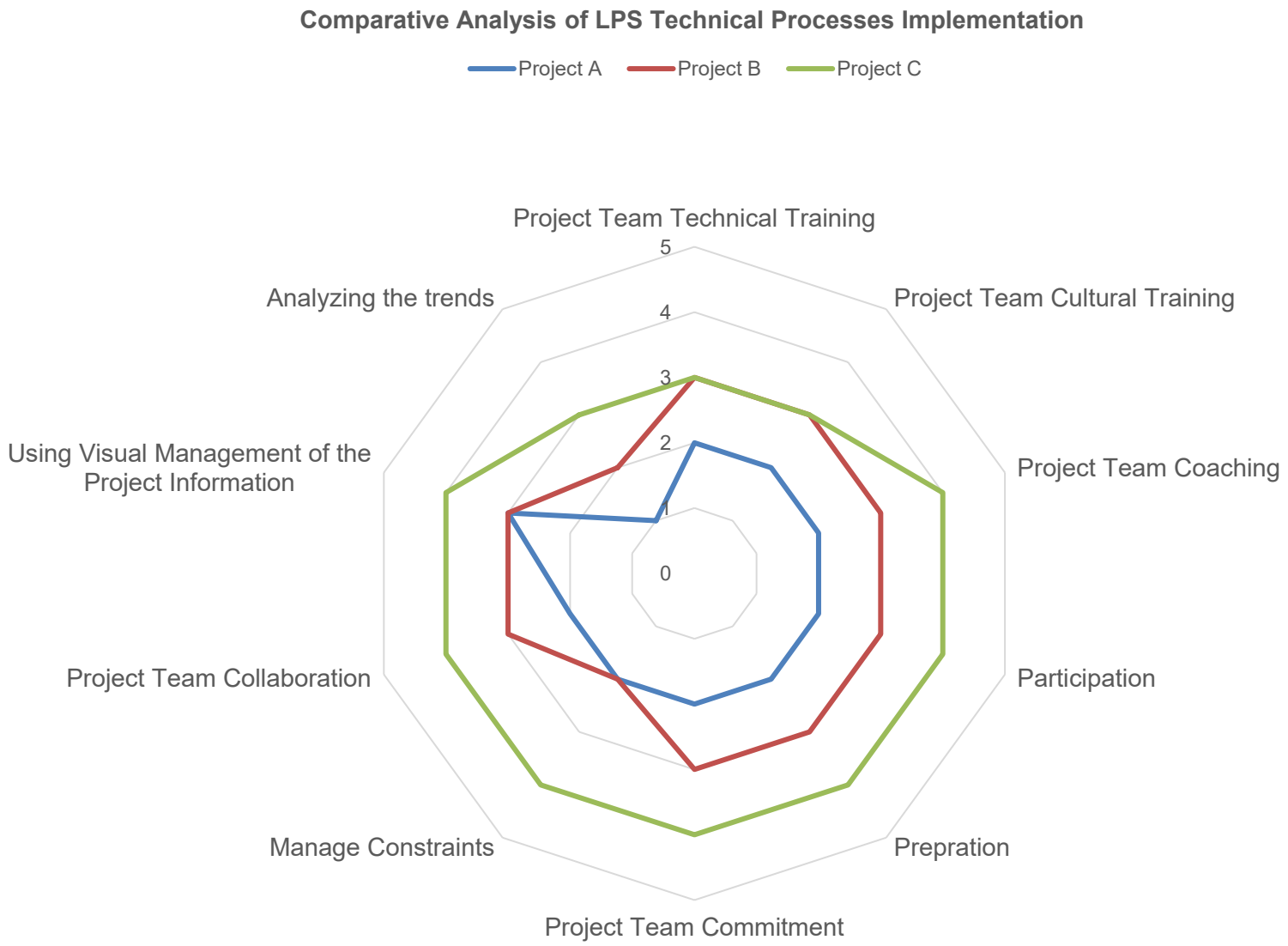


Inter-rater Reliability

To ensure the consistency of the analysis between different observers, the extent to which they record the same scores for the same phenomena should be measured.

Project Results

Technical Assessment

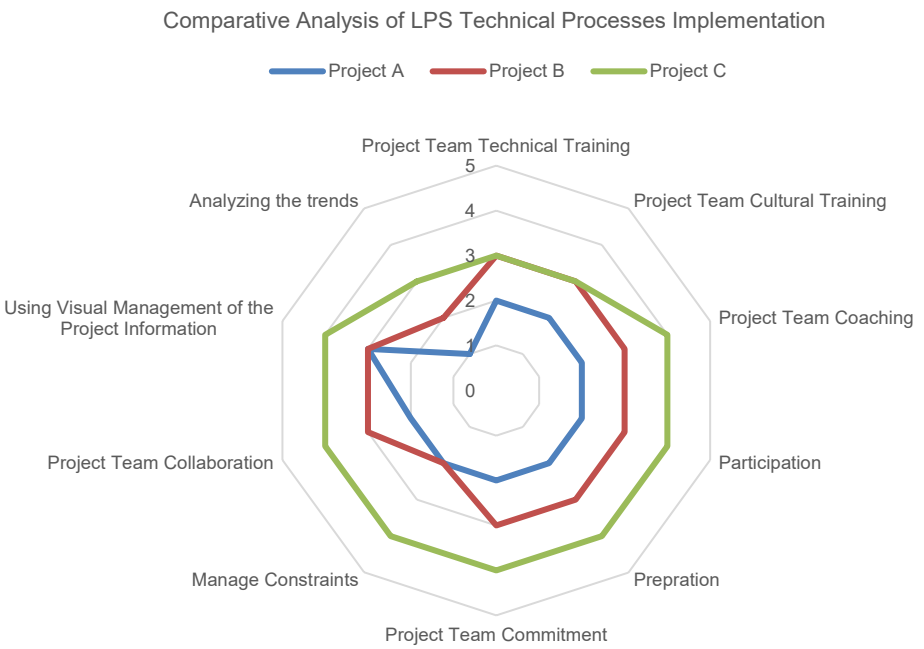


Distinguishable Differences:

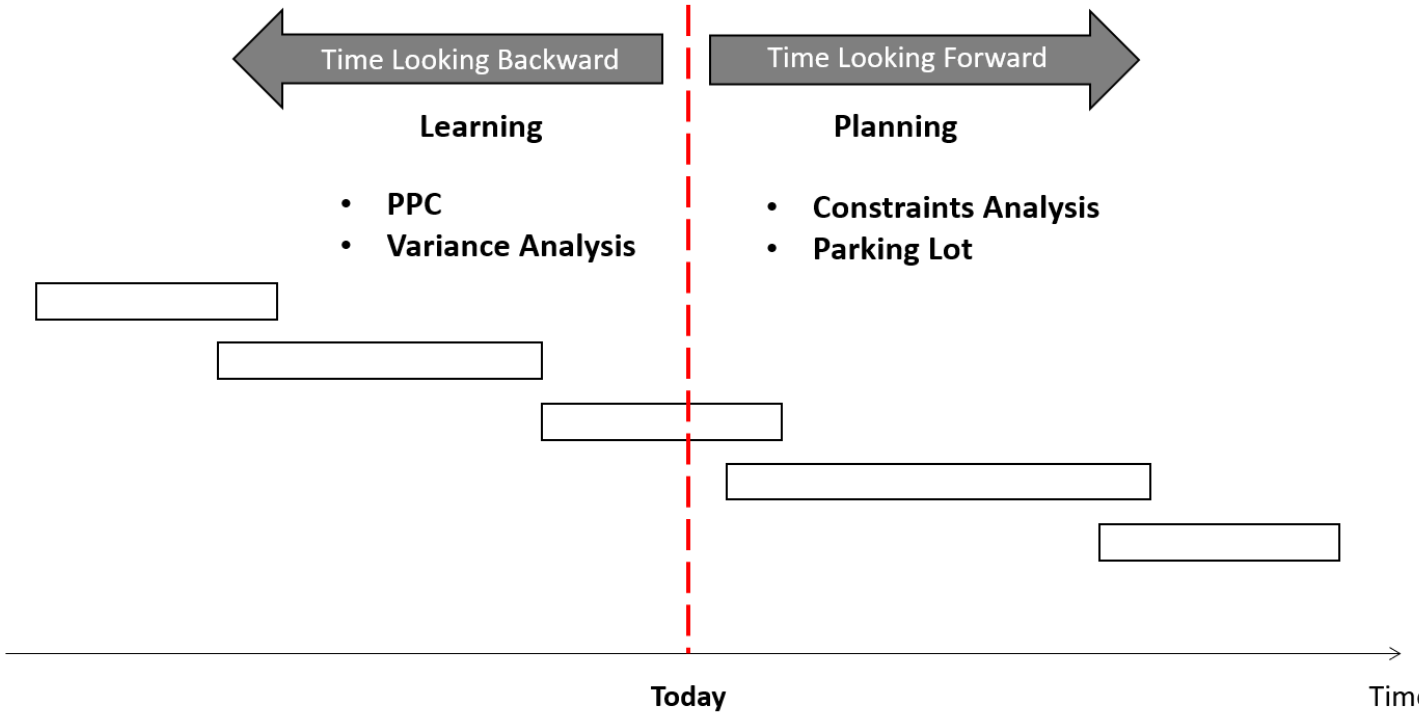
- Use of meeting time
- Formal resources offered to the team in terms of training and coaching
- In-meeting interactions
- Tracking and sharing of planning-related information

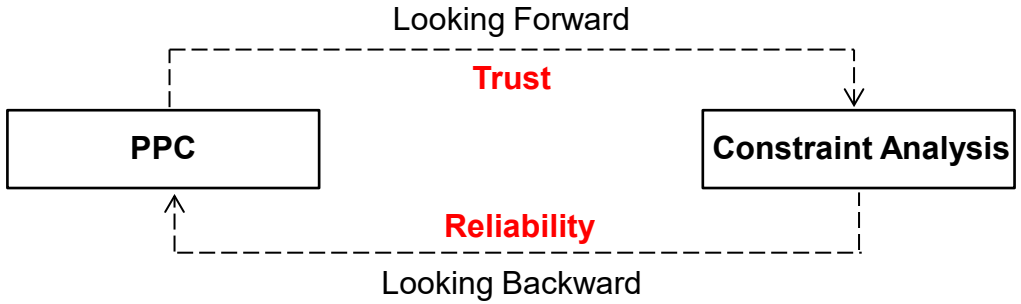
Technical Assessment

Use of meeting time



Technical Assessment





Technical Assessment

Training

Current Maturity Level

Project A	Project B	Project C
2	3	3

- During the observation period, no formal training was provided to the Last Planners.

