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Determining Safety Inspection Thresholds for Employee Incentives Programs on Construction Sites

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Abstract

The goal of this project was to evaluate approaches of determining the numerical value of a safety inspection score that would activate a reward in an employee safety incentive program. Safety inspections are a reflection of the physical working conditions at a construction site and provide a safety score that can be used in incentive programs to reward workers. Yet it is unclear what level of safety should be used when implementing this kind of program.

This study explored five ways of grouping safety inspection data collected during 19 months at Harvard University-owned construction projects. Each approach grouped the data by one of the following: owner, general contractor, project, trade, or subcontractor. The median value for each grouping provided the threshold score. These five approaches were then applied to data from a completed project in order to calculate the frequency and distribution of rewards in a monthly safety incentive program. The application of each approach was evaluated qualitatively for consistency, competitiveness, attainability, and fairness.

The owner-specific approach resulted in a threshold score of 96.3% and met all of the qualitative evaluation goals. It had the most competitive reward distribution (only 1/3 of the project duration) yet it was also attainable. By treating all workers equally and maintaining the same value throughout the project duration, this approach was fair and consistent. The owner-based approach for threshold determination can be used by owners or general contractors when creating leading indicator incentives programs and by researchers in future studies on incentive program effectiveness.

Keywords

Leading indicators; incentives; construction; reward threshold; worksite safety program

1. Introduction

Worksite approaches to address the high morbidity and mortality rates in the construction sector (CPWR, 2008) include a variety of programs and policies ranging from requiring specific worker safety training to sophisticated pre-task safety planning. One approach, employee safety incentive programs, addresses worksite safety by improving feedback to the

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employees about the worksite's safety performance and thus provides workers with additional motivation to create a safer work environment (Cooper and Phillips, 1994; Gilkey et al., 2003). With the goal of changing safety culture, the mechanics of employee safety incentive programs use a given safety performance threshold to reward workers when a certain performance criterion is achieved (Figure 1). If the workers exceed this predetermined threshold level of safety at the end of a reward period (i.e. one month, one quarter), they receive a reward(Fell-Carson, 2004).

The typical safety performance metric and threshold for employee safety incentive programs is the number of lost time or recordable injuries; however, the lagging nature of this safety performance metric raises doubts about its effectiveness in truly reducing injuries and moreover changing the work environment (Mohamed, 2003). Lagging indicator incentive programs may give only the illusion of lowering injury rates since the reward is based on an absence of reported injuries, which may incentivize under-reporting of injuries(Brown and Barab, 2007; Duff et al., 1994; Michaels, 2010). More specifically, workers may feel pressured not to report an incident to their supervisor, as it could cause the period without a recordable injury to be reset, and thus prevent the rest of the employees from receiving the reward (Fell-Carson, 2004).

Novel proposed employee incentive programs use safety performance metrics that precede an incident, mainly the reduction of physical hazards on a worksite; however, identifying a threshold for a leading indicator reward system based on a systematic method to quantify the control of hazards on a worksite has not been described before (Haslam et al., 2005; Nelson, 2008). Methods to quantify the control of hazards on a worksite involve some form of a safety audit, walkthrough, or safety inspection completed by a project or safety manager (Dennerlein et al., 2009; Dyck and Roithmayr, 2004; Mikkelsen et al., 2010). These construction safety audit programs have been packaged into commercially available programs (e.g., Predictive Solutions). Data from these inspections, which include both safe and unsafe work practices, can generate a weighted safety score that reflects the number of safe observations out of the total observations (Cooper and Phillips, 1994).

Current published studies focus only on one subgroup of workers or one type of work practice (Cooper and Phillips, 1994; Duff et al., 1994; Lingard and Rowlinson, 1997; Wiscombe, 2002). None have addressed the complexity associated with construction worksites. A typical construction project is comprised of an owner, a general contractor, and numerous subcontractors (of various trades), all of whom have different experiences and attitudes towards safety (Gittleman et al., 2010). Hence, there is no standard published protocol for selecting an appropriate threshold value for an employee safety incentive program based on quantifiable safety inspections/walkthroughs.

