IGLC 2021
LIMA, PERÚ - 29TH ANNUAL CONFERENCE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

APPLICATION OF INFORMATION THEORY IN LAST PLANNER® SYSTEM FOR WORK PLAN RELIABILITY

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PRESENTATION OUTLINE

- Research Background
- Objective and Scope of Research
- Literature Review
- Methodology
- Data Collection
- Data Analysis and Interpretation
- Conclusion and Future Scope

RESEARCH BACKGROUND

- Last Planner System® is being used in the AEC industry for more than 20 years.
- It uses **pull driven** scheduling approach to improve the planning reliability.
- One of the main features of LPS is the ***constraint removal discussion***.

> *Identifying and removing the constraints prior to the execution can influence the reliability of the look-ahead plan and ultimately improve the project performance.*
>
> (Hamzeh et al. 2015)

LITERATURE REVIEW

1) Understanding LPS
2) Learning Importance of Make-ready process (i.e. Removing constraints)
3) Quantitative method of assessing the effect of constrain removal discussion on work progress – *Information Theory*
   i. **Only PPC was used as an indicator of work plan reliability**
   ii. **Only 7 categories of constraints were considered**
4) More reliable performance indicators – *TA & TMR*
5) Additional categories of constraints

(Javanmardi, Abbasian-Hosseini, Hsiang, & Liu, 2018; Hamzeh, Ballard, & Tommelein, 2012; Hamzeh, Zankoul, & Rouhana, 2015; Hamzeh, Saab, Tommelein, & Ballard, 2015; Lindhard & Wandahl, 2012)

RESEARCH OBJECTIVE

- To ***quantify the effect of weekly constraint removal discussions*** on the quality of the work plans.
- To ***identify the important constraint categories*** for improvement of the work plan reliability indicators (i.e. PPC, TA and TMR) using the Information theory.

- To ***assess the discrepancy in the important constraint categories*** for different work plan reliability indicators.

METHODOLOGY

1

Review of Research papers and Journal articles
1

2

Literature Review

Perform detailed literature review
2

Identify Research gaps
3

Determine the Research goals and scope
4

3

Case study selection

Select an ongoing construction project in India and collect the project background information
5

4

Data collection

Collect the details of constraint discussions from the weekly meetings at sites
5

Collect lookahead plan, weekly plans and weekly progress details form site for calculating the work plan reliability indicators - PPC, TA and TMR
6

5

Data analysis - Using Information theory

Divide the performance indicators into two groups, high and low, using k-means clustering algorithm
7

Calculate constraint removal entropy, performance indicator's entropy, mutual information between constraint removal and indicator, and information gain from constraint removal discussions
8

6

Research outcomes

Identification of the importance of all the constraint categories on work plans
9

Quantify each constraint removal's impact on all the work plan reliability indicators
10

Measure information gain from constraint removal discussions and identify the main constrains for improving the various work plan reliability indicators
11

Ascertain if variation exists among the important constraint categories for improving different performance indicators
12

DATA COLLECTION

Details	Case study 1	Case study 2	Case study 3
Type	Residential	Industrial	Residential
Built-up area	23,000 sqm	3,10,000 sqm	17,000 sqm
Status of work during data collection	Finishing	Finishing	RCC, Finishing
Contractor	C1	C1	C2
Avg. Duration of weekly meetings	54 minutes	65 minutes	38 minutes
Avg. nos. of participants	18	22	8

For each site, the discussion data was collected by attending the weekly meetings for 5 Weeks.

DATA COLLECTION

- To calculate the performance indicators – PPC, TA and TMR of each week, the Look-ahead plan, Weekly plan and Actual weekly progress data was collected.

$$Percentage\ Plan\ Complete = \frac{Number\ of\ tasks\ executed\ in\ a\ week}{Total\ number\ of\ tasks\ planned\ for\ a\ week} \times 100\%$$

$$Task\ Anticipated = \frac{Number\ of\ anticipated\ tasks\ from\ look\ ahead\ plan}{Total\ number\ of\ tasks\ on\ weekly\ work\ plan} \times 100\%$$

$$Task\ Made\ Ready = \frac{Number\ of\ completed\ tasks\ out\ of\ anticipated\ tasks}{Total\ number\ of\ tasks\ on\ weekly\ work\ plan} \times 100\%$$

COLLECTED DATA

- The cross-tab represents the number of times the constraint was discussed.

Case Study - 1 | Case Study - 2 | Case Study - 3

Week	X_1	X_2	X_3	X_4	X_5	X_6	X_8	PPC	TA	TMR
1	3	4	5	2	3	5	3	72%	82%	62%
2	0	1	3	0	3	3	2	67%	75%	46%
3	1	3	2	0	0	4	2	85%	75%	48%
4	1	1	2	0	1	4	3	72%	82%	66%
5	0	3	2	0	4	2	2	68%	72%	46%

Here; X_1 - Design availability, X_2 - Material availability, X_3 - Worker availability, X_4 - Equipment availability, X_5 - Space availability, X_6 - Completion of predecessor activities, X_7 - External Conditions (weather related), X_8 - Safe working conditions, X_9 - Unknown working conditions

COLLECTED DATA

Case Study - 1 | Case Study - 2 | Case Study - 3

Week	X_1	X_2	X_3	X_4	X_5	X_6	X_8	PPC	TA	TMR
1	1	3	5	1	0	1	1	79%	83%	52%
2	1	1	3	0	1	0	0	77%	80%	48%
3	0	4	5	1	1	3	0	85%	70%	38%
4	2	2	4	1	0	2	0	70%	86%	39%
5	0	2	3	1	0	2	0	74%	65%	26%

Here; X_1 - Design availability, X_2 - Material availability, X_3 - Worker availability, X_4 - Equipment availability, X_5 - Space availability, X_6 - Completion of predecessor activities, X_7 - External Conditions (weather related), X_8 - Safe working conditions, X_9 - Unknown working conditions

COLLECTED DATA

Case Study - 1 | Case Study - 2 | Case Study - 3

Week	X_1	X_2	X_3	X_4	X_5	X_6	X_8	PPC	TA	TMR
1	0	0	2	0	2	1	0	89%	86%	76%
2	0	1	2	1	4	2	0	68%	87%	52%
3	0	2	3	1	3	0	0	74%	74%	50%
4	1	1	2	0	3	0	0	78%	69%	52%
5	2	0	4	0	4	0	2	56%	72%	33%

Here; X_1 - Design availability, X_2 - Material availability, X_3 - Worker availability, X_4 - Equipment availability, X_5 - Space availability, X_6 - Completion of predecessor activities, X_7 - External Conditions (weather related), X_8 - Safe working conditions, X_9 - Unknown working conditions

DATA ANALYSIS

Case study - 1
Performance indicator - TA

- Division of Performance indicator into two clusters using k-means analysis.
- *Find out -

  H(X), H(Y) - Information gained in bits

  I(X,Y) - Amount of Information obtained about the Performance indicator (Y) by observing the frequency of constraint removal discussion (X)

Refer the paper for detailed calculation steps

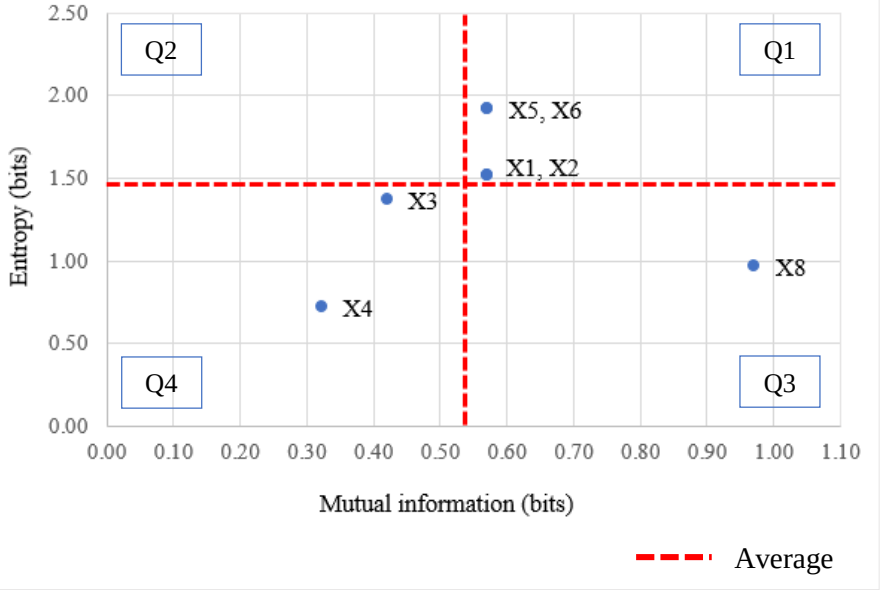
Week	Constraint Categories							TA (%)	TA Category
	X1	*X2*	*X3*	*X4*	*X5*	*X6*	*X8*		
1	3	4	5	2	3	5	3	82%	A
2	0	1	3	0	3	3	2	75%	B
3	1	3	2	0	0	4	2	75%	B
4	1	1	2	0	1	4	3	82%	A
5	0	3	2	0	4	2	2	72%	B

Constraint	*H(X)*	*H(X)* Rank	*H(Y)*	*H(X,Y)*	*I(X,Y)*	*I(X,Y)* Rank
X1	1.52	3	0.97	1.92	0.57	2
X2	1.52	3	0.97	1.92	0.57	2
X3	1.37	5	0.97	1.92	0.42	6
X4	0.72	7	0.97	1.37	0.32	7
X5	1.92	1	0.97	2.32	0.57	2
X6	1.92	1	0.97	2.32	0.57	2
X8	0.97	6	0.97	0.97	0.97	1

Here; X_1 - Design availability, X_2 - Material availability, X_3 - Worker availability, X_4 - Equipment availability, X_5 - Space availability, X_6 - Completion of predecessor activities, X_7 - External Conditions (weather related), X_8 - Safe working conditions, X_9 - Unknown working conditions

DATA INTERPRETATION

1) Finding the important constraint categories for improving performance indicators



H(X) vs. I(X,Y)

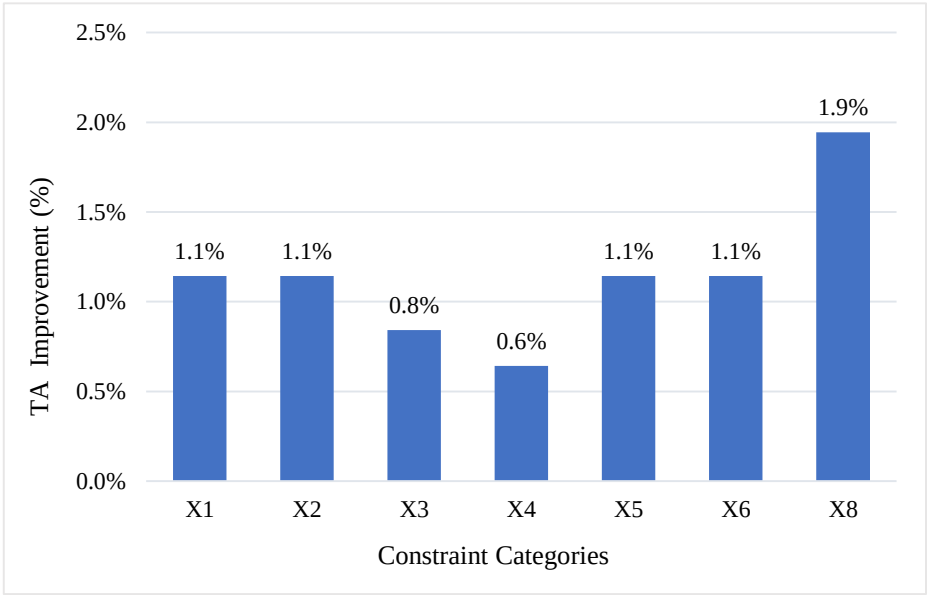
QUADRANT-1: **Important** for work plan indicator improvement and **were efficiently discussed** - *Highest priority for discussion*

QUADRANT-2: **Less important** for Performance indicator improvement, but they were **efficiently discussed** - *will be addressed briefly with less effort and will have second priority for discussion*

QUADRANT-3: **Important** but **not discussed efficiently** - *more effort to be addressed and will have third priority for discussion*

QUADRANT-4: **Less important** and **not discussed efficiently** - *lowest priority for discussion*

2) Quantifying the expected improvement in Work plan Reliability Indicator when each constraint category is removed*



Refer the paper for detailed calculation steps

Here; X_1 - Design availability, X_2 - Material availability, X_3 - Worker availability, X_4 - Equipment availability, X_5 - Space availability, X_6 - Completion of predecessor activities, X_7 - External Conditions (weather related), X_8 - Safe working conditions, X_9 - Unknown working conditions

CONCLUSION

- Similarly, the analysis was done for each site & each performance indicator.

Case Study	Week	For PPC	For TA	For TMR
Case study - 1	Important Constraint Categories	X_1 ,X_2 , X_5 ,X_6	X_1 , X_8	X_1 , X_8
	Improvement (%)	**11%**	**3%**	**6%**
Case study - 2	Important Constraint Categories	X_2 , X_3 ,X_6	X_1 , X_2 , X_3	X_1 , X_2 , X_3
	Improvement (%)	**6%**	**13%**	**12%**
Case study - 3	Important Constraint Categories	X_2 , X_6	X_6 , X_8	X_6 , X_8
	Improvement (%)	**9%**	**8%**	**18%**

Here; X_1 - Design availability, X_2 - Material availability, X_3 - Worker availability, X_4 - Equipment availability, X_5 - Space availability, X_6 - Completion of predecessor activities, X_7 - External Conditions (weather related), X_8 - Safe working conditions, X_9 - Unknown working conditions

RESEARCH OUTCOMES

- The most and least **Important constraint categories affecting the Work plan reliability** were identified.
- The **quantified expected improvement of Performance indicators-** PPC, TA and TMR helped in understanding the importance of constraint removal discussions.
- The analysis showed that the **Important constraints vary for PPC and TA-TMR**. As TA & TMR are proved to be better indicators of work plan reliability, their result will be considered for improving the efficiency of Future meetings.

Case Study	Week	For PPC	For TA	For TMR
Case study - 1	Important Constraint Categories	X_1 ,X_2 , X_5 ,X_6	X_1 , X_8	X_1 , X_8
	Improvement (%)	**11%**	**3%**	**6%**
Case study - 2	Important Constraint Categories	X_2 , X_3 ,X_6	X_1 , X_2 , X_3	X_1 , X_2 , X_3
	Improvement (%)	**6%**	**13%**	**12%**
Case study - 3	Important Constraint Categories	X_2 , X_6	X_6 , X_8	X_6 , X_8
	Improvement (%)	**9%**	**8%**	**18%**

FUTURE SCOPE

- The research **can be applied to any construction project using LPS** anywhere in the world.
- The organizations may **apply this analysis to their projects at every stage** and the results can be used to **create a database** of important constraint categories at various stages of the project.
- It was observed that few of the **constraints were interrelated**. It can be studied to enhance the outcomes of the research.
- The constraint removal discussion were counted based on frequency regardless of the **duration of discussion**. Future research work can look into finding a way to incorporate the time aspect in the data analysis.

THANK YOU!

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