Case Study	# of members who received training	# of members with zero training	% of team members received training
Project A	7	9	44%
Project B	10	2	83%
Project C	13	3	81%

Projects B and C:

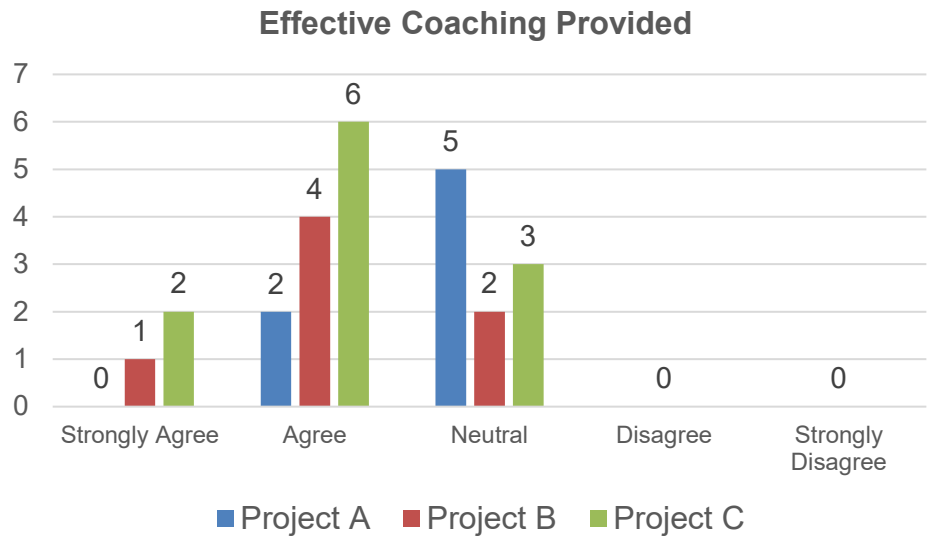
- **Provision of cultural training** in addition to the technical aspects, such as trust and open communication among team members.
- The training emphasized the need for buy-in, honest commitments, and individual voices.

Coaching

Current Maturity Level

Project A	Project B	Project C
2	3	4

- **Project A:** a few times (1-2 times per meeting) , general guidance to the team
- **Project B:** more frequent (4-5 times per meeting), aided last planners in the planning process
- **Project C:** More frequent (up to 10 times per meeting), more individualized coaching

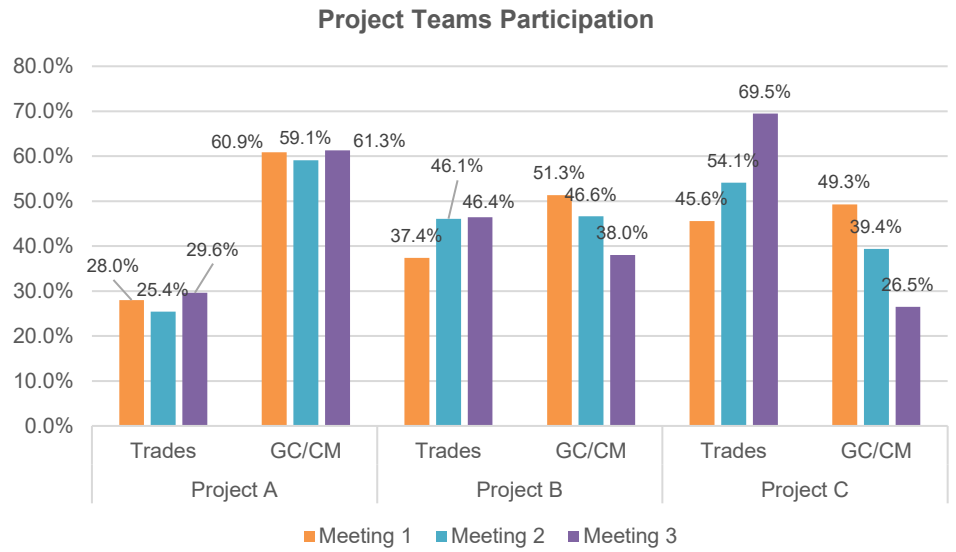


Technical Assessment

Participation

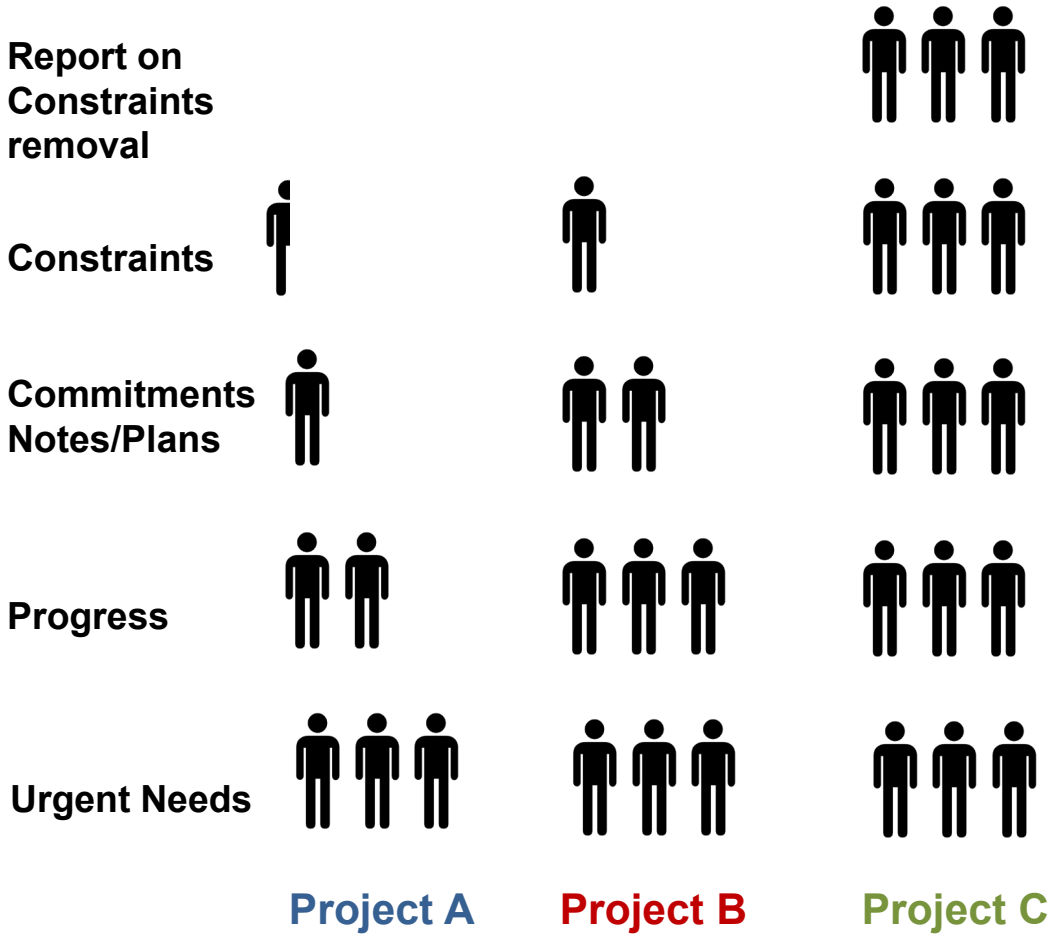
Project A	Project B	Project C
2	3	4

Role	Meeting 1	Meeting 2	Meeting 3
Trade A	VP (1)	VP (1)	VP (1)
Trade B	Senior Project Manager (1) Superintendent (1) General Superintendent (1)	Senior Project Manager (1) Superintendent (1) General Superintendent (1)	Senior Project Manager (1) Superintendent (1) Foreman (1)
Trade C	Foreman (1)	Foreman (1)	Foreman (1)
Trade D	None	None	Project Manager (1)
GC/CM	Superintendent (1) Assist Superintendent (2) Scheduler (1) Project Engineer (1)	Assist Superintendent (2) Scheduler (1) Project Engineer (2)	VP (1) Assist Superintendent (2) Scheduler (1) Project Engineer (2)



