

Reducing Human Errors in the Pipeline Construction Industry

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In underground pipeline construction, mistakes in the field can negatively affect the success of a project. These mistakes often occur because workers do not check their work and managers are inconsistent in verifying the work. To correct these mistakes involves costly re-work. This process eliminates profit on the project or causes project loss. The Masters Project study identifies measures that contractors employ to bring awareness to human errors and mistakes before they happen and to help eliminate or reduce costly re-works and reviews human behavior in the workplace, work teams, and workplace errors and mistakes in other industries to determine appropriate survey questions. An online survey of North Carolina contractors was utilized to measure the frequency and impact of workplace errors in the industry. This research will lead to the future development of set of procedures or process changes that can potentially result in a reduction in workplace errors in pipeline construction, and produce a better understanding of human factors in the workplace that result in errors and mistakes.

Key Words: Pipeline Construction, Pipe Installation Error Reduction, Human Errors, Infrastructure

Introduction

Underground pipelines can be expensive to build. Existing soils and groundwater conditions may require the contractor to undercut soils, dewater the excavation by well points, or excavate the trench by drilling and blasting rock materials. In addition to this below-ground cost, there are additional restoration and demolition costs, such as tree removal or clearing, asphalt replacement, concrete replacement and restoration of the disturbed areas by seeding or sodding. With these installation costs and unknown factors, it is critically important for contractors to install the work correctly the first time.

Human error and its types and causes as it relates to human factors in the workplace are critical issues. Industries such as healthcare, manufacturing, and aviation investigate how industries address the issue of human error in the workplace. In general, there are three types of errors: design errors, communication errors, and management system errors (Petersen, 2003). According to Rooney, Vanden Heuvel, and Lorenzo (2002), human errors are divided into two types: unintentional and intentional. Understanding the types of human errors and the worker thoughts and behaviors will be beneficial to this project.

In addition, the processes and best practices of underground pipeline contractors are implemented to improve organizational excellence as it relates to human errors. Industries mistakes in the workplace lead to learning and improved performance. Instead of assigning blame and punishing bad performers, as is typical in the construction workplace, leaders must learn to use mistakes as learning opportunities. Employees who learn from their mistakes and the mistakes of others will likely avoid the same mistake in the future. Additionally, the atmosphere of learning lets employees know they do not have to conceal their mistakes (Prather, 2008).

This study addresses how contractors can reduce or eliminate human errors in the field by understanding their underlying causes and implementing preventive procedures. These changes will lead to contractors to be organizations that are more successful. By establishing the correct systems and processes in underground pipeline construction, contractors can lead the way in overall quality control and profitability.

Problem Statement

In underground pipeline construction field operations, human errors result in major losses for the contractor.

Hypothesis

Establishing preventive procedures and adopting best practices in pipeline construction can reduce or even eliminate human errors, resulting in less risk, fewer losses and a more profitable and successful company.

*Outcome Questions to Define***:**

1. What measures to catch, reduce, eliminate, or bring awareness to human errors before they happen can be implemented in construction companies?
2. How can contractors and project managers understand human behavior of employees and human error in construction and why they occur?
3. How can contractors and project managers improve on identifying the "root" cause of human errors on our projects?
4. How can organizations train and create awareness of their workforces about eliminating errors and "do-overs"?
5. How can an organization create an environment of learning from mistakes instead of hiding or covering them up?

Limitations of the Study

This study is focused and limited to benefit underground pipeline contractors. No research or output was created in this study to benefit any other industry. This study is limited geographically to North Carolina pipeline contractors.

Literature Review

The literature review identifies what human error is and its types and causes and establishes parameters for understanding human behavior and human factors in the workplace environment based on previous research. When applied to underground pipeline construction, this understanding of humans assists in understand the errors and how to prevent them in the future. Literature provides explanations of the following topics as background information 1) Understanding Human Behavior and Human Error, 2) Types of Human Error, and 3) Causes of Human Error.

Three important research themes were developed for this study. They were: 1) learning from mistakes is important and such things as "lessons learned program" and "team learning" are useful tools that could be employed in pipeline construction, 2) industry has developed ideas and tools for addressing errors and mistakes in the workplace, and 3) there are processes used in other industries that apply and benefit the construction industry.