As demonstrated in research in other industries and other incentive-based behavioral change programs, a reward threshold score should feel attainable by all workers on-site, yet it also should be competitive enough that it encourages improvement in safe work practices (Fell-Carson, 2004). While a reward threshold of 100% might be ideal, it is unrealistic to implement such a standard. If workers never meet the threshold and never receive a reward, they may grow weary of the incentive program and stop trying to improve their safety behavior. At the same time, if the threshold is too low, and workers receive the reward each month, they may not see the point in trying to improve their safety behavior (Lingard and Rowlinson, 1997).

The goal of this descriptive study was to evaluate various approaches to selecting a threshold value from inspection data for design of a leading indicator employee safety incentive program. All approaches use pre-existing safety inspection data (leading indicators), collected prior to the start of this study, from multiple projects from a 19-month period on a large university campus. The use of safety inspection data replicates a process that could be easily completed in a real-world health and safety program for construction.

Potential approaches to threshold calculation vary by different groupings of inspection data within large scale commercial construction work, either from a general contractor or owner perspective. Evaluation of the threshold consisted of calculating the frequency and distribution of a monthly reward program at a completed construction project. The evaluation criteria are qualitative in nature and require that the resulting score and its reward frequency and distribution are consistent, competitive, attainable, and fair.

2. Methods

2.1 Inspection Data

This study utilized data from inspections (walk-through safety audits) conducted by the Harvard Construction Safety Group (HCSG) at 65 Harvard projects between January 2009 and July 2010 (Table 1). Although safety performance scores were available from September 2007 on, this study only used data from January 2009 onward for threshold development, as by that time inspectors had become more familiar with the inspection process. This allowed for a more standardized, and thus more accurate, inspection process and data collection. This study was exempt from the Harvard School of Public Health Institutional Review Board as the data contained no human subjects identifying information.

Inspections were conducted approximately once per week at each of the 65 construction projects, covered the same safety parameters (mainly physical working conditions), and were completed by the same four expert inspectors (HarvardConstructionSafetyGroup, 2010). The inspectors then entered their detailed safety inspections into Predictive Solutions (Industrial Scientific, Oakdale, PA, http://www.predictivesolutions.com/solutions/SafetyNet/), an online data management program formally known as Design Build, Own, and Operate (DBO^2). Once in the system, the data were exported to statistical programs for further analysis. All inspections occurred prior to the start of this study, thus inspectors did not know that the data would be used to generate a safety incentives reward threshold.

The observations that were entered into the Predictive Solutions database by the inspectors included most of the variables used in this study: the name of the subcontractor responsible for the work practice observed; the project where the observation occurred; the general contractor of the project; the number and type of safe observations on a certain date; and the number and type of unsafe observations on a certain date. Two other variables, owner and trade, were also used in this study but not explicitly specified in the each observation. The owner of all projects the database was Harvard University, thus this was not denoted in observations. The first author assigned each subcontractor a construction trade based on discussions with HCSG inspectors and review of company webpage's. The system was not designed for observations at the worker level, thus information on individual workers at the sites was not collected and is not discussed here.

2.2 Threshold calculation approaches

This study explored five approaches to calculate a reward threshold for a leading indicator employee incentive program. Each approach grouped the individual safety inspections together in different ways based on different organizational structures of the construction worksite: by owner, general contractor, project, trade, or subcontractor (Table 2). Our rationale for selecting these five approaches was that safety perceptions vary among different groups on a worksite (Gittleman et al., 2010), which could be reflected in the breakdown of safety scores. We selected the five approaches based on the availability of information in the inspection scores. As all data was collected before the study began, we were limited by the level of detail included by the inspectors and organization of the database.

The owner-based grouping approach provided a single threshold value for all projects at Harvard University. To calculate the threshold under the owner-based grouping, the safety scores for each project were compiled as the ratio of the weighted number of all safe observations in a given month divided by weighted number of all the safe and unsafe observations in that month. All unsafe observations were weighted by severity and all safe observations were weighted by category, thus attempting to account for the inherent risk differences experienced by all trades on a worksite.

The scores in the owner-based approach were not separated by subcontractor or trade, as the goal of this approach was to look at all projects under the same owner at the project level. The selected threshold was the median value of monthly scores from all 65 projects over the 19-month period, which consisted of 149 monthly scores (not all 65 projects ran for the full 19-months) (Figure 2). The median was selected as the threshold due to the highly skewed distribution of the safety performance scores.

The General Contractor grouping approach provided a single threshold value for each general contractor that had completed work at Harvard during the 19-month period. The safety scores for each general contractor were compiled as the ratio of the weighted number of all safe observations in a given month divided by weighted number of all safe and unsafe observations in that month. For each contractor, the selected threshold was the median value of the monthly scores for the given general contractor observed during the 19-month period. There were 28 different thresholds, one for each of the general contractors.

The project-based approach provided multiple threshold values for a single project, where each month the new threshold at a given project was that project's safety performance score from the previous month. In other words, an incentive program that uses this approach gives the simple message to do better than last month. As the first month of a project has no data from the previous month to generate a threshold, the overall safety score from all projects was selected as the threshold. For example, the overall May 2010 score from all projects at the University would be used to determine whether or not the project would receive the reward for a project started in June 2010.

The subcontractor and trade-based approaches provided a single threshold value for each subcontractor and trade, respectively. The safety scores for each subcontractor and trade were compiled as the ratio of the weighted number of all safe observations in a given month divided by the weighted number of all safe and all unsafe observations in that month. For each subcontractor or trade, the selected threshold value was the median value of the compiled monthly score for the given subcontractor or trade, respectively. As a result, each subcontractor or trade had a unique threshold and would be evaluated separately and compared to its own threshold during reward distribution.

2.3 Evaluation through calculation of reward frequency and distribution at a completed project

Threshold values were calculated for each of the five approaches using 19-months worth of inspection data from the University and then applied to data from 48 inspections (4,254 observations) of a 17-month long completed project on the Harvard University campus to calculate the reward frequency and distribution under each approach. The project involved construction of a new 43,500-square foot building intended for office and laboratory use. The project was completed between January 2009 and July 2010; hence, its inspection data were included in the calculation of the thresholds.

For each threshold approach, the number of months (frequency of reward) and the number of subcontractors (distribution of reward) that would have received the reward were calculated. In the discussion, these quantitative data will be evaluated qualitatively in terms of providing workers with a fair, consistent, attainable, and competitive incentive reward program. A fair reward program is defined as one that treats all workers on-site equally; that is, all workers are held to the same reward threshold and the program offers everyone the same opportunity for reward. A consistent program is defined as one that has the same eligibility and threshold requirements throughout the course of a project, either for a subcontractor or for the whole project. The definitions of attainable and competitive programs refer to the level of the threshold. The threshold value should be low enough that workers feel they can achieve the level of safety each month, but high enough that it still feels like a challenge.

3. Results

There were 280 safety inspections recorded between January 2009 and July 2010 at 65 different projects across Harvard University. These inspections resulted in 22,586 observations, of which 1,061 were unsafe and 21,525 were safe.

The compiled monthly safety scores at all Harvard projects ranged from 58.9% to 100%, with a mean of 92.7% and a median of 96.3% (Figure 2). Hence, the owner-based approach provided a threshold of 96.3%. When this threshold was applied to the calculated reward distribution and frequency at the 17-month completed project, all workers on that project would receive the reward 6 out of 17 months, or 35% of the project duration (Figure 3).

The general contractor approach utilized data from two University-owned projects between January 2009 and July 2010 to select the threshold for the general contractor on the 17-month completed project. There were 37 inspections for these two projects. The monthly median and mean scores of these inspections were 93.0% and 92.1%, respectively. Using the median as the threshold in the reward distribution and frequency calculation, all workers on that project would receive the reward for 9 out of 17 months (52.9% of the project duration). Median scores for all other general contractors at Harvard from January 2009 to July 2010 ranged from 58.8% to 100% (Table 3).

The project-based approach to select a threshold for reward resulted in a value that changed from month to month. At the 17-month project use in the reward distribution and frequency calculation, the scores ranged from 78.8% to 99.6%, with a mean and median of 92.5% and 92.8%, respectively (See the red-circles in Figure 3). All workers on that project would receive the reward 8 out of 17 months, or 47% of the project duration (Figure 3).