Preparation

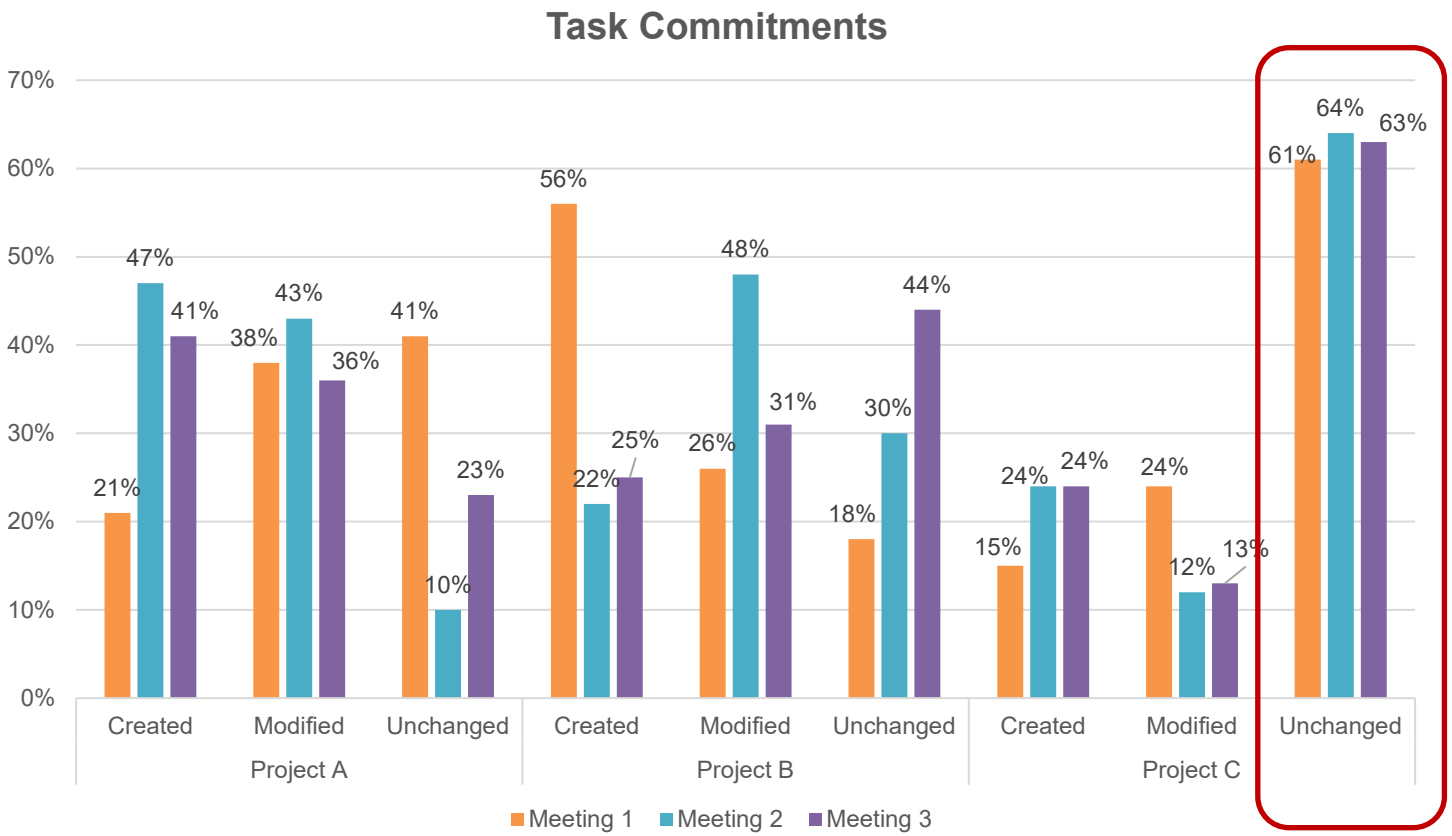
Project A	Project B	Project C
2	3	4



Technical Assessment

Team Commitment

Project A	Project B	Project C
2	3	4



Using VM of the Project Information

Project A	Project B	Project C
3	3	4

Safety Sticky Notes

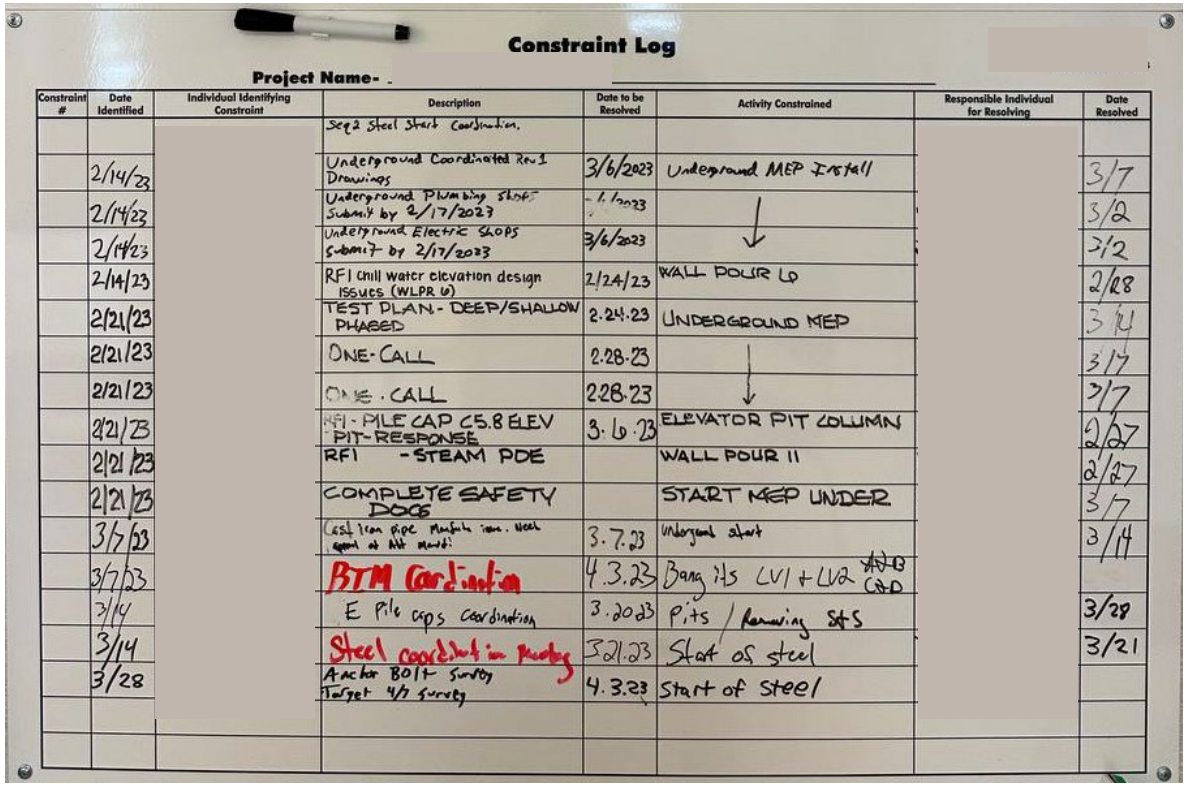
Project C

Technical Assessment

Manage Constraints

Project A	Project B	Project C
1	1	4

Project C



Constraint Log

Project Name- _____

Constraint #	Date Identified	Individual Identifying Constraint	Description	Date to be Resolved	Activity Constrained	Responsible Individual for Resolving	Date Resolved
			Seq2 Steel Start Coordination.				
	2/14/23		Underground Coordinated Rev 1 Drawings	3/6/2023	Underground MEP Install		3/7
	2/14/23		Underground Plumbing Shop Submit by 2/17/2023	- 1 /2023	↓		3/2
	2/14/23		Underground Electric Shops Submit by 2/17/2023	3/6/2023			3/2
	2/14/23		RFI Chill water elevation design issues (WLPR U)	2/24/23	WALL POUR 10		2/28
	2/21/23		TEST PLAN - DEEP/SHALLOW PHASED	2.24.23	UNDERGROUND MEP		3/4
	2/21/23		ONE-CALL	2.28.23	↓		3/7
	2/21/23		ONE-CALL	2.28.23	↓		3/7
	2/21/23		RFI - PILE CAP C5.8 ELEV PIT-RESPONSE	3.6.23	ELEVATOR PIT COLUMN		2/27
	2/21/23		RFI - STEAM PDE		WALL POUR 11		2/27
	2/21/23		COMPLETE SAFETY DOCS		START MEP UNDER		3/7
	3/7/23		Cast iron pipe manhole issue. Need quote at Alt round	3.7.23	Underground start		3/14
	3/7/23		BTM Coordination	4.3.23	Bang 1's LV1 + LV2 ~~ADD~~ CAD		
	3/14		E Pile caps coordination	3.2023	Pits / Removing SOS		3/28
	3/14		Steel coordination meeting	3.21.23	Start of steel		3/21
	3/28		Anchor BOLT Survey Target 4/7 Survey	4.3.23	Start of steel		

Collaboration

Project A	Project B	Project C
2	3	4

Observation	Project A		Project B		Project C	
	% to GC	% to Trades	% to GC	% to Trades	% to GC	% to Trades
Meeting 1	78%	22%	67%	33%	52%	48%
Meeting 2	73%	27%	64%	36%	51%	49%
Meeting 3	77%	23%	64%	36%	49%	51%
Average	**76%**	**24%**	**65%**	**35%**	**50%**	**50%**

Project C:

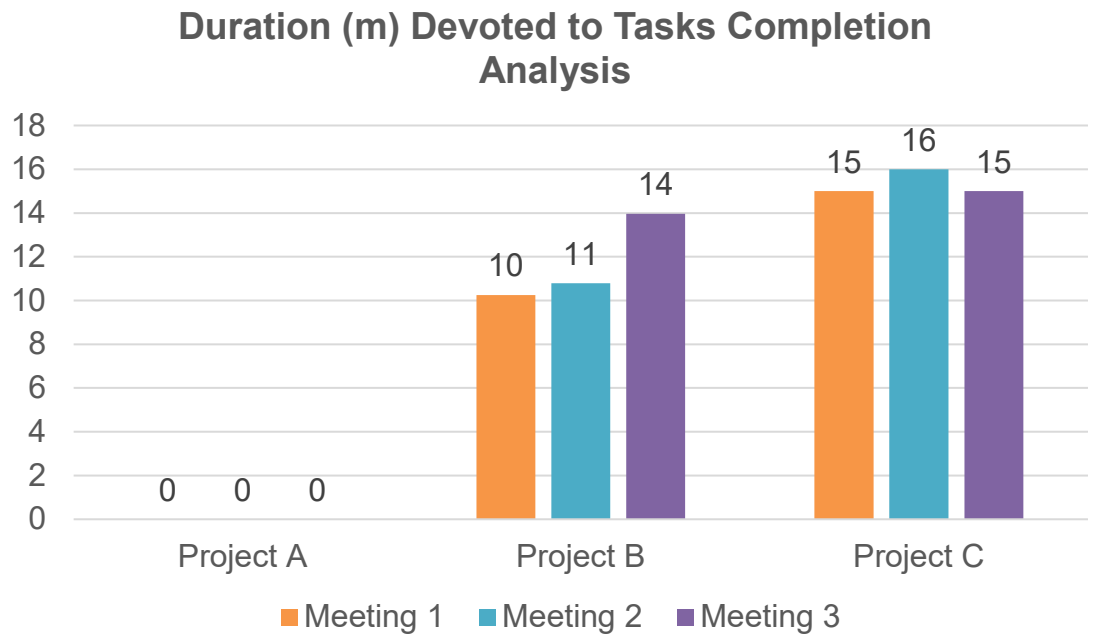
- The Last Planners' willingness to challenge unrealistic or unachievable requests and propose alternative solutions to meet project goals.