Learning from Mistakes

Managers frequently do not see the "stupid mistakes" as preventable. Management can be adamant that the mistakes could not have been avoided or prevented. John Davies (2004) argues that change in performance can only be made by challenging and ultimately changing the way managers think. There is a need to collect and use "stupid mistakes" to raise the collective awareness of the overall company. The collection and interpretation of minor events is a resource management that should be utilizing for prevention of human error. The "what" and "why" of these events must be collected at two levels to affect the human error problem. The first level is a description of the actions the person performed within the system. The second level is the motives and intentions of the person who carried out the act or error. An attempt must to be made to discover why the person acted as they did, and then collect this information for future use (Davies, 2004).

Lessons Learned Programs

Lessons Learned Programs (LLP) is defined as the knowledge gained from experience, successful or otherwise, for the purpose of improving future performance, or knowledge captured and shared to avoid recurrence. LLP emerged as a potentially important tool for implementation in the construction organization. LLP consist of the people, processes and tools that implement and validate lessons learned in organizations (Caldas, Gibson, Weerasoriya, and Yohe, 2009).

In construction, this could consist of capturing, sharing, and utilizing knowledge of the field workforce. This information is a vital and valuable asset to any contractor. Lack of knowledge from past failures within a company should not be a cause of human error. If LLP's can be established by management, this information can become corporate knowledge for the future development of the company.

Checklists

Hales and Pronovost (2006), discuss the use of checklists as a tool in human error management across fields such as aviation, aeronautics, manufacturing and healthcare. They examined how checklists contribute to reductions in the risk of costly mistakes and improving overall outcomes.

A checklist is a tool used in error management in industries such as aviation, aeronautics, manufacturing and healthcare, which can provide guidance to a user and act as verification after completion of a task. The principle purpose of the checklist should be error reduction or best practice adherence. Checklists may reduce errors, improve safety, and improve outcomes (Hales and Pronovost, 2006). Checklists can be very useful in the construction process and used daily as a best practice in field processes.

Understanding Human Behavior and Human Error

Human behavior and human error are major factors in industry. While many quality control programs succeed in reducing other quality related issues, human error remains a persistent problem. There is widespread acknowledgement that human error is implicated in a major proportion of quality related costs. A broad definition states that a human error consists of any significant deviation from a previously established, required or expected standard of human performance (Petersen, 2003). Most of what people do throughout the day at work follows a pattern of 1) recognition, 2) selection, and 3) action, with very little conscious thought needed. For organizational excellence, a well-informed and systematic approach to gather information about the risk of human error is necessary to avoid naïve and ineffective attempts to mitigate it (Evans, 2006).

The late human factors and ergonomics pioneer Alphonse Chapanis stated "*When a system fails it does not fail for any one reason. It usually fails because the kinds of people who are trying to operate the system, with the amount of training they have had, are not able to cope with the way the system is designed, following procedures they are supposed to follow, in the environment in which the system has to operate" (Peterson, 2003).*

Types of Human Error

Human errors are divided into two groups, unintentional errors and intentional errors. Actions committed or omitted with no prior thought are unintentional errors. These errors, such as misreading a measurement or bumping a switch, are usually thought of as accidents. Actions deliberately committed or omitted because workers believe their actions are correct or better than the prescribed actions are considered intentional errors. For example, in manufacturing an intentional error would be when a worker skips a step in the process in order to increase productivity (Rooney, Vanden Heuvel, Lorenzo, 2002).

Petersen (2003) suggests that the following types of errors be considered:

- Design Error – an example would be the DC-10 aircraft, where jet engines fell off in the air and lives were lost as a result.
- Communication Error – an example would be two 747's crash on an island in the Atlantic Ocean, resulting in the worst loss of life in history from an air crash. Miscommunications lead to the mishap.

- Management System Error – examples would be the Chernobyl disaster or the Columbia Space Shuttle disaster. Management decisions lead to a series of events which causes the accidents.

Furst (2010) constructs that human error is simply a difference between an actual state and a desired state. With human error, the reasons or causes may reside with the individual or the organization's systems. He suggests two methods to prevent human error from affecting performance: stop people from making mistakes (avoidance), or keeping the mistake from affecting (interception) the system. Traditional approaches to combat human error are not highly effective. The performance of individuals has to be reliable and the organizations systems must be accurately designed.

