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Complete List of Authors:	Arias, Scott; ACE Consulting Li, Huimin; North China University of Water Resources and Electric Power Zhang, Chengyi; University of Wyoming, Civil and Architectural Engineering Jiang, Aiyin; University of North Florida, Department of Construction Management
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PREDICTIVE ANALYTICS ON ENGINEER MANUAL 385 EFFECTIVENESS OF REDUCING NUMBER AND SEVERITY OF MISHAPS

Scott Arias, Ph.D.

President, ACE Consulting, sarias@ace-consulting.net

Huimin Li, Ph.D.

Associate Professor, Department of Construction Engineering and Management, Department of Construction Engineering and Management, North China University of Water Resources and Electric Power, lihuimin3646@163.com

Chengyi Zhang, Ph.D. Corresponding author

Assistant Professor, Department of Civil and Architectural Engineering, University of Wyoming, chengyi.zhang@uwyo.edu

Aiyin Jiang, Ph.D.

Associate Professor, Department of Construction Management, University of North Florida, a.jiang@unf.edu

ABSTRACT

The United States Army Corps of Engineering Manual 385 (EM 385) has become a vital part of construction operations on all Department of Defense (DOD) construction projects to create a safer work environment. With tremendous effort on developing and enforcing the EM 385, the question of whether the EM385 provides any value for project safety is critical to the construction industry at large. This study looks for causation between the EM 385 and mishap reduction by isolating three dependent variables and a variety of explanatory variables. The data was compiled using both the OSHA Data Initiative (ODI) and the Federal Spending Database. A structural equation is developed to conduct multiple regression analysis assuming EM 385 will reduce the number of mishaps and the severity of mishaps. However, the result shows the effectiveness of EM 385 on reducing the number and severity of mishaps is not significant.

Key Words: Construction Safety, Engineer Manual 385, Predictive Analytics.

INTRODUCTION

The Engineer Manual 385 (EM 385) is composed of extensive safety planning guidelines that have cost millions of dollars to develop and implement over its 73-year history. The EM 385 has become a vital part of construction operations on all Department of Defense (DOD) construction projects, to create a safer work environment (Rekus 2003). The use of the EM 385 attempts to bridge the gap left from the lengthy safety mandates and the actual construction that takes place on the job site. Essentially the EM 385 defines the planning processes of preventing mishaps, ensuring compliance and accountability, and fostering a positive safety culture. After an extensive review of all the extant research and literature on the subject, it became apparent that there is a lack of quantitative research on the relationship between the actual safety performance and the use of the safety manual guidance. Before this study, there has been no formal quantitative assessment of the EM 385 effectiveness. The absence of this empirical evidence is perhaps why the EM 385 has not been adopted within the federal government widely.

Insurance costs are rising, and workers are dying. That is the reality of the construction industry in America today, with between “1100 and 1300 workers killed per year” (Broderick and Murphy 2001). Construction in the United States has consistently experienced higher fatality and injury/illness rates (Weil 2001). The post-accident cost of safety is high. Research utilizing 2004 mishap data reveals that disabling injuries had an annual cost of \$15.64 billion (Willard 2009). Both

productivity and the costs incurred resulting from worker injuries makes performing work safely a vital characteristic of a profitable company (Huang & Hinze 2006). A study done in 2009 supports this idea that the more a firm spends on workplace safety, the lower its worker's compensation rates (Huang 2009).

A historical perspective reveals that the tremendous foresight went into the creation of the EM 385 and the implementation urgency. Over time the EM 385 has evolved in content and complexity as a result of proven advancements in mishap reduction regulation developed by the Occupational Safety and Health Administration (OSHA). The "print architecture and nomenclature of the EM385 manual is similar to that of the Occupational Safety and Health Administration (OSHA) regulations, with a few variations" (Decoopman 2011). The difference between OSHA regulations and the EM 385 is that OSHA develops the rules for safety and the EM 385 implements them through on-site safety management. Based on the assumption that the number and severity of mishaps could be reduced by regulation and oversight, the safety planning principles contained in the EM 385 were intended to foster safer conditions for various construction projects.

