Seongkyun Cho and Glenn Ballard (2011) Last Planner and Integrated Project Delivery *Lean Construction Journal* 2011 pp 67-78 - Lean and Integrated Project Delivery Special issue www.leanconstructionjournal.org

Last Planner and Integrated Project Delivery

Seongkyun Cho[1] and Glenn Ballard[2]

Abstract

Research Questions: 1) Does the use of Last Planner (LP) improve project performance? 2) Does Integrated Project Delivery (IPD) show different project performance? 3) Do IPD projects use LP?

Purpose: The first objective is to figure out the relationship between IPD, LP, and project performance.

Research Method: survey of 'Lean' projects known to adopt LP, including IPD projects, to determine the correlation between LP implementation and Project performance (cost reduction + time reduction); and a T test between IPD and non-IPD projects.

Findings: 1) There is significant correlation between the degree of implementation of LP and project performance; 2) IPD projects do not show significantly different performance from that of others not adopting IPD; and 3) IPD projects do not show significantly different implementation of LP from that of others but their implementation is near to significance

Limitations: Limitations in sample size and data quality reduce the credibility of generalizations.

Implications: This exploratory research revealed interesting and important relationships between project structures and practices on the one hand and project performance on the other.

Value for practitioners: The findings from this paper can be used by industry practitioners to design project delivery systems for better performance.

Keywords: Integrated Project Delivery, Last Planner, Lean Construction, survey.

Paper type: Full paper.

Literature Review

According to the American Institute of Architects (AIA), the Integrated Project Delivery (IPD) contract form includes:

- Early involvement of Key participants;
- Shared risk and reward;

[1] PhD Candidate, Civil and Env. Engineering. Department, 407-A McLaughlin Hall, Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 510/725-7929, seongKyuncho@berKeley.edu

[2] Director, Project Production System Laboratory, http://p2sl.berKeley.edu, and Adjunct Associate Professor, Civil and Env. Engineering. Department, 215-A McLaughlin Hall, Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 415/710-5531, ballard@ce.berkeley.edu

- Multi party contract;
- Collaborative decision making and control;
- Liability waivers among key participants; and
- Jointly developed and validated project goals (Cohen et al., 2010).

Similarly, the National Association of State Facility Association (NASFA), Construction Owners Association of America, Association of Higher Education Facilities Officers, Associated General Contractors in America, and American Institute of Architects defined IPD as a project delivery system using a multi party contract that has more than two parties selected by qualification based procurement, managed/shared risk, compensation based on team performance without GMP, and open book accounting (NASFA et al 2010). According to CMAA, the purpose of IPD is to solve currently acknowledged problems in the construction industry such as low rates of productivity, high rates of inefficiency and rework, frequent disputes, excessive cost, and excessive duration--all caused by organizational, commercial, and operational problems in current project delivery systems (Thomsen et al., 2009)

The Last Planner (LP) is a production planning and control system implemented on construction projects to improve planning and production performance. It has four main processes:

- Master schedule;
- Phase schedule;
- Look ahead Plan; and
- Weekly Plan (Hamzeh, 2009).

Many researchers have proved reducing plan variability helps increase productivity, such as Liu et al (2008) suggesting a regression line[3] between plan reliability and productivity, and Alarcon et al (1997) showing difference in productivity before and after implementing LP. Again, the LP has been created to maximize reliability of the work/material/information flow to minimize waste in time/money in project processes and to maximize customer value (Ballard, 2000)

While IPD has tried to integrate project participants' roles and relations contractually in order to improve project outcomes, LP has enforced systematic production control reducing plan variability for the same purpose. Our question is if having project organization integrated by using contractual alignment, such as IPD, is enough to maximize desired outcomes, such as cost/time reduction. If it is not enough, our next concern is whether the implementation of LP can achieve those outcomes. To find out the answers to those questions, we did some hypothesis testing in this research.

Hypothesis testing regarding project performance based on a large number of projects is a well established methodology. For example, Choi (2008) used one way ANOVA (Analysis of Variance) to investigate if there is significant difference in schedule performance among three different contract types, selected from a government database of more than 1,700 projects. More similar to our research design, Sanvido et al (1998) made a survey questionnaire, sent it to 7600 projects, and got 378 responses on which they did multivariate t-test, chi square test, ANOVA, and regression to identify performance differences among three project delivery systems.

