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USING REASONS FOR NON-COMPLIANCE TO ASSESS PROJECT PERFORMANCE IN THE LAST PLANNER SYSTEM®

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Introduction

Traditional management:

- Focused solely on the transformation view
- Result oriented

Koskela et al., 2002

Control:

- Focus on the iron triangle
- Earned Value Method (EVM)
- Use of aggregated indicators
- Comparing planned and actual progress

Toor and Ogunlana, 2010; Sarhan and Fox, 2012

Planning:

- One-time event based on methods such as Critical Path (CPM)
- Fixed, complex schedules with extensive use of slack
- Following the critical route rather than dynamic planning

Ballard, 2000

- Problems:
- Deviations are only detected after the fact
- Use of slack can hide deviations
- Aggregated indicators conceal variability
- Traditional methods fail to detect and prevent early signs of deviation

Toor and Ogunlana, 2010; Alarcón et al., 2014

Contributions to planning and control

Understanding causes of deviation:

- Multiple analyses of factors that cause deviation
- Cross-impact analyses of multiple deviation factors
- Benchmarking metrics combining multiple factors that affect performance

Venkatesh et al., 2017; Doloi et al., 2011; Iyer et al., 2015

Improving detection and predictability:

- Graphical approaches to improve detection
- Probabilistic approaches to improve EVM predictability
- Multivariate models of project performance

Acebes et al., 2013; Abdel Azeem et al., 2014; Chen et al., 2016

The Last Planner System ®

- Focus on processes: Work preparation, work-flow stabilization and short-term compliance.
- Systematical planning and control cycles to align long, mid and short-term scopes.
- Process-oriented metrics for work preparation, constraint management, compliance, variability and schedule accomplishment.
- Registering and learning from problems
- Over 27 years of experience

Ballard and Tommelein, 2016

Research contributions to the Last Planner System® (LPS)

Quantitative impacts of LPS

Alarcón et al., 2008; Leal et al., 2010; Viana et al., 2010; Kim et al., 2019; Lagos et al., 2019

Complements with traditional control:

- Understanding key differences between LPS and EVM approaches
- Combination of LPS and EVM

Kim et al., 2010; Buitrago, 2016; Novisky et al., 2018

- Relationships between LPS metrics and performance KPI
- Impact of LPS practices on project KPI

Gonzalez et al., 2008; Alarcón et al., 2014; Castillo et al., 2017; Kim, 2019

New metrics

Hamzeh et al., 2017; 2019

Limitations and needs:

- Partial implementations
- Small samples
- Need for more quantitative research

Daniel et al., 2015; Dave et al., 2015; Hamzeh et al., 2019

Opportunities:

- Information Technologies Support Systems
- New quantitative approaches and tools
- Early assessment capabilities using LPS metrics

Hamzeh et al., 2019; Kim et al., 2019; Lagos et al., 2019

Our aim and scope of research

- Most quantitative research focused on high-rise building
- Quantitative use of Reasons for Non-Compliances (RNC) information has not been explored in depth
- Opportunity to assess frequency and impact of RNC

Gonzalez et al., 2014; Daniel et al., 2015

Focus on quantitatively assessing RNC in industrial construction projects

- What differences can be identified in projects with different schedule accomplishment?

We will try to:

1. Develop quantitative assessment metrics using RNC
2. Identify differences between successful and non-sucessful projects

Scope:

- 23 complete Chilean industrial projects using technological LPS support system
- Standardized weekly information (PPC, progress, constraints, RNC)
- Projects were classified into sucess and failure groups using clustering algorithms

Methodology of research

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1. Literature review:
   - Quantitative LPS research and new metrics
   - Assessment of delay and deviation factors
2. Collection of information:
   - Data collection with IT system
   - Standardization of RNC data
3. Project clustering:
   - Based on K-Means using schedule metrics (Accomplishment and deviation)
4. Constructing RNC metrics:
   - Using RNC frequency and impact to develop new metrics
5. Comparing LPS metrics based on performance:
   - Aggregating data for successful and non-successful projects
   - Performing statistical analysis of differences
6. Using new RNC metrics to assess performance:
   - Aggregating RNC data for successful and non-successful projects
   - Performing statistical analysis of differences
   - Determining applications of the new metrics

Information

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Sample:

23 industrial construction projects using the same IT support system

Collected data:

- 773 weeks
- Percent Plan Complete (PPC)
- Percent Constraints Removed (PCR)
- Over 4.000 Reasons for Non-Compliances (RNC)
- Results:
  - Schedule Performance Index (SPI)
  - Schedule Deviation (SD)

RNC information:

- % impact on each commitment
- Standardized type, source and origin:

Origin:
Internal
External

Source:
Contractor
Client
Third parties

Type:	
Planning	Supply
Coordination	Design
Productivity	Requirements
Manpower	Delivery

RNC Relevance = Frequency * Average Impact

Clustering

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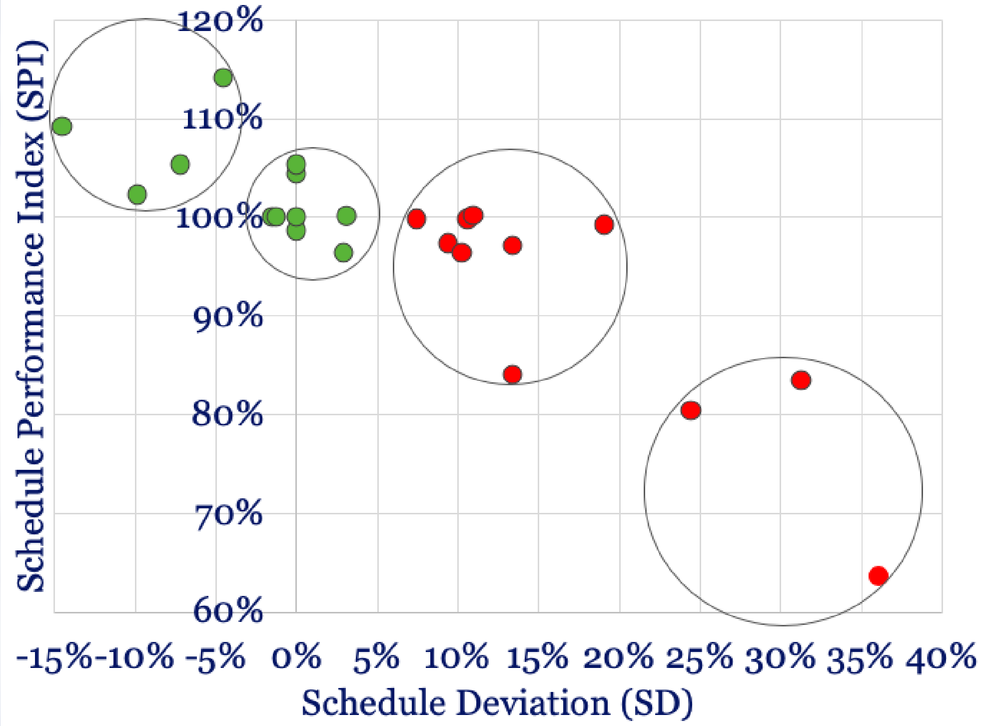
We used a recursive algorithm based on K-means, using the project SPI and SD as parameters.

- It minimizes the distance from each project to its cluster
- It maximizes the distance between cluster centers

We selected 4 clusters based on the algorithms results.

Classification rules represent the separation between the two center clusters

Success rule: SPI ≥ 96% and SD < 5%



Comparison of LPS metrics

We tested statistical differences between:

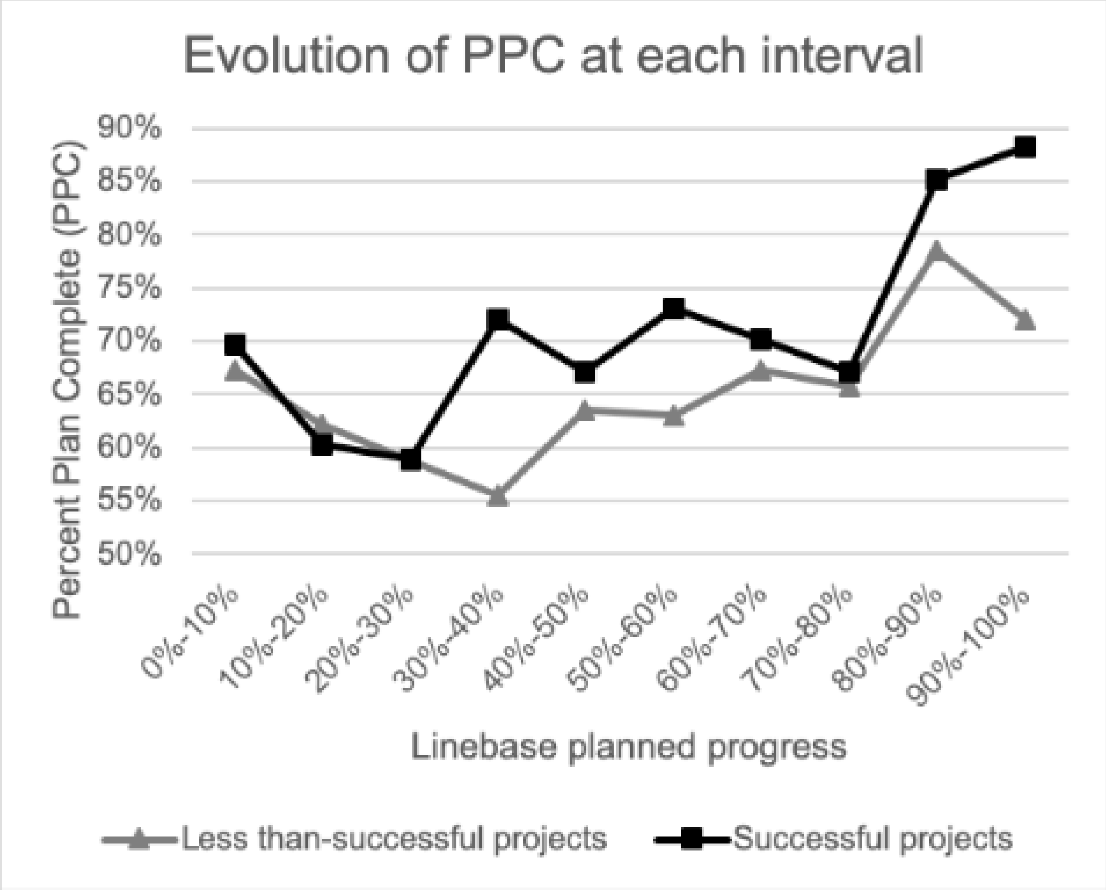
- final SPI and SD
- PPC Average
- PCR Average
- Total number of RNC
- Total number of Constraints
- Average number of constraints per period
- Constraints per period (Normalized per 100 tasks)

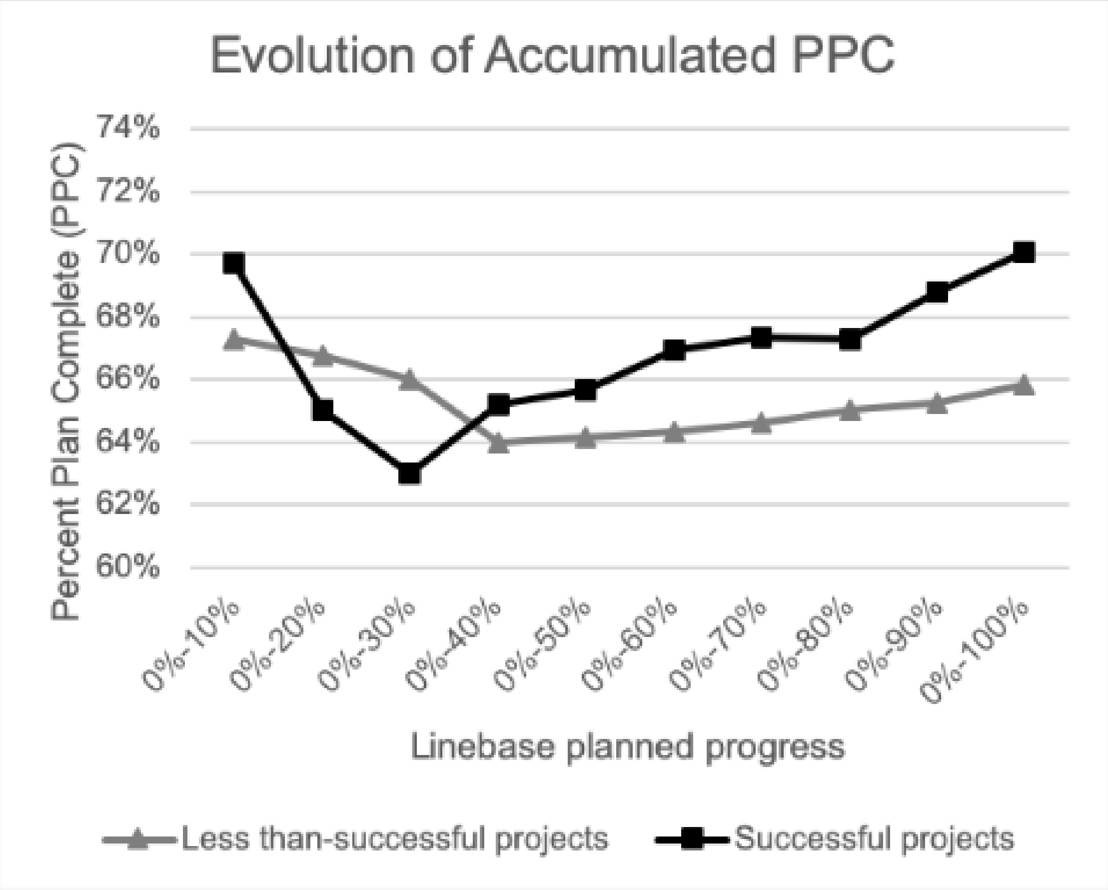
We used the Mann Withney's U test with a confidence level of 95% (p<0.05) to validate our results.

Group Means	Success	Failure	Ratio
Number of projects	12	11	
Final SPI	103%	91%	1,13**
Final DP	-3%	17%	-6,04**
PPC Average	71%	66%	1,06
PCR Average	60%	68%	0,88
Total number of RNC	169	194	0,87
Total number of constraints	394	242	1,63*
Number of constraints per period	13,8	10,1	1,37*
Constraints per period by 100 tasks	8,4	4,1	2,05*
*Significant to a 95% level	**Significant to a 99% level		

- No significant differences in PPC and PCR values
- No find significant differences in the total number of RNC
- Successful projects manage twice as many constraints per task

PPC evolution over time





PPC differences were not statistically significant at a 95% confidence level (p>0.05)

RNC Analyses by origin

Quantitative Relative Importance Index (QRII)

$$QRII = \frac{WR_i}{WR_{i..N}}$$

- Weighted Relevance (WR) = RNC Frequency * Average % Impact

RNC Indicators per group	Success	Failure	Difference Ratio
Percent of Internal RNC	39,80%	62,50%	1,57*
QRII Internal source	0,38	0,61	1,61*
QRII External source	0,62	0,39	0,63*
QRII ratio of internal to external causes	0,61	1,57	2,57**

*Difference is statistically significant to a 95% level **Difference is significant to a 99% level

RNC Analyses by source

Quantitative Relative Importance Index (QRII)

$$QRII = \frac{WR_i}{\overline{WR_{i..N}}}$$

- Weighted Relevance (WR) = RNC Frequency * Average % Impact

RNC Indicators per group	Success	Failure	Difference Ratio
Percent RNC caused by main contractor	37,81%	60,87%	1,61*
QRII Main contractor	0,54	0,92	1,70*
QRII Client	0,7	0,29	0,41*
QRII Third parties	0,27	0,28	1,04
Ratio of QRII Main Contractor to Client	0,77	3,2	4,16**

*Difference is statistically significant to a 95% level **Difference is significant to a 99% level

Correlations between RNC metrics and performance

We found two strong correlations and two moderate correlations

	Percent internal RNC	Percent RNC caused by the main contractor
SD	0,74*	0,77*
SPI	-0,47**	-0,53**
* r is considered strong if ≥0.6 and **moderate if between 0.59-0.4		

- If a higher percent of RNC originate from internal problems (controllable issues), lower Schedule Performance Index (SPI) and higher Schedule Deviation (SD) values can be expected
- Similarly, the percent of RNC caused by the main contractor is positively correlated to Schedule Deviation (SD) and negatively correlated to Schedule Performance Index
- Relationships are stronger using Schedule Deviation as the project success metric

Correlation between RNC source and Schedule Deviation (SD)

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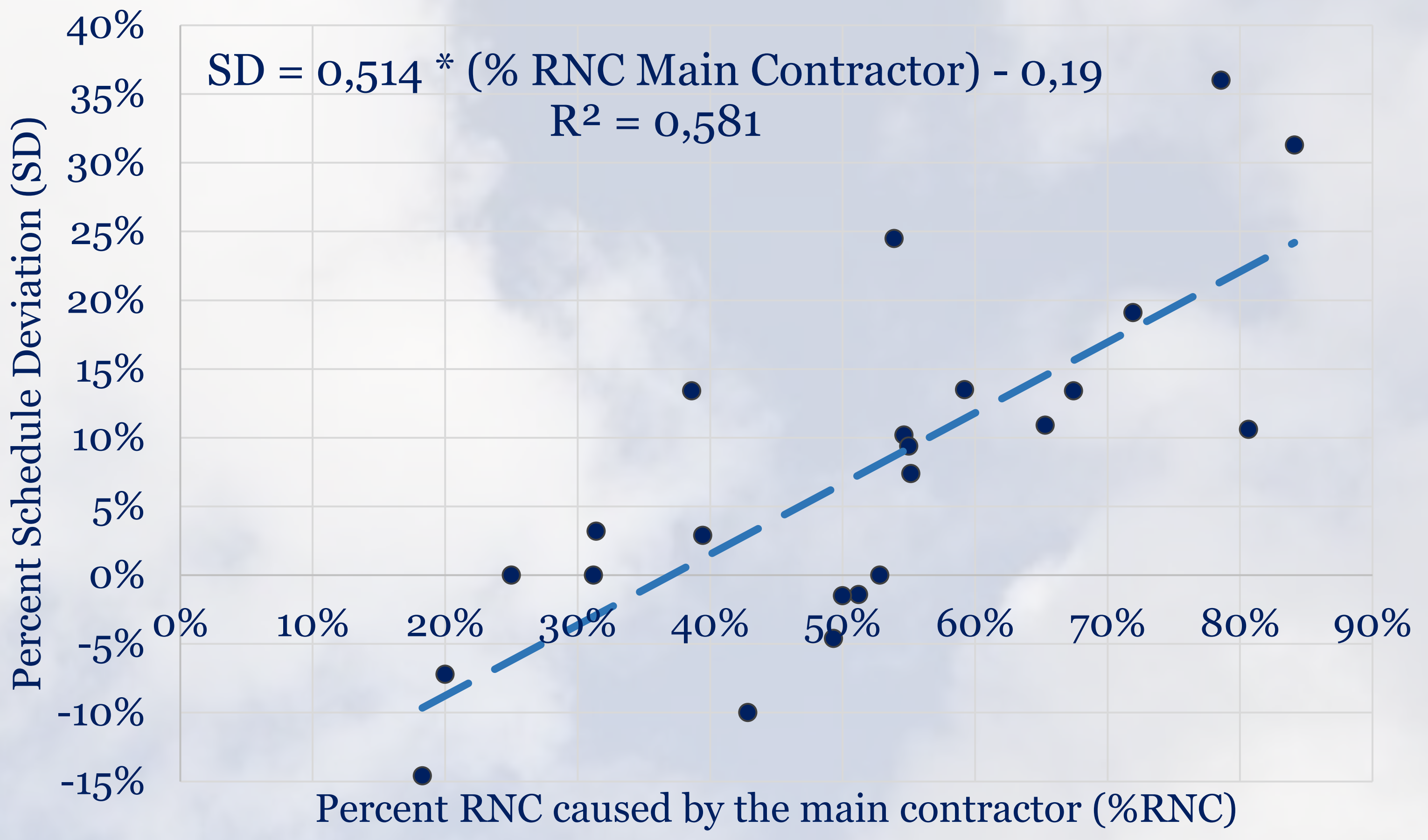
The expected Schedule Deviation (SD) is positively correlated to the proportion of RNC caused by the main contractor in industrial construction projects



Conclusions

- Correlation between RNC metrics and project performance
- RNC metrics can significantly differentiate successful and non-successful projects
- Differences found using RNC metrics are significantly higher than other LPS metrics

- Limitations:
  - Small sample (23 projects), using one IT support system and result classification is based on schedule performance
- Opportunities:
  - LPS metrics can be used to assess expected performance at early stages
  - Data Science tools like Machine Learning can be used to develop success rules
- Needs:
  - More quantitative research with larger samples