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Mining big data to create a tool for empirical observation of continuous safety improvement in a construction company - A progressive case study in the lean environment

Nicolas J. Michuda
Purdue University

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MINING BIG DATA TO CREATE A TOOL FOR EMPIRICAL OBSERVATION OF CONTINUOUS SAFETY IMPROVEMENT IN A CONSTRUCTION COMPANY - A PROGRESSIVE CASE STUDY IN THE LEAN ENVIRONMENT

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Is approved by the final examining committee:

Bryan Hubbard
Co-chair

James Jenkins
Co-chair

Brad Benhart

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Approved by: Randy Rapp 4/25/2016

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MINING BIG DATA TO CREATE A TOOL FOR EMPIRICAL OBSERVATION OF CONTINUOUS SAFETY IMPROVEMENT IN A CONSTRUCTION COMPANY - A PROGRESSIVE CASE STUDY IN THE LEAN ENVIRONMENT

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TABLE OF CONTENTS

Page

ABSTRACT

Michuda, Nicolas. MSBCM, Purdue University, May 2016. Mining Big Data To Create A Tool For Empirical Observation Of Continuous Safety Improvement In A Construction Company - A Progressive Case Study In The Lean Environment. Major Professor: James Jenkins

In any iterative process, without a system of measurement, controlled improvement cannot be recorded. This is especially true in the construction industry, where error occurs, often with fatal repercussions. As part of a process to facilitate the establishment of this metric, an entirely new application was created. The goal of this application is to measure the causal factors that lead to incidents, which will allow the user and administration to track the circumstances and types of incidents. This enables the company to focus on these problem areas and improve through training. By analyzing these incident trends over time, the company can conclude the following: if training reduces the total number of incidents for a given category (identified through these trends), then the corrective action is working. If not, the team must then redefine the problem, which is part of the aforementioned iterative process.

The purpose of this study was to identify a viable metric that captures safety practice improvement over time, and verify that the company's records indicate a correlation between quantity of incidents recorded and man-hours of exposure decreasing over time. Live server data was provided and a series of queries were performed on relevant tables. These result sets were then placed into a database created by the researcher and manipulated to display trend lines representing incident rates over time, as well as specifically identifying a metric of incident count per month/man-hours per month (companywide). Descriptive statistics were performed, with results indicating that although the reporting process itself was becoming standardized and the latter half of the trend chart showed comparable numbers, there was simply not enough reported data as of yet to provide conclusive evidence on the impact of lean practices as it relates to incidence quantity. It is the researcher's belief, however, that the data suggests an inverse relationship, as the quantity of human reported incidents had increased as a result of standardized practices and effectively captured more instances that may have likely previously gone unrecorded.

CHAPTER 1. INTRODUCTION

The following chapter will cover the scope, significance, purpose, research question, definitions, assumptions, limitations, and delimitations of the thesis research.

1.1 Background

Lean principles have been utilized in the manufacturing industry since the 1970's. The practices involved, derived from Six Sigma concepts, have revolutionized the business world and improved both quality control and metrics, ranging from leadership engagement to strategic project selection (Schroeder, 2007). Though the concept of utilizing lean practices in the construction workplace has often been associated with increasing productivity and decreasing waste, this concept in turn directly impacts the safety of the workforce. As jobsite efficiency increases, man-hours of exposure to potential accidents or issues decreases accordingly. In 2014 alone, 4251 total fatalities were recorded in the private sector, with 20.5% (874 people) being attributed to construction (OSHA, 2015). This is a significant improvement when compared to the 38 fatalies per day average reported in 1970, but more must be done on the part of the company in keeping its workforce safe, rather than relying on regulatory organizations to do so.

More recently, the construction industry has experienced a growth in both productivity and reduced accidents on jobsites due to the application of lean principles. According to the AGC Smart Market Report, 67% of survey respondents indicated a noticeable improvement in safety practices after implementing lean principles. Though there has been a positive response to the embrace of lean construction, none have been able to provide factual evidence that support this claim. The ability to monitor and establish both a baseline and level of improvement would benefit construction firms both financially and strategically; however, metrics have not been developed to monitor improvement of safety practices. By partnering with a small construction firm in the greater Chicagoland/Indiana area, the researcher aims to establish baselines of performance, observe the recorded data and practices used, and develop a metric that accurately captures the improvement of safety practices in empirical form.

1.2 Significance

The bulk of lean studies in industry are primarily centered on the production and assembly aspects, where companies seek to cut manufacturing or process costs. For the construction industry, where the hazards of a jobsite can make or break repeat business and reputation, jobsite safety is a key facet into which firms have sought to incorporate lean improvements. The results of this study's research should provide companies with a metric of quantitatively measuring the success of the general contractor's current jobsite safety practices, identify trends from incident reporting to create effective resolutions, and subsequently prevent repeat incident types.

1.3 Statement of Purpose

The purpose of this study is to quantifiably measure the degree of improvement in a company's safety practices, subsequently creating a tool for monitoring this improvement as data is added.

1.4 Research Questions

After consideration of both the available data and academic material, the following central research question was created:

> Can the safety of a company's jobsite and impact on its surroundings be quantifiably measured?

1.5 Definitions

Good catch – a potential error or near-miss event that is documented by a witness, which can later be analyzed for mitigation opportunities. ("How to Prevent Medication Errors", 2004)

Huddle – A 15 minute meeting that occurs each morning prior to work beginning, where employees check in, describe the work to be done for the day, and list any relevant information or authorizations that need to be obtained before work can commence.

Incident – Any recorded event, positive or negative, that may impact a worker or bystander's safety and well-being.

Lean – the concept of maximizing customer value and minimizing waste. ("What is Lean?", 2015)

Six Sigma - a set of techniques and tools for process improvement by identifying and removing the causes of errors and minimizing variability in manufacturing and business processes. (Schroeder, 2007)

1.6 Assumptions

The assumptions of this study include:

- There is a need to record and categorize jobsite incidents in the construction industry that provides companies with a means of analysis and subsequent empirical measurement of their safety performance over time.
- The results reported are standard of any construction firm that performs comparable work, as the ratio of incidents and amount of work performed will be comparable.

- The information provided by the company in this study is not altered in any way before being accessed by the researcher.
- The company identified in this study will possess accurate reports of daily reporting, any necessary financial data, and jobsite incidences for at least 10 consecutive months.