Ability to say "NO"

Technical Assessment

Analyzing the trends

Project A	Project B	Project C
1	2	3



Project A:

- No analysis of weekly assignments to recognize the degree of task completion
- No root cause analysis

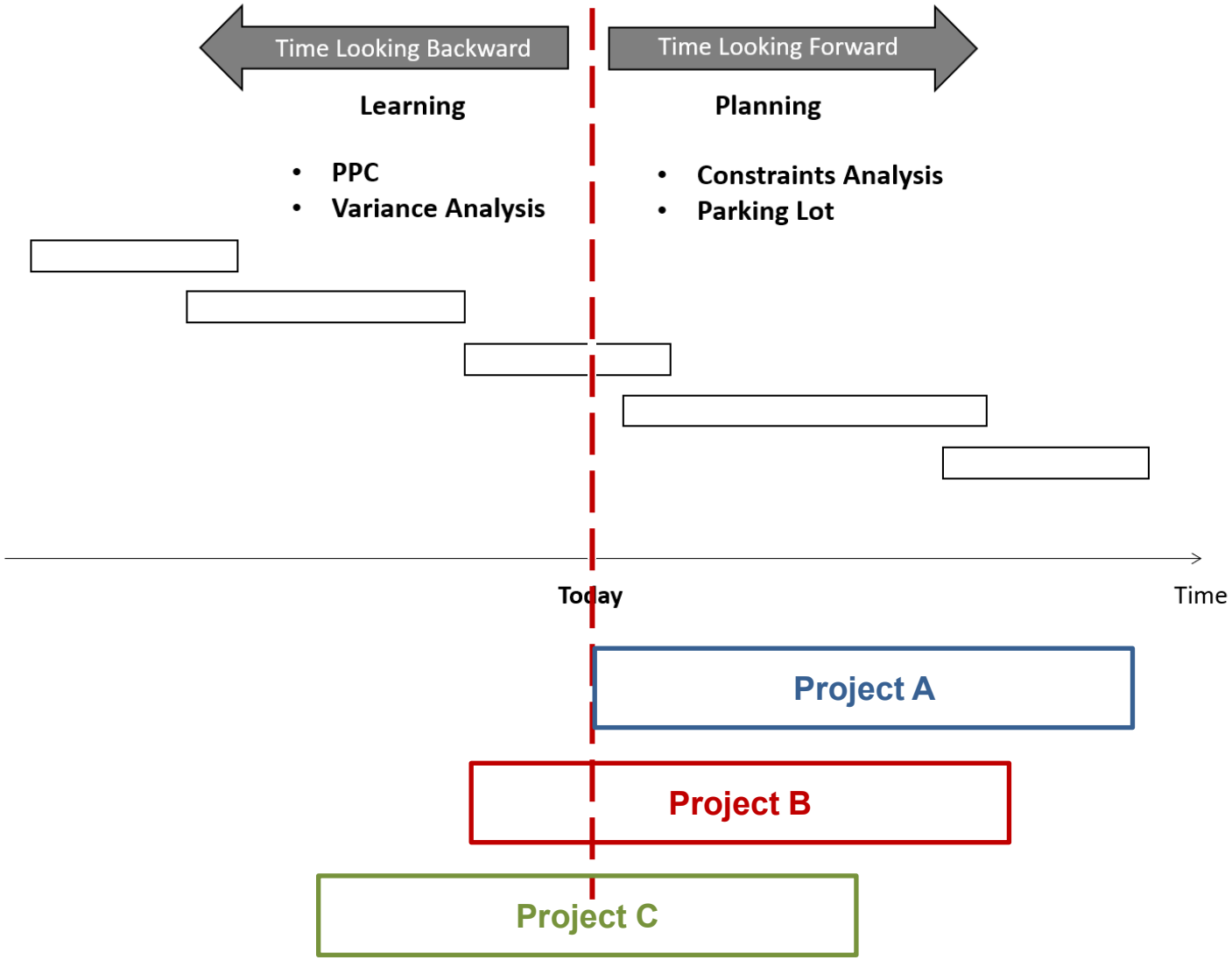
Project B:

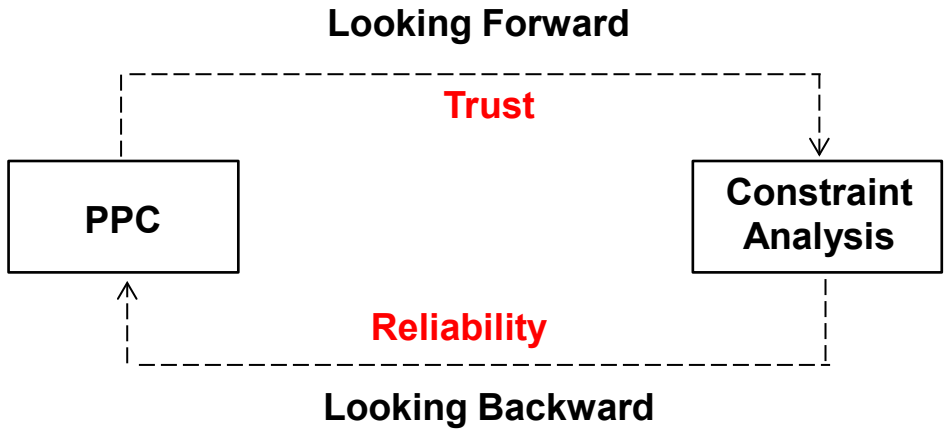
- Brief weekly review of commitments met
- No PPC analysis of their weekly performance

Project C:

- Team commitments tracked and analyzed
- The team discussed disruptions
- Reasons for failing identified
- Consistent PPC and Variance Analysis

Technical Assessment

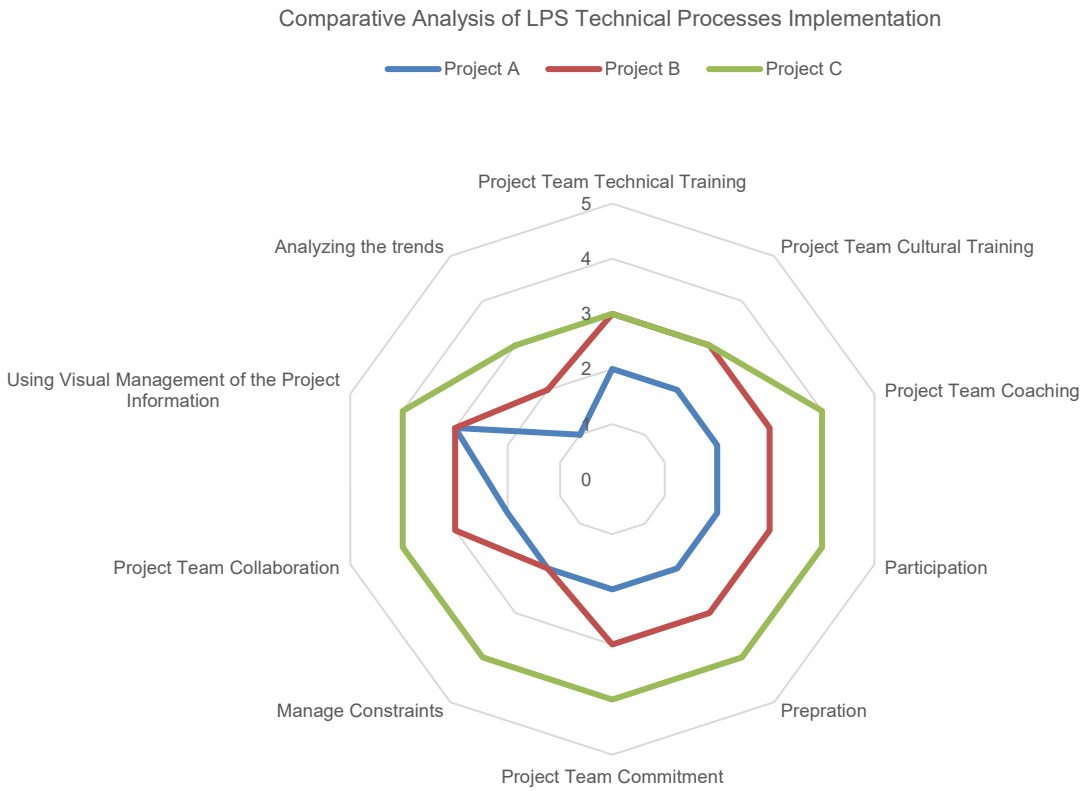




Managing constraints and collaboration is the direct function of how they structure their time.

Technical Assessment

For each project, the maturity scores were reviewed with the point of contact.



Social Interactions

Social Interactions

Interaction Process Analysis (IPA) by Bales (1950)

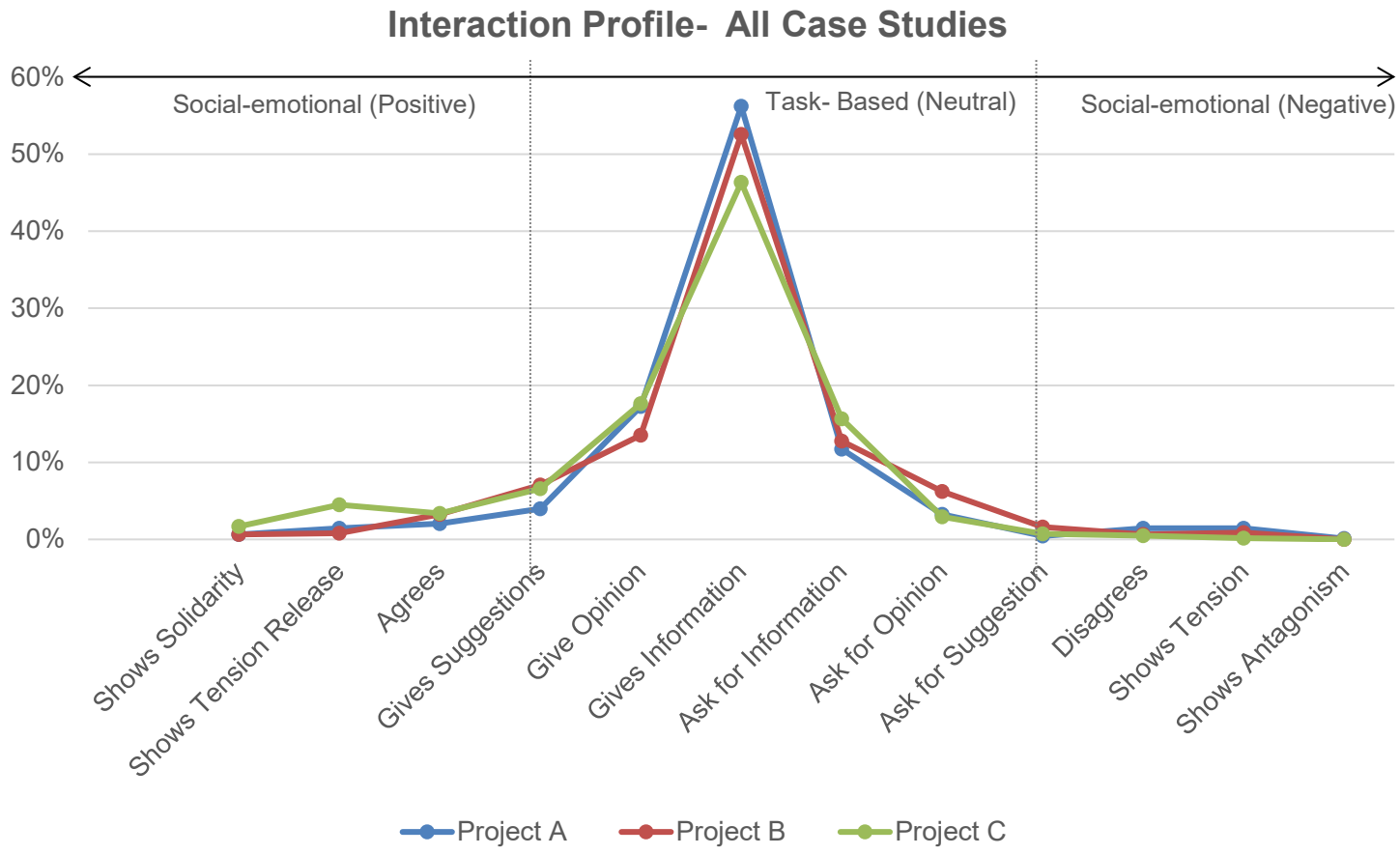
Social-Emotional Area Positive Reactions		**1. Shows Solidarity**: raises other's status, gives help, rewards
		2. Shows Tension Release: Jokes, laughs, shows satisfaction
		3. Agrees: shows passive acceptance, understands, concurs, complies
Task Area Neutral	Attempted Answers	**4. Gives Suggestions**: direction, implying autonomy for other
		5. Gives Opinion: evaluation, analysis, expresses feeling, wish
		6. Gives Orientation: Information, repeats, clarifies, confirms
	Questions	**7. Asks for Orientation**: information, repetition, confirmation
		8. Asks for Opinion: evaluation, analysis, expression of feelings
		9. Asks for Suggestion: direction, possible ways of action
Social-Emotional Area Negative Reactions		**10. Disagrees**: shows passive rejection, formality, withholds help
		11. Shows Tension: asks for help, withdraws out of field
		12. Shows Antagonism: deflates other's status, defines, or asserts self