Causes of Human Error

Cohen (1991) suggests that we do not have to accept human error as unavoidable. Mistakes are a reflection of the people who cause them. Mistakes are not random events. The suggested approach is to identify and eliminate accident prone situations, not accident prone individuals.

The causes of human error in the workplace (Petersen, 2003) can be grouped into the following three categories:

1. Overload –The worker cannot help but make an error if given more work than he or she has the ability to handle. This overload can be physical, physiological, or psychological.
2. Decision to Error – In some situations it would be logical for a worker to choose an unsafe or erroneous act. This could be due to the worker's motivation, mental condition, or belief that he or she will not make a mistake.
3. Traps – This cause of human error involves the traps that can cause a worker to make a mistake. One trap is incompatibility, such as when working conditions are not compatible with a worker's physique or with what he or she is used to. A second trap is a workplace design that is conducive to human error.

These causes would lead one to believe that more progress can be made by changing the situation rather than by preaching or disciplining. Human errors at lower levels of the organization are symptoms of things that are wrong in the organization at higher levels.

Methodology

A survey questionnaire "Reducing Errors in the Pipeline Construction" was developed to investigate the qualifications, best practices, and understand human error in pipeline construction and were intended to help prevent or eliminate human error for contractors. The survey was made accessible to North Carolina pipeline contractors respondents using the online survey tool SurveyMonkey.com . The survey questionnaire consisted of 23 questions that requested the following information from respondents. The first six questions of the survey establish the qualifications and experience level of the survey respondents. Questions 7 through 15 were established to understand human error in pipeline construction, while Questions 16 through 23 were utilized to develop best practices used in the industry. (See Appendix A – Survey Questionnaire)

A total of 50 individuals representing 33 contractor companies in North Carolina were contacted by email. Included in the email was an explanation of the research project, instructions on how to complete the survey, a deadline for completion of the survey and a link to click to go to the survey questionnaire. The authors, utilizing the capabilities of surveymonkey.com, was able to monitor the results of the surveys completed on a daily basis. A follow-up email midway through to the survey period reminded the prospective respondents about the survey and the deadline. After the deadline passed no further survey responses were received.

Results

Name, Company and Qualifications of Respondents

A total of 18 responses to the survey were received from managers representing 14 utility contractors in North Carolina. Of the respondents, 41% were company owners or executives, while 47% were either project managers or

estimators at the management level. The remaining 12% of the respondents were in the field supervisor level, such as superintendent or foreman. All of the respondents had more than 5 years of experience in underground pipeline construction, and over 55% of the respondents had more than 20 years of experience. All of the respondents had completed more than 20 pipeline construction projects.

Three Most Common Human Errors or Mistakes

All 18 respondents provided three common human error answers. There are a wide variety of human errors that meet these criteria. The following are the most commonly found human errors:

- Improperly calculating the grade, slope and/or elevations – 17 responses
- Improper alignment and/or incorrect layout – 13 responses
- Improper installation resulting in leaks in the pipeline – 5 responses
- Improper backfill of the trench excavation – 4 responses
- Damaging existing underground utilities/facilities – 3 responses

From these results, it can be assumed that the most common issues with human error occur during the set-up of grade, elevation, and alignment. All of these areas are part of daily operations in pipeline type construction. All the aspects of pipeline construction are provided either by design drawings from the design engineer, or from the construction survey information generally provided by a licensed surveyor. The contractor is then responsible for verifying and applying this information to the construction and installation to meet the project requirements or design.

How frequently do these mistakes happen?

As a follow up to the above question, the respondents were asked how frequently these mistakes happen. 33.3% of respondents said that errors were common, occurring in one of every three projects completed. Most of the respondents, 55.6%, felt that errors occurred less frequently, on one project in 10 or less.

Financial and Operational Impact of the Mistakes

Contractors were asked to briefly describe the financial and operational impact of mistakes on a recent project. Financially, the results show that mistakes in the field can result in major financial loss. One response stated that "depending on the size of the project, mistakes can erase anywhere from 20% to 130% of the profit" on a project. Cost estimates ranged from $1,500 to $40,000 per error, depending on the situation in which the mistake occurred. Another response stated "one mistake can cost thousands of dollars and days of delay, turning a profitable job into a money-loser." Publicly bid pipeline projects are typically unit price contracts. Unit prices and quantities are established for bidding purposes, and the final quantities are measured in the field and paid at the unit prices provided in the successful bid. One respondent stated, "You only get paid to install the pipe one time. When you have to do the same work over it not only costs the money to replace the materials, but also the time spent discovering the problem and correcting the problem. The momentum that the crew had started is all of a sudden stopped." With unit price contract work, the contractor is paid for the quantity just one time, and thus is easy to analyze the cost to re-do the work.