The subcontractor and trade -based approaches resulted in different thresholds for each subcontractor and trade, respectively. The threshold scores for the individual subcontractors ranged from 55.6% to 100%. Under the calculated reward distribution, workers in each subcontractor would receive the reward from 0% to 100% of the time depending upon the subcontractor, with an across subcontractor average of 64% (Table 5). Hence workers of some subcontractors would never receive a reward where workers of others would always receive the reward. The subcontractor-based approach was dependent on the company’s previous experience working for the owner. As a result, thresholds for some subcontractors were based on only a few inspections. Thresholds for the various trades ranged from 86.5% to 95.0%, with a mean of 92.1% and a median of 92.8%. Under the reward distribution calculation, workers for the trades received the reward 67% of the time they were on-site and were thus eligible for the reward (Table 4).

The five approaches were each evaluated qualitatively for fairness, consistency, attainability, and competitiveness (Table 6). The owner-based approach met all of the attribute definitions, whereas each of the other four approaches lacked at least one of the attributes.

4. Discussion

The goal of this study was to create and evaluate different approaches of selecting a reward threshold from pre-existing inspection data for use in a future study on the effectiveness of leading indicator employee safety incentive programs. Of the five approaches evaluated, the owner-based approach was the most competitive yet it was also attainable and fair and maintained high standards of safety while accounting for inherent risk differences between trades (Table 6).

In the owner-based approach, a reward was achieved only about 1/3 of the time, making it the most competitive threshold. The threshold of 96.3% promoted the highest standard of safety across the whole worksite when compared to the other approaches. The program was consistent across the duration of the program and the single threshold for all workers on-site would make it easy for everyone to understand. This high threshold and low distribution rate

(1/3 of the time) represent an achievable level of safety performance without compromising the integrity of the reward (Fell-Carson, 2004). In addition, the threshold was fair, as it was the same for all workers on-site and did not leave anyone out of the reward distribution. All unsafe observations were weighted by severity and all safe observations by category, thus accounting for the inherent risk differences experienced by all groups on the worksite and allowing for direct comparison across groups (HarvardConstructionSafetyGroup, 2010)..

General contractors can also adapt the owner-based approach to determine a threshold for their own leading indicator employee safety incentives program by increasing the quantity of inspection data used in threshold determination. Instead of restricting the safety performance data used in threshold determination to projects under a single owner, as described above in the general contractor approach, general contractors can use data from any of their sites from multiple owners. The number of inspections used in the threshold determination will thus increase and be a much more representative reflection of the general contractor's safety performance. The range of threshold scores experienced by the general contractors is a reflection of the range in available inspection data for each of the general contractors. General contractors with limited inspections tend to have much higher or much lower scores when compared to general contractors with more inspection data (Table 3), which in turn can lead to a score that would not be both attainable and competitive. Furthermore, general contractors would only need about four months of inspection data in order to determine a threshold, as demonstrated from the stabilization of the cumulative monthly safety inspection score seen in Figure 1.

Given the high turnover rates and fluid work environment found in construction, worksite safety programs should have requirements that are consistent throughout the course of the program and are easy to understand by all workers. A threshold score that changes from month to month (like in the project-based approach) may be confusing to workers who do not fully understand the reasoning behind the changing value and thereby lead to resentment of the incentives program. Thresholds that change between groups should also be avoided, as they can be confusing and seem arbitrary to workers. This can in turn hinder the impact of a team approach towards safety and adversely affect the worksite dynamic. The owner-based approach led to a threshold value that was consistent over the course of the project duration, as it remained the same for everyone on the worksite for the entire project duration. The other approaches had much more variability, as they either varied across the duration of the project or between groups within the project.

The project, subcontractor, and trade-based approaches also have many logistical challenges related to implementation. The classification of subcontractors into trade categories can be problematic for companies that participate in more than one trade. It also can be very time consuming for the individual managing the safety scores to calculate multiple thresholds for all the different subcontractors that come through a project. Furthermore, the subcontractor approach was limited in the quantity of inspection data available for some subcontractors, meaning that some scores were based on data that may not have accurately represented the safety performance of the company.

The reward distribution and frequency calculation of each approach was performed at only one project because there was only one in the inspection database that was of average size and duration when compared to the rest of the Harvard projects (Table 1) and had consistent inspections throughout the entire project. Due to the lack of regularly conducted inspections at all Harvard projects, the thresholds used in the reward distribution and frequency calculations were based on projects with incomplete datasets. However, this irregularity was not likely to dramatically change the results of this study, as thousands of observations were still able to be used in the threshold determination.

The physical working conditions on a construction site can change drastically from one moment to the next (Kramer et al., 2009), which makes the inspection process quite difficult. The changing worksite tasks and the movement of trades on and off the site directly impact the level of safety on a worksite. A single inspection conducted by one inspector at a given moment in time may not accurately represent the level of safety at the worksite.

The selection of a threshold in a leading indicator incentive program must account for the uncertainty associated with the inspection process. The inspector should be part of the program process, and inspections should be frequent and site-wide. In the leading indicator-based safety incentive program described in this study, one individual (trained in the inspection process) conducted weekly inspections, during which the inspector referenced a manual that described in detail methods for observing, recording, and weighting observations (HarvardConstructionSafetyGroup, 2010).

The data used in this study may be biased due to many reasons, including the inspector's previous experience with certain subcontractors or their views on certain work practices. However, a history in the safety field is needed to inspect a worksite as much of the hazard identification process comes from experience. The resulting bias would most likely overestimate the number of unsafe observations, as they are easier to identify than the safes, and lead to a lower final safety performance score. Any biases are expected to affect the inspection data at random. While this could lead to an overall lower threshold value, the conclusions should not be affected. This is another reason why general contractors and owners should use their own inspection data to generate a threshold value.

The reward distribution scheme presented here relied on multiple weekly inspections that were summed together to generate a single monthly safety performance score. In relying on multiple inspections to determine the reward status, the safety inspection score provided a more accurate representation of a project's safety conditions.

The methods described here rely on inspection data collected prior to the start of the study when inspectors had no knowledge that their inspections would be used in development of an incentives program. All data were collected from the same four inspectors over one year after the development and implementation of a standard inspection process. The type of data used prevented the testing of inter- or intra-assessor reliability among the inspectors in this study. While the use of pre-existing inspection data collected by individuals who may hold some biases towards subcontractors does pose a limitation, it should not impact the study findings, as our goal was to replicate a real-world scenario that can be used by general contractors and owners.

In conclusion, the owner-based approach was competitive, attainable, fair, and consistent. As this approach met all of the evaluation criteria, it should be used to determine the threshold in a leading indicator employee safety incentive program. The goal of this study was not to evaluate the threshold's ability to impact safety performance; rather, it proposed an approach to using pre-existing inspection data in order to develop a threshold that will be used in a future study on the effect of leading indicator employee safety incentive programs. The approaches described here for selecting such a reward threshold can help guide future research efforts, which can in turn provide assistance to general contractors and site owners in expanding their health and safety programs to include an incentive program.

While it is believed that leading indicator incentive programs, when part of comprehensive health and safety programs, have the potential to improve working conditions and reduce injury rates, this has yet to be proven. Until the effectiveness of such programs is studied in detail, the full impact of these programs is unknown.

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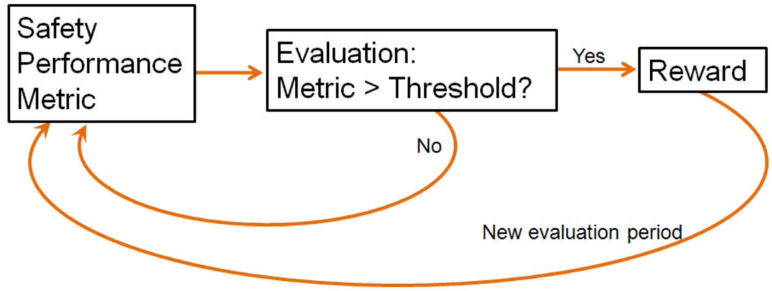

Figure 1.

In any incentive program, workers are evaluated based on a safety performance metric. If the metric exceeds a pre-determined threshold at the end of the evaluation period (i.e., one month, one quarter), they receive a reward. The program restarts at the end of the evaluation period and the workers have a new chance to receive the reward at the end of the following evaluation period.

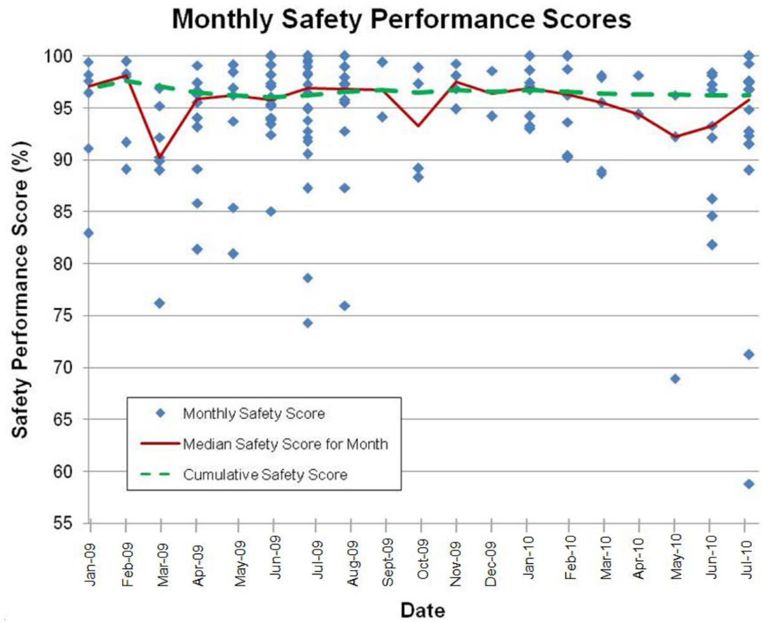

Figure 2.

Distribution of the compiled monthly safety performance scores for each project at Harvard University between January 2009 and July 2010. Each dot represents the monthly overall safety score for a single project (n = 65). The red solid line represents the median safety performance score in a given month. The green dashed line represents the cumulative median safety score across all projects over the 19-month period.

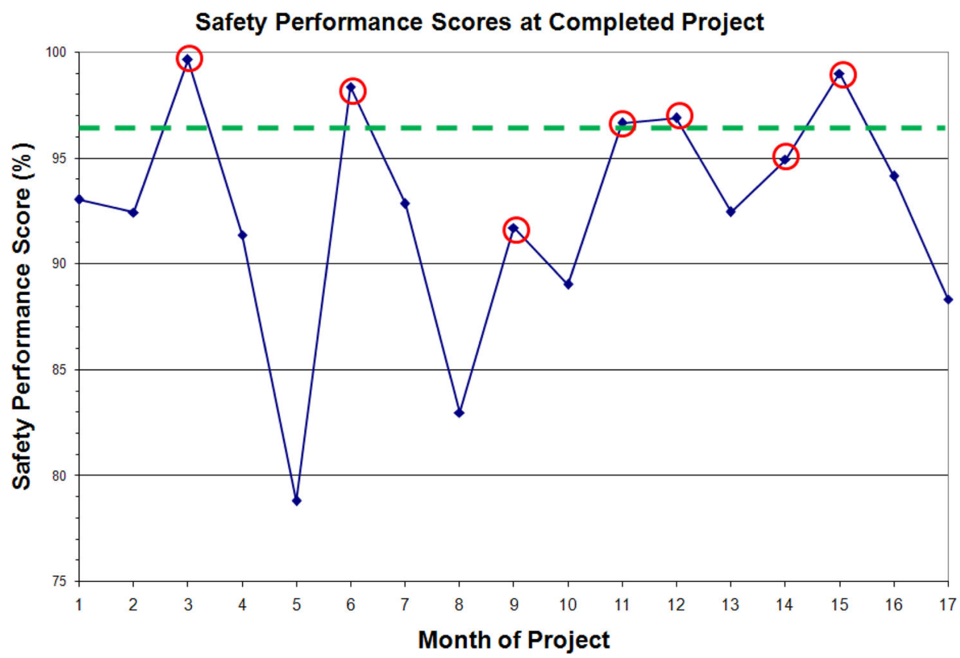

Figure 3.

Safety performance of the owner-based and project threshold approaches score for the 17-month project during the reward distribution and frequency calculation. The dots represent the monthly scores at the completed project. The dashed line represents the owner-based approach threshold (96.3%). In this approach, rewards would have been distributed in all months in which the project scored above the green line. In the project-based approach, rewards would have been distributed each month that had a score higher than the previous month (red-circles).

Table 1

Summary of 65 Harvard University Construction Projects Between January 2009 and July 2010

The table includes information on the projects used in the threshold calculations. The projects ranged in size from small renovations of two or three rooms in an existing space to large demolitions and reconstruction of buildings. Information was not collected on the worker population at the individual sites, as the unit of analysis in this study was the worksite. All inspections were conducted by one of four expert inspectors.

	Minimum	Maximum	Average	Median
Project duration (weeks)	8	60	16.7	15.5
Individual workers	10	175	45	35
Subcontractors	1	17	8	7
Inspections per week	0	2	0.8	0.92

Table 2

Summary of threshold determination approaches and results at the completed project

Five different approaches to calculate a threshold for a leading indicator incentive program were explored. Each approach looked at a different subset of safety inspection data from construction sites. Thresholds were then applied to a completed 17-month project in order to calculate reward frequency and distribution in a leading indicator incentive program.

Approach	**What data was the threshold based on?**	**What time frame was used to calculate the threshold?**	**Is the threshold the same from month to month?**	**Was the threshold the same for everyone at a specific project?**	**Threshold value used in reward distribution and frequency calculation at the completed project.**
Owner	Median value of project monthly scores from all owner projects	All available University-wide data (19-months)	Yes, consistent	Yes	96.3%
General Contractor	Median value of a general contractor's monthly scores	All available University-wide data	Yes, consistent	Yes	93.0% (2 sites, 37 inspections)
Project	Project's previous month's safety performance score	A single month of data.	No, changes each month	Yes	Ranged from 78.8% to 99.6%
Subcontractor	Median value of compiled monthly scores for a given subcontractor	All available University-wide data	Yes, consistent	No, each subcontractor has a different threshold	Ranged from 55.6% to 100.0%
Trade	Median value of compiled monthly scores for all subcontractors within a certain trade	All available University-wide data	Yes, consistent	No, each trade has a different threshold	Ranged from 86.5% to 95.0%

Table 3
Mean and Median values for threshold levels for each General Contractor

The data in this table show the median and mean monthly safety scores of the general contractors who worked at Harvard-owned projects between January 2009 and July 2010. These projects only account for the contractors who were identified as general contractors in the Predictive Solution database or through conversations with HCSG personnel.

Table 3: Summary of General Contractor Safety Scores

General Contractor	Number of Projects	Number of Inspections	Median Safety Score	Mean Safety Score
A	2	6	97.2%	97.2%
B	6	19	97.9%	97.6%
C	1	1	93.8%	93.8%
D	2	8	99.0%	95.4%
E	2	10	82.5%	82.5%
F	1	1	90.0%	90.0%
G	2	37	93.0%	92.1%
H	1	6	97.8%	97.8%
I	1	12	92.2%	94.4%
J	20	68	98.7%	96.2%
K	2	18	99.5%	98.4%
L	3	8	98.8%	97.2%
M	2	4	95.6%	95.6%
N	1	9	95.8%	96.0%
O	5	33	98.1%	97.1%
P	1	1	58.8%	58.8%
Q	1	1	100.0%	100.0%
R	1	1	96.9%	96.9%
S	1	2	99.0%	99.0%
T	2	6	75.1%	75.1%
U	1	1	71.3%	71.3%
V	1	2	93.3%	93.3%
W	1	1	93.8%	93.8%
X	1	1	100.0%	100.0%
Y	1	4	97.5%	97.5%
Z	1	1	100.0%	100.0%
AA	1	1	91.7%	91.7%
BB	1	1	76.2%	76.2%

Table 4

Summary of Threshold Scores Using the Trade-Based Approach at the Completed Project

In the calculation of reward distribution and frequency using the trade-based approach, individual subcontractors received the reward an average of 64% of the time, with a median distribution of 67%. Trade type for contractors in the "specialty" trade was unavailable for 5 subcontractors. They were thus not included in the calculation. The trade threshold was based on data collected throughout the University between January 2009 and July 2010.

Subcontractor Trade	Number of Subcontractors in Trade at University Construction Projects	Subcontractor ID	Number of Inspections Between January 2009 and July 2010	Trade Threshold	Number of Months Subcontractor Received Reward	Number of Months Subcontractor Worked on Project	Percent of Months that Subcontractor Received Reward out of Total Months Worked on Project
Construction	16	M	57	94.9%	6	10	60%
Construction of Buildings	10	J	100	94.8%	7	17	41%
Construction of Buildings	10	T	100	94.8%	4	9	44%
Electrical	29	E	156	94.6%	7	9	78%
Electrical	29	Q	156	94.6%	1	1	100%
Finishing	11	K	22	89.9%	0	1	0%
Finishing	11	W	22	89.9%	3	3	100%
Flooring	10	U	18	92.5%	2	3	67%
Glass	14	P	15	90.0%	2	3	67%
Heavy and Civil Engineering	5	B	25	94.3%	3	8	38%
Painting	12	D	26	95.0%	1	2	50%
Plumbing and HVAC	30	L	175	93.6%	8	11	73%
Poured Concrete	17	H	26	94.12%	5	8	63%
Roofing	8	N	31	88.0%	5	7	71%
Roofing	8	R	31	88.0%	6	9	67%
Scaffolding	8	O	13	91.4%	4	4	100%
Specialty	40	A	73	93.4%	3	3	100%
Specialty	40	C	73	93.4%	0	2	0%
Specialty	40	G	73	93.4%	2	2	100%
Specialty	40	S	73	93.4%	2	3	67%
Specialty	40	V	73	93.4%	0	1	0%

Subcontractor Trade	Number of Subcontractors in Trade at University Construction Projects	Subcontractor ID	Number of Inspections Between January 2009 and July 2010	Trade Threshold	Number of Months Subcontractor Received Reward	Number of Months Subcontractor Worked on Project	Percent of Months that Subcontractor Received Reward out of Total Months Worked on Project
Steel	16	F	9	88.4%	4	5	80%
Steel	16	I	9	93.9%	2	4	50%
Average percentage of months reward was received out of total months on-site							61%
Median percentage of months reward was received out of total months on-site							67%

Table 5

Summary of Threshold Scores Using the Subcontractor-Based Approach at Completed Project

The data in the table above represents the overall safety score at the completed project. In the calculation of reward distribution and frequency using the subcontractor-based approach, reward distribution for individual subcontractors received the reward an average of 64% of the time, with a median distribution of 67%. The subcontractor threshold was based on data collected throughout the University between January 2009 and July 2010.

Subcontractor ID	Number of Subcontractor Inspections	Subcontractor Threshold	Number of Months Subcontractor Received Reward in Calculation	Number of Months Subcontractor Worked on Project in Calculation	Percent of Months that Subcontractor Received Reward out of Total Months Worked on Project
A	8	100.00%	3	3	100%
B	5	90.30%	3	8	38%
C	3	55.60%	1	2	50%
D	3	71.90%	1	2	50%
E	20	95.30%	7	9	78%
F	7	97.00%	4	5	80%
G	4	96.20%	2	2	100%
H	3	72.70%	5	8	75%
I	7	92.40%	2	4	50%
J	37	92.50%	8	17	59%
K	3	83.30%	0	1	0%
L	69	95.70%	8	11	73%
M	25	92.30%	6	10	60%
N	13	92.80%	4	7	57%
O	9	94.10%	4	4	100%
P	7	87.80%	2	3	67%
Q	1	100.00%	1	1	100%
R	16	92.80%	5	9	56%
S	5	93.90%	2	3	67%
T	15	91.50%	6	9	67%
U	6	96.20%	2	3	33%
V	3	72.70%	0	1	0%

Subcontractor ID	Number of Subcontractor Inspections	Subcontractor Threshold	Number of Months Subcontractor Received Reward in Calculation	Number of Months Subcontractor Worked on Project in Calculation	Percent of Months that Subcontractor Received Reward out of Total Months Worked on Project
W	9	100.00%	3	3	100%
Average percentage of months reward was received out of total months on-site					63%
Median percentage of months reward was received out of total months on-site					67%

Table 6

Qualitative Review of Threshold Development Approaches

Each of the five approaches was reviewed qualitatively for fairness, consistency, attainability, and competitiveness. The results from this review are presented in the above table. Each "+" sign indicates that the approach met the attributes definition. The "−" sign means the approach did not meet the attribute definition. The "o" sign means the approach was neutral with respect to the attribute. As demonstrated in the table, the owner-based approach met the definition of the most attributes when compared to the other four approaches.

	Approach				
Attribute	**Owner**	**General Contractor**	**Project**	**Subcontractor**	**Trade**
Fair	+	+	+	−	−
Consistent	+	+	−	+	+
Attainable	+	+	o	o	o
Competitive	+	o	o	o	o
Sum of positives	4	3	1	1	1