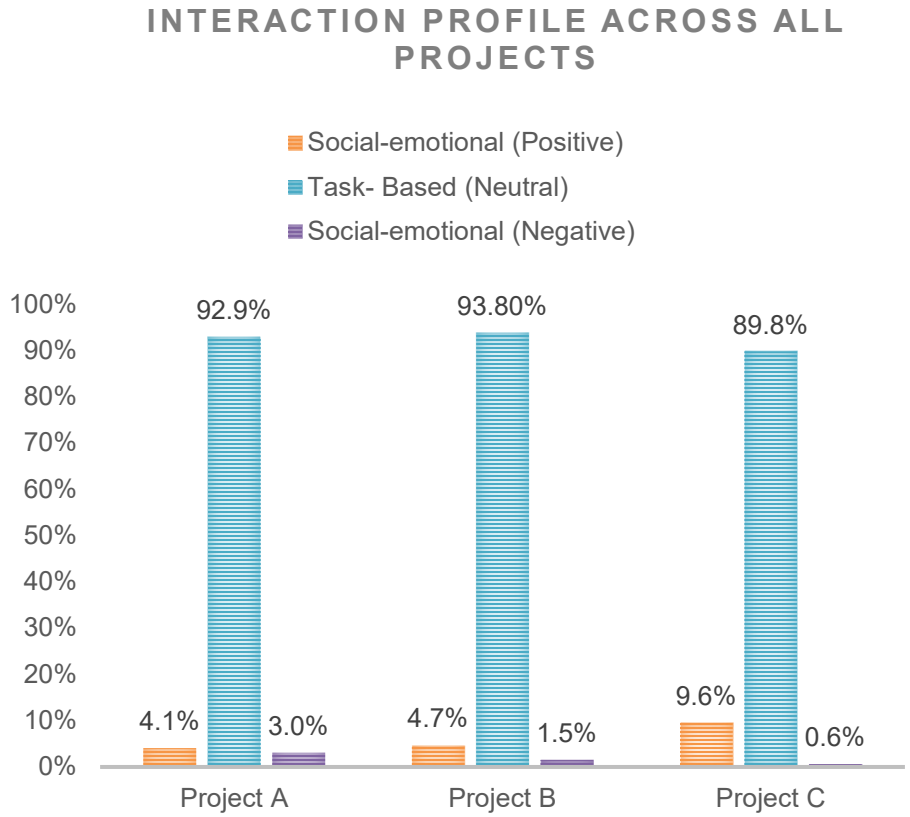
Social Interactions

Interaction Profile for Case Studies

Area	Interaction	Project A			Project B			Project C		
		#	%	Total	#	%	Total	#	%	Total
Social-emotional (Positive)	Shows Solidarity	18	0.6%	**4.1%**	11	0.6%	**4.7%**	47	1.7%	**9.6 %**
	Shows Tension Release	41	1.4%		14	0.8%		124	4.5%	
	Agrees	59	2.1%		56	3.3%		93	3.4%	
Task-Based (Neutral)	Gives Suggestions	114	4.0%	**92.9%**	122	7.1%	**93.8%**	181	6.6%	**89.8%**
	Give Opinion	496	17.3%		233	13.5%		485	17.6%	
	Gives Information	1615	56.2%		906	52.6%		1277	46.3%	
	Ask for Information	337	11.7%		220	12.8%		431	15.6%	
	Ask for Opinion	94	3.3%		107	6.2%		81	2.9%	
	Ask for Suggestion	13	0.5%		28	1.6%		20	0.7%	
Social-emotional (Negative)	Disagrees	42	1.5%	**3 %**	11	0.6%	**1.5%**	13	0.5%	**0.6%**
	Shows Tension	41	1.4%		15	0.9%		4	0.1%	
	Shows Antagonism	3	0.1%		0	0.0%		0	0.0%	

Social Interactions





Lean Team Dynamics

A-B-C Framework

Attitudes, shared Behaviors, and Cognition of the individuals that make up the team.

Attitudes

What team members believe or feel:

- **Openness**
- **Trust**
- **Cohesion**
- **Team viability**

Behaviors

What team members do:

- **Collaboration**
- **Communication**
- **Conflict**
- **Leadership**

Cognitions

What team members think or know:

- **Information and knowledge sharing**
- **Shared mental model**

Salas, E., Cooke, N. J., & Rosen, M. A. (2008). On teams, teamwork, and team performance: Discoveries and developments. Human factors, 50(3), 540-547.

Lean Team Dynamics

Team Dynamics

Lean Principles

Team Dynamics/ Lean Principles and Ideas	Openness	Trust & Psychological Safety	Cohesion	Team Viability	Collaboration & Communication	Conflict	Leadership	Info Sharing & Knowledge Exchange	Shared Mental Model
Respect for People	√	√					√		
Continuous Improvement & Perfection	√	√		√		√	√	√	
Optimize the Whole	√	√				√			√
Customer Orientation			√						
Having a Long-term Vision			√	√					√
Information, Communication & Process Structure					√			√	
Establishing Integrated Teams & Collaboration					√				
Decentralizing Decision-making & Empowering Project Participants					√		√		
Pull					√				
Increase Process Transparency		√						√	

Association between team constructs and lean principles and ideas

Lean Team Dynamics

Openness:

Openness is defined as the degree to which teammates openly share and receive information.

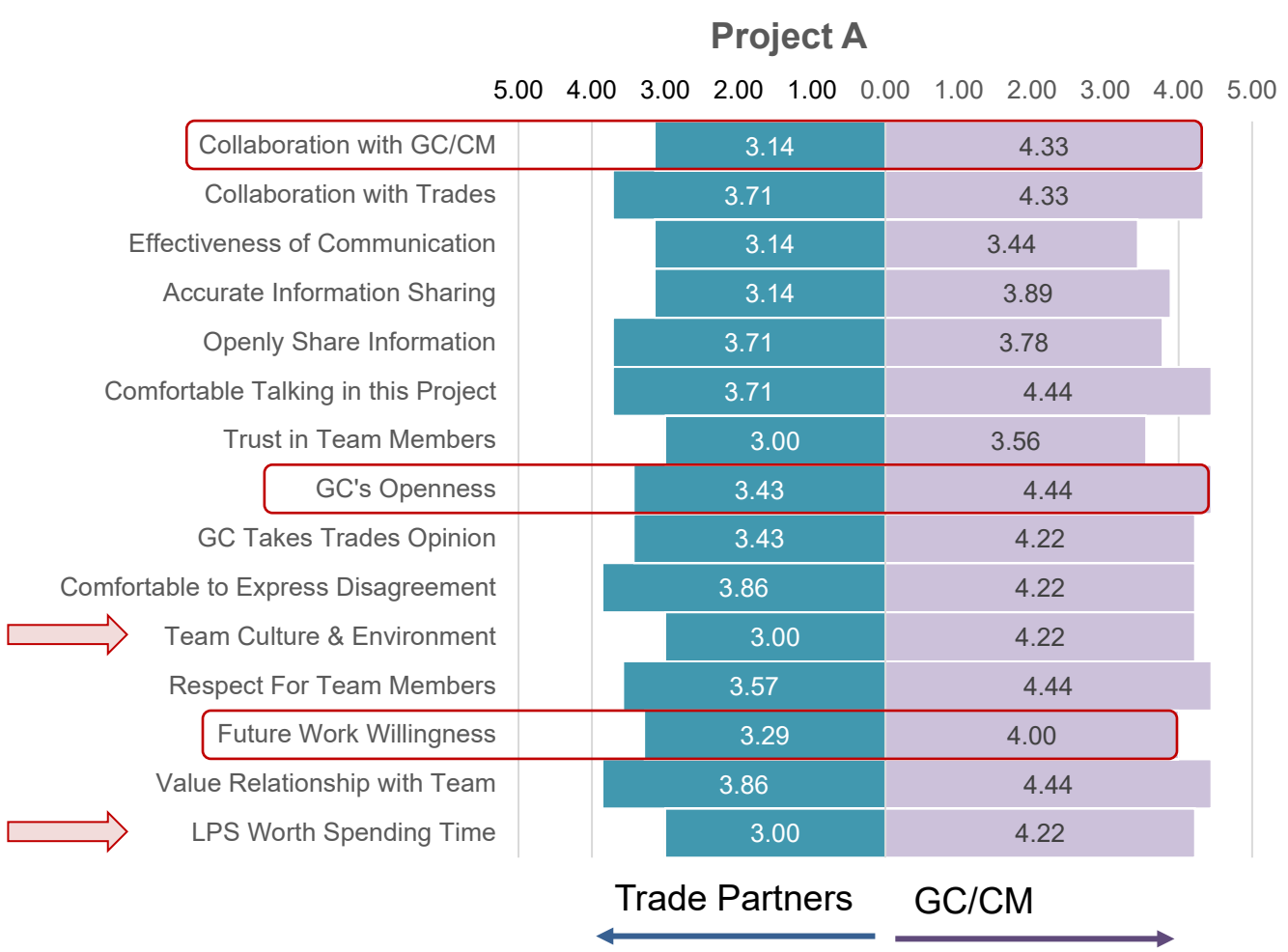
- Respect for people
- Continuous improvement
- Optimization of the whole

- Continuous improvement and seeking perfection
- Having a long-term vision

Team Viability:

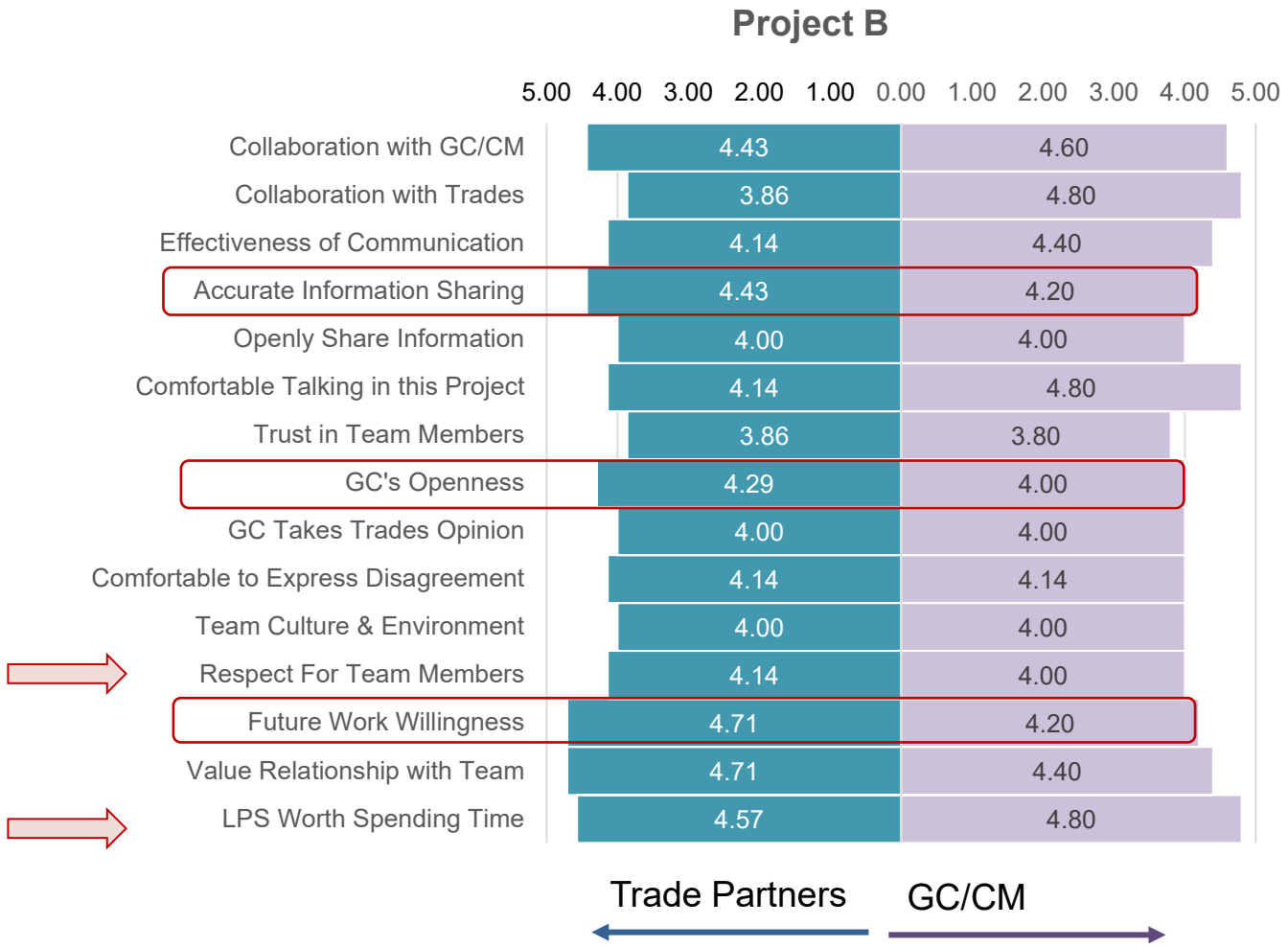
It is a team's capacity for growth, which is required for success in future performance. It is viewed as a team members' willingness to remain in the team.

Team Dynamics



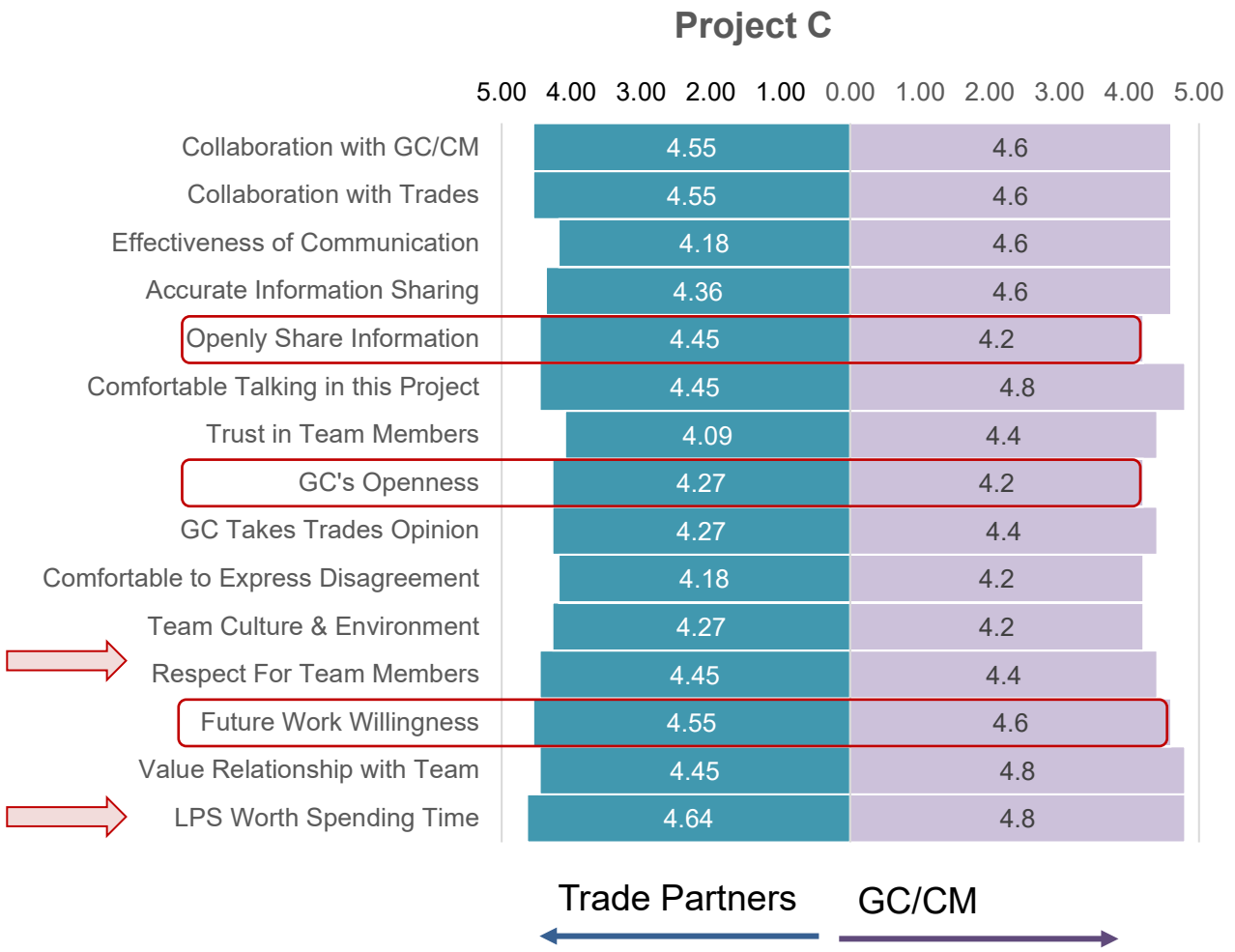
Δ = GC - Trades
1.19
0.62
0.30
0.75
0.06
0.73
0.56
1.02
0.79
0.37
1.22
0.87
0.71
0.59
1.22

Team Dynamics



Δ = GC - Trades
0.17
0.94
0.26
-0.23
0.00
0.66
0.00
-0.29
0.00
0.00
0.00
-0.14
-0.51
-0.31
0.23

Team Dynamics

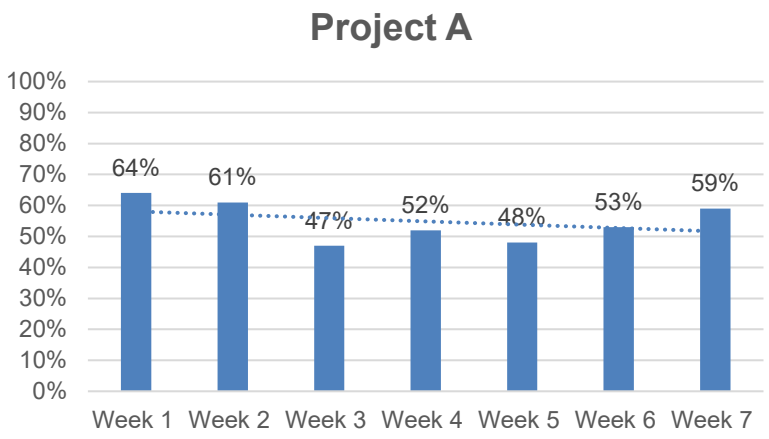


Δ = GC - Trades
0.05
0.05
0.42
0.24
-0.25
0.35
0.31
-0.07
0.13
0.02
-0.07
-0.05
0.05
0.35
0.16