This research has assessed the causal link between the EM 385 and mishap reduction by isolating a variety of explanatory variables. This research examined three standard safety metrics. These metrics are created, collected, and actively tracked by OSHA. The metrics include the Total Case Rate (TCR), Days Away, Restricted or Transferred (DART), and Days Away From Work (DAFWII). For analysis, this

research used a structural equation modelling technique, specifically multiple regression, to estimate and assess the number (TCR) and severity of mishaps (DART and DAFWII), in order to gauge the effectiveness of the EM 385 guidelines (U.S. Army Corps of Engineers 2008).

Since the publication of Heinrich's 1931 classic accident prevention text, it has been widely accepted that the most preventable injuries and illnesses are attributed to the actions of people. With the primary focus of most safety research on engineering controls, behaviour-based safety research lacks adequacy (Findley et al. 2014). For this reason, this research could be critical to the construction industry at large.

LITERATURE REVIEW

Workplace safety has been driven by the 1970 Occupational Safety and Health Act. This legislation was enacted to mitigate a trend of mishap occurrences that have plagued almost every industry in America. Two years after the OSH Act was enacted, the first retrospective case study analysis was done by Dr. Michael Dong. This research tested the OSHA's center-periphery model and looked at multiple counties in California in order to analyze the OSHA's enforcement program (Dong 1981). The objective was to determine whether there was a behavior-based correlation between the number of safety inspections and the number of accidents. No correlation was found by the researchers, who drew upon data from interviews, post-accident analysis, and a time-series study. This regional industry-wide research did, however, show that

there was a probable correlation between safety enforcement and mishap reduction in the construction industry (Dong 1981). This foundational research showed that within the construction industry mishap reduction could potentially be achieved through the creation and implementation of safety guidelines.

Comparing with the OSHA standards, the EM 385 addresses more details to the topic of safety management (Rekus 2003). Safety management, as defined by the EM 385, takes the form of the accident prevention plan, which encompasses a detailed activity hazard analysis. Heinrich's theory predicted that 88% of all accidents were caused by a human decision to carry out an unsafe act (Johnson 2001). It also predicts that when minor accidents increase, serious accidents and fatalities will increase as well, which prompt the company to improve its prevention efforts by enforcing safety management system (Pablo et al. 2018; Bourassa et al. 2016). It is essential to understand that these safety management mechanisms are project and activity-specific outlining the precautions necessary to mitigate the hazards that are inherent in every construction task. It is supported by a 2006 study in which safety management was linked to improved safety performance (Bradbury 2006). In a 2008's study, it was found that most safety management programs were being applied informally rather than using a safety management model (Hallowell 2008). Looking at ways to learn from mishaps that have occurred, construction research has attempted to study precautionary techniques to mitigate hazards and prevent accidents.

Safety training program by using EM385 can have a great impact in reducing

construction safety hazards. Demirkesen and Arditi (2015) study the effectiveness of training practices in safety training sessions by surveying safety professionals from the top 400 contractors in the U.S. They found the effect of the training program are influenced by many factors, such as organizational issues, feedback issues, content issues, and even language problems. Bena et al. (2009) assessed the impact of the training program on injury rates at a major railway construction project. The result of the study shows a moderately positive effect on the health of construction workers. Brahm and Singer (2013) investigated a sample of 2,787 Chilean firms' safety training programs, and they found that engaging training methods reduced more accidents than non-engaging methods.

The EM 385 provides essential management information through qualitative post-hazard analysis (Malek et al. 2010). This allows project participants to take precautions accordingly against future accident reoccurrence (Wang 2010). The EM 385 safety planning requirements are meant to initiate and cultivate a safer construction safety and health program. Teo et al. (2005) argued that insufficient safety knowledge of workers is one of the significant causes of site accidents. Given the content of behavioural-based safety research, it can be concluded that controlling behavior is essential to better safety performance. For this reason, development of safety programs, that institute pre-hazard assessment, is becoming more prominent in the construction industry.

Causation between the EM 385 and a reduction in mishap quantity and

severity was this research's objective while considering other explanatory variables that could affect this predictive model. The following influence factors tie safety research to the variable selection utilized in this study.

Safety Metrics: Total Case Rate (TCR), Days Away, Restricted or Transferred (DART), and Days Away From Work (DAFWII) were founded on a theoretical basis known as the Parkinson Law, which acknowledges that expectations are the key to establishing performance. By establishing these standard metrics and publishing the averages each year, standards are set for the industry to manage procurement, assess performance, and dictate changes (Teo & Ling 2006). Using these principles, research conducted in 1998 showed that there was a correlation between mishap reduction and keeping records on incident rates (Garza & Hancher 1998).

Safety by Region: In a 2008 survey of occupational injuries and illnesses, 22 states were found to have a higher number of mishaps than the national average, with 14 states experiencing lower than national average rates. It is with this reality that the region where the work takes place must be considered as a factor in the assessment of mishap rates. From a purely statistical perspective, OSHA Data Initiative (ODI) surveys have shown that there are regional variations in safety performance. This has to do with numerous factors, including variation in climate, culture, worker knowledge, and most importantly organized labor.

Safety by Size: The size of the project is the primary factor that companies use to determine the necessary crew size that would be required to complete the job.

Foundational research done with project superintendents has revealed that smaller organizations in construction tend to have better communication (Hinze 1976).

Through this improved communication, safety becomes much more vital to the crew, project, and company. The close-knit dynamics of smaller organizations tend to result in fewer mishaps, even when the organizational safety program of a project is absent (Maloney & McFillen 1983).

Safety by Industry: The 2008 Bureau of Labor and Statistics report that the sectors that had the highest annual average employment were contained in the building construction sector. This sector was then subdivided into residential and commercial for analysis. The 2008 report showed that by the normalized number and severity of mishaps, commercial construction was a more hazardous industry than residential construction.

Safety by Contract Type: The motives behind contractors working under lump-sum and unit-price contracts varied greatly. Contractors working under a lump-sum contract were driven by higher profitability to complete the project more quickly, which resulted in less general requirement costs. Inversely unit-price contracts were driven by the time and cost that were incurred. These contract methods can drive contractors working under lump-sum contracts to assume more safety risks since the faster a project gets completed, the fewer project overhead costs are incurred (Hatush & Skitmore 1997). More risk can equate to more mishaps, and for that reason, contract type was considered as a variable in this research.

Safety by Solicitation: In an article on prequalification importance in a tough economy, Douglas Mcleod stated that in a tough economy such as the one in 2008, lowest bid procurement in the competitive bid world could result in working with contractors with poor safety performance (Mcleod 2012). Under the negotiated solicitation model, safety can be a critical factor in selection, since selection can be based on intangibles, such as past safety performance, rather than on the lowest price. On the other hand, competition could breed better safety performance. An understanding of this variation in safety performance resulted in this research utilizing solicitation procedures as one of its explanatory variables.

Safety by Business Type: Disadvantaged business entities (DBE) under Federal acquisition regulations (Liu et al. 2008) are required to set aside work for performance in almost every procurement sector. Construction is particularly affected by this requirement due to the large volumes of money involved in the work. For this reason, this research considered DBEs and the set-asides they were given as a factor in its statistical assessment of the EM 385 and its contribution to a reduction in mishaps.

METHODOLOGY

The primary objective of this research is to assess whether a quantitative relationship can be determined between the use of the Engineering Manual 385 processes and mishap rates. In the following text, the approaches used for data

collection and analysis are identified, along with a description of the research protocol utilized.

The Problem Statement

The following two research questions were posed to determine if a relationship exists between the number and severity of mishaps and the use of the EM 385. Question 1: What was the effect of the EM 385 on reducing the number of mishaps? Question 2. What was the effect of the EM 385 on reducing the severity of mishaps?

Data Selection

The data for this research comes from two sources. The first source was collected from the OSHA Data Initiative (ODI). The ODI gathers data annually from randomly selected contractors within construction industries from 1996 through 2011. Since not all states participate in the ODI from 1996 to 2011, this research utilized the 2008 data based on quality and accuracy. Given an initial lack of explanatory variables found within the ODI database, the second source of data from Federal Spending Database was obtained. The data from each database was sorted by the contractor and then merged. The data of a random selection of 190 building contractors from the consolidated database with dependents variables and explanatory variables.

Establishing the Structural Equation

The following structural equations estimate the causation between the number and severity of mishaps and the use of the EM 385 while partitioning several other key explanatory variables. The predictive analytics dictate the following structural equation 1:

$$Y_i = \beta_0 + \beta_j(EM385_j) + \beta_k(REGION_k) + \beta_m(EMPL_m) + \beta_r(SOLIC_r) + \beta_s(DIS_s) + \varepsilon_0 \quad (1)$$

Variables Explanation, as shown in table 1.

Table 1 Variables Explanation

Variables	Explanation
$Y_{i=1}$	TCR – Total Case Rate
$Y_{i=2}$	DART – Days Away, Restricted or Transferred
$Y_{i=3}$	DAFWII – Days Away From Work
β_0	Intercept
$EM385_{j=1}$	EM385 - Major Funding Agency Category
$EM385_{j=2}$	EM385 - Major Agency Category of Contract
$REGION_{k=1}$	OSHA Regions 1: Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont
$REGION_{k=2}$	OSHA Regions 2: New Jersey, New York, Puerto Rico, Virgin Islands
$REGION_{k=3}$	OSHA Region 3: District of Columbia, Delaware, Maryland, Pennsylvania, Virginia, West Virginia)
$REGION_{k=4}$	OSHA Region 4: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
$REGION_{k=5}$	OSHA Region 5: Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
$REGION_{k=6}$	OSHA Region 6: Arkansas, Louisiana, New Mexico, Oklahoma, Texas
$REGION_{k=7}$	OSHA Region 7: Iowa, Kansas, Missouri, Nebraska
$REGION_{k=8}$	OSHA Region 8: Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
$REGION_{k=9}$	OSHA Region 9: Oakland, San Diego, Phoenix, Honolulu, Las Vegas
$REGION_{k=10}$	OSHA Region 10: Alaska, Idaho, Oregon, Washington
$EMPL_m$	Contractor Size by Employees (#)
$SOLIC_{r=1}$	Solicitation Procedures (Negotiated)
$SOLIC_{r=2}$	Solicitation Procedures (Competitive Bid)
$DIS_{s=1}$	Disadvantaged Business
$DIS_{s=2}$	Non-Disadvantaged Business
ε_0	Error

Three dependent variables, including Total Case Rate (TCR), Days Away, Restricted or Transferred (DART), and Days Away From Work (DAFWII), are used in this research. The TCR reflects the number of mishaps, while DART and DAFWII reflect the severity of those mishaps. The more mishaps, the higher the TCR. The

more severe the mishap, the higher the DART and the DAFWII.

The p-value significance was assessed to select the explanatory variables. A p-value shows the level of significance, and a low p-value (< 0.10) shows the probability of occurrence by chance is relatively high. An original seventeen explanatory variables were collected from the database. They are EM 385 Proxy, Contractor Size by Revenue, Contractor Size by Employees, Project Size, Project Type (Residential or Commercial), Contract Type, Solicitation Procedures, Place of Performance OSHA Region, Disadvantaged Business, Set-Aside Used, Women-Owned Business, Veteran Owned Business, Minority-Owned Small Business, Foreign-Owned and Located, Sole Proprietorship, Partnership or LLC Partnership, Corporate Entity. Twelve of explanatory variables did not display a p-value less than 0.10, provided they were not necessary for consideration in the research model. Following several stepwise regression analysis of the explanatory variables, the revised research model became apparent, retaining both explanatory variables with a significant p-value and variables key to answering the research questions posed.

The five explanatory variables with a high level of significance include 1. EM385 Proxy, an explanatory variable to assert the use or non-use of the EM385, 2. OSHA Region, the place of performance by project location, 3. Contractor Size by Employees, 4. Solicitation Procedures, 5. Disadvantaged Business, the disadvantaged business status of contractors.

Based on the consolidated database, TCR, DART, DAFWII, and the

Contractor Size by Employees require no preparation for statistical analysis. The data listed below required preparation for statistical analysis.

EM 385 Proxy: 1= EM385 Use, 0= EM385 Non-Use, _=Not Identified

Solicitation: 1= Competitive Bid, 0=Negotiated, _= Not Identified

Disadvantaged Business: 1=DBE Used, 0=No DBE Used, _No DBE identified

Research Assumptions

Three assumptions are made in order to complete this research. These assumptions include:

- (1) Contractors working on projects outside of Department of Defense do not use the EM 385 safety requirements since it is not mandated for use by their respective federal agencies.
- (2) The data self-reported to OSHA, thru ODI, is the most accurate and the only widely assessable data that can be used for research.
- (3) The contractor working within specific federal government construction agencies operate in that sector almost exclusively due to the specialized nature of each federal agency and the qualification and certifications the contractor must possess.

DATA ANALYSIS

This section reviews the data and research questions posed, describe the demographics within the research model, test the hypothesis, and offer descriptive statistics along with data analysis and interpretation.

Descriptive Statistics

Considering the significance of the data given by both the ODI and federal spending databases, the five explanatory variables listed above reflect and represent the critical data areas needed for this research. Shown below in Table 2 through Table 6, the descriptive statistics of the explanatory variables retained in the research model.

Table 2 EM385 Proxy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 - Do not use EM385	16	8.4	8.4	8.4
	1- Use the EM385	174	91.6	91.6	100.0
	Total	190	100.0	100.0	

Table 3 Contractor # of Employees

Number of Employees Per Hundred	Frequency	Percent	Valid Percent	Cumulative Percent
0.00	30	15.8	15.8	15.8
0.01 – 0.10	109	58.3	58.3	74.2
1.01 – 2.00	13	6.7	6.7	78.9
2.01 – 3.00	6	3	3	81.6
3.01 – 4.00	4	2	2	83.7
4.01 – 5.00	1	5	5	82.1
5.01 – 10.00	12	6.1	6.1	88.9
10.01 – 20.00	6	3	3	94.2
20.01 – 50.00	3	1.6	1.6	95.8
50.01 – 100.00	4	2.1	2.1	97.9
100.01 – 500.00	2	1	1	98.9
501.00 – 1000.00	1	0.5	0.5	99.5
1000.00 – 2013.66	1	0.5	0.5	100
Total	190	100.0	100.0	

Table 4 Solicitation Procedures

		Frequency	Percent	Valid Percent
Valid	0 – Negotiated Bidding	47	24.7	24.7
	1-Competitive Bidding	143	75.3	75.3
	Total	190	100.0	100.0

Table 5 OSHA Region

		Frequency	Percent	Valid Percent
Valid	Region 1	7	3.7	3.8
	Region 2	10	5.3	5.4
	Region 3	22	11.6	12.0
	Region 4	45	23.7	24.5
	Region 5	24	12.6	13.0
	Region 6	39	20.5	21.2
	Region 7	12	6.3	6.5
	Region 8	12	6.3	6.5
	Region 9	11	5.8	6.0
	Region 10	2	1.1	1.1
	Total	184	96.9	100.0
Missing	Region Not Provided	6	3.1	
Total		190	100.0	

Table 6 Disadvantaged Business (DBE)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 – Not DBE	113	59.5	59.5	59.5
	1- DBE	77	40.5	40.5	100.0
	Total	190	100.0	100.0	

Multiple Regression Analysis

This process analyzed the causation between explanatory variables and dependent variables. Multiple uses of dependent and explanatory variable combinations were regressed to retain variables that showed causation. The R Square from this model was 0.223 for the TCR estimation, 0.132 for DART estimation, and a 0.126 for DAFWII estimation, as shown in Table 7. In the regression models, the explanatory variables can predict the value of Y, which is the number and severity of mishaps based on the percentage of estimation. These percentages show the variation in the dependent variables that are attributable to the explanatory variables used in this model. The R Square reveals that very little of the variation of the dependent variables is attributable to the explanatory variables due to missing observations, little variation in the data, and behavioral issues. As revealed in the coefficient analysis in Table 8, 9 and 10, these types of issues have resulted in a low R Square.

Table 7 Multiple Regression R Square and Std. Error Table

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
TCR	.472a	.223	.163	5.30296
DART	.363a	.132	.065	3.43742
DAFWII	.355a	.126	.059	2.23218

Table 8 Multiple Regression TCR Coefficient Tables

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	(Constant)	2.044	1.796	1138	0.257
	EM385 Proxy	1.203	1.491	0.807	0.421
	Contractor # of Employees	-0.001	0.003	-0.031	0.656
	OSHA Region 1	6.232	2.211	2.816	0.005
	OSHA Region 2	-0.691	1.889	-0.027	0.715

OSHA Region 3	-1.417	1.416	-0.080	-1.001	0.318
OSHA Region 4	-1.309	1.167	-0.097	-1.122	0.263
OSHA Region 5	1.907	1.385	0.111	1.377	0.170
OSHA Region 7	1.141	1.778	0.049	0.642	0.522
OSHA Region 8	6.620	1.753	0.283	3.777	0.000
OSHA Region 9	-0.911	1.819	-0.037	-0.501	0.617
OSHA Region 10	9.707	3.857	0.174	2.517	0.013
Solicitation Procedures	0.511	0.937	0.038	0.545	0.587
Disadvantaged Business	1.962	0.829	0.166	2.367	0.019

Table 9 Multiple Regression DART Coefficient Table

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	1.093	1.164		0.939	0.349
EM385 Proxy	0.761	0.967	0.059	0.787	0.432
Contractor # of Employees	0.000	0.002	-0.009	-0.118	0.906
OSHA Region 1	2.675	1.433	0.144	1.866	0.064
OSHA Region 2	0.048	1.224	0.003	0.039	0.969
OSHA Region 3	-1.170	0.918	-0.107	-1.275	0.204
OSHA Region 4	-1.166	0.756	-0.141	-1.542	0.125
OSHA Region 5	0.576	0.898	0.055	0.642	0.522
OSHA Region 7	0.067	1.153	0.005	0.058	0.954
OSHA Region 8	2.380	1.136	0.166	2.095	0.038
OSHA Region 9	-1.096	1.179	-0.073	-0.929	0.354
OSHA Region 10	-2.679	2.500	-0.078	-1.071	0.286
Solicitation Procedures	0.448	0.607	0.054	0.738	0.461
Disadvantaged Business	1.203	0.537	0.166	2.238	0.027

Table 10 Multiple Regression DAFWII Coefficient

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	0.016	0.756		0.021	0.983
EM385 Proxy	0.648	0.628	0.077	1.033	0.303
Contractor # of Employees	0.000	0.001	-0.027	-0.369	0.713
OSHA Region 1	2.249	0.931	0.187	2.417	0.017
OSHA Region 2	1.431	0.795	0.141	1.800	0.074
OSHA Region 3	-0.184	0.596	-0.026	-0.309	0.758
OSHA Region 4	-0.302	0.491	-0.057	-0.614	0.540
OSHA Region 5	0.688	0.583	0.101	1.180	0.240
OSHA Region 7	0.334	0.748	0.036	0.446	0.656
OSHA Region 8	0.563	0.738	0.061	0.764	0.446
OSHA Region 9	-0.663	0.766	-0.068	-0.866	0.388
OSHA Region 10	-1.301	1.624	-0.059	-0.801	0.424
Solicitation Procedures	0.251	0.394	0.047	0.637	0.525
Disadvantaged Business	1.023	0.349	0.219	2.932	0.004

The EM385 Extraction Model

The following structural equation removed the EM385 Proxy explanatory variable from the original research model. The purpose of the new equation is to provide a comparative analysis of causation between the number and severity of mishaps and the explanatory variables, minus the EM385 variable. This model

dictates the following structural equation 2:

$$Y_i = \beta_0 + \beta_k(\text{REGION}_k) + \beta_m(\text{EMPL}_m) + \beta_r(\text{SOLIC}_r) + \beta_s(\text{DIS}_s) + \varepsilon_0(2)$$

Variables Explanation is the same as shown in Table 1.

After removing the EM385 from the research model, the results reflect that the EM 385’s effect on the number and severity of mishaps is inconclusive, as seen in Table 11 through Table 14. This attempt to show causation mainly reviewed the coefficients of all the explanatory variables looking for a change in p-values, R Square, and importance when removing EM385 from the model. Comparing the research model to EM385 extracted model, it shows R Squares that are nearly identical in both models. The R square in both regression models indicates that the explanatory variables can predict the value of Y. The R Square from both models, with the EM385 Proxy and without, shows almost no variation. Thus, it is logical to conclude that the EM385 contribution to the model is indeed insignificant and inconclusive.

Table 11 Multiple Regression R Square and Std. Error Table with EM385 Extraction Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
TCR	.469 ^a	.220	.165	5.29754
DART	.359 ^a	.129	.067	3.43359
DAFWII	.347 ^a	.121	.059	2.23262

Table 12 EM385 Extracted TCR Model Coefficient Table

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
	B	Std. Error	Beta		
1 (Constant)	3.133	1.185		2.645	0.009
Contractor # Of Employees	-0.001	0.003	-0.30	-0.440	0.660
OSHA Region 1	5.997	2.186	1.198	2.734	0.007
OSHA Region 2	-0.577	1.881	-0.023	-0.307	0.759
OSHA Region 3	-1.460	1.413	-0.082	-1.033	0.303
OSHA Region 4	-1.293	1.166	-0.096	-1.109	0.269
OSHA Region 5	1.982	1.380	0.115	1.435	0.153
OSHA Region 7	1.288	1.767	0.055	0.729	0.467
OSHA Region 8	6.654	1.750	0.284	3.802	0.000

OSHA Region 9	-0.806	1.812	-0.033	-0.445	0.657
OSHA Region 10	9.854	3.849	0.177	2.560	0.011
Solicitation Procedures	0.560	0.934	0.042	0.599	0.550
Disadvantage Business	1.849	0.816	1.157	2.265	0.025

Table 13 EM385 Extracted DART Model Coefficient Table

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
	B	Std. Error	Beta		
1 (Constant)	1.781	0.768		2.320	0.022
Contractor # Of Employees	0.000	0.002	-0.008	-0.112	0.911
OSHA Region 1	2.514	1.417	0.136	1.774	0.078
OSHA Region 2	0.120	1.219	0.008	0.099	0.922
OSHA Region 3	-1.197	0.916	-0.110	-1.307	0.193
OSHA Region 4	-1.156	0.755	-0.140	-1.530	0.128
OSHA Region 5	0.624	0.895	0.059	0.697	0.487
OSHA Region 7	0.160	1.145	0.011	0.140	0.889
OSHA Region 8	2.402	1.134	0.167	2.117	0.036
OSHA Region 9	-1.029	1.175	-0.069	-0.876	0.382
OSHA Region 10	-2.586	2.495	-0.076	-1.037	0.301
Solicitation Procedures	0.479	0.605	-0.58	0.792	0.429
Disadvantage Business	1.131	0.529	0.156	2.137	0.034

Table 14 EM385 Extracted DAFWII Model Coefficient Table

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
	B	Std. Error	Beta		
1 (Constant)	0.603	0.499		1.207	0.229
Contractor # Of Employees	0.000	0.001	-0.026	-0.361	0.719
OSHA Region 1	2.112	0.921	0.176	2.292	0.023
OSHA Region 2	1.493	0.793	0.147	1.883	0.061
OSHA Region 3	-0.208	0.596	-0.029	-0.348	0.728
OSHA Region 4	-0.293	0.491	-0.055	-0.596	0.552
OSHA Region 5	0.728	0.582	0.107	1.252	0.212
OSHA Region 7	0.413	0.745	0.044	0.554	0.580
OSHA Region 8	0.582	0.738	0.063	0.789	0.431
OSHA Region 9	-0.606	0.764	-0.063	-0.793	0.429
OSHA Region 10	-1.222	1.622	-0.055	-0.753	0.452
Solicitation Procedures	0.278	0.394	0.052	0.706	0.481
Disadvantage Business	0.962	0.344	0.205	2.796	0.006

DISCUSSIONS

The result of the coefficient and significant are summarized in Table 15.

Table 15 Final Model Multiple Regression Analysis

	Regional unionization	expected			actual			sig.
		TC R	DA RT	DAF WII	TC R	DA RT	DAF WII	
EM385 Proxy		-	-	-	+	+	+	no
Contractor # of Employees		-	-	-	-	+	+	no
OSHA Region 1	Strong	-	-	-	+	+	+	sig.

OSHA Region 2	medium				-	+	+	DAFWII sig.
OSHA Region 3	medium				-	-	-	no
OSHA Region 4	weak	+	+	+	-	-	-	no
OSHA Region 5	Strong	-	-	-	-	-	-	no
OSHA Region 6	weak	+	+	+				
OSHA Region 7	no	+	+	+	+	+	+	no
OSHA Region 8	no	+	+	+	+	+	+	TCR, DART sig.
OSHA Region 9	no	+	+	+	-	-	-	no
OSHA Region 10	weak	+	+	+	+	-	-	TCR sig.
Solicitation Procedures		-	-	-	+	+	+	no
Disadvantaged Business		+	+	+	+	+	+	sig.