[3] Labour Productivity = 0.530 + 1.095*Weekly Plan Percent Completion

Research Design

Research Hypothesis

Our research assumption: project performance varies with Last Planner (LP) implementation. Based on this assumption, we diagnosed the degree of LP implemented in Integrated Project Delivery (IPD) projects to determine the correlation between LP implementation and IPD projects' performance. This assumption must be supported by general hypothesis testing. Thus, our first research hypothesis is:

> *If a project implements Last Planner (LP) more, it achieves better project performance better than those employing LP less.*

If the first hypothesis had not been supported, it would be meaningless to go further comparing IPD projects with others in terms of LP and our research would have been redirected to a qualitative exploration seeking what caused LP to fail. However, the first hypothesis was supported, making it meaningful to test the second and third hypothesis. The second hypothesis is:

> *If a project adopts Integrated Project Delivery (IPD), its performance is different from those of other projects.*

And the third hypothesis is:

> *If a project adopts IPD, its degree of implementation of Last Planner is different from those of other projects.*

This paper is devoted to the interpretation of the results from the first, the second and the third hypothesis testing.

Research Measurement

The first thing that we have to do after forming hypotheses is to specify the measurement of variables. We conceptualized our variables as shown in Figure 1, following Adcock et al (2001).

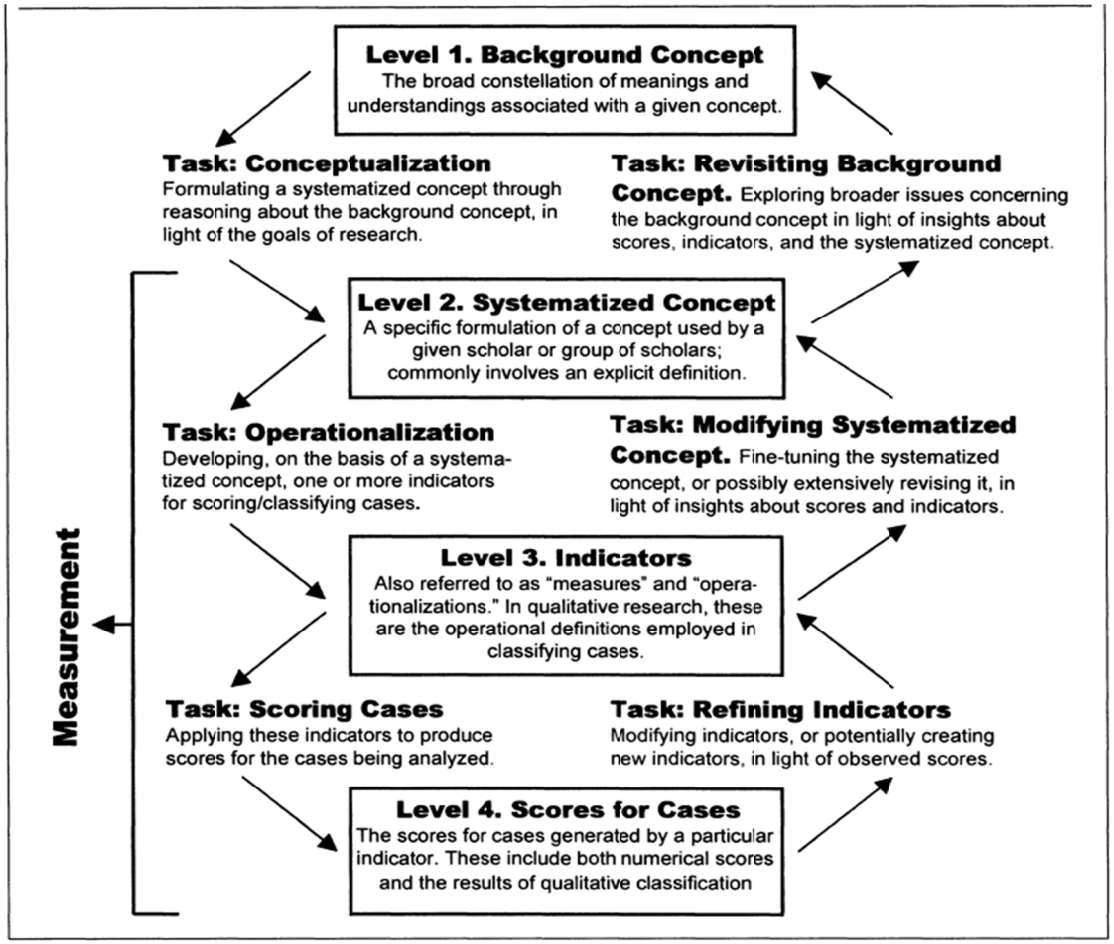

Figure 1: Conceptualization and measurement: Levels and task (Adcock et al., 2001)

We structured the variables in the hypotheses so they could be measured in the following parts.

The independent variable of the first hypothesis is the degree of implementation of Last Planner (LP). To measure this abstract concept, we developed indicators to be scored based on the following five elements:

1. ***Pulling production**: each worker investigates the readiness of the next workers (immediate customers) before execution of tasks (Tommelein, 1998)*
2. ***Lookahead process**: each front line supervisor removes constraints (prerequisite work, contractual approvals, sequential inappropriateness, insufficient resource as well as labour & equipment, inadequate duration, funding problem, problems found in first run study, etc) before execution of its tasks. Constrained tasks are not eligible for inclusion on daily or weekly work plans (Ballard, 2000)*
3. ***Learning from breakdowns**: failures to complete planned tasks are analyzed to root causes and actions are taken to prevent reoccurrence (Ballard, 2000)*

4 ***Phase scheduling**: every handoff in a phase should be defined by collaboration of all relevant specialists in the phase before the handoff is produced (Ballard et al., 2003)*

5 ***Distributed control**: Work is planned in greater detail as you get closer to execution, and planning is done collaboratively by those who are to do the work. (Ballard et al., 2003)*

The indicators in the box above are transformed into survey questions:

Table 2: Survey questions measuring Last Planner

#	Questions	Answer type & Scoring Rule
1	What percentage of specialty contractors participated in scheduling the project phase(s) in which they were to do their work?	Percentage ⇒ None: 1/6; 0-25%:2/6; 25-50%:3/6; 50-75%:4/6; 75-100%:5/6; and All: 1
2	To what extent was the principle followed that only work that was ready to be performed could be placed on a weekly work plan? Bear in mind that work is ready to be performed when all constraints are removed.	Frequency ⇒ Never: 1/5; Rarely: 2/5; Sometimes: 3/5; Often: 4/5; And Always: 1
3	To what extent was the principle followed that work should be done in response to a request from an immediate customer, such as the next trade?	Frequency ⇒ Never: 1/5; Rarely: 2/5; Sometimes: 3/5; Often: 4/5; And Always: 1
4	Did the project measure the extent to which you 'did what you said you were going to do?' (The measure is the percentage of weekly work plan tasks completed as planned. If there were 100 tasks on weekly work plans and 70 were completed as planned (no partial credit), the percentage would be 70%)	Yes/No ⇒ Yes: 1; and No: 1/6
5	How often were reasons for not completing planned tasks (on weekly work plan) analyzed to root causes and action taken to prevent reoccurrence?	Frequency ⇒ Never: 1/5; Rarely: 2/5; Sometimes: 3/5; Often: 4/5; And Always: 1

So far, we have specified the measurement of the independent variable in the first hypothesis. Next, we address the dependent variable of the same hypothesis, project performance. We decided to use the sum of cost reduction ratio (%) (actual cost under final approved budget) + duration reduction ratio (%) (actual duration relative to final approved schedule) as a measure of project performance because of the low probability of getting good data on other performance dimensions.

The dependent variable of the second hypothesis is the same as the dependent variable of the first hypothesis. The dependent variable of the third hypothesis is same as the independent variable of the first hypothesis. And the independent variable of the second hypothesis is the same as the independent variable of the third hypothesis. Thus, the last concept that we define is the independent variable of the second and the third hypothesis; i.e., to what extent a project adopts Integrated Project Delivery (IPD), or whether a project adopts IPD. We decided to take the binary variable, whether a project adopts IPD, as the type of this variable because we could not get enough IPD projects to measure the extent of implementation. In addition, it would be difficult for respondents to score the degree of adopting IPD structures if we had used continuous variables.

Hypothesis testing methodology

The hypothesis testing was performed differently according to the type of variable. The independent variable (degree of Last Planner implementation) of the first hypothesis is a quantitatively continuous ordinal variable because the sum of scores of the five questions in Table 2 is the total degree of Last Planner implementation of a project, represented as a real number. The dependent variable (cost reduction + time reduction) of the same hypothesis is a ratio variable represented as a real number. Thus, regression between the two variables is appropriate for testing the hypothesis. However, the independent variable of the second and the third hypothesis is a binary categorical variable, 'whether or not a project adopts IPD', for which regression analysis is not appropriate. In this case, we used a T-test, to determine whether the categorization (IPD or otherwise) has a significantly different influence on dependent variables: project performance in the second hypothesis, and the degree of implementation of Last Planner in the third hypothesis.

Sampling Strategy

In common sense, the most appropriate form of sampling to support a hypothesis is randomized sampling. However, Last Planner (LP) is a very specific tool for production control so that we need the very specific respondents who can determine the degree of LP implementation in their projects. Thus, we decided to use a purposive sampling taking advantage of e-mail lists in relevant groups such as general IGLC group in Yahoo[4], or participants in workshops such as those sponsored by the Project Production System Laboratory[5]. The same applies to selection of IPD projects. If we were to select projects randomly from anywhere in the world, very few, if any, IPD projects would be included. Purposive sampling is widely used in studying unusual critical cases. For example, it can be used effectively in identifying communities across the United States that have voted for the winner in the past, or it is used in selecting key informants for ethnographic studies such as one describing gangster's lives (Bernard, 2000)

Results

Regression model from testing the first hypothesis

There is a significant correlation between the implementation of Last Planner (LP) and project performance—the sum of cost and schedule reduction percentages. That means we have successfully supported the first hypothesis. This is represented as a regression model in Table 3 in the Appendix.

Figure 2 is a graphical representation including scatter plotting and a linear regression line. Even though we used a straight line, the scatter plot seems to show a curve is more appropriate in describing behaviour of variables. Thus, we tried several linear regressions, whose independent variables are 'square of independent variable (X) in Figure 2' or X^2 and 'cube of X' or X^3

The result is encouraging. The regression model with 'square of X' or X^2 is 'Y(Sum of cost reduction and time reduction) = $0.7371101 \times X^2 - 3.89088$' with its $P<|t(2.98)|$ is 0.005,

[4] http://finance.dir.groups.yahoo.com/group/iglc/message/677
[5] http://p2sl.berkeley.edu/

which is less than 0.009, the P<|t(2.71)| in Table 3 with mere X. The less p value of t (P<|t|) means there is greater significance in the coefficient of the regression line. Furthermore, the regression model with X^3 is 'Y = 0.1484254×X^3-1.617307' with its p value of t is 0.004, which is less than 0.005 in the regression model with X^2. But, X to the fourth does not show more significance than X^3.

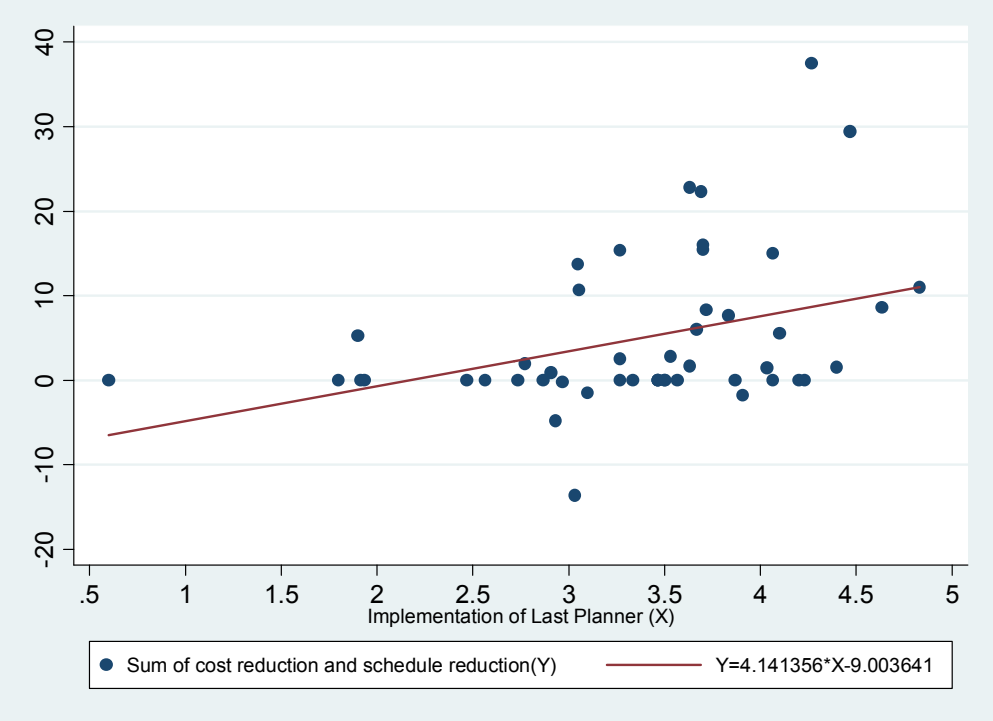

Figure 2: Regression of Last Planner on Project Performance

The final regression line with X cubed, saying that the project performance is proportionate to the degree of Last Planner's implementation cubed, is visually represented as blue diamond type plots in Figure 3. We decided to call it 'Cho-Ballard curve', which shows that Project Performance (sum of cost reduction and schedule reduction) = 0.1484254 ×(Implementation of Last Planner)^3-1.617307.

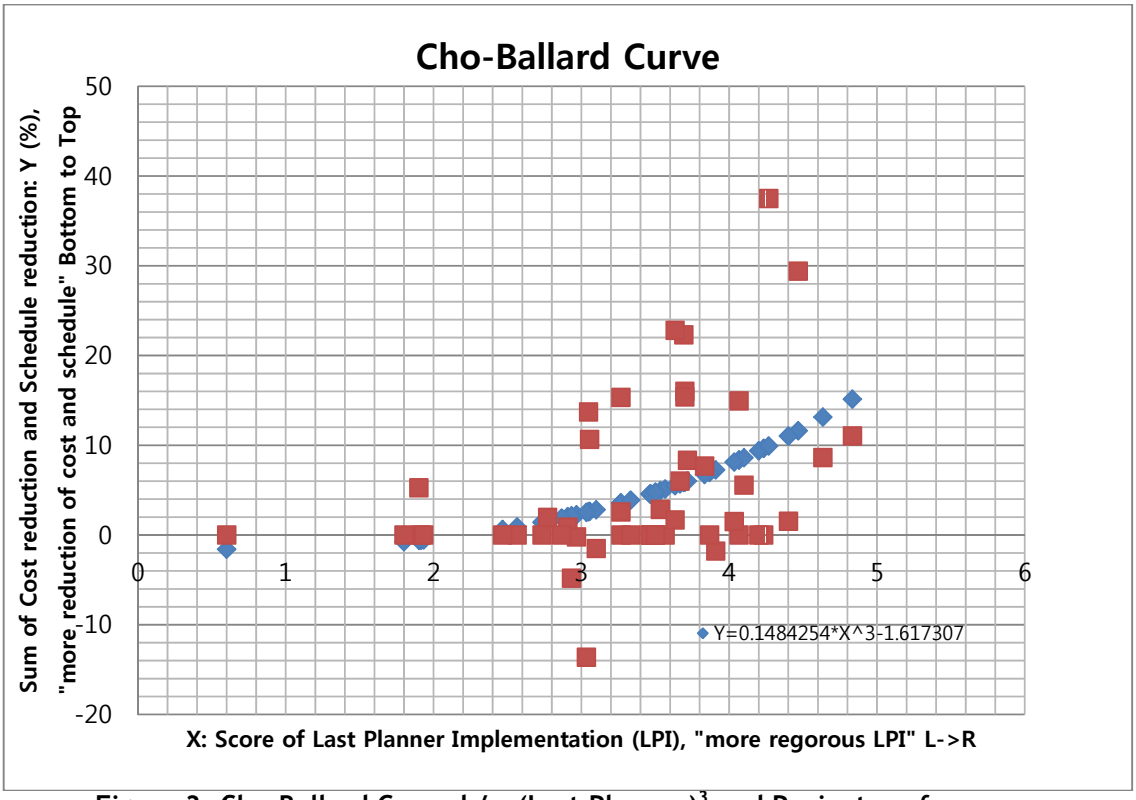

Figure 3: Cho-Ballard Curve b/w (Last Planner)[3] and Project performance

Summary of Hypothesis testing[6]

The following box summarizes the results of hypothesis testing so far.

Hypothesis 1

If a project implements Last Planner (LP) more, it achieves project performance better than those employing LP less

=> Strongly supported by the regression model: Project Performance (sum of cost reduction and schedule reduction) = 0.1484254 × (Implementation of Last Planner)^3-1.617307

Hypothesis 2

If a project adopts Integrated Project Delivery (IPD), its performance is different from those of other projects.

=> Failed to be supported definitively

Hypothesis 3

If a project adopts IPD, its degree of implementation of LP is different from those of other projects.

=> Failed to be supported. However, IPD projects in our sample implemented LP to a certain degree even though the level is not significant statistically.

[6] For detail of hypothesis testing, please see Appendix

Conclusion

We found in this research that project performance improves with the implementation of Last Planner. However, we did not find a strong relationship among Last Planner, Project Performance, and Integrated Project Delivery (IPD).

This research does not prevent us from believing that if IPD, aligning goals of participants, and LP, reducing project variability, are combined, any project can achieve better performance. Indeed, this is the claim put forward by Lean Construction adherents, criticizing forms of IPD that rely only on alignment of commercial interests and organizational integration, while neglecting the lean 'operating system', which addresses how the work is actually done. Future research is needed to validate this claim.

Appendix

Detail of the first hypothesis testing

Table 3 is the result produced by STATA v.10, a statistics package, using data from the 49 projects. Simply, we need to see the 'coefficient', written on the right side of 'Y in Figure 2' in Table 3. This is the gradient of the regression line. Y is 'sum of cost reduction and duration reduction' and X is 'the degree of implementation of Last Planner'. The significance of this coefficient is determined by P > |t|, 0.009 (red-underlined number in Table 3). Usually, if P>|t| is less than 0.05, we can say this coefficient (the regression model) is significant. In our case, the regression model is Y=4.141356×X-9.003641

Table 3: Result of Regression for the first hypothesis

Source	SS	DF	MS	Number of object = 49	
Model	543.294059	1	543.294059	F(1, 47) = 7.36	
Residual	3467.23372	47	73.7709302	Probability > F = 0.0093	
Total	4010.52778	48	83.552662	R-squared = 0.1355	
				Adjusted R-squared = 0.1171	
				Root Mean Square Error = 8.859	
Y in Figure2	Coefficient	Std Errors	T	P>|t|	95% confidence Interval
X in Figure2	4.141356	1.526046	2.71	0.009	1.071347 7.211366
Constant	-9.003641	5.279548	-1.77	0.095	-19.62472 1.61744

Detail of the second hypothesis testing

The second hypothesis is < If a project adopts Integrated Project Delivery (IPD), its performance is different from those of other projects>. Before T test, we needed to see if the two groups (IPD and Non IPD) have significantly different variance in project performance because general T test is performed based on equal variance. If not, T test should be performed under the unequal variance condition. Table 4 is the variance ratio test, named as "sdtest" in STATA v.10. The f value stands for the ratio between the variance of IPD and that of Non IPD, which is expressed as 'Ratio' in Table 4. When the probability, expressed as p (F<f), p (|F|>|f|), and p (F>f) in Table 4, is less than 0.05, the alternative hypothesis, located right above the probability, is chosen. In this test, the

target alternative hypothesis is Ha: ratio!=1. The probability right under the alternative hypothesis is 0.0843, which is bigger than but near to 0.05 so that we came to decide to do another T test with unequal variance for more assurance

Table 4: Variance Ratio Test on performance between IPD and otherwise

Group	Obs.	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Non IPD	40	5.105027	1.55351	9.825258	1.962757	8.247297
IPD	9	4.160776	1.822258	5.466773	-.0413577	8.362909
Combined	49	4.931593	1.305816	9.140715	2.306073	7.557113
Ratio = standard deviation (Non IPD)/standard deviation (IPD) Null hypothesis: Ratio =1					f = 3.2302 degrees of freedom = 39 (=40-1), 8 (=9-1)	
Alternative Hypothesis (Ha): ratio <1 Probability: p (F<f)=0.9578			Ha: ratio !=1 2*p (F>f) = 0.0843		Ha: Ratio > 1 P (F > f) = 0.0422	

Table 5 is the result of T-test with equal variance of STATA v.10. The 't' value stands for 'the remainder of the Performance mean of Non IPD after subtracted by the Mean of IPD', which is expressed as 'Difference' in Table 5. When a probability, expressed as p (T<t), p (|T|>|t|), and p (T>t) in Table 5, is less than 0.05, the alternative hypothesis, located right above the probability, is chosen. In our case, the target alternative hypothesis is Ha: Difference!= 0, a different expression but one having the same meaning as that of our second hypothesis. p (|T| >|t|) right below the alternative hypothesis, Ha: Difference!=0, is 0.7828, much bigger than 0.05 so that we cannot choose the alternative hypothesis, our second hypothesis

Table 5: T-test with equal variance on performance between IPD and Non IPD

Group	**Obs.**	**Mean**	**Std. Err.**	**Std. Dev.**	**[95% Conf. Interval]**	
Non IPD	40	5.105027	1.55351	9.825258	1.962757	8.247297
IPD	9	4.160776	1.822258	5.466773	-.0413557	8.362909
Combined	49	4.931593	1.305816	9.140715	2.306073	7.557113
Difference		.6551067	3.15756		-5.906144	7.794646
Difference = Mean (Non IPD)-Mean (IPD) Null hypothesis: Difference = 0					t = 0.2773 degrees of freedom = 47	
Alternative Hypothesis (Ha): Difference < 0 Probability: p (T<t)=0.6086			Ha: Difference !=0 p (|T|>|t|) = 0.7828		Ha: Difference > 0 P (T > t) = 0.3914	

As we mentioned, we did another T – test with unequal variance, whose result is similar to that of equal variance. Unequal T test says the probability p (|T|>|t|) is 0.6972, much bigger than 0.05.

Detail of the third hypothesis testing

The third hypothesis is <If a project adopts IPD, its degree of implementation of Last Planner (LP) is different from those of other projects> The variance test said there is no significant difference between the variance of the two groups (IPD and Non IPD) in LP implementation by showing the probability, used in determining whether to choose the alternative hypothesis (standard deviations of the two groups are different), is 0.1948,

bigger than 0.05.

Table 6 shows the result of t test with equal variance in testing our third hypothesis. Similar to Table 5, if a probability right under the alternative hypothesis, represented as p (T<t), p (|T|>|t|), and p (T>t), is less than 0.05, we can choose the alternative hypothesis, located right above the probability. Our alternative hypothesis is 'Difference (between means of IPD and Non IPD)!=0', a different expression but one having the same meaning as that of our third hypothesis. Even though P (|T| >|t|), 0.074 is bigger than 0.05, it is not clear for us whether to discard our third hypothesis. As for second hypothesis, it is clear in that the probability, P (T<t), is 0.7828, much bigger than 0.05. But, the third hypothesis is at the border. In short, even though Integrated Project Delivery projects do not show implementation of Last Planner significantly different from otherwise, it seems to employ Last Planner to a certain degree

Table 6: T-test with equal variance on performance between IPD and Non IPD

Group	Obs.	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non IPD	40	3.266667	.1321312	.8356714	2.999406	3.53927
IPD	9	3.801471	.1802989	.5408968	3.385701	4.217242
Combined	49	3.364896	.116053	.8123707	3.131556	3.598236
Difference		-.5348048	.2926632		-1.123567	.0539576
Difference = Mean (Non IPD)-Mean (IPD) Null hypothesis: Difference = 0					t = -1.8274 degrees of freedom = 47	
Alternative Hypothesis (Ha): Difference <0 Probability: p (T<t)=0.0370			Ha: Difference !=0 p (|T|>|t|) = 0.0740		Ha: Difference > 0 P (T > t) = 0.9630	

References

Adcock, R., and Collier, D. (2001). Measurement validity: A shared standard for qualitative and quantitative research. *American Political Science Review, 95(3)*.

Alarcon, L. F., and Cruz, J. C. (1997). "The impact of project planning and Performance on project outcomes", *Tenth World Productivity Congress*. Santiago, Chile, October

Arbulu, R., Tommelein, I., Walsh, K., and Hershauer, J. (2002). "Contributors to Lead time in Construction Supply Chains: Case of Pipe Supports used in power Plants." *Proceedings of the 2002 Winter Simulation Conference*. Sandiego, CA, USA, Dec 8-11

Ballard, G. (2000). "The last planner system of production control" PhD. Diss. School of Civil Eng., Univ. of Birmingham, UK. Available at www.leanconstruction.org (26 Mar 2010)

Ballard, G. (2006). "Rethinking project definition in terms of target costing". *Proceedings of the 16th annual conference*, International Group for Lean Construction, Santiago, Chile.

Ballard, G. (2008). "LPDS Update". *Lean construction journal*, 2008, pp. 1-19.

Ballard, G., Iris Tommelein, Lauri Koskela, and Greg Howel (2002). "Lean Construction Tools and Techniques", In Rick Best and Gerard De Valenche (Eds), *Design and Construction building in Value*. Woburn, MA: Elsevier Science. Pp. 227-255

Ballard, G., and Howell, G. (2003). "An update on last planner." *Proceedings of the IGLC 11th* , BlacKsburg, VA, USA, July 2003, pp. 329-341.

Ballard, G and Gregory A. Howell (2004). "Competing Construction Management Paradigms", *Lean Construction Journal*, 1(1)38-45.

Bernard, R. (2000). The social research methods-qualitative and quantitative approaches. CA: Sage publication.

Cho, Seongkyun and Ballard, G. (2010), *building and argument with hypothesis testing, proceedings IGLC-18,* July 2010, Technion, Haifa, Israel

Choi, Kunhee (2008). "A new Decision Support Model for Innovative Contracting Strategies through a Quantitative Analysis on Aspects of Project Performance" PhD. Diss. Civil and Environmental Eng., Univ. of California, Berkeley. CA, USA.

Chuck Thomson, Joel Darrington, Dennis Dunne, and Will Lichtig (2009). *Managing Integrated Project Delivery.* Construction Management Association of America. Available at http://cmaanet.org/files/shared/ng_Integrated_Project_Delivery__11-19-09__2_.pdf (9 Jan 2011)

Cohen, Jonathan and FAIA (2010). *Integrated Project Delivery: Case studies.* American Institute of Architects California Council, Sacramento, CA, USA.

Hamzeh, Farook, R. (2009). "Improving Construction Workflow-the role of Production Planning and Control" PhD. Diss. Civil and Environmental Eng. Univ. of California, Berkeley, CA, USA.

Lieberman.E. (2005). Nested analysis as a mixed method strategy for comparative research. *American Political Science review, 99(3)*

Liu, M., and Ballard, G. (2008). "Improving Labor Productivity Through Production Control." *Proc 16th Ann. Conf. Int'l Group of Lean Constr., IGLC 16,* 16-18 July, Manchester, UK.

National Association of State Facility Association (NASFA), Construction Owners Association of America, Association of Higher Education Facilities Officers, Associated General Contractors in America, and American Institutes of Architects (2010). "Integrated Project Delivery for Public and Private Owners" Available at http://www.agc.org/galleries/projectd/IPD%20for%20Public%20and%20Private%20Owners.pdf (10 Jan 2010)

Sanvido, Victor, and Konchar, Mark (1998). *Project Delivery Systems: CM at Risk, Design-Build, and Design-Bid-Build.* Construction Industry Institute Design Build Research Team 133, Austin, Texas, USA.