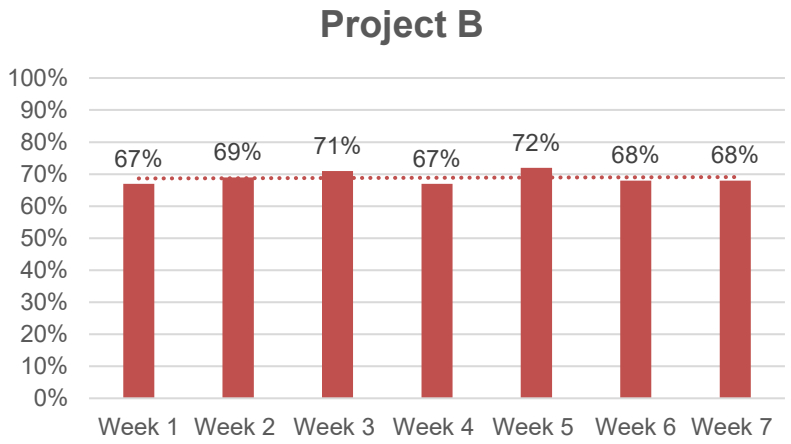
Planning Outcomes

Planning Outcomes

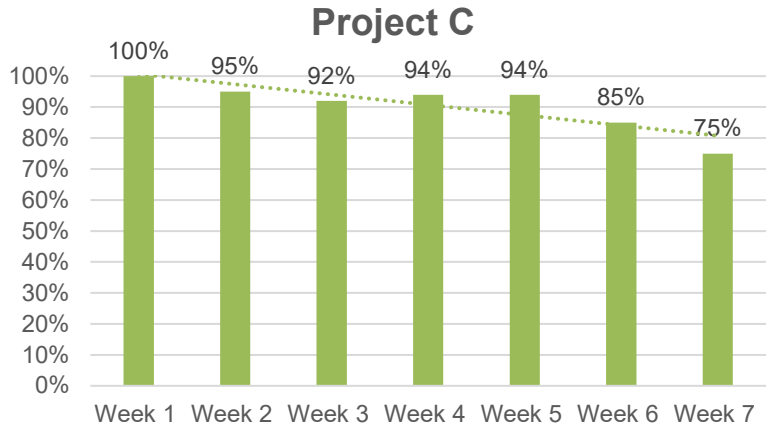
Range: 47% - 64%



Range: 67% - 72%

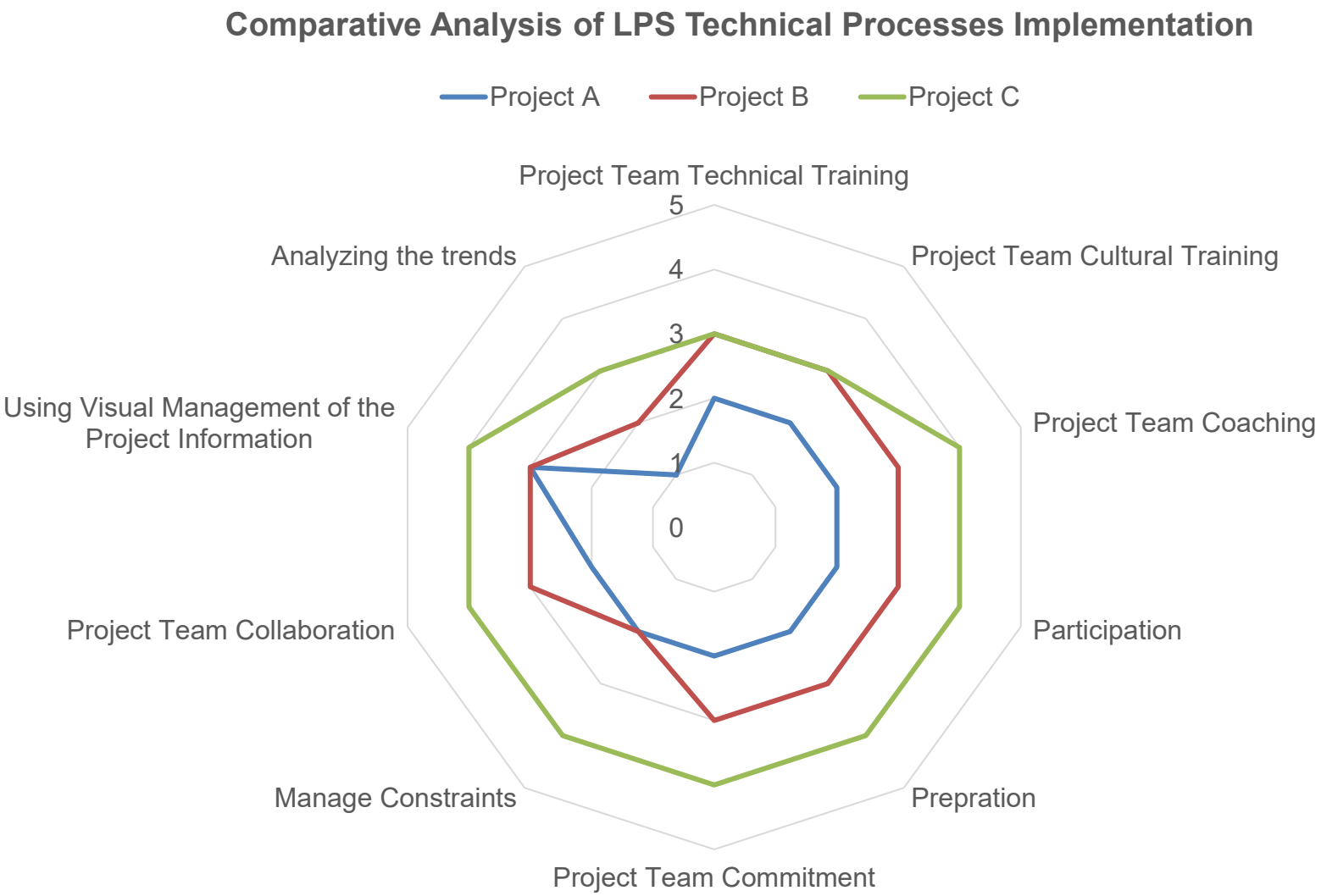


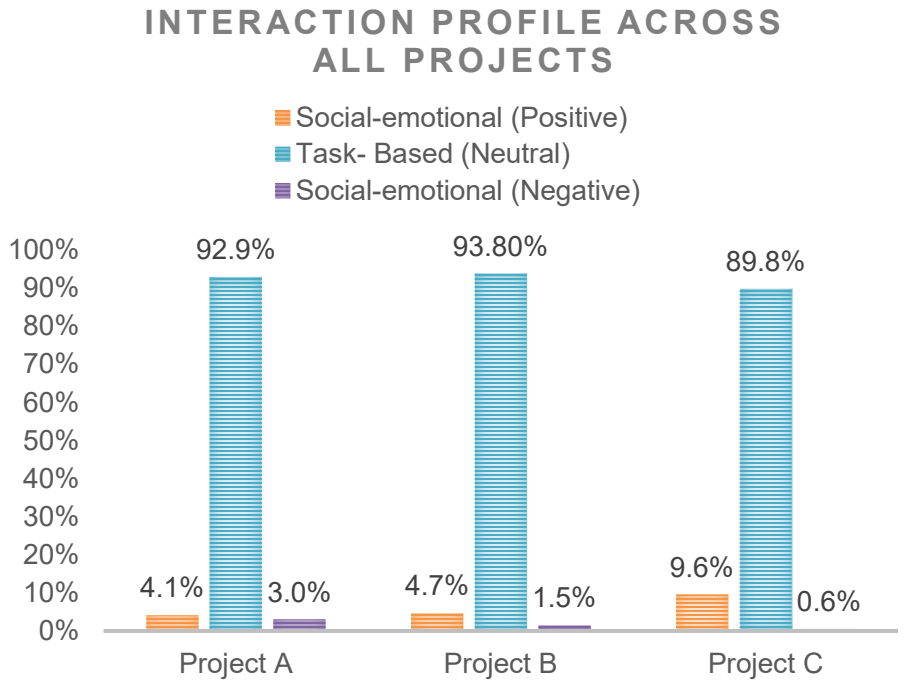
Range: 75% - 100%



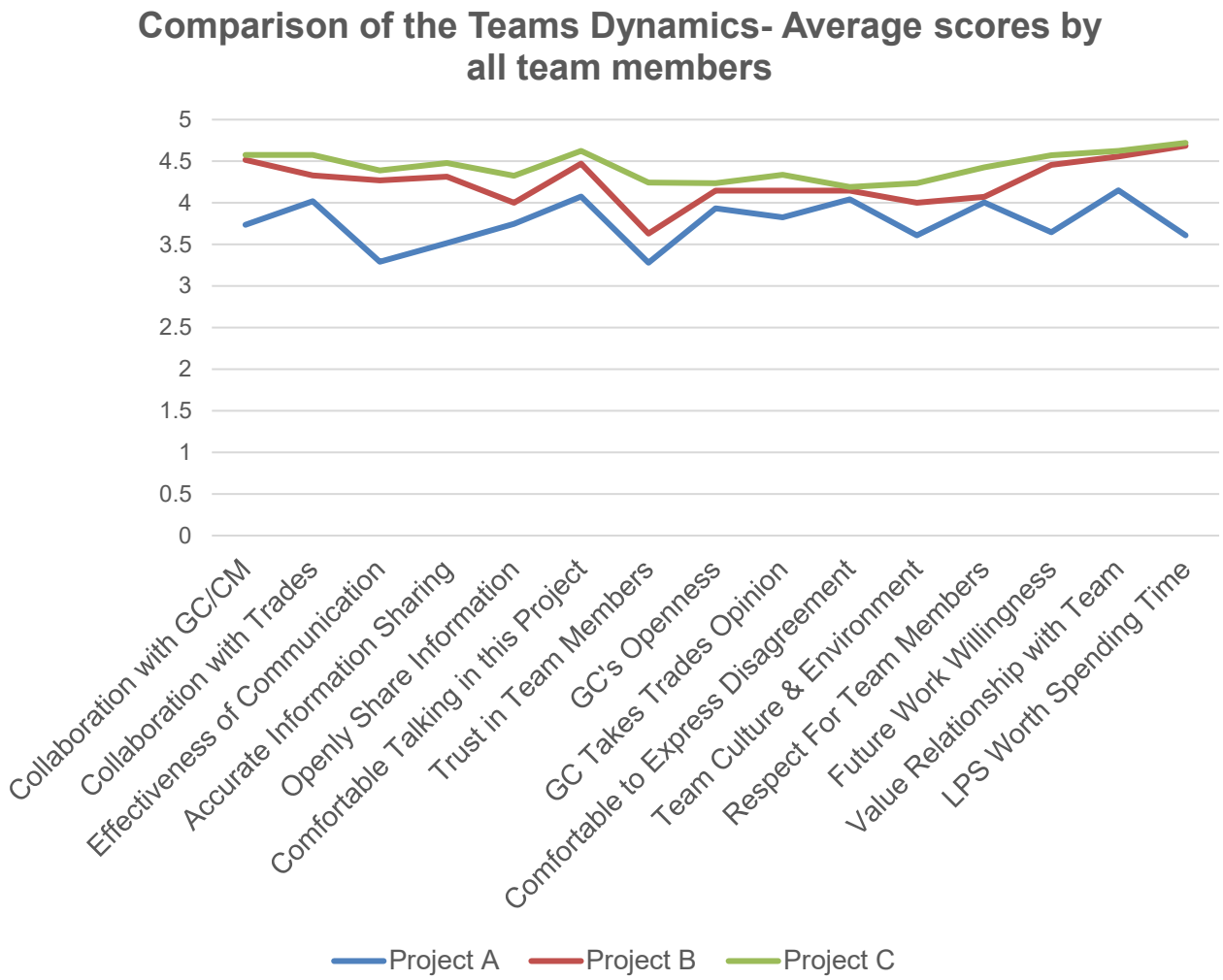
$$\textbf{Planned Percent Complete (PPC)} = \frac{\text{The tasks that were done}}{\text{The tasks that were supposed to be done}}$$

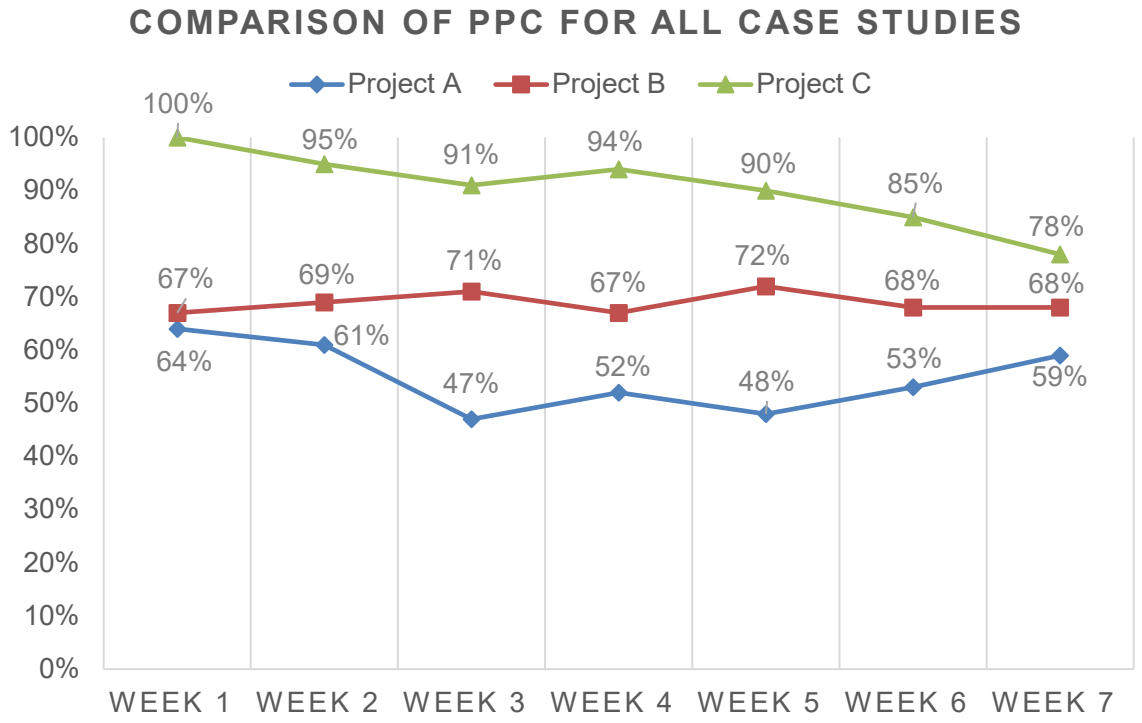
Comparative Analysis



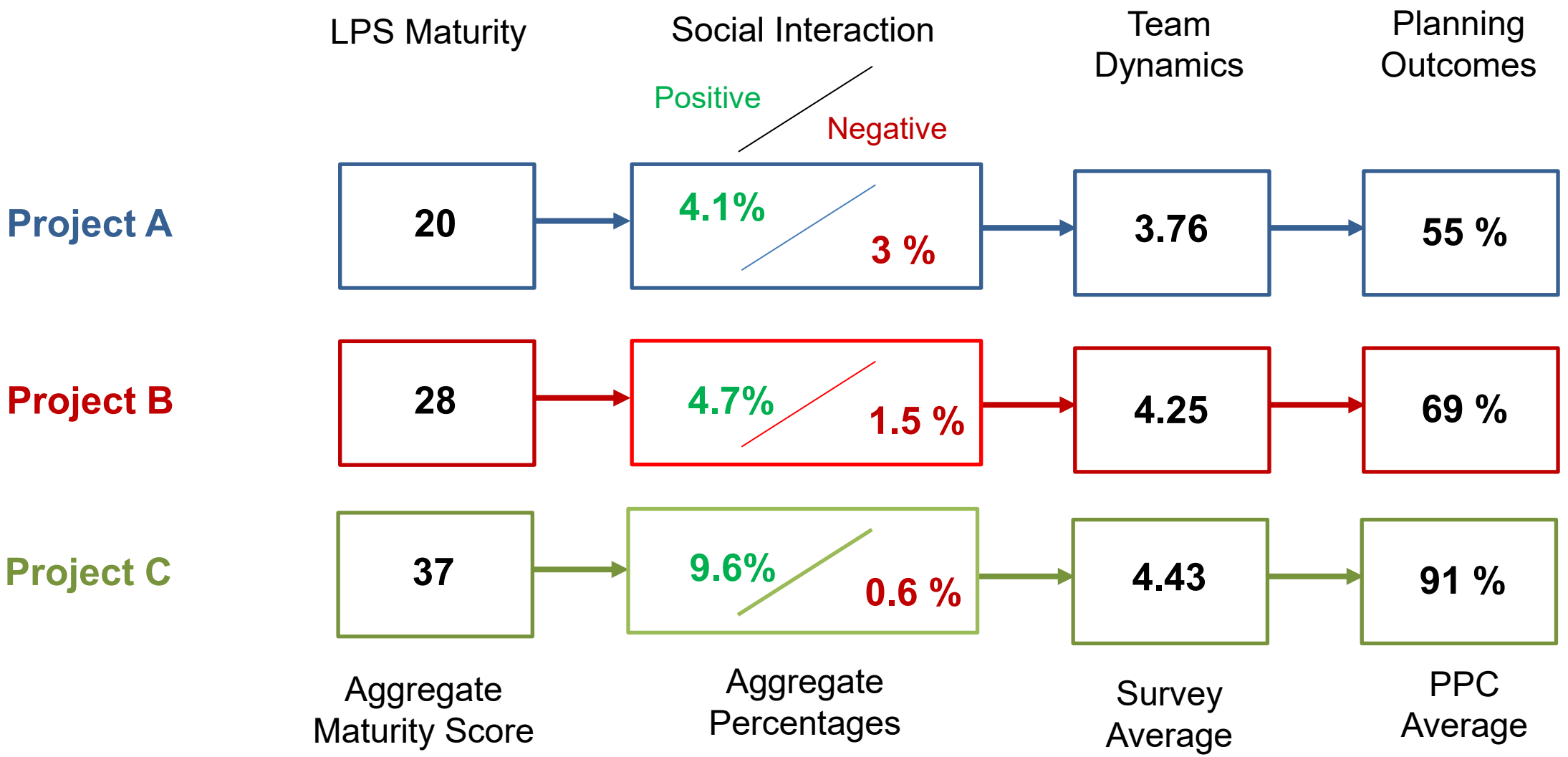


Comparative Analysis



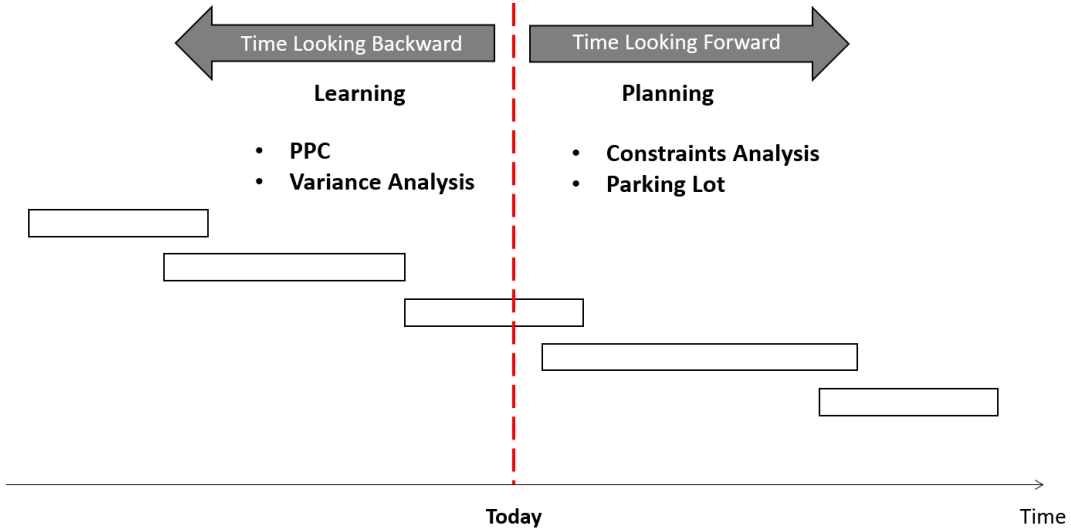


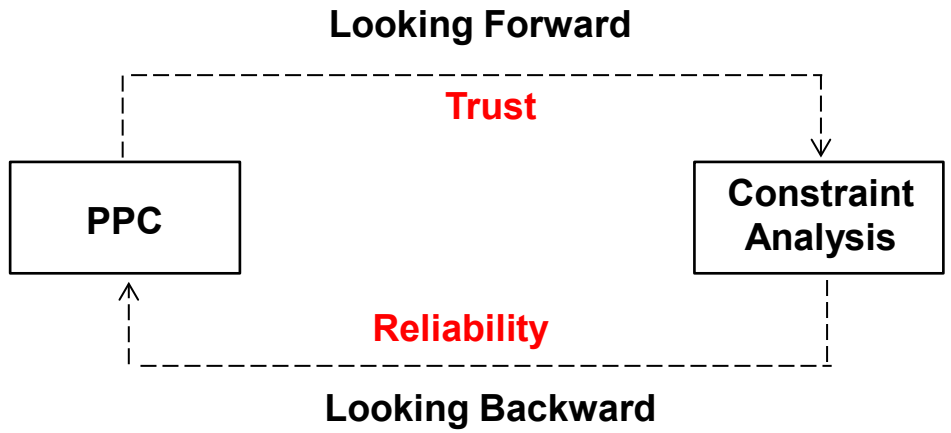
Conclusion


LPS Maturity
Social Interaction
Positive
Negative
Team Dynamics
Planning Outcomes
Project A
20
4.1%
3 %
3.76
55 %
Project B
28
4.7%
1.5 %
4.25
69 %
Project C
37
9.6%
0.6 %
4.43
91 %
Aggregate Maturity Score
Aggregate Percentages
Survey Average
PPC Average

Takeaways

- Not Culture or Methods – Sociotechnical Process requires BOTH
  - Training needs to support BOTH
- Meeting time is a shared resource – use it wisely!
- You need to look back and reflect to improve your plan to move forward
- Reliability and transparency build trust – it's a slow process and it starts over with *every project and every relationship*





Thank you!

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Link to download
Maturity Model - >>