One common theme in the responses to the question involved the operational impact to the project schedule. One response stated, "Operationally, the re-work can delay the completion of the current project, thus creating delayed start dates for subsequent activities and/or projects." The operational impact is a major scheduling concern for contractors. Several of the responses stated that human error would result in failure to complete the task in the time allotted, thereby creating delay in the work planned for the future. Human error also causes the contractor to be late meeting a deadline, which could result in the payment of liquidated damages for the delay, since liquidated damages on pipeline projects are typically established at a range of $200 to $2,500 per calendar day of delay past completion.

The results of this question show that the impact of mistakes is important, and reducing human error in this type of construction is critical to successful contractors. Contractors are paid to install the product one time. The time spent discovering and correcting the problem cannot be recovered.

How did you or your field personnel come to realize the mistake or mistakes had been made?

This question allowed written descriptive responses for the survey respondents. All 18 respondents provided a written response to this question; some respondents provided more than one written response. After analysis of the responses, the most common answers are:

- During routine grade or alignment checks (12 responses).
- During critical tie-ins or connections (6 responses).
- During required testing of the work (3 responses).

As a follow-up question, contractors were asked if they or their team were able to determine the root cause of the human error or why it occurred. All 18 respondents were able to determine the root cause of the human error. Seventeen respondents provided written descriptions of the root causes; some provided more than one written description. The primary descriptive responses regarding root causes of human errors received were:

- Incorrect Set-up – alignment, etc.
- Math Calculation Error – calculating grade, slope, distance, etc.
- Double Checking Behind Yourself/Others – procedures, confirmation, etc.
- Communication – notification, confirmation, adopted procedures, etc.
- Carelessness – in a hurry, knew better, math error, etc.
- Lack of Training – processes, procedures, policies, etc.

An analysis of these responses indicates that some of these root causes are interrelated. For example, the crew could improve on checking behind each other by developing better communication procedures and skills. Incorrect set-up can be improved by developing specific training periodically to improve the set-up skills of the field personnel. Lack of training in basic everyday skills could be the underlying cause of mistakes made during set-up, such as mathematical error or not following the proper protocol.

Development of Best Practices

Questions 16 through 23 were utilized to assist in the development best practices for the industry to help prevent or eliminate human error in pipeline construction. Results provided a better understanding of what contractors practice within their organizations. All respondents were open to trying new process changes that would help reduce or eliminate human error.

The results showed that 75% of respondents only occasionally or never provided training for daily processes. This suggests that improved training could play a role in reducing error. Company-wide awareness to mistakes on projects showed that companies used employee meetings during a variety of times prior, during, and after completion of projects. In addition, respondents did not currently use “Lessons Learned Programs”, which shows the potential need of such activities to take place. Checklist were used by 50% of respondents, with most concerned with safety concerns, equipment inspection, daily reports, and time sheets. When addressing errors on site, respondent felt they effectively communicated to personnel the corrective actions that were required. Results showed the majority of firms provide personnel training for employees and management as it related to human error issues. Costs associated with human error were primarily in the $5000 to $50,000 range, although 18% stated their annual cost of workplace errors to be more than $50,000. Finally, all respondents were open to trying process changes that could have the potential to reduce errors on their projects.

Conclusions

The survey responses identified the most common causes of pipeline construction errors to be carelessness, lack of communication, distractions and lack of knowledge or training. These error types are consistent with the categorization of errors in other industries as discovered in the research literature review.

Considering the pipeline construction industry, human error can be categorized into unintentional and intentional groups. Using this framework of analysis, the errors identified in the pipeline construction survey fit into the same two categories: 1) carelessness and distractions would be considered unintentional errors and 2) failure to communicate effectively and a lack of knowledge or training would be intentional errors. This categorization of errors brings clarity to the variety of errors identified in the survey.

Unintentional Errors and Intentional Errors

Carelessness and distractions are considered unintentional errors. Based on the survey results, carