A SEMINAL CASE STUDY ON APPLICATION OF LAST PLANNER SYSTEM WITH CASH FLOW DATA FOR IMPROVEMENTS IN CONSTRUCTION MANAGEMENT PRACTICES

A Thesis

by

NISHI LAGOO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2012

Major Subject: Construction Management

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Approved by:

Chair of Committee:	José L. Fernández-Solís
Committee Members:	Zofia Rybkowski
	Rodney Hill
Head of Department:	Joseph Horlen

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ABSTRACT

A Seminal Case Study on Application of Last Planner System with Cash Flow Data for Improvements in Construction Management Practices.

(May 2012)

Nishi Lagoo, B. Arch., Rajiv Gandhi Technical University

Chair of Advisory Committee: Dr. José L. Fernández-Solís

A major challenge faced by project managers is balancing the variables of scope, cost, and schedule. Changes in scope usually result in cost/schedule overruns. Variance in either or both of them creates disorder (typically increases) in the estimated or projected time and cost. Therefore, controlling cost and schedule are two of the most critical aspects of a construction project. This research uses two already existing management theories, specifically Management by Means (MBM) and Management by Results (MBR), and analyzes a case where these two theories are combined with the goal of improving construction practices.

This research compares an eight month schedule in a construction project and relates Percentage of Planned activities Completed (PPC) with projected and actual draw (cash) calls. The research analyzes the question of how lean construction PPC captures variance in cost. The research method is based on a literature review, data collection, case study and data interpretation to answer the hypothesis that improvement in PPC over a particular month has a positive correlation with difference between cash calls. Because this research is limited to a time frame of 8 months in a single project, it is not

statistically significant. However, this research serves to create a model template or pilot study for a larger study.

DEDICATION

To my family, friends and guides

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. José L. Fernández-Solís and my committee members, Dr. Zofia Rybkowski and Dr. Rodney Hill, for their guidance and support throughout the course of this research.

I also want to thank my friends and colleagues, the department faculty and staff for making my time at Texas A&M University a great experience. In addition, I want to extend my gratitude to Linbeck LLC and Mr. Brian Dupre, for providing the data required for the research.

Finally, thanks to my parents and my sister for their encouragement and love.

NOMENCLATURE

ABC	Activity Based Costing
ACWP	Actual cost of work performed
ADC	Actual Draw calls (also called actual monthly billing)
ASCE	American Society of Civil Engineering
BAC	Budgeted cost at completion
BCWP	Budgeted cost of work performed
BCWS	Budgeted cost of work scheduled
CPI	Cost Performance Index
CV	Cost Variance
EVM	Earned Value Management
GMP	Guaranteed Maximum Price
IGLC	International Group of Lean Construction
JIT	Just in time
LCI	Lean Construction Institute
LPS™	Last Planner System
MBM	Management by Means
MBR	Management by Results
PDC	Projected Draw calls (also called projected monthly billing)
PPC	Percent Planned Complete
RBC	Resource Based Costing

SPI	Schedule Performance Index
SV	Schedule Variance
TAMU	Texas A & M University
VSM	Value stream mapping

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1. INTRODUCTION

Construction is an extremely complicated field with a high degree of unpredictability in every task, time and condition (Allen and Iano 2004) when compared to other industries. Thus, the coordination and supervision of the construction process from inception to completion, while making certain that the project is completed on schedule and within budget, is both a science and art. According to Warburtan (2011), any project consists of major constraints based on its scope, cost, and schedule. Coordinating these constraints is the major challenge faced by construction management.

Construction managers tend to determine the best way to execute the task of coordination and supervision with the most cost-effective plan and schedule. This is typically done in a command and control top-down setting also called a “push schedule” (Xiong and Nyberg 2000). Another theory, chaos theory, indicates that minor changes in the project typically have major schedule and cost implications and activating any corrective adjustment late into the project is often ineffective and expensive (Sterman 1992). In addition, the later the remedial action, the less is the ability to influence the project outcomes (Nepal et al. 2006). Along with the traditional goals of schedule and budget, factors like client satisfaction and total quality delivery of product and services makes any project successful or unsuccessful.

Hence, special attention to continuously track and revise the variances in either or both schedule and cost aids in avoiding escalating disorder in the estimated or

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This thesis follows the style of *Journal of Construction Engineering and Management.*

projected time and cost. This leads to evaluation and restructuring of control theories and practices in construction project management for the successful execution of a project. Typically, theories and practices are observed and evaluated through case studies and surveys (Kim and Ballard 2010).

It has been argued that improvement in practice cannot be achieved without improved theory (Koskela and Vrijhoef 2000). Explanations of observed behavior and its contribution in understanding as well as predicting future behavior can be obtained through theory (Koskela and Howell 2002). Typically implementation of theories acts as source for the advancement of analyzing, designing, and controlling tools.

This research focuses on establishing a clear categorization of two different management theories, namely Management by Results (MBR) and Management by Means (MBM). The research employs a case study where these two theories can be combined for improved construction practices (see Fig. 1).

Management by Results, as the name itself suggests, is a target oriented management principle. In MBR, all of the processes, products and services contribute to the accomplishment of desired goals. Management or the organization focuses primarily on financial outcomes and their relationship with the schedule. Management by Means, on the other hand, is a new philosophy that focuses on resources, rather than finances, to achieve long term success through improvement in process, methods, approaches and their interrelations. These two generalized terms incorporate two principles of Earned

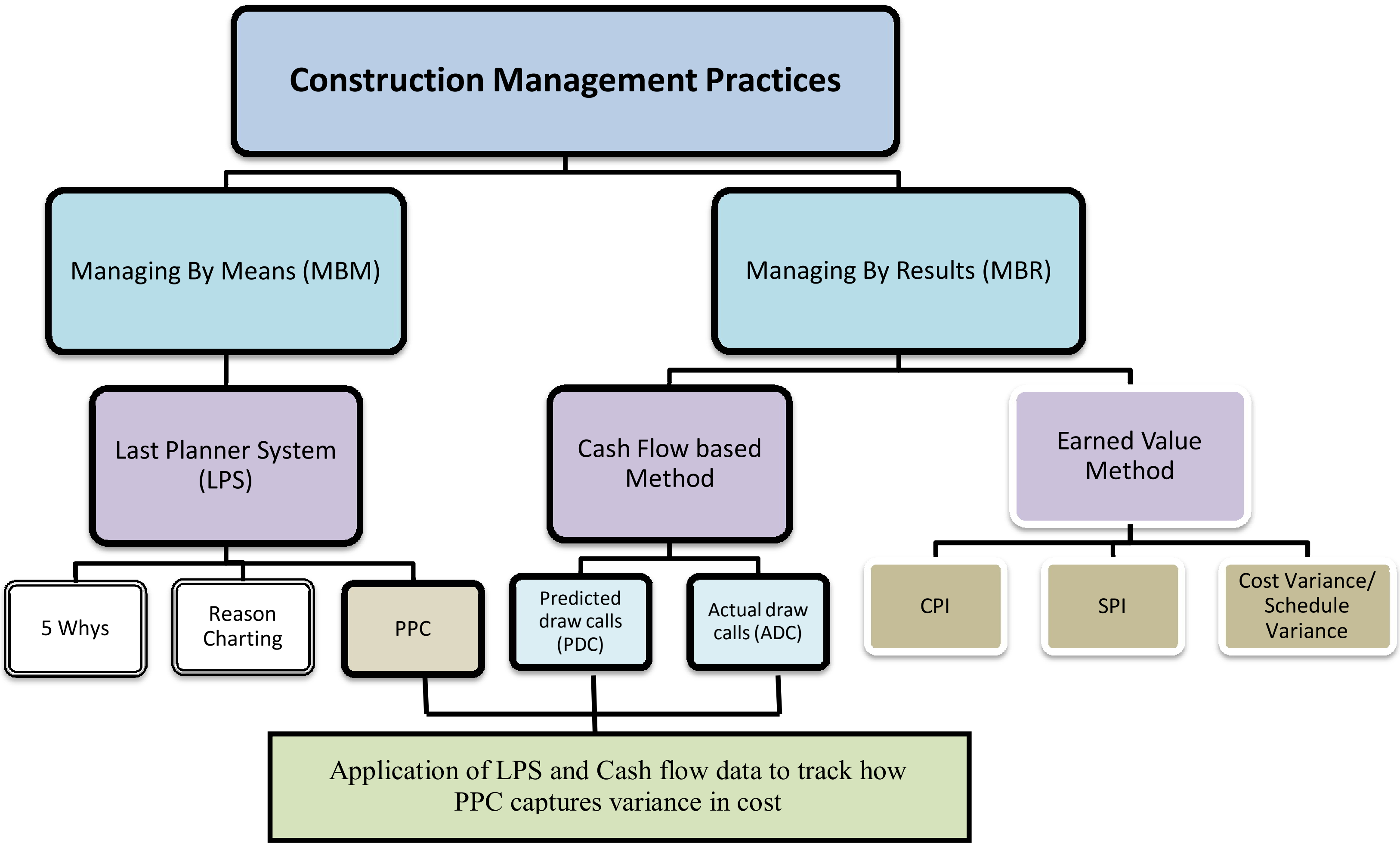


Figure 1 Thesis logic chart showing flow of the research and topic selection.

Value Management (EVM) and Last Planner System (LPS) (Johnson and Broms 2000) respectively.

EVM is a project management technique that measures both performance and progress of the project as an objective approach. It has the ability to unite the triple constraints of scope, time and cost, as quoted by Warburtan (2011), whereas Last Planner System uses flexible production planning procedures from the bottom up, in contrast to the standard top-down management principle. It tracks promise fulfillments made to deliver production as an element to keep the production environment stable (Ballard and Howell 1994).

Although the literature shows significant evidence that some managers implement a micro-MBR management tool by assigning and tracking costs on each weekly assignment with Last Planner System, it is rare to find a project that uses both systems simultaneously (Kim and Ballard 2010). Since a current project that uses both theoretical practices was not available; an alternate approach is created that takes cash flow into account rather than directly using the EVM system. This new approach compares an eight month schedule in a construction project and establishes relationships between different combinations of variables: Percentage of Planned activities Completed (PPC), Projected Draw Calls (PDC) and Actual Draw Calls (ADC). The research analyzes the question of how lean construction PPC captures variance in cost. This is done through multivariate analysis in which variables with strong correlations are identified.