EM385 Proxy: The EM385 proxy coefficient is expected to be negative, and there should be fewer mishaps using EM385. However, it is not the result determined in the regression results for all three structural equation models, which is reflected in a positive sign on the coefficient. Meaning, the use of EM385 has no significant influence on the reduction of the mishap. While the EM385 intent is to reduce mishaps, it may just encourage proper reporting, while businesses outside the control of the EM385 could be underreporting and misreporting, whether intentional or not.

Contractor Size by Employees: The contractor size coefficient is expected to be negative. However, the regression result reflects a positive sign on the severity of mishap coefficients (DART and DAFWII), while there is a negative sign on the number of mishaps (TCR). A positive sign mathematically would result in the DART and DAFWII to increase because of more employees; however, a negative sign on the TCR would result in the number of mishaps decreasing because of an increase in contractor size by employees. DART and DAFWII coefficient results are contrary to the original hypothesis that an increase in contractor size by the employee would

result in less severe mishaps, mathematically showing a negative coefficient.

OSHA Region: The OSHA Regions coefficients are expected to be half negative and half positive, which reflects the mathematics associated with regression techniques used. A negative sign mathematically would result in the three dependent variables to be reduced because of the place of performance region. The conclusive results reflect that OSHA regions 1 and 8 have more mishaps that are more severe, while OSHA region 10 has a fewer number of mishaps. In summary, OSHA regions effect on safety can be related to multiple issues. Safety can have a causal link to education, worker knowledge, management focus, and training. With organized labor focus on apprenticeships, having dedicated safety personnel on the project site and continuous safety training and oversight, the focus on unions in this research is warranted.

Solicitation Procedures: The solicitation procedures coefficient is expected to be negative. However, the regression results reflect a positive coefficient. It is contrary to the original hypothesis that more bidders would result in fewer mishaps, resulting in a negative coefficient. The theory behind the hypothesis is that competition breeds better results. However, in this research, less competition results in less severe mishaps.

Disadvantaged Business: Disadvantaged Business' coefficient is expected to be positive. This is because disadvantaged businesses tend to be smaller, have less experience and lack the professional knowledge gained through experience and

formal education. This research confirms the original hypothesis.

CONCLUSIONS

Safety is the paramount concern on every construction project. Whether driven by monetary or moral considerations, construction safety should be an essential aspect of each construction project. The Engineering Manual 385 is a tactical guide used by the Army Corps of Engineers for construction safety management. The objective of this research is to determine the impact of the Engineering Manual 385 on reducing the number and severity of mishaps. The research hypotheses theorized that the using EM 385 in construction project could reduce the number and severity of mishaps. The research data is collected from the OSHA Data Initiative and Federal Spending Databases. Three dependent variables and five explanatory variables are identified to use in the multiple regression analysis. The result reveals that the presented model does not quantitatively prove the EM385's effectiveness at reducing the number and severity of mishaps. It could be due to the lack of enforcement, the actual use of the EM 385, and the self-reporting system in the ODI. While this research has not exhausted the efforts to prove the effect the EM 385 has on reducing mishaps, it does serve as a foundation in identifying the issue. This research believed with time, money, and resources used by the federal government to improve the EM 385, it is worth additional effort to evaluate the effectiveness of the EM 385.

There are limitations to the study. First, the results and conclusions are based on the data taken from 2008. The findings can only be generalizable, at best, to this

specific timeframe. Second, in the year of 2008, there was a significant recession that impacted the global economy. This recession had a major affected the construction industry specifically. Due to this recession, these results could be inaccurate because of contractors entering and exiting the construction sectors or construction industry.

The researchers recommend a qualitative study on EM 385 to be conducted in the future to help identify the issues that are not clear through the current quantitative study. Since the reduction of mishaps is founded on behaviorally based issues, a qualitative study regarding the behavior aspect of the EM385 will bring greater insight into the effectiveness of the EM 385.

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DATA AVAILABILITY

Some or all data, models, or code generated or used during the study are available in a repository online in accordance with funder data retention policies.

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