1.7 Limitations

The following are the understood limitations of this study:

- Benefits measured can vary due to circumstances beyond the researcher's control.
- There can be errors in recorded data on the company side.
- The study will utilize an experimental form of process improvement measurement, which may not encapsulate all aspects involved in the lean improvement phase.
- The intended sample size is limited to one company.
- Reporting practices have not been fully standardized, so reporting characteristics and quantity in earlier months may vary.

1.8 Delimitations

The delimitations of this study include:

- The participants in the survey will be exclusively located in the greater Chicagoland area.

- The study is solely based on the recorded information derived from the past 10 months of tracked figures.
- The study will focus on the provided categories of measurement that the company has been able to capture through reporting thus far.
- The study will be conducted exclusively in the first twelve weeks of the spring 2016 semester.

1.9 Summary

The intent of this chapter was to provide an overview of the scope, significance, definitions, assumptions, limitations, and delimitations. The following chapter provides background on the emerging technologies and methods found in the construction industry, particularly as they may apply to lean practices and hospital procedures, the initial intended audience of this study.

CHAPTER 2. REVIEW OF RELEVANT LITERATURE

Safety management (as it relates to productivity) has recently emerged as a central topic in the construction field, affecting contractor/client relations, employee morale, and the triple bottom line. Looking at the year 2014, the construction industry alone was responsible for 933 fatalities, which comprises 19.4% of the total recorded incidents for the entire year, among the highest of any given industry sector for the recorded period (Bureau of Labor Statistics, 2014). With the ongoing advancements in technology, the field is on a trajectory aimed toward decreasing accidents to an unprecedented low. Technology, patient satisfaction, subcontractor coordination, general contractor accountability, and owner facilitation account for only a few of the numerous stakeholders and necessities of a strong safety method. In this review, topics including the current state of safety in a hospital setting, future developments on the subject, and its correlation to process improvement are addressed.

2.1 Current Innovation

While the process of recording and reporting incidents itself is not uncommon and already a part of nearly every company's procedures, very little has been done to create action based upon the data that is being stored over time. Applications such as iAuditor exist that allow the creation of checklists and recording information in various formats, but the capability to analyze and capture the surrounding causal factors of the incident, as well as who and how it impacts others beyond just the company itself is not present in currently available programs. This is a void that the application (from which the researcher draws his data) seeks to fill.

Addressing the topic of technology's impact on safety, the implementation of radio frequency identification (RFID)-based real-time locating system (RLTS) has been a recent focus in the sector and is discussed in the collaborative journal article *RFID-Based Real Time Locating System for Construction Safety Management* by Lee, Park, Lee, Baek, and Lee. This same technology is currently utilized in the application from which data has been collected for this study. In the article, it is suggested that RFID tags be used as a way to continuously track the activities and efficiency of employees on site, a concept that many hospitals seek to implement in coming years for patient care and facilitation of tracking information. According to Lee, Park, Lee, Baek, and Lee (2012), "a construction site changes as it progresses, seeing an increase in obstacles, which can hamper effective radio signal transfer. Therefore, the robust and accurate localization performance becomes important in construction sites, particularly if it is used for safety management" (p. 367). While an RFID system would be an invaluable addition to any job site, there are inherent challenges to this concept that were addressed in the article. As Lee, Park, Lee, Baek, and Lee (2012) described, one crucial dependency is the type of environment the system is utilized in, classified as either a “line of sight (LOS)” or non-line of sight (NLOS) environment (p. 367). In a hospital setting, constant radio communications, human interference, and thick plaster walls/lead-lined barriers prevent any consistent connection from being established, rendering most hospital sites as a NLOS environment. As such, if there were an emergency situation, the repercussions could be severe. James M. Walker detailed this in his chapter entitled *Using Health IT to Improve Health Care and Patient Safety* (taken from the collaborative work *Health IT and Patient Safety: Building Safer Systems for Better Care*). In it, Walker (2012) found that:

> The proactive identification and control of hazards arising from errors in health IT (HIT) design and from the interaction of HIT with other healthcare systems prevent those hazards from ever stressing clinicians or harming patients. In this way, proactive hazard control achieves substantially greater safety benefits than the retrospective analysis of care-process compromises with or without patient harm (i.e., safety incidents and accidents). (p. 308)

The ongoing process of refining safety measures in the context of IT applications is detailed in Figure 2.1 below:

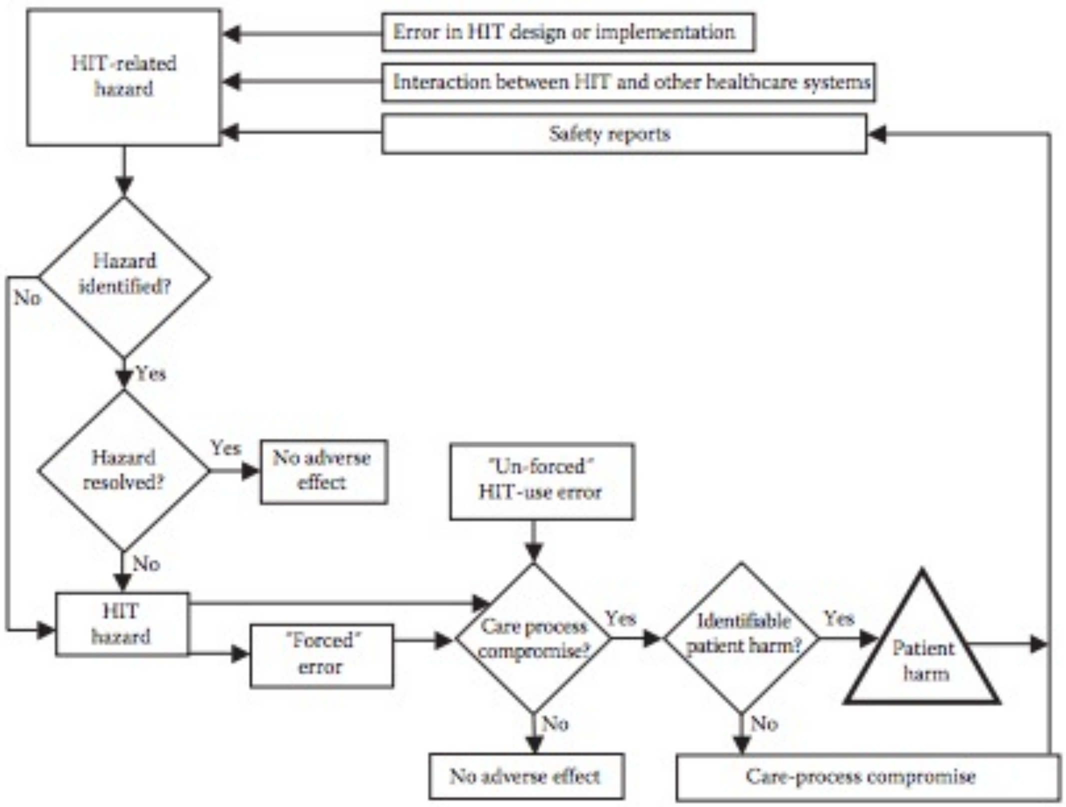

Figure 2.1 HIT Hazard Control 1 (source: Walker, 2012, p. 309)

Walker suggested that the introduction of technology into a system with no previous iterations could potentially introduce new complications into the process, a probability that cannot be afforded in such a high-risk environment. If the proposed RFID concepts by Lee, Park, Lee, Baek, and Lee could be properly pre-tested and trialed (especially with the combination of fiber optic networks, which would eradicate the aforementioned connectivity issues), it could reasonably reduce operational costs and time spent on both the owner and general contractor sides of business. Of course, this would require moderate capital investment on the part of the healthcare organization in order to find a suitable implementation plan for the new telecommunication infrastructure designs. This workflow is analyzed in *Visualization of Work Flow to Support Lean Construction*, in which the authors argued for the transparency of the process state to all participants (Sacks, 2009). Coinciding with the implementation of previously discussed RFID technology, this could facilitate the development of transparent practices that were discussed in Sacks' article.

2.2 Facility Management

Training presents another key component in creating a safer and more productive healthcare work environment. Currently, many hospital systems require (at the very minimum) OSHA 10-hour training and ASHE Healthcare Construction certification from certain individuals to be considered for work on site. However, each hospital system abides by its own training program, resulting in a wide variance of what is considered "high quality" practices. In a survey conducted by Andrea L. Steege, PhD, MPH, James M. Boiano, MS, CIH, and Marie H. Sweeney, PhD, MPH, responsiveness and understanding of what was conveyed in employee training (specifically regarding chemical and gas handling) was tested, with 12,028 respondents providing eligible data for the survey (2014). Table 2.1 below details the percentage of employees trained to handle each chemical/gas and/or are knowledgeable in emergency procedures:

Table 2.1 Chemical Handling Statistics

(source: Steege, 2014)

Trained on safe handling/ minimizing exposure to these chemicals	Ambulatory (n)	Ambulatory, never trained (%)	Hospital (n)	Hospital, never trained (%)	P-value for X^2
Aerosolized medications					
Antibiotics: tobramycin, amikacin, colistin	11	—[a]	257	48	—
Pentamidine	15	—	171	23	—
Ribavirin	3	—	37	14	—
Antineoplastic drugs					
Compounding	250	7	172	16	<0.01
Administration	716	5	1,181	5	0.77
Chemical sterilants					
Ethylene oxide (EtO)	23	39	131	5	<0.01
Hydrogen peroxide gas plasma	31	3	289	9	0.29
High level disinfectants	1,339	14	2,423	17	0.02
Surgical smoke	767	43	3,817	44	0.49
Anesthetic gases	824	14	2,524	18	<0.01
Employer has standard procedures for handling/ minimizing exposure to these chemicals	**Ambulatory (n)**	**Ambulatory, no procedures/ unaware (%)**	**Hospital (n)**	**Hospital, no procedures/ unaware (%)**	**P-value for X^2**
Aerosolized medications					
Antibiotics: tobramycin, amikacin, colistin	11	—	255	45	—
Pentamidine	16	—	171	15	—
Ribavirin	3	—	37	16	—
Antineoplastic drugs					
Compounding	251	20	172	13	0.07
Administration	717	7	1,177	5	0.02
Chemical sterilants					
Ethylene oxide (EtO)	23	30	131	4	<0.01
Hydrogen peroxide gas plasma	31	10	288	9	0.96
High level disinfectants	1,342	22	2,422	15	<0.01
Surgical smoke	766	69	3,818	68	0.97
Anesthetic gases	827	37	2,525	45	<0.01

[a]Dash indicates that due to small numbers no statistic was calculated.

Regarding the above information, Steege, Boiano, and Sweeney (2014) stated that “Although all workers who use or have potential exposure to hazardous chemicals should be trained and have procedures for their safe use, these administrative controls were not universal for all chemical agents included in this study”, and that “hospital workers who administered antineoplastic drugs were more likely to report their employer had safe handling procedures than those who worked for ambulatory health care settings. Health and safety practices in different types of healthcare work settings should be examined further” (Steege, Boiano, Sweeney, 2014, p. 642). It can be inferred from the article that there is often an inadequate administration of proper training practices to all relevant staff members, indicating also that the onus of what is perceived as "adequately trained" on ambulatory employees differs greatly from the expectations set in a hospital setting. It can also be inferred that a hospital demands comparable expectations of any associated contractors and vendors as it would its employees.

2.3 Contractor Focus

On the contractor side of business, a report titled *Facility Design Focused on Patient Safety*, by John Reiling, identifies the notion of facility design as a measure of fortification towards human safety. In it, Reiling states:

> If we focus on facility designs in which equipment and technology support human safety as the primary goal, we can lower the adverse events, near misses, errors, and preventable medical deaths. Examples of design features that would accomplish this are standardization, noise reduction features or specific design features related to magnetic resonance imaging failures, infections, and falls (see the safety design principles including designing around precarious events). In fact, from a mission standpoint, lowered adverse events, near misses, errors, and preventable medical deaths bring a positive return in value (Reiling, 2004, p. 43).