The research is based on the hypothesis that improvement in PPC over a particular month has a positive correlation with differences between PDC and ADCs. Based on this hypothesis, listed below are two expected findings:

- Improvements in PPC also improve the budget of the project.
- The outcomes are explained and summarized through cross matrix where the first variable is difference between PDC and ADC, and the second variable is improvement in PPC.

This research uses data from a $43 million, 600-bed north side residence hall at Texas A&M University, which is being built by Linbeck LLC. The data was provided by the project manager. Since the financial data received each month is billed for the work performed in the previous month, a shift was made to correlate the available fiscal data with its corresponding PPC information for the same month. For example, a billing amount in December is actually for the work performed in November. Therefore, while comparing the PPC with the cash flow data, PPC of November is compared with billing data in December.

Similarly, following are other limitations and delimitations in the research:

- The research paper is confined to only one case study.
- The research data collection time frame is 8 months.
- This pilot study cannot be construed to provide statistically significant data.
- There appears to be a lag and lack of direct correlation between financial data and Last Planner System data.

This pilot study provides a framework that may be replicated in the future to achieve statistically significant results.

2. LITERATURE REVIEW

2.1 Background

This literature review identifies theories behind construction management practices, planning strategies, execution and planning tools used mostly during the preconstruction and construction planning and execution stages. The literature search is based on different search engine results for relevant data sources, keywords, and management practices as applicable to construction projects.

Initially, a wide-ranging topic was selected to gain a wider perspective of construction management theories, principles and tools. Certain recurring words, most cited authors and practices were noted. These frequent recurrences were noted as keywords leading to a defined literature survey. A wide ranging database was created for the literature search that provided access to reputable publications like *Journal of Construction Engineering and Management*, *International Journal of Project Management*, *Conference Proceedings of the Annual Conferences of the International Group of Lean Construction (IGLC), Lean Construction Journal (LCI), Conference Proceedings of the Construction Congress of the American Society of Civil Engineering (ASCE),* etc.

The literature argues that improvement in practice cannot be achieved without improved theory (Koskela and Vrijhoef 2000). A theory helps in understanding observed behavior and predicting future behavior (Koskela and Howell 2002). A theory also provides a basis for the development of tools for analyzing, designing, and controlling.

However, it is argued that construction does not have an explicit theory (Koskela and Howell 2002).Theories that are strong in their base and at the same time can be easily applied to construction practices need to be established. According to Kim and Ballard (2010), the construction industry has neglected management theories, and activating any adjustment late into a project is often ineffective and expensive (Sterman 1992). According to Nepal et al. (2006), the later the corrective action, the less the ability to influence a project's outcomes.

Therefore, literature that supports existing theories and validates them through case studies and surveys was selected. This effort led to a holistic relation between construction theories and their practices. Similarly, this literature survey is first applied to record management principles prevalent in the construction industry. Second, it establishes a relation between these theories of management and third, it validates the benefits from applying both theories in practice.

2.2 Management principles prevalent in construction industry

Theories of Management by Results (MBR) and Management by Means (MBM) are recent theories that are continually compared, sparking arguments about selecting the better of the two. Consequently, there are few proposals that advocate applying both management theories for improvements in management strategies that would ensure a project that is on schedule and within budget (Kim and Ballard 2010).These theories will be discussed in detail later in the research to establish the basis of selecting the research topic.

2.2.1 *Management by Results (MBR)*

As the name itself suggests, MBR focuses on results or goals as its management principle. In order to achieve these project goals, a definite ability for attainment of results, systematic supervision, self-assessment and progress reporting is vital. Nevertheless, project control based on MBR is sometimes believed to be inept for managing highly interdependent tasks at the operational level. As proposed by Drucker (1954), MBR does not have an elaborated theory. This approach motivates managers to amalgamate their efforts by setting goals for the organization as a whole (Antoni 2005).

This popular management system is followed in the majority of organizations where the target is set on bottom line goals and intangible indicators like financial records (Johnson 2000). In this kind of theory, management concentrates only on factors like profits and loss. It has been observed that application of MBR is valuable for short term goals where the stakes are low (Johnson 2000).

This system tracks the status and progress of a project while predicting the likely future performance. This generalized term incorporates the principle of Earned Value Management System (EVM) (see Fig. 2). Earned Value Management (EVM) is a project control technique. It provides a quantitative measure of work performance on a reporting date (Fleming 1983). Good planning, in addition to effective use of the EVM technique, can reduce a significant amount of issues caused due to schedule and cost overruns (Kim and Ballard 2010). Thus, tracking the predicted schedule and cost should be carefully directed to keep the project on schedule and within budget.

EVM consists of three primary elements (Hinze 2008), for example:

(i) Basic element

a. BCWS: Budgeted cost of work scheduled
b. BCWP: Budgeted cost of work performed
c. BAC: Budgeted cost at completion
d. ACWP : Actual cost of work performed

Once these basic elements are known, calculations for resultant variables are performed. These include,

(ii) Cost Variance

a. Cost Variance (CV) = BCWP- ACWP
b. CV % = (CV/BCWP)X 100

(iii) Schedule Variance

a. Schedule Variance (SV) = BCWP- BCWS
b. SV % = (SV/BCWS)X100

Calculations for PPC and actual and projected cash calls are fundamental, but the EVM calculations need critical attention. After these calculations, Cost Performance Index (CPI) and Schedule Performance Index (SPI) are calculated by the formula:

a. CPI = BCWP/ACWP

If, CPI >= 1 (project is within/under budget)

b. SPI = BCWP/BCWS

SPI >= 1 (project is on/ahead of the schedule)

The values of SPI and CPI indicate whether the project is on schedule and within the budget or vice versa.

EVM is considered a highly developed technique for integrating schedule and cost (Kim and Ballard 2000), yet it is still susceptible to distortions. Listed are a few limitations of EVM systems:

- One limitation is rooted in the assumption that one earned hour equivalent to another, and the productivity of one activity does not affect the performance of another, even if they are mutually dependent.
- The graphical representation of outcomes simply indicates variance between the amount to be spent in spite of progress and the actual expense (Kim and Ballard 2000).
- It lacks a provision to measure quality and customer satisfaction; hence, if EVM indicates a project to be under or on budget, ahead of schedule and fully executed scope, it does not mean that the client is happy.
- The schedule variance, SV, does not indicate its statistical implications, but is in fact a difference in schedule. Further, the SV unit is in dollars (rather than weeks or

months), making it difficult to determine units for the schedule (Cioffi 2006).

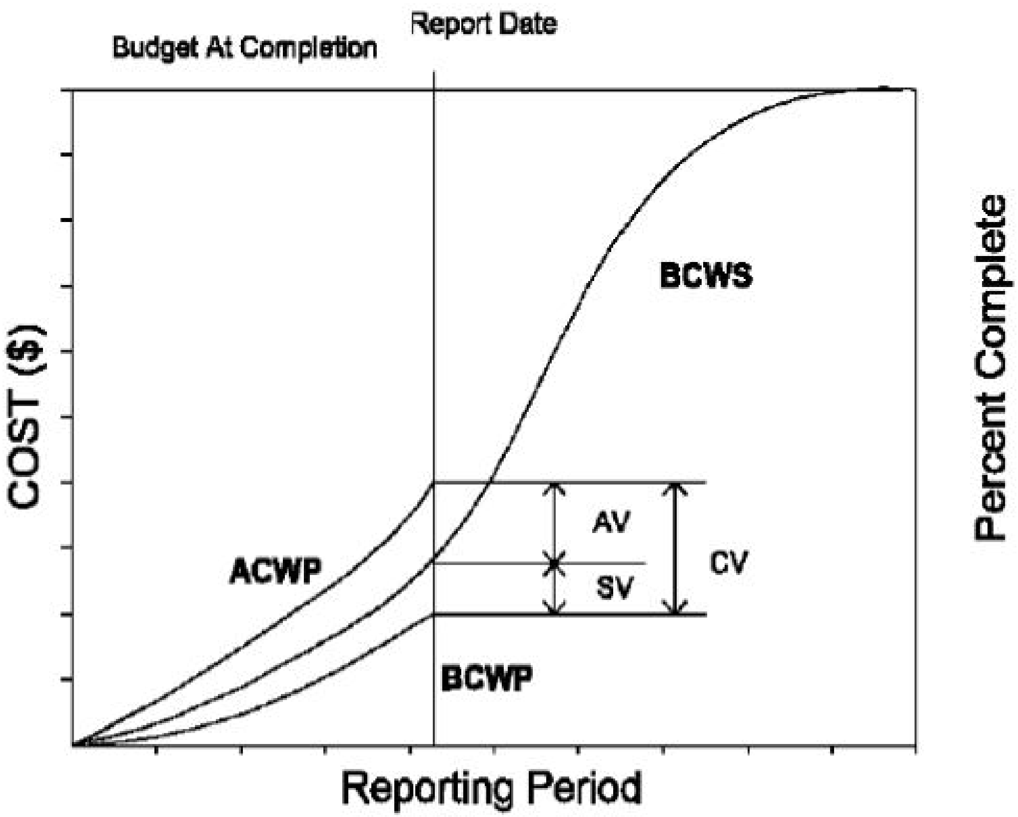


Figure 2 Variance Analysis for EVM curve (Kim and Ballard 2000)

Most management approaches focus on peripheral domains like structures-processes-outcomes, leading to management approaches and tools which are less sustainable (Pavez et al. 2010). The reason behind this is the lack of importance attached to internal factors like people and their interests, personalities and views (Beck and Cowan 2005). To deal with this situation, many theories have been established that support the implementation of both inner (people) and outer worlds of management (Barrett 2006; Kofman 2006). One theory includes lean construction, a new management philosophy that has reached great impacts in the construction industry.

Although there is extensive use of technical tools used for construction planning, scheduling, modeling, etc., there is no evident improvement in project performance. Thus, there is a need to establish management principles that can help improve construction performance by encapsulating both internal and external management theories (Ballard and Kim 2001).

2.2.2 *Management by Means (MBM)*

Management by means, on the contrary, is developed and driven not by explicit predetermined targets, but by common values and principles. This new philosophy focuses on resources, rather than finances, to achieve long term success through improvement in process, methods, approach and their interrelations (Johnson 2000). Many misinterpret this as a lack of attention to financial aspects. But, the truth is, once these goals are aligned for the long term, desired financial conditions will be achieved as a natural outcome. Thus, MBM philosophy is to be maintained from the very beginning of the process where the management team makes every effort to adhere to disciplined practice which drives the commitment for how work is done and coordinated (Kim and Ballard 2010).

MBM as a generalized term incorporates Last Planner System (LPS™) as a part of lean construction principles. The Last Planner System (LPS™) was developed by

Ballard (2000) as a planning and control system based on lean production principles. It is a tool that plans, monitors and controls the construction process through lean construction principles such as just-in-time (JIT) delivery, pull scheduling (also known as reverse phase scheduling) and value stream mapping (VSM) (Porwal 2010). It improves reliability in planning and reduces the negative impacts caused by variability by monitoring the Percentage of Plan Completed (PPC) in a short-term period through promoting a series of actions (Gonzalez et al. 2008). Percent plan complete (PPC) is calculated by dividing the number of tasks completed as planned by the total number of tasks planned for the particular period (Ballard 2000).Thus, an increase in planning reliability allows construction managers to achieve more control and stabilization of the complex and dynamic nature of construction projects.

Reliability and client satisfaction support the foundation of lean principles. The measure of reliability in lean construction is based on PPC data. It depends upon whether planned work is done rather than focusing on how much of the work is performed/ completed. Therefore, if a task is performed correctly and completely, as planned, it is counted as “1” and those not completed as planned are considered “0”. Thus, the 1’s are summed and divided by total number of tasks planned for that particular week. A PPC closer to 100% is considered high reliability, whereas lower PPC depicts unreliable planning.

2.3 Relation between management theories

MBM needs nurtured system principles, whereas MBR requires continuous hard work to attain and maintain success (Johnson 2006). The difference between MBR and MBM practices reflects the differences between the principles that govern natural living systems and those that govern mechanistic systems (Johnson and Broms 2000). At the operational level with task interdependencies, project control based on MBR is considered to be less applicable. Whereas, the literature and case study suggest that the MBM view is more appropriate for managing work in this case (Kim and Ballard 2010).Thus, for the research performed by Kim and Ballard (2010), a survey was proposed of various construction projects that implement both EVM and LPS in their project management agenda and a data sheet compiled the feedback. A case study was conducted to understand how factors affect work flow reliability (Liu and Ballard 2008) and thus hamper productivity. Many companies have adopted this method and have reported the results of case studies, and numerous reports and academic papers have provided evidence that last planner improves work flow reliability, thereby reducing project duration and cost (Kim and Jang 2005; Johansen and Porter 2003; Fiallo and Revelo 2002; Ballard et al. 2007).

According to a presentation by Professor H. Thomas Johnson (2006), MBR and MBM are two ways of improving performance. Their methods, concepts and goals are different, but they both lead to better performance. According to Johnson (2006), the MBR progress curve is saw toothed with intermittent low and high growth; whereas, MBM is a stepped progress, with gradual ascent to a desired goal (see Fig 3).

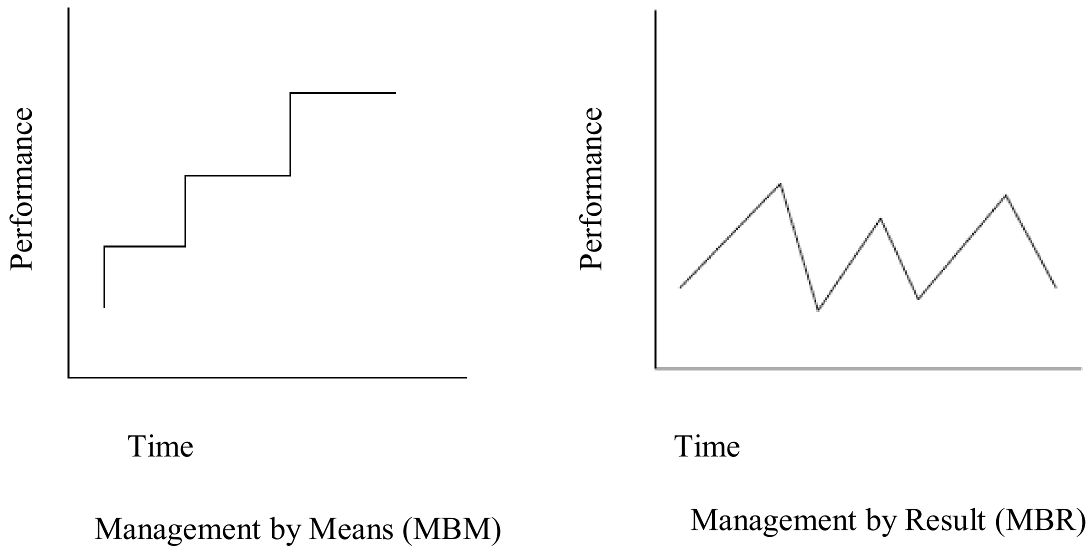


Figure 3 MBM and MBR progress curve (Johnson 2006)

2.4 From EVM to cash flow data

Uncertainties exist in both planning and scheduling practices; there are inadequacies in solving these problems. These inconspicuous uncertainties affect production and thus, affect schedule management (Alarcon and Ashley 1999). The increased uncertainties and hence, variability, lead to additional working-in-processes, or equivalently, to longer lead times. This increased time in processing results in declination of productivity and to more operating expenses (Koskela 2004). Therefore, according to Kenley and Seppanen (2010), inefficient production directly influences cost; for example increased labor costs in major projects directly impacts financial outcomes, and consequently, the organization itself.

Some research has concentrated on Activity Based Costing (ABC) and Resource Based Costing (RBC) (Kim and Ballard 2001), but this lacks in incorporating the concept of quality. These aspects of budgeting can help in reducing cost in many ways. For every budgeting cycle there is a chance of analyzing and improving performance in order to reduce cost.

Few construction projects incorporate EVM and lean construction principles together (Kim and Ballard 2010).While the MBR focuses primarily on financial goals, relevant financial data can also be studied by combining both construction practices. The attention to achieving a particular fiscal goal makes a management practice equivalent to MBR. Therefore, even if a project does not incorporate EVM, an alternate strategy aiming for a particular fiscal goal can be considered as MBR. Thus, a guaranteed maximum price (GMP) contract which considers the risk of delivering the project on time and within the original GMP amount (Conner et. al 2009) follows MBR as its management policy

2.5 Existing research that applies both theories

As suggested by Chu et al. (2003), there are three aims central to any theory. These aims are rephrased as predictive component, exploratory component and control component (Fernández-Solís 2008). Only with these components can a scientific theory explain, predict and facilitate control at the same time. Evidence supports the view that improvement in PPC results in changes in the EVM curve (Kim and Ballard 2010). Also, there are surveys that apply EVM and PPC together with improved project schedule, scope and cost. A recent study (Liu and Ballard 2008) has shown the significant correlation between work flow reliability and labor productivity for construction projects.

Surprisingly, while there are numerous examples in the literature of productivity in lean construction and other higher level issues, there are relatively few dealing with the quantification or modeling of direct costs (Kenley and Seppanen 2010).

According to Kenley and Seppanen (2010), it may be perceived that while cost is universally seen as an important factor for lean methodologies, there is a scarcity of research that analyzes or models the ways of reducing cost under a lean methodology. Usually, cost estimates in early stages in construction are not accurate and thus they are committed during various stages of the project.

Therefore, an alternative tracking system is needed to establish an interrelation between quality and cost. This paper deals only with the use of available information during implementation of the project. Choosing a tracking method that reflects the effect of reliability on cash flow can aid in channelizing the future work schedule and budget. However, such use in the preparation of the project is possible only after activity cost data is detailed. A wider perspective of costing analysis can also be effective in cost controls.

Considering these limitations with EVM systems, Kim and Ballard (2000) suggest that an alternative system needs to be explored that incorporates work flow reliability measures with traditional cost and schedule measures. A system is needed that provides insight into actual project conditions and helps the construction manager make better decisions in project controls.

3. RESEARCH METHOD

The research method revolves around the hypothesis that improvements in PPC also improve the budget of the project. In this research, two different management theories are referred through a case study, where these two theories are combined for improved construction practices. The research design compiles a literature review (for establishing background on related studies), data collection (present scenario), case study, and data interpretation (establishing the hypothesis) as sources to provide a graphical and coherent outcome. The research paper is confined to a single case study with a time frame of 8 months.

The research method is comprised of three steps that lead to better understanding and consequences of applying MBM and MBR theories together in a project. The research design goes through four phases before data interpretation and coming to conclusions (see Fig 4). These steps are:

a. Preliminary Design
b. Identification based Design
c. Analysis Design
d. Interpretation and Validation

The data interpretation is done with the help of statistical analysis. This statistical analysis will be helpful in establishing and validating the hypothesis.

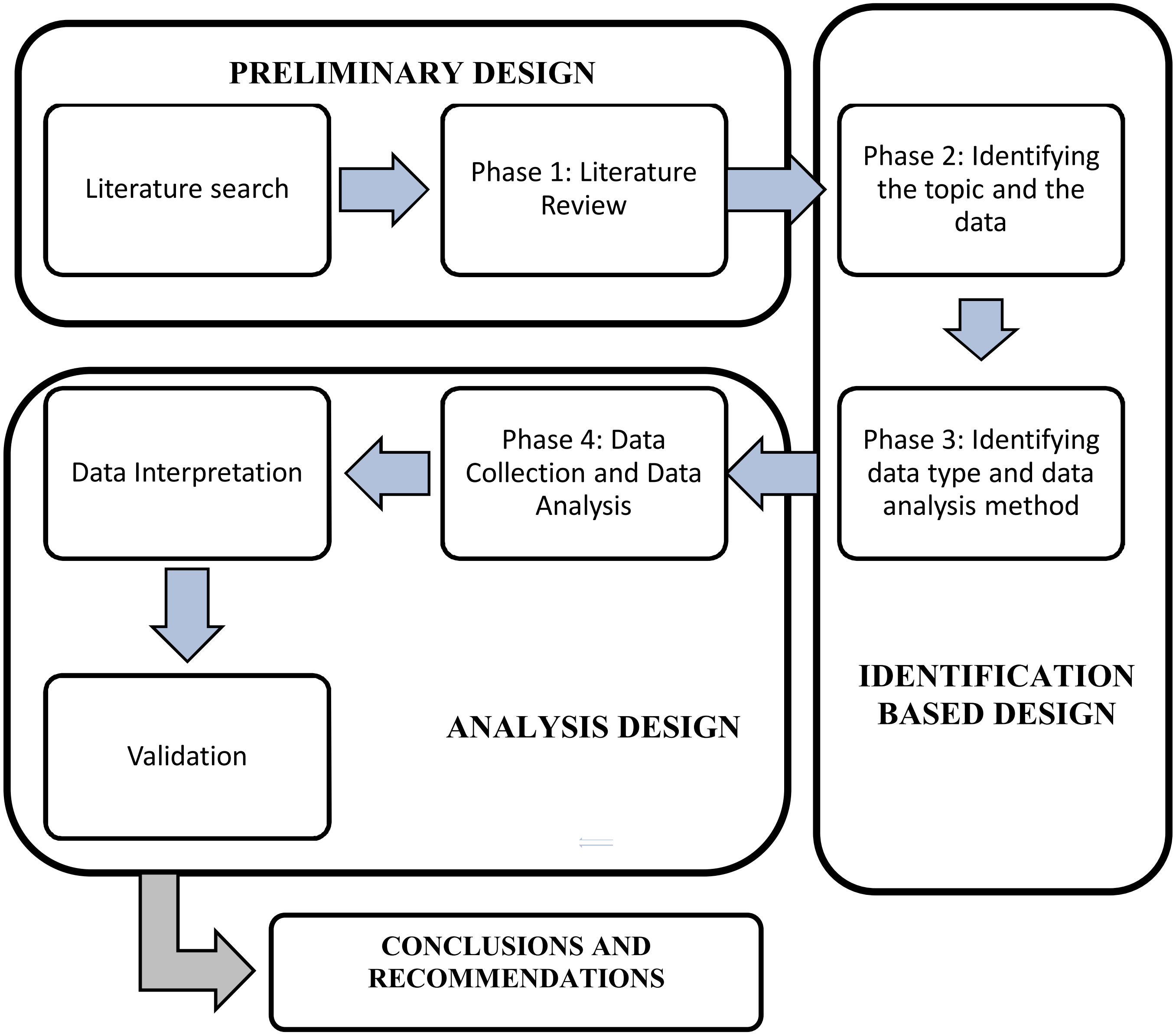


Figure 4 Research design depicting all four steps and interim phases.

3.1 Preliminary design

Preliminary design concentrates on finding various avenues in which a thesis can be created that relates to lean construction principles and construction management principles.

3.1.1 Literature search

This design is limited to a literature search from reputed publications and their reviews. Based on this review, various possible fields were sorted that were new and required further study.

3.1.2 Literature review

Phase 1 includes compilation of results from the literature search. These results include analysis of various relevant topics and papers based on construction management principles and lean construction tools. This continuous process throughout provided the issues with unexplored possibilities that need further attention.

3.2 Identification based design

Following the preliminary design, a relevant and presumed topic was established. Prospective and relevant data was listed and compiled in order to complete the research work. Identification of data and research method was considered the most critical step in the research and was performed with utmost attention.

3.2.1 Data identification

Phase 2 focuses on compiling data for validating the thesis topic hypothesis. In accordance with the literature review and the topic decided, the data from an ongoing construction project that uses lean tools (especially Last Planner System) throughout the project to track the project progress was gathered. Another important dataset includes schedule of payments that show projected and actual cash flows for a time frame of 8 months.

3.2.2 Analysis method identification

Once the data identification was done, methods for data collection and data analysis were decided. Data was collected from a construction project led by Linbeck LLC (used with permission). The Texas A&M System is currently working with Linbeck Group, LLC, to provide construction management at risk services for a new 600-bed residence hall worth $43 million. The Northside Residence Hall is an academically-centered residence hall providing both living and multipurpose space. The facility will include:

- Residential units for 600 students (doubles, suite doubles, suite singles and paired singles).
- Public and private areas to be used in support of community living.

3.3 Analysis design

This design consists of two models:

(i) Data Collection and Data Analysis

(ii) Data interpretation.

3.3.1 Data collection and data analysis

This phase started with data collection from the Northside Residence Hall project; it incorporated analyzing the PPC for each week, and analyzing the predicted and actual cash calls (see Fig.5).

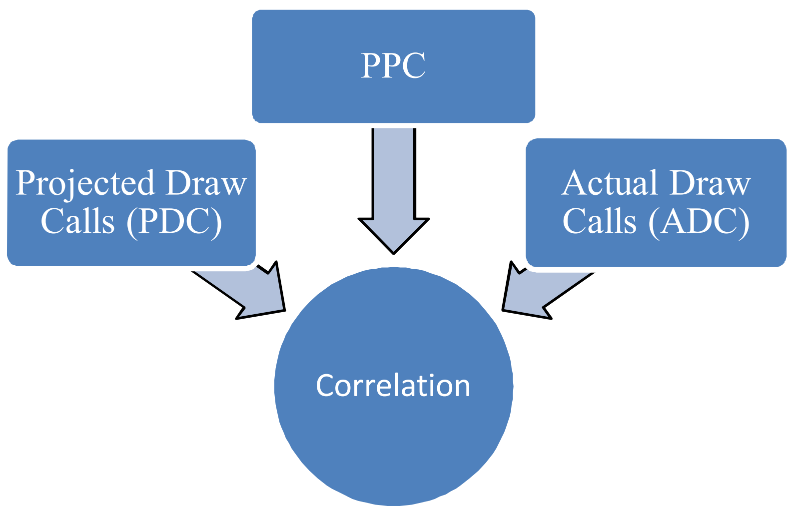


Figure 5 Data Collection model

The data was collected in two ways:

(i) PPC

(ii) Projected and Actual Cash calls

3.3.1.1 PPC

The PPC data was directly attained from the project manager (see Fig.6). Tasks and activities were decided in daily meetings and weekly work plans. Subcontractors, project engineers and project managers discussed the weekly plans to be performed and completed during that particular week. Each meeting was arranged to plan for the coming week as well as to get updates of task completions from the previous week. The tasks completed as planned were counted "1" and those delayed/unperformed were counted as "0". The summation of completed as planned tasks was divided by number of activities. This calculation gives the PPC for that particular week. All PPC data was collected and compiled in the template with overall PPC to be used in the following weeks.

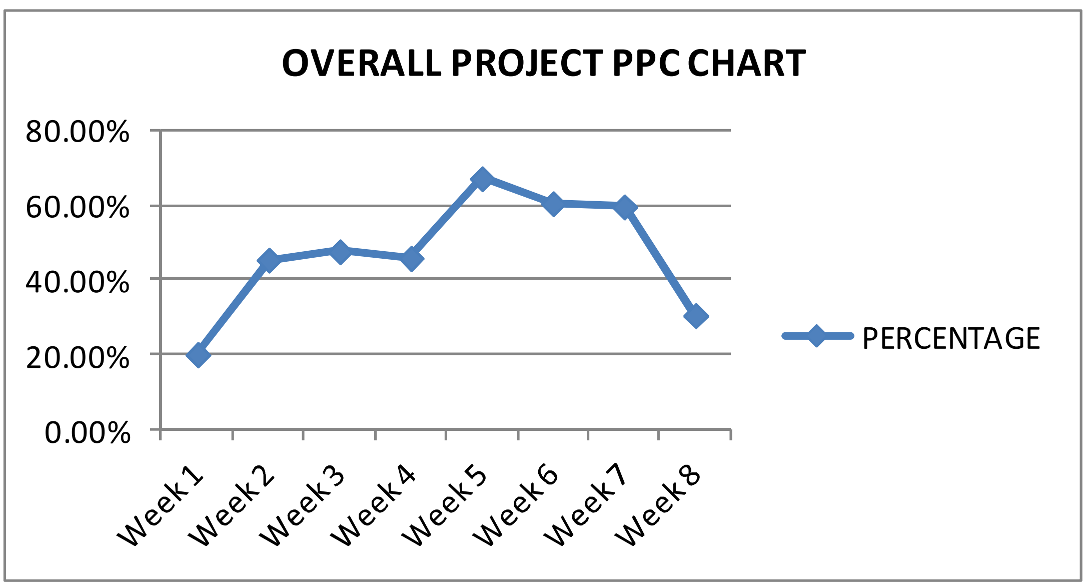


Figure 6 Sample overall project PPC

3.3.1.2 Projected and Actual Draw calls (PDC and ADC)

This data was obtained monthly, as a part of schedule of payments. Fig. 7 shows the difference in ADC and PDC (see Fig 7). Since financial data received each month is billed for the work performed in the previous month, a shift was made to correlate the relevant fiscal data with the corresponding PPC. A delta between PDC and ADC was obtained in order to see the variations in prediction each month. This makes comparisons even more holistic, because it directly compares improvement or worsening in cash flows with changes in PPC. This serves the purpose of validating the hypothesis by comparing all the financial changes each month with reference to reliability variations.

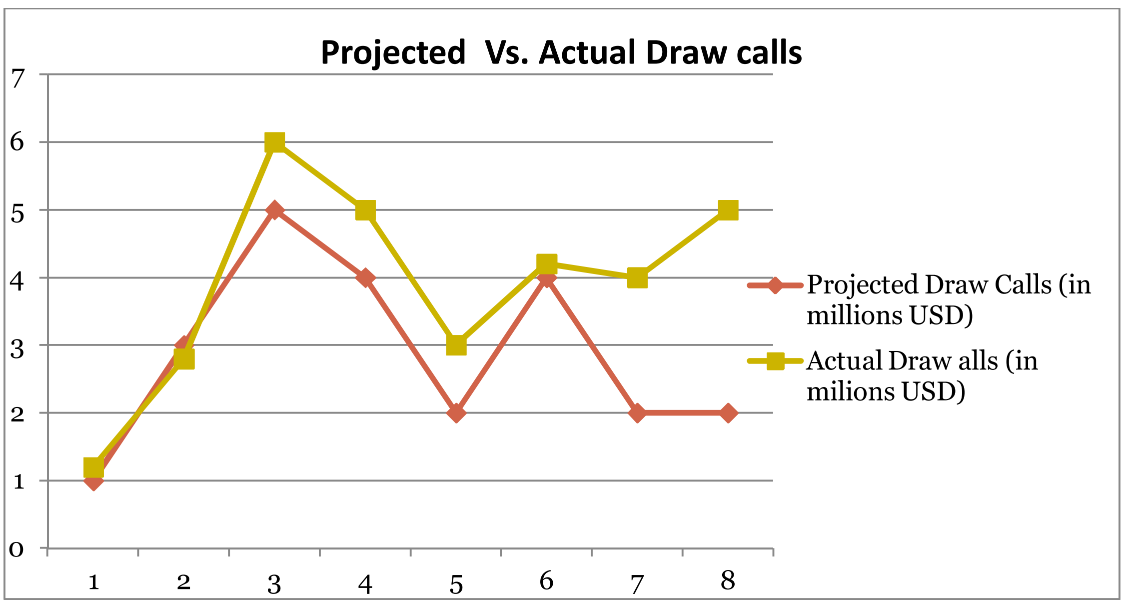


Figure 7 Sample PDC vs. ADC graph.

Later, a data table was constructed that summarizes and includes all the relevant variables needed for data analysis (see Table 1). These variables were derivatives of cash calls (ADC and PDC) and PPC. The variants were created because they illustrated better relations rather than using the direct variables.

Table 1 Data calculation table showing all the variables

Month	Planned Activities	Completed Activities	(P_i)	PDC($)	ADC($)	PDC-ADC($)	$P_{(i)} - P_{(i-1)}$	(-(PDC-ADC)/PDC)X100	$P_{(i)} - P_{(i1)}$
June									
July									
August									
September									
October									
November									
December									
January									

3.4 Data interpretation and validation

Once the calculations and graphics were finished, interpretation became more comprehensible and succinct. Based on these data and inferences, a correlation analysis method was chosen to validate the hypothesis..

Relevant outputs like correlation coefficient and probabilities are typically obtained in order to get statistically significant outcomes. Although this study is based on a single case study and statistically significant data cannot be obtained, it can give foundation to future studies.

4. DATA ANALYSIS

4.1 Results from literature review

The literature review supports the idea that even though the Management by Results method is widely accepted and used, it has its limitations which need to be overcome. These management principles are based on the assumptions that all the tasks in a schedule are independent of their preceding activities and thus when a schedule time or cost is predicted, it is less accurate. Although EVM is a popular tool, it lacks significant consideration of quality and customer satisfaction. Therefore, considering the fact that MBR does not incorporate important factors like quality and client satisfaction, the Management by Means concept was originated.

The case studies performed by Kim and Ballard (2010) show empirical evidence that suggests that better performance was visible in the production planning based on MBM thinking when it was applied to highly interdependent tasks at the operational level. According to them both, the usage of the tool and the method of use are equally important. MBM, as compared to MBR, focuses on how things are done rather that what needs to be achieved. Thus, following MBM aids in achieving long term success. As the literature review supports the selection of appropriate management principles, it also favors the right use of financial data to achieve control over budget overruns.

Few researchers have studied the different ways of costing, specifically activity based costing and resource based costing. Costing is considered to be dependent on lean construction and vice versa. Hence, some studies state that lean saves money, while others illustrate that the right method of costing is useful in achieving lean goals.

4.2 Results from case study

Three types of data were collected from Linbeck LLC and the Northside Residence Hall project. These data are:

- Percent Planned Complete (PPC) (see Table 1)
- Projected Monthly Billing (see Appendix A)
- Actual monthly billing (see Appendix A)

4.2.1 Data collection

The figures mentioned above depict the crude form in which data was obtained. Their variants were tabulated in the later stage when they were compared and correlated with each other and PPC. These data were created in Linbeck templates with the help of project managers during their daily and weekly meetings. Research focused on comparing variables that related to the PPC data. Using only PPC and the ADC or PDC directly show no strong correlation to conclude. Therefore, these collected data were transformed into various combinations of data derivatives and then they were analyzed through Spearman's correlation coefficient.

Table 2 PPC table

Linbeck LLC					
Northside Residential Hall, Texas A & M University Systems					
	WEEKS	No. of planned activities	No. of completed tasks	PPC	Average PPC per month $P_{(i)}$
1	6/6/2011	10	9	90%	86%
2	6/13/2011	12	10	83%	
3	6/20/2011	22	19	86%	
4	6/27/2011	29	25	86%	
5	7/4/2011	35	31	89%	90%
6	7/11/2011	25	24	96%	
7	7/18/2011	27	26	96%	
8	7/25/2011	25	20	80%	
9	8/1/2011	26	20	77%	85%
10	8/8/2011	22	18	82%	
11	8/15/2011	15	10	67%	
12	8/22/2011	10	10	100%	
13	8/29/2011	5	5	100%	
14	9/5/2011	8	7	88%	83%
15	9/12/2011	3	3	100%	
16	9/19/2011	4	2	50%	
17	9/26/2011	15	14	93%	
18	10/3/2011	18	14	78%	80%
19	10/10/2011	16	10	63%	
20	10/17/2011	15	14	93%	
21	10/24/2011	19	16	84%	
22	10/31/2011	26	22	85%	
23	11/7/2011	35	29	83%	84%
24	11/14/2011	28	24	86%	
25	11/21/2011	19	17	89%	
26	11/28/2011	32	25	78%	
27	12/5/2011	26	20	77%	83%
28	12/12/2011	32	25	78%	
29	12/19/2011	19	18	95%	
30	12/26/2011	22	18	82%	
31	1/2/2012	28	22	79%	84%
32	1/9/2012	33	30	91%	
33	1/16/2012	35	32	91%	
34	1/23/2012	45	34	76%	
		741	623		

This tabular format was later converted into a graphic showing weekly as well as average PPC for that particular month (Fig. 8).

- PPC: A tabular format was provided that showed number of activities planned and number of activities completed as planned. Calculations for PPC were also done and an average PPC for each month was calculated for further data comparisons (see Table 2).
- ADC and PDC: Data was compiled as schedule of payment for each month that comprised of original Guaranteed Maximum Price (GMP) amount ADC, PDC, cumulative amounts for each month and graphical representation of ADC and PDC.

4.2.2 Data calculations

Once the data was compiled, required comparative variables were formulated (see Table 3). These formulated variables account for the source of multivariate analysis, while considering the results of all variables on the responses of interest. These variables include:

- Average monthly PPC (P_i): It was difficult to relate or compare weekly PPC with monthly cash flow. Hence, average monthly PPC was calculated to relate it with ADC and PDC. P represents PPC while, $_{(i)}$ represents month, with i=1 as June.
- PDC-ADC: This difference was calculated in order to see whether actual draw calls were greater than the projected. Therefore,

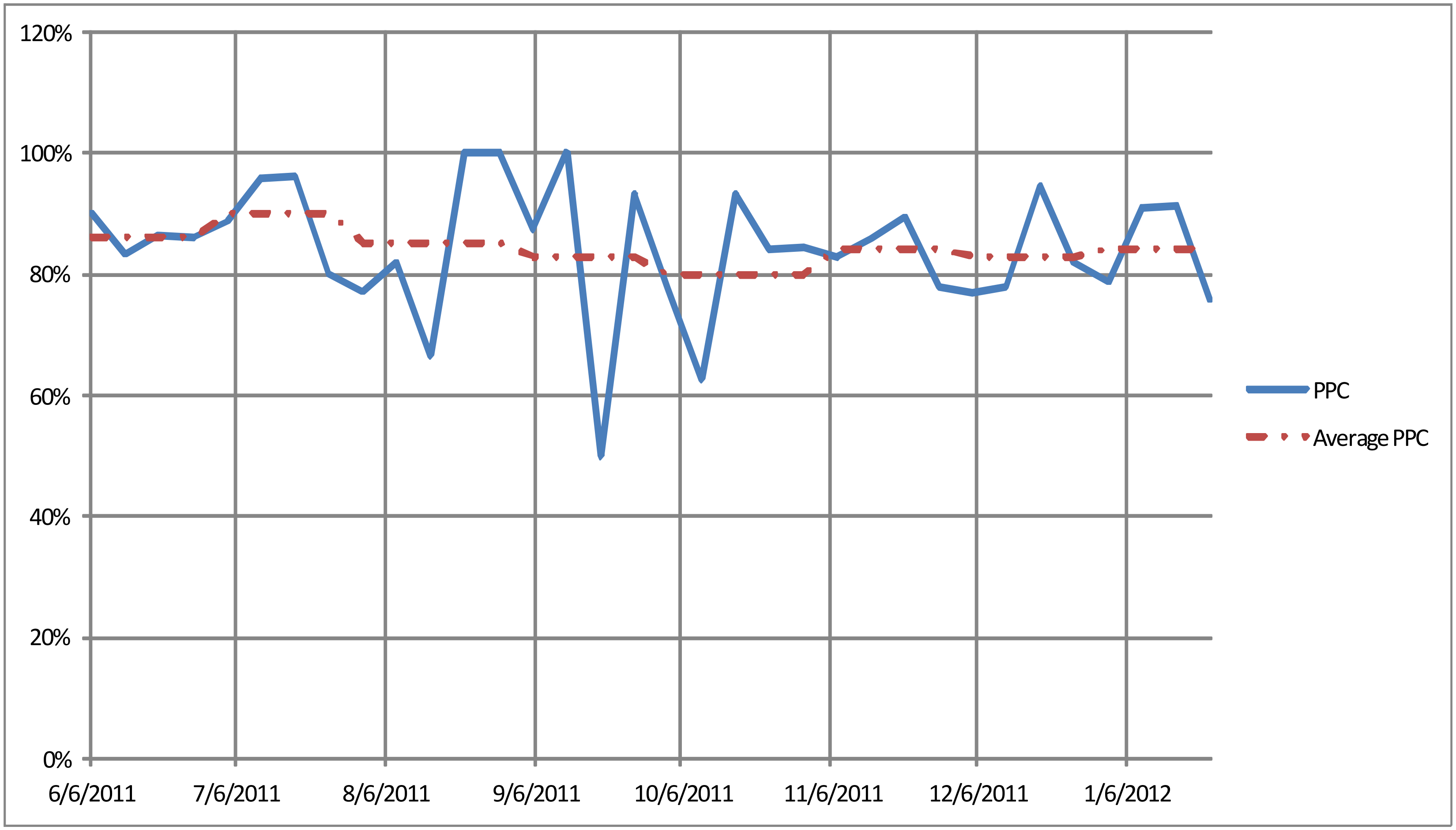


Figure 8 Overall PPC and average monthly PPC combined.

Table 3 Data calculation table showing all the variables incorporated in multivariate data analysis

Month	Planned Activities	Completed Activities	(P_i)	PDC ($)	ADC ($)	PDC-ADC ($)	$P_{(i)} - P_{(i-1)}$	(-(PDC-ADC)/PDC)X 100	$P_{(i)} - P_{(i1)}$
June	10,12,22,29	9,10,19,25	0.86	$602,180	$804,673	($202,493)	0	33.63	-3.52%
July	35,25,27,25	31,24,26,20	0.90	$993,877	$885,695	$108,182	0.04	-10.88	1.65%
August	26,22,15,10,5	20,18,10,10,5	0.85	$1,371,080	0	$1,371,080	-0.05	___	8.16%
September	8,3,4,15	7,3,2,14	0.83	$1,728,291	$2,016,139	($287,848)	-0.02	16.66	-4.79%
October	18,16,15,19,26	14,10,14,16,22	0.80	$2,060,298	$1,985,895	$74,403	-0.02	-3.61	2.71%
November	35,28,19,32	29,24,17,25	0.84	$2,362,262	$2,265,852	$96,410	0.04	-4.08	1.19%
December	26,32,19,22	20,25,18,18	0.83	$2,629,779	___	___	-0.01	___	5.98%
January	28,33,35,45	22,30,32,34	0.84	$2,858,948	___	___	0.01	___	5.54%

(P_i)	Average monthly PPC	$P_{(i)} - P_{(i-1)}$	Increase or Decrease in PPC
PDC ($)	Projected Draw Calls	(-(PDC-ADC)/PDC)X 100	Percentage change in draw calls
ADC ($)	Actual Draw Calls		
PDC-ADC ($)	Difference between cash calls	$P_{(i)} - P_{(i1)}$	Average PPC – PPC for first week of month

If PDC-ADC is negative, it shows actual expenses were more than projected.

If PDC-ADC is positive, it shows actual expenses were less than predicted.

- Increase or Decrease in PPC ($P_{(i)} – P_{(i-1)}$): This was calculated by subtracting PPC for 1 month from that of previous month, where, $_{i-1}$ is preceding month. If,

  Difference is positive, there is improvement.

  Difference is negative there is worsening in performance.

- Average PPC – PPC for first week of month ($P_{(i)}$ - $P_{(i1)}$): This calculation shows whether there was improvement in PPC over a month from the beginning. The formula shows $P_{(i)}$ as average PPC of a month, whereas, $P_{(i1)}$ shows PPC for the first week of the month. Therefore, if this difference is,

  Positive, it means there is improvement and

  If it is negative, it means there is declination.

- Percentage change in draw calls ((-(PDC-ADC)/PDC)*100: The variable represents whether there was increase or decrease in expense from the PDC amount. If,

  The value is positive: expenses are more than projected and if,

  It if negative, fewer expenses exist than were projected.

The PPC chart shows both weekly PPC and monthly average PPC (see Fig. 8). The chart graphically represents whether there was improvement in PPC over the week as compared to the first week of the month.

The research, being a pilot study, concentrates on mining as much data or as many variables with considerable effect on PPC. The research showcases and tracks the interrelation between PPC and cash flow data; thus all the derivatives of variables are based on PPC and cash calls.

4.2.2.1 Hypothesis

The research was based on the hypothesis that improvement in PPC over a particular month has a positive correlation with difference between cash calls.

4.2.2.2Null hypothesis

There is no relation between cash calls and PPC.

4.2.3 Data analysis

In this research, analysis and observation of multiple variables was needed as a part of the data interpretation. These observations included finding the strength of the relationship between two variables. Therefore, a correlation analysis model was selected for data analysis. Since the data collected showed a monotonic relationship between some of the variables, it was determined that Spearman's correlation model would be appropriate. After computing these variables, they were composed in tabular form and their correlations were determined through Spearman's correlation analysis (see Appendix B). Spearman's correlation coefficient is usually denoted by ρ (rho).

It signifies statistical dependence between two variables. When one variable is a perfect function of the other, a perfect Spearman correlation of +1 or −1 occurs.

Spearman's correlation coefficient shows that the variables PDC-ADC and P (i) - P (i1) have a strong positive correlation of 0.8286. Although the correlations between variables like ADC and PDC increase/decrease vs., average-first week, the relationships in PDC- ADC, PDC and ADC, average PPC vs. ADC and PDC are strong, but the effects are not significant. The reason for this is they all are derived from the same or similar variable. Thus, their strong correlation does not insinuate any valid conclusion.

Table 4 JMP output for nonparametric correlation coefficients for all the variables

Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|
PDC ($)	(Pi)	-0.6145	0.1050
ADC ($)	(Pi)	-0.5429	0.2657
ADC ($)	PDC ($)	0.7714	0.0724
PDC-ADC ($)	(Pi)	0.4286	0.3965
PDC-ADC ($)	PDC ($)	-0.0286	0.9572
PDC-ADC ($)	ADC ($)	-0.4286	0.3965
P(i) - P(i-1)	(Pi)	0.4512	0.2618
P(i) - P(i-1)	PDC ($)	0.1084	0.7983
P(i) - P(i-1)	ADC ($)	0.4414	0.3809
P(i) - P(i-1)	PDC-ADC ($)	0.0000	1.0000
(-(PDC-ADC)/PDC)X 100	(Pi)	-0.3000	0.6238
(-(PDC-ADC)/PDC)X 100	PDC ($)	-0.4000	0.5046
(-(PDC-ADC)/PDC)X 100	ADC ($)	-0.3000	0.6238
(-(PDC-ADC)/PDC)X 100	PDC-ADC ($)	-0.9000	0.0374*
(-(PDC-ADC)/PDC)X 100	P(i) - P(i-1)	-0.6325	0.2522
P (i) - P (i1)	(Pi)	-0.0602	0.8873
P (i) - P (i1)	PDC ($)	0.3810	0.3518
P (i) - P (i1)	ADC ($)	-0.4857	0.3287
P (i) - P (i1)	PDC-ADC ($)	0.8286	0.0416*
P (i) - P (i1)	P(i) - P(i-1)	-0.3012	0.4684
P (i) - P (i1)	(-(PDC-ADC)/PDC)X 100	-0.6000	0.2848

Warning: sample size of 5 is too small, P value suspect.

From the above correlation coefficients, a scatter plot matrix was generated using the same Spearman's correlation analysis (Table 4).

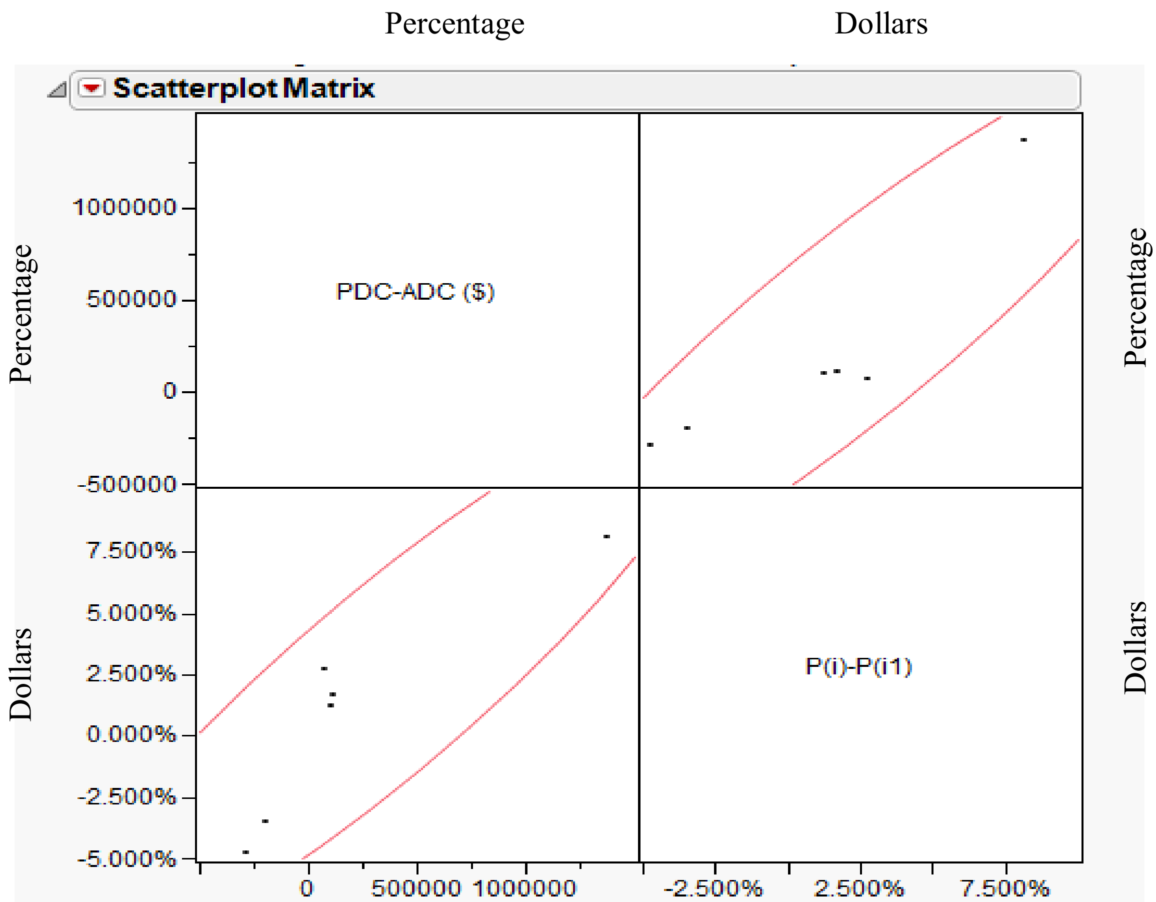
The scatter plot matrix suggests that for every negative value of PDC-ADC, there is a corresponding negative value for $P_{(i)} - P_{(i1)}$. Hence, they are positively correlated with a correlation coefficient of 0.8286 (Fig. 9). Therefore, whenever there is decrease in reliability over the consecutive weeks of a month, there is an increase in ADC as compared to the projected value.

The scatter plot matrix represents the distribution of both variables. The cross matrix shows correlation between ($P_{(i)} - P_{(i1)}$) and PDC-ADC in diagonal cells with percentage and dollars as units (see Fig. 9). From the p-value calculated in Spearman's test of 0.0416 (Fig. 9); we can be 95% confident that the null hypothesis is rejected. There is significant evidence that the two variables are dependent. Since the sample size is too small to conclude and establish statistically significant data, these outcomes can be considered for a future study that incorporates significant sample size.

Multivariate

Correlations

	PDC-ADC ($)	P(i)-P(i1)
PDC-ADC ($)	1.0000	0.9083
P(i)-P(i1)	0.9083	1.0000



Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|	-.8 -.6 -.4 -.2 0 .2 .4 .6 .8
P(i)-P(i1)	PDC-ADC ($)	0.8286	0.0416*	

Warning: sample size of 6 is too small, P value suspect.

Figure 9 Scatter plot matrix showing correlation between PDC-ADC and $P_{(i)} - P_{(i1)}$

5. CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The research identified different management theories and principles. Later, a categorization between two management principles, namely MBR and MBM, were established. Differences between these two theories in terms of concepts, goals, applications, and benefits were determined. This practice helped in elaborating the argument behind using a particular management practice. Afterwards, a relevant literature review, surveys and case studies were followed to determine the benefits behind using the principles of MBR and MBM together. MBM uses common values and principles as a way of continuous improvement for a long term goal, whereas MBR uses target oriented practice, where the target is usually finance based. Since one principle lacks some of the considerations incorporated in the other management principle, it was perceived that combining both would be beneficial for construction practices.

Accordingly, the form of the data and case study were selected. Since there are very few construction projects that use both LPS and EVM, an alternative was coined which used monthly schedule of payments as a source of financial data. The case study is based on the Northside Residence Hall at TAMU. This project is a GMP contract; all the schedules and scopes are dependent on the original GMP amount. Thus, the type of contract makes this practice comparable to using MBR.

Data was obtained in the form of PPC, ADC and PDC. Cumulative monthly billing and its graphical curve was also obtained. Some additive data, like daily count of workers (see Appendix A) working on site for a particular contractor other than Linbeck LLC, was also provided.

Appropriate data was assembled and pertinent variables were worked out from the original given variables. A primary test was run using all the variables and their interrelations. This test indicated a relation between all of the variables, but their correlation and p-values were not determined. Later, a similar test was done using significant variables in a Spearman's correlation analysis.

5.2 Conclusion

The data analysis shows there is a positive correlation of 0.8286 between PDC-ADC and $P_{(i)} - P_{(i1)}$. The outcomes suggest that when there was an improvement in PPC throughout the month from the PPC of the first week, the ADC was less than or equals PDC. This shows that even a slight improvement over the month or in consecutive months can help achieve the goal of an on-budget project. The p-value (0.0416) calculated in the Spearman's test rejects the null hypothesis by 95% confidence. There is significant evidence that the two variables are dependent. Since the sample size is too small (one, in this case) to conclude and establish statistically significant data, these outcomes can be considered for a future study that incorporates significant sample size.

5.3 Recommendations

This pilot study explored various avenues related to management principles and their applications. The primary goal of the research was to track the relation between cash flow and LPS and how PPC reflects variations in cash flow or vice versa. From the data analysis, the null hypothesis was rejected and hence, it gives suggestive implications on using a similar type of related data for detailed research on a similar path. Following are a few surmised contributions to industry and research:

- Suggests opportunity for future studies along the same direction with a more detailed study to achieve statistical significance.
- Correlations between various variables acting in a construction project.

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APPENDIX A

Projected and Actual Monthly Billing data as received from Linbeck LLC.

LINBECK

#02-3067 Northside Residence Hall

Construction Cash Flow Analysis

Updated 12/31/11

Total Contract Amount	**$55,330,000**	
Construction Start	**6/1/11**	
Total Duration, Months	26	(26 months construction)

Element	**Northside Residence Hall**
Start Month	1
Duration	26
Original GMP Amount	$55,330,000
Revised GMP Amount	$55,330,000

Billing Number	Month Ending	Projected Monthly Billings	Projected Monthly Total Billing
1	Jun-11	$201,703	$201,703
2	Jul-11	$602,180	$602,180
3	Aug-11	$993,877	$993,877
4	Sep-11	$1,371,080	$1,371,080
5	Oct-11	$1,728,291	$1,728,291
6	Nov-11	$2,060,298	$2,060,298
7	Dec-11	$2,362,262	$2,362,262
8	Jan-12	$2,629,779	$2,629,779
9	Feb-12	$2,858,948	$2,858,948
10	Mar-12	$3,046,425	$3,046,425
11	Apr-12	$3,189,481	$3,189,481
12	May-12	$3,286,025	$3,286,025
13	Jun-12	$3,334,652	$3,334,652
14	Jul-12	$3,334,651	$3,334,651
15	Aug-12	$3,286,025	$3,286,025
16	Sep-12	$3,189,481	$3,189,481
17	Oct-12	$3,046,425	$3,046,425
18	Nov-12	$2,858,948	$2,858,948
19	Dec-12	$2,629,779	$2,629,779
20	Jan-13	$2,362,262	$2,362,262
21	Feb-13	$2,060,298	$2,060,298
22	Mar-13	$1,728,291	$1,728,291
23	Apr-13	$1,371,080	$1,371,080
24	May-13	$993,877	$993,877
25	Jun-13	$602,180	$602,180
26	Jul-13	$201,702	$201,702
Totals		$55,330,000	$55,330,000

L I N B E C K

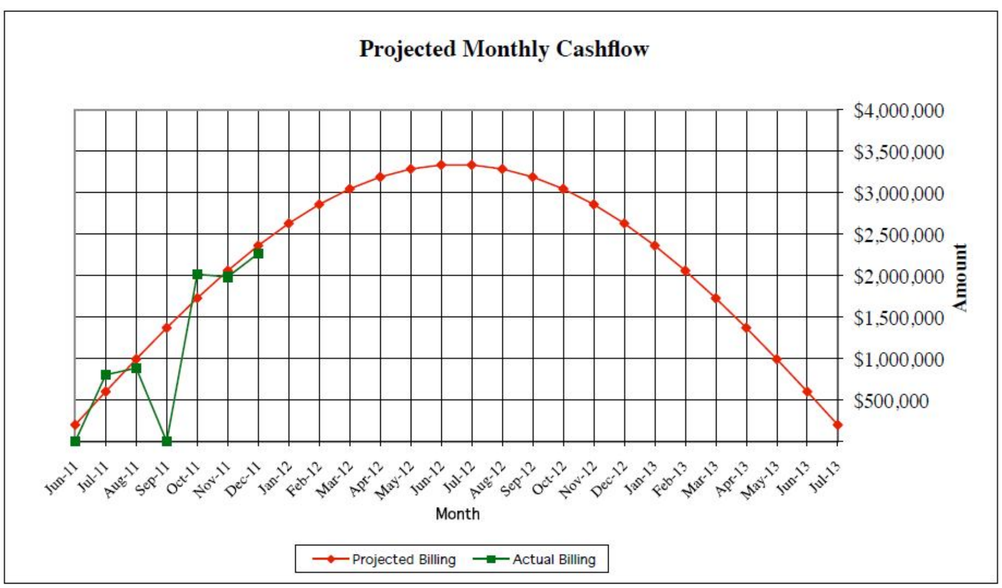
#02-3067 Northside Residence Hall

Construction Cash Flow Analysis

Updated 12/31/11

Used data (rows 1–8)

Billing Number	Month Ending	Projected Monthly Total Billing	Actual Monthly Billing	Projected Cumulative Totals	Actual Cumulative Totals
1	Jun-11	$201,703		$201,703	
2	Jul-11	$602,180	$804,673	$803,883	$804,673
3	Aug-11	$993,877	$885,695	$1,797,760	$1,690,368
4	Sep-11	$1,371,080		$3,168,840	$1,690,368
5	Oct-11	$1,728,291	$2,016,139	$4,897,131	$3,706,507
6	Nov-11	$2,060,298	$1,985,895	$6,957,429	$5,692,402
7	Dec-11	$2,362,262	$2,265,852	$9,319,691	$7,958,254
8	Jan-12	$2,629,779		$11,949,470	
9	Feb-12	$2,858,948		$14,808,418	
10	Mar-12	$3,046,425		$17,854,843	
11	Apr-12	$3,189,481		$21,044,324	
12	May-12	$3,286,025		$24,330,349	
13	Jun-12	$3,334,652		$27,665,001	
14	Jul-12	$3,334,651		$30,999,652	
15	Aug-12	$3,286,025		$34,285,677	
16	Sep-12	$3,189,481		$37,475,158	
17	Oct-12	$3,046,425		$40,521,583	
18	Nov-12	$2,858,948		$43,380,531	
19	Dec-12	$2,629,779		$46,010,310	
20	Jan-13	$2,362,262		$48,372,572	
21	Feb-13	$2,060,298		$50,432,870	
22	Mar-13	$1,728,291		$52,161,161	
23	Apr-13	$1,371,080		$53,532,241	
24	May-13	$993,877		$54,526,118	
25	Jun-13	$602,180		$55,128,298	
26	Jul-13	$201,702		$55,330,000	

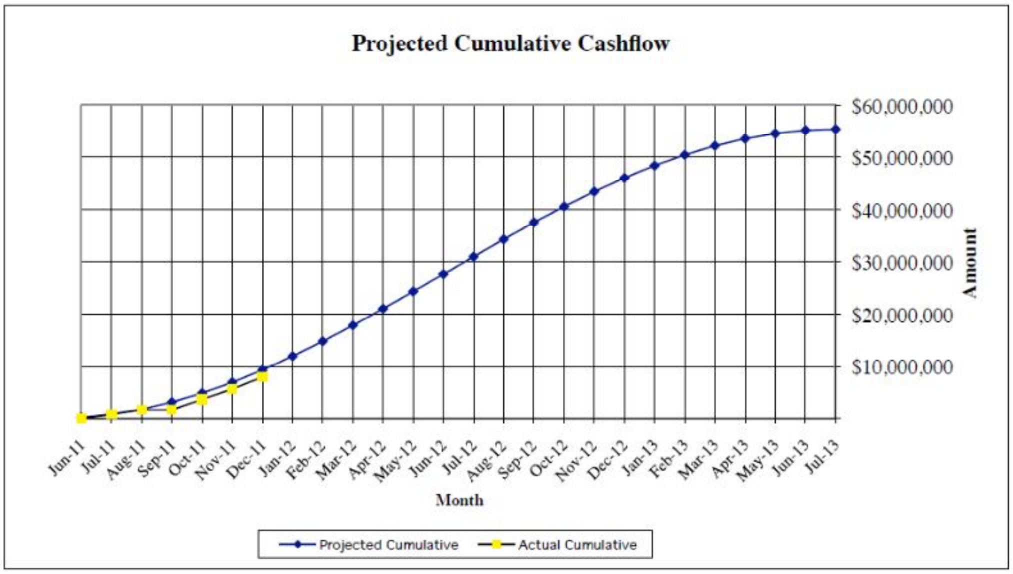


LINBECK

#02-3067 Northside Residence Hall

Construction Cash Flow Analysis

Updated 12/31/11



Week	Date Used	Contractor	Daily Count
	6/6/2011		
1		Linbeck	3
1		Garrett Mechanical	2
1		Britt Rice Electric	3
1		BIO Landscape and Maintenance	1
1		Action Mobile Industries	1
Total			
	6/13/2011		
2		Linbeck	3
2		Britt Rice Electric	9
2		Garrett Mechanical	4
2		Lindamood Demolition	18
Total			
	6/20/2011		
3		Linbeck	3
3		Garrett Mechanical	3
3		Britt Rice Electric	7
3		Lindamood Demolition	26
Total			
	6/27/2011		
4		Britt Rice Electric	9
4		Garrett Mechanical	7
4		Linbeck	2
4		Lindamood Demolition	29
Total			
	7/5/2011		
5		Linbeck	3
5		Britt Rice Electric	2
5		Garrett Mechanical	5
5		Lindamood Demolition	28
Total			
	7/11/2011		
6		Linbeck	3
6		Garrett Mechanical	6
6		Lindamood Demolition	31
6		BIO Landscape and Maintenance	3
Total			

Week	Date Used	Contractor	Daily Count
	7/18/2011		
7		Linbeck	3
7		Lindamood Demolition	28
7		Britt Rice Electric	3
7		Garrett Mechanical	5
7		Bio Landscape and Maintenance	2
Total			
	7/25/2011		
8		Linbeck	3
8		Lindamood Demolition	32
8		Britt Rice Electric	3
8		Garrett Mechanical	6
Total			
	8/1/2011		
9		Linbeck	3
9		Lindamood Demolition	18
9		Britt Rice Electric	3
9		Garrett Mechanical	3
Total			
	8/8/2011		
10		Linbeck	3
10		Lindamood Demolition	7
10		Terracon	1
10		Britt Rice Electric	3
10		Garrett Mechanical	6
Total			
	8/15/2011		
11		Linbeck	3
11		Lindamood Demolition	6
11		Britt Rice Electric	2
11		Garrett Mechanical	3
Total			
	8/22/2011		
12		Linbeck	3
12		Lindamood Demolition	6
12		Britt Rice Electric	7
12		Garrett Mechanical	3
Total			

Week	Date Used	Contractor	Daily Count
	8/29/2011		
13		Linbeck	3
13		Lindamood Demolition	8
Total			
	9/6/2011		
14		Linbeck	4
14		Lindamood Demolition	8
14		Garrett Mechanical	3
Total			
	9/12/2011		
15		Linbeck	4
15		Lindamood Demolition	8
15		Garrett Mechanical	4
15		Britt Rice Electric	2
Total			
	9/20/2011		
16		Linbeck	3
16		Lindamood Demolition	5
16		Britt Rice Electric	10
16		Garrett Mechanical	4
Total			
	9/26/2011		
17		Linbeck	3
17		Lindamood Demolition	3
17		Britt Rice Electric	9
17		Garrett Mechanical	6
Total			
	10/3/2011		
18		Linbeck	4
18		Britt Rice Electric	8
18		Garrett Mechanical	9
18		Lindamood Demolition	4
Total			
	10/10/2011		
19		Linbeck	3
19		Kelly Burt Dozer	1
19		Garrett Mechanical	8
19		Britt Rice Electric	5

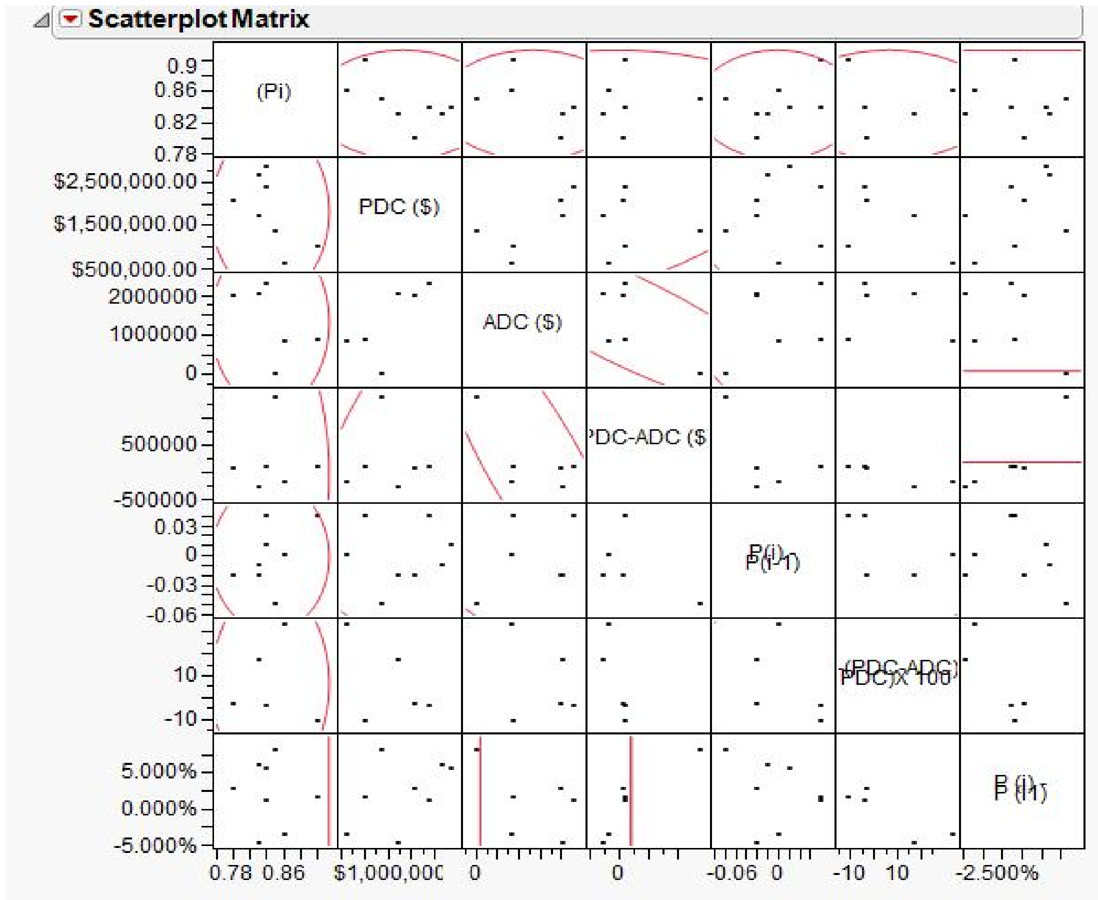
Week	Date Used	Contractor	Daily Count
	10/18/2011		
20		Linbeck	3
20		Garrett Mechanical	8
20		Britt Rice Electric	7
Total			
	10/24/2011		
21		Linbeck	3
21		Garrett Mechanical	8
21		Britt Rice Electric	9
Total			
	10/31/2011		
22		Linbeck	3
22		Kelly Burt Dozer	1
22		Garrett Mechanical	8
22		Britt Rice Electric	3
Total			
	11/7/2011		
23		Linbeck	4
23		Garrett Mechanical	8
23		Britt Rice Electric	2
Total			
	11/14/2011		
24		Linbeck	5
24		Kelly Burt Dozer	3
24		Britt Rice Electric	1
24		Garrett Mechanical	9
Total			
	11/21/2011		
25		Linbeck	6
25		Garrett Mechanical	10
Total			
	11/28/2011		
26		Linbeck	6
26		Jayco	4
26		Garrett Mechanical	9
Total			

Week	Date Used	Contractor	Daily Count
	12/5/2011		
27		Linbeck	7
27		Garrett Mechanical	6
Total			
	12/12/2011		
28		Linbeck	7
28		Kelly Burt Dozer	1
28		Garrett Mechanical	8
28		Britt Rice Electric	4
28		Jayco	4
Total			
	12/19/2011		
29		Linbeck	8
29		Kelly Burt Dozer	2
29		Jayco	7
29		Garrett Mechanical	9
29		Britt Rice Electric	3
Total			
	12/27/2011		
30		Linbeck	8
30		Britt Rice Electric	3
30		Garrett Mechanical	9
Total			
	1/3/2012		
31		Linbeck	1
31		Britt Rice Electric	3
31		Garrett Mechanical	9
31		Jayco	5
31		United Forming	6
Total			
	1/10/2012		
32		Batten	3
32		United Forming	5
32		Jayco	5
32		Linbeck	9
32		Britt Rice Electric	5
Total			

Week	Date Used	Contractor	Daily Count
	1/16/2012		
33		Batten	4
33		Kelly Burt Dozer	5
33		Linbeck	6
33		United Forming	7
33		Jayco	2
33		Garrett Mechanical	13
33		Britt Rice Electric	6
Total			
	1/23/2012		
34		Kelly Burt Dozer	5
34		Batten	5
34		Linbeck	5
34		United Forming	9
34		Jayco	4
34		Britt Rice Electric	5
34		Garrett Mechanical	7
Total			

APPENDIX B

A tabular format showing correlations between all variables, determined through Spearman's correlation analysis



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