Reiling’s (2004) findings concur with those of Pascale Carayon (2012), who analyzes from a psychological and cognitive perspective of those in the hospital, rather than the building itself. Carayon states, “Working environments in health care can impose many physical, cognitive, or psychosocial stressors on the health care providers and workers as well as on patients and families” (Carayon & Alvarado, 2012, p. 7). She also stresses the importance of “designing the healthcare workplace for optimal human performance and using technologies such as lifting devices to minimize the need for human strength can help reduce the physical stressors experienced” (p. 7). Many companies seem to operate under the notion that they must operate in a broken environment, yet the solution itself seems to be remedying the environment itself so that more conducive practices can begin to be developed. Forbes and Ahmed (2011) provide an illustration of the construction process within such a facility and how the progress towards completion is inversely related to the level of control over safety measures available, as shown in Figure 2.2.

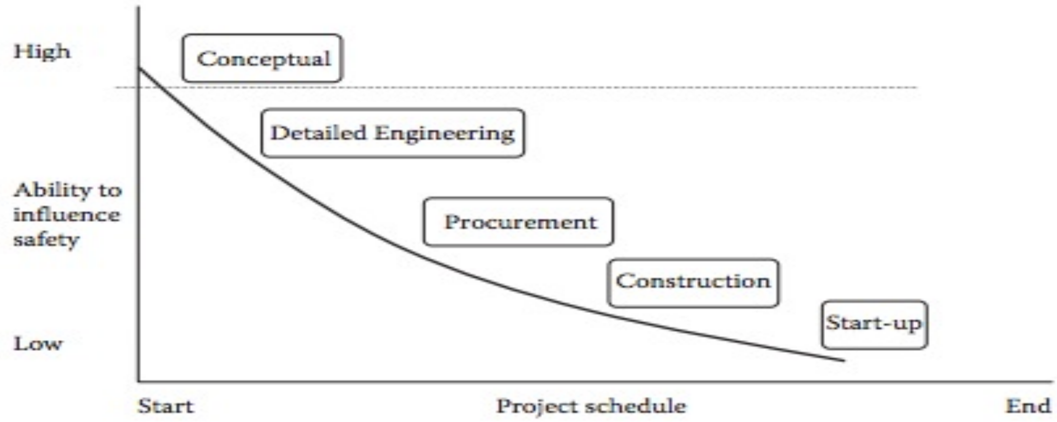

Figure 2.2 Project Schedule vs. Safety Influence
(source: Forbes, Ahmed, 2011)

Michael Taylor and William Moore, who wrote *Emphasizing Job Site Safety*, conveyed a potential solution through the opinion that “Officially designating someone to be in charge of demolition safety is essential. Even if he or she has other, unrelated responsibilities, he or she should have the title of safety director” (Taylor & Moore, 2000, p. 241). Many systems have adopted the practice of designating a safety director who works on site and regularly inspects ongoing job areas for any early indicators of an accident or complication, as well as ensuring that any code compliant items are approved and acceptable for official inspection on a local and state level. If this level of accountability persists throughout the duration of work, contractors can be more assured of the responsibility maintained by their employees and subcontractors, and hospital management can be directly involved in the process to ensure that the work being performed is conducive to the environment they seek to create.

2.4 Market Need

In recent news, the ebola epidemic scare brought to light many deficiencies in the U.S. healthcare system, particularly in the department of isolation facilities. Looking toward the public, Steven Ross Johnson's article entitled *Divisions Surface Between Healthcare Workers, Public Over Ebola Quarantines* (2014) addresses the issue, with interviewees stating:

> "One thing that was very striking to us compared to what we see going on here in the U.S. was the level of awareness that people had in Nigeria," said Dr. Sola Olopade, a professor of family medicine and clinical director for the University of Chicago Medicine's Center of Global Health…"It wasn't out of fear," Olopade said of the preventive measures. "It was out of understanding of what Ebola was, and what precautions they needed to take." That clearly wasn't the case in the U.S., where even healthcare workers remain sharply divided over how potentially exposed individuals should act (Johnson, 2014, p. 44).

While the situation was handled effectively in the Texas-based health centers, many systems across the country immediately began looking into preventative measures in the event that the incident became a serious pandemic. From a political perspective, Bob Kirsch's article *America Takes Action on Disease Prevention* reads:

> "An additional strength is how the action plan has been structured to catalyse local and regional action plans," said Andrew Rein, Associate Director for Policy at the CDC: "It's not a federal prevention strategy but a national prevention strategy, and it really has the greatest impact when people across the country pick it up in their own work" (Kirsch, 2012, p. 715).

As hospitals become more of a regional brand than a local business, it is important that each system adopts a form of effective prevention through early contact with contractors to ensure that their existing facilities are suitably equipped to handle any potential influx that may result from the virus. Figure 2.3 (Carayon & Alvarado, 2012) illustrates the requirements of effective disease prevention on the owner's side, as well as the input potentially required from a contractor to create these necessary spaces:

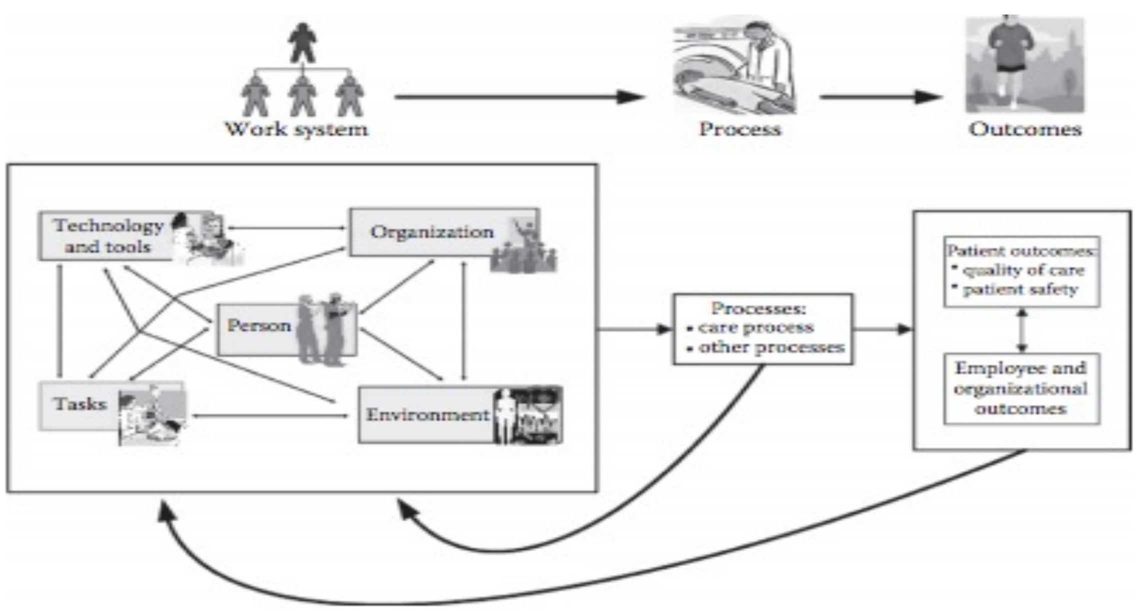

Figure 2.3 Owner Disease Prevention Methods
(source: Carayon, Alvarado, 2012, p. 795)

At the heart of the topic, lean principles have become one of the most impactful developments within the construction industry, improving the infrastructural quality of a firm and cutting waste from a jobsite, both financially and from a safety perspective. Eric Antillon's thesis on the correlation between lean practices and safety management presents strong evidence as to the benefits of implementing processes such as pull scheduling (*kanban*) and in-process quality control. In it, he methodically conducts interviews and subsequently develops an interaction matrix between lean construction and safety management practices by using these interviews in a research synthesis (Antillon, 2010). Moving forward, it is possible that the researcher may model a similar research process to build upon the correlation that Antillon identified.

2.5 Offsite Pre-Manufacturing

The concept of offsite prefabrication and its role in the "lean" process as it pertains to construction has played a large role in cutting costs, time, and by direct correlation, safety incident occurrence. Steadily becoming a commonplace procedure in modern jobsites, offsite prefabrication has become a major method of innovation in establishing a work climate of continuous improvement. The positive results of a more controlled environment and subsequent reduced risk in the workplace have been proven in working in an occupied facility, detailed in Table 2.2.

Table 2.2 Benefits of Offsite Prefabrication (source: Gibb, 2003)

Benefit (from most highly rated to lowest rating)	Cost related
1. Minimises on-site operations	
2. Reduces congested work areas and multi-trade interfaces	
3. Minimises on-site duration	#
4. Improved health & safety by reduction and better control of site activities	
5. Produces high quality or very predictable quality finishes	
6. Minimises number of site personnel	
7. Benefits when only limited, or very expensive on-site labour	+
8. Enables existing business continuity	
9. Can cope with restricted site storage area	
10. Enables inspection and control off-site works	
11. Provides certainty of project cost outcomes	+
12. Provides certainty of project completion date	
13. Less environmental impact by reduction and better control of site activities	

Aside from productivity and safety benefits directly produced from this process, companies can take advantage of reduced costs due to lower labor unit cost for offsite versus onsite work, as union wages are lower in the shop.

Being that offsite prefabrication provides the benefit of reducing overall man-hours of exposure for working employees, this ties directly into the data being gathered by the researcher. The process itself could also potentially be implemented as a standalone factor for analysis in the root application for future development.

2.6 Summary

Looking toward the future of healthcare safety, it is obvious that the primary focus should undoubtedly be the well-being and experience of the patients. With this in mind, future endeavors should cater to establishing a hassle free environment that not only minimizes the percentage of error and accidents in a given area, but also facilitates the process for subsequent work to be done. For example, asbestos abatement that is still being performed on today's renovated buildings should serve as a reminder of the long-reaching effects of current practices. By providing a more effective, documented, and adaptable structure of work that ensures safety, as well as efficiency, companies can eliminate a degree of mystery and minimize risks for subsequent work to be done.

CHAPTER 3. FRAMEWORK AND METHODOLOGY

This thesis will be presented through the use of a quantitative case study that is focused on one small general contractor. The methods in this study will seek to identify a quantifiable metric through which the success of a general contractor's safety practices can be measured. By identifying variables in the site operations and procedures, a concise scale of success and improvement can be developed.

3.1 Methodology

The methodology for this study is to first generate queries from the server via SQL Server Management on the live data, with a cutoff date of March 31, 2016 for recorded results. This server is accessed by first logging into the company Citrix server, then initiating a remote desktop connection to the IT company's server that manages the application and all relevant records held within. Upon accessing this second server, the SQL Server Management Client can be utilized to view and query all live data files within the company-designated folder. After extracting the result sets from the required tables, a separate query is created in MS Access, connecting the common columns in each table to create a filterable database. This table is then converted to an Excel format to allow data analysis and inclusion of a small data dashboard, with information such as total number of green, yellow, and red severity incidents to date, total issues identified, and other key data necessary to determining the central question of empirically ascertaining safety levels.

The table is then manipulated to display incidents by month, with duplicate "Huddle ID" entries eliminated to avoid double-counting entries in the "Number of Hours Worked" column. Since it has been established that man-hours of exposure is the key to determining the chance of an incident occurring, and each incident pertinent to a given huddle is associated with a unique Huddle ID that has multiple instances of the same man-hour count (from each recorded incident), the researcher totaled the number of unique hours to that point for each month of activities. This total represents the sum of all associated workers with that Huddle ID up to the point that the incident occurred. A count was also performed on the number of incidents that occurred each month. Using these two totals, an array was created showing the ratio of incident count per total man-hours for both the full totals each month (which includes auto-generated incidents) and corrected totals (without auto-generated incidents), seen in Table 4.2. This array represents the target metric that the researcher set out to establish, which also provided identification of factors that influenced the figures collected.

3.2 Population/Sampling Approach

The considered experiment population was limited to one general contracting firm in the greater Chicagoland area who:

1. Primarily performs work in the healthcare sector
2. Approves release of tracked incident information and site huddle information.
3. Possesses an EMR of 0.89
4. Performs approximately $60,000,000 of work per year

The researcher's sample approach was to work with this general contractor due to the willingness to share data, variety of data collection sources, and consistency of annual performance records. The collected data set will span all 10 available recorded months, beginning with the earliest available period of June 2015 and ending in March 2016.

3.3 Measurement/Variables

As a form of exploratory research that seeks to identify the form of metric required for encapsulating all considered data, it has been determined that the following data is necessary in reaching that goal (capitalized to reflect the name of each column on the query database, as seen in Table 3.2): Incident Title, Date, Time, "Original" and "Revised" Severity, Number of Hours Worked, Number Checked In/Out, Work Area, Incident Factory Type ID, Incident Factor Category, Incident Factor Sub Category, whether the incident has been Identified In Huddle, and Incident Status. The independent variable is the amount of time passed per set of incidents, as this determines the frame of measurement for each subset of data. The dependent variable is the number of incidents (per set time frame, in this case per month) divided by the quantity of hours worked company wide for that same month, as this will determine the ratio of how often an incident occurs throughout the total man-hours worked that month. Other variables include the state of the market for the designated time period, success of the company before measurement, type of work performed, and quality of subcontractors used.

3.4 Analysis

Through the utilization of SQL Server Management and Microsoft Access databases, raw data is translated to trends that can be visually represented as outputs through the software. These outputs identified number of incidents by category, location, severity, and other criteria that make it possible to discern any contributory common traits that require attention on the part of the contractor.

It has been determined that quantitative analysis techniques will be applied to this study, as the researcher is seeking to establish the aforementioned metric using tools and procedures for inferential statistical analysis.

After identifying that the key variables included the number of hours worked per huddle and the quantity of incidents over a given time period, tables were created. One contained the total each month (including auto generated categories, which is comprised of “Auto-Check Out an Employee” and “Lacks Proper Authorizations”) and was labeled as “Total”, while the other only contained man made entries, excluding the previous two categories, and was labeled “Corrected”. Keeping in mind that the time scale was reduced to a monthly basis for the purpose of this study, the researcher determined that the count of incidents each month per total number of hours worked companywide in that same month would provide a quantifiable means of measuring safety. The researcher also deemed it necessary to analyze the issues encountered during the data collection process that influenced the results, as well as their potential impact on the data set.

3.5 Summary

This chapter provided the framework and methodology used in the research study. The following chapter will cover data collection, data analysis, and results from observation.

CHAPTER 4. DATA ANALYSIS AND FINDINGS

Given the information provided from the literature review, the current necessity and future application of incidence tracking has been made clearer, as well as validating the goals of this study. By confirming that a measurement system with post situation analysis does not publicly exist, the data pulled for the purpose of this study is exclusively applicable given the previously stated limitations and delimitations.

The researcher was provided access to the live server data as of March 14, 2016, in which queries were performed within SQL Server Management Studio. The time frame for data collection was June 1, 2015 through March 31, 2016, in order to obtain the most recent results available by complete months. Compiling this data together, then exporting the result set to Excel yielded the following table:

4.1 Data Representation

The following is a breakdown of each column heading and the data it

Table 4.1

	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Title	Date	Time	inal Severity	ed Severi	er Of Hours	per Checked	Work Area	dent Factor T	cident Factor Cate	ident Factor Sub Cat	ID'd In Huddle	Incident Statu
2	Dialysis Construction Separation	6/3/15	5:00:00 PM	R	R	245	32	North	10	Fire Protection	Other Fire Protection	0	C
3	Life Safety Systems Compromised	6/3/15	5:00:00 PM	Y	Y	245	32	Northwest	10	Fire Protection	Fire Sprinklers	0	C
4	Ceiling Tiles Missing in Corridor	6/3/15	10:53:00 PM	R	Y	245	32	North	10	Fire Protection	Fire Sprinklers	0	C
5	Electrical Distribution Tape on Fire Alarm Detector	6/3/15	11:00:00 PM	R	G	245	32	Southwest	1	Fire Protection	Fire Alarm Detecters	0	C
6	Life Safety System Compromised	6/3/15	11:04:00 PM	Y	Y	245	32	Southwest	10	Fire Protection	Fire Sprinklers	0	C
7	Fire Protection Heads Not Turned Up at Deck in Construction Area	6/3/15	11:08:00 PM	R	R	245	32	Southwest	1	Fire Protection	Fire Sprinklers	0	C
8	1.5" Natural Gas Line Broke	6/24/15	2:21:00 PM	R	R	88	17	Other	1	Excavations	Soil Stabilization	0	C
9	1.5" Natural Gas Line Broke	6/24/15	2:21:00 PM	R	R	88	17	Other	1	Policy / Procedure	Risk Assessment	0	C
10	Knee Injury Exiting Excavation	7/9/15	7:20:00 PM	Y	Y	103	13	Other	10	Other	Other	0	C
11	Auto-Check Out an Employee	8/6/15	9:48:16 PM	Y	Y	174	24	North	8	Policy / Procedure	Other Policy / Procedure	1	C

represents:

Title: references the title of the incident itself

Date: date the incident was reported (M/D/YY)

Time: Hour, minute, and second that the incident was reported

Original Severity Level: The original classification of how severe the incident was.

G: Green – low severity

Y: Yellow – moderate severity

R: Red – high severity

Revised Severity Level: The classification of severity determined after the incident was reviewed and resolved.

Number of Hours Worked: Total count of attributable man-hours to an incident from every employee that attended the associated Huddle ID (Huddle ID column hidden on query spreadsheet).

Number Checked In/Out: Total count of employees tied to a unique Huddle ID that checked in or out to the project location associated with the particular incident.

Work Area: Area/wing of a jobsite in which the incident occurred. This information is derived from linking the name label with the Location ID given in the data set (Location ID column hidden on spreadsheet).

Incident Factor ID: Number given to each Factor type for a given incident. While the numbers themselves are not significant to data interpretation, they are utilized in linking both the Factor Category and Sub Category columns to their respective associated incidents.

Incident Factor Category: The causal circumstances leading up to an incident occurring. These fields are selected from a predetermined drop down menu of 18 categories.

Incident Factor Sub Category: The specific aspects of circumstances identified in the Incident Factor Category column that contributed to the incident occurring. These fields are selected from a predetermined drop down menu of 38 sub categories.

ID'd In Huddle: Indicates whether the incident was identified and recorded in the daily huddle at the beginning of the workday. A "0" indicates no, and a "1" indicates yes.

Incident Status: Indicates whether the incident has been reviewed and successfully resolved with a course of corrective action. A "C" indicates that the incident has been successfully closed, and an "O" indicates that the incident is still open and unresolved.

Each column can be filtered to display only a specific set of data, and cross column filtering is available to analyze the conditions of one data set given the effects of variables from other specified columns.

4.2 Trend Line Analysis

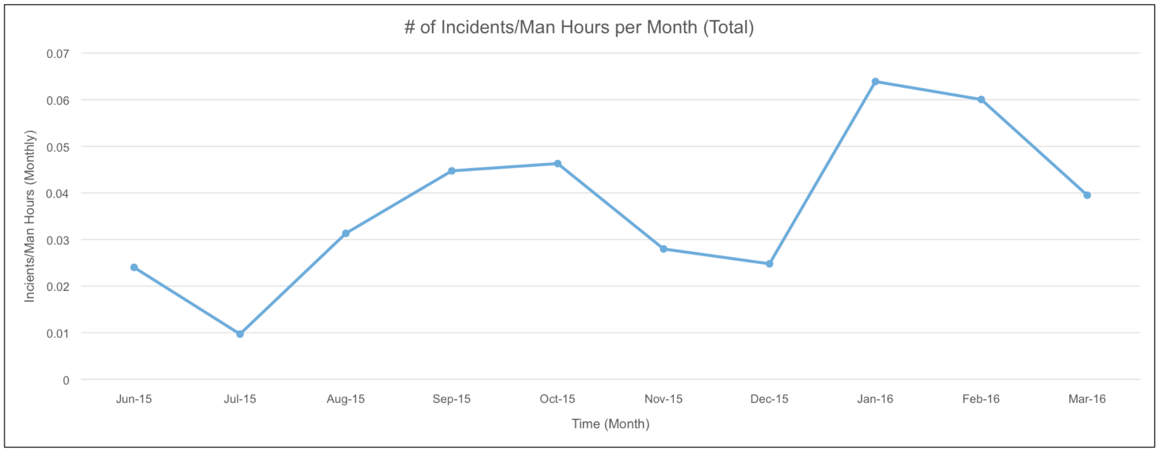

Figure 4.1

First considering the line graph containing incidence rates of the “Total” ratios each month in Figure 4.1 above, there is a noticeably low incidence rate for the first 3 months. This is due to a lack of standardized reporting procedures within the company, therefore impacting the quality of data recorded. However, as the auto-generated fields became implemented by the system beginning in September, the quantity of incidents reported climbed steadily, decreasing only during the end of 2015 due to a slowdown in work during the winter months. The sharp upturn in the reported line in January represents the beginning of quality data that can be considered for use in noting real trends.

This change is more accurately reflected when we remove the auto-generated events, using the information generated in the “corrected” column to populate the line graph below:

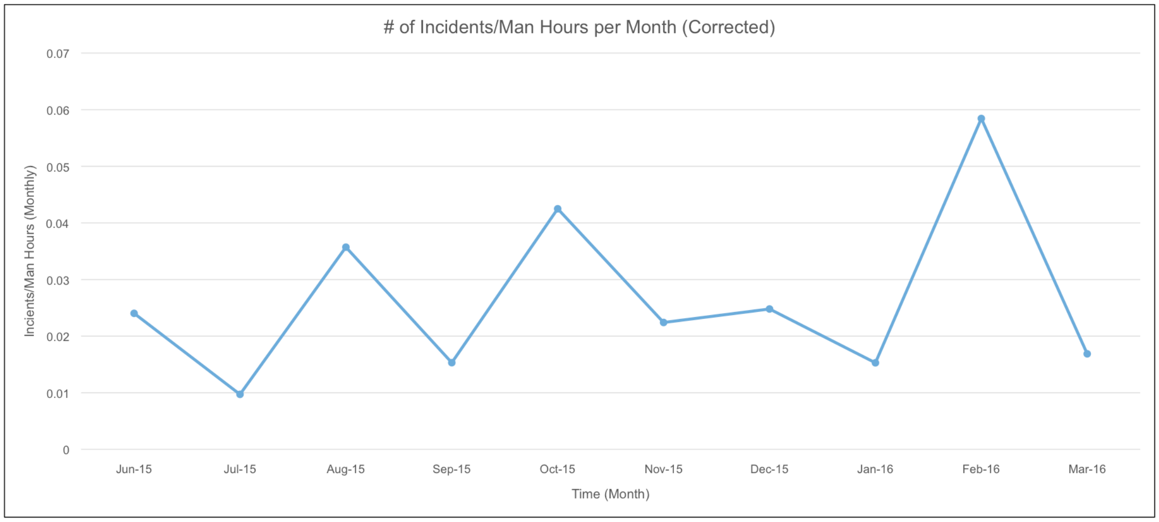

Figure 4.2

While Figure 4.1 indicates that there was a sharp increase in incident occurrence over total man-hours for that month, the auto-generated events began populating in July, inflating numbers beyond the actual values. With the application only starting to gain traction within the company, the process of reporting incidents had not been standardized until January 2016, creating erratic patterns of recorded data that indicated fluctuation between low and high incident ratios from June 2015 to November 2015.

As stated previously, from June 2015 to January 2016, the make-up of the data is significantly different from that of February and March 2016 due to the change in reporting procedures and data collection. The outlier that exists in February 2016 (seen in Figure 4.2) can be attributed to the introduction of "positive" incident recording, where good catches and near misses were included in the reporting process. This saw a large spike in total quantity of incidents reported, with the same Huddle ID used to sort each incident being used to track total man-hours for that month. Aside from this outlier during the more established reporting period of January 2016 to March 2016, the results became normalized to where meaningful data can be collected and used to establish a baseline of performance. At this point, additional data collected cannot be removed nor distinguished from the existing data until a filterable reporting process can be implemented into the application

4.3 Statistical Analysis

With a limited quantity of data available to the researcher at the point that the study was conducted, it was determined that descriptive statistics would be performed to adequately establish a baseline so that as greater quantities of data are input into the query, the results will become more accurate. Pearson's product-moment correlation test was also performed to identify the relationship between the quantity of time passed and the ratio of incidents per total man-hours. A Pearson's test, which measures the "strength of a linear association between two variables" by "drawing a line of best fit through the data of two variables" (Laerd), would provide an output of *r.* This output exhibits the following characteristics:

> *r* can take a range of values from +1 to -1. A value of 0 indicates that there is no association between the two variables. A value greater than 0

> indicates a positive association; that is, as the value of one variable increases, so does the value of the other variable. A value less than 0 indicates a negative association; that is, as the value of one variable increases, the value of the other variable decreases (Laerd).

Though the Pearson's test will not necessarily be accurate in the application of this study for the issues outlined in section 4.4, it has been provided nonetheless to show the current state of the data set. Below is the resulting data table and aforementioned tests performed on the data arrays for the recorded 10 month interval:

Table 4.2

Incidents per Month/Total Man Hours per Month				
	Total		Corrected	
Jun-15	0.024024		0.024024	
Jul-15	0.009709		0.009709	
Aug-15	0.031341		0.035714	
Sep-15	0.044743		0.015306	
Oct-15	0.046308		0.042493	
Nov-15	0.027977		0.022406	
Dec-15	0.024793		0.024793	
Jan-16	0.063915		0.015284	
Feb-16	0.060056		0.058442	
Mar-16	0.039514		0.016867	
AVERAGE	0.037238		0.026504	
MEDIAN	0.035427		0.023215	
PEARSON'S	0.626802		0.226708	

With the inclusion of the auto-generated incidents, the ratios of the "Total" column represent inflated figures that are more accurately represented in the "Corrected" column. Because the available data only spans a period of 10 months, with August 2015 indicating the start of the auto-generated incident reports, and standardized reporting procedures not taking hold until January, the current data shown above cannot be counted as either significant or reliable for any basis of factual evidence indicating a definitive outcome.

4.4 Data Set Issues

Looking at the contributory issues that caused the data to skew, the first prevalent issue was the lack of standardized procedures regarding the reporting process itself. Being that the program was relatively new to the company, there was no uniform method of reporting issues that existed until January 2016. As such, the data was scattered for the first 7 months. Being that this is an issue of company culture alignment and adoption techniques, it has been discussed as a future topic for study in section 5.2.

As the program progressed, coding was implemented to track the check in/check out times of employees to monitor jobsite presence. This was done to mitigate the possibility of an event such as an employee performing work after hours unmonitored and being involved in an accident unbeknownst to management or fellow employees. Coding was similarly implemented to track the authorizations of each employee as they enter a work area via the Huddle ID. If an employee does not have the proper authorization to be on site, in a specific area, or performing a specific type of work, the system will generate an incident report with the associated contributing factors that lead to the occurrence. With employees forgetting to check out at the end of a work day, or failing to report certain authorizations required in the system for site work, large quantities of auto-generated events were created and diluted the overall results, as seen in the differences between Figure 4.1 and Figure 4.2. This issue serves as an additional complication that mainly stems from the aforementioned lack of standardized reporting procedures.

The third and final data complication was the addition of good catch reporting, beginning in February 2016. Without a method of differentiating between “good” and “bad” incident types, the over-reporting of good catches caused the data to spike heavily during that month, as seen in Figure 4.2. This was caught and regulated sufficiently to the point that data appeared to be normalized when comparing January 2016 to March 2016, indicating some semblance of standardization and uniformity in the data set. This, however, was not sufficient to make conclusive claims.

4.5 Summary

This section looked at the resulting data sets and determined a lack of conclusive evidence to make any substantiated claims about the relationship between the dependent and independent variables; however, the researcher was successfully able to establish a metric that quantifiably measures the safety of a company based on the ratio of total incident count per total man hours (companywide) over time. Issues within the data set were also identified in order to prevent further studies from including these same variables in their procedures.

CHAPTER 5. CONCLUSIONS

The results in this study were solely based upon the available 10 months of data; as such, the results are not conclusive enough at this point to accurately indicate any correlation between lean principles and the decreases in incident rate over time. If a longer time period were available to pull data from, this data set could easily be substituted in the created database and provide more accurate trend charts and line graphs for future projections on a management level.

Given that the biggest limiting factor of this study was the length of time from which data was interpreted, it would be beneficial to conduct the same test type of monthly incidents at a later date, once sufficient data has been standardized and properly reported. As the current study has established a form of baseline, a greater quantity of results can provide more accurate ratios and definitively indicate the relationship between incident quantity and man-hours of exposure over time that the Pearson product-moment correlation coefficient describes in Table 4.2. Based on what has been discovered thus far in this study, the data and background research have lead the researcher to infer that there may likely be an inverse relationship between quantity of incidents per total man-hours spent and time elapsed as the study becomes more refined.

Regarding the incident types reported, the researcher suggests that further studies should consider the differentiation between “positive” and “negative” incidents recorded, and their impact on a particular company’s safety habits. While this study provided the means of tracking incident titles and incident factor categories, there is not a differentiating system in place that would separate a “good catch” or “near miss” from an accident that did, in fact, occur. To capture this would provide even more accurate results in a measurement of overall safety. Methods of accomplishing this could be modifying the system through which data is collected itself to be able to reflect this change through code, or adding an entirely new filterable column of data through which the incident is associated with a “positive” or “negative” label.

One method of expediting the standardization process is to combine the performance review directly with consistent and responsible use of the application, which would subsequently affect any potential bonuses. Incentive based programs such as monetary compensation will be tied to who is using and reporting the site accurately as an incentive based program and a metric for employee reviews

As this tool and study becomes more refined and continued, the researcher hopes to see a visible decrease in jobsite accident occurrence, and continuous improvement from a top down perspective in management making a difference across the industry.

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APPENDIX

Appendix A - Company Data Release Form

MICHUDA
CONSTRUCTION INC.
ESTABLISHED 1919

18505 West Creek Drive, Suite 1A
Tinley Park, IL 60477
TEL: 773-445-5505
FAX: 773-445-5518
www.michuda.com

April 7, 2016

Professor James Jenkins
Knoy 435
Building Construction Management
Knoy Hall of Technology, Room 453
401 N. Grant Street
West Lafayette, Indiana 47907-2021

RE: IRB Request
Graduate Candidate Nicolas Michuda Thesis

Dear Professor Jenkins:

Please be advised that Michuda Construction, Inc. hereby consents to the release and transfer of its data to Nicolas Michuda in fulfillment of his graduate research studies. If you require further information, please contact the undersigned

Yours Very Truly,
MICHUDA CONSTRUCTION, INC

Josef L. Michuda
Executive Vice President

JLM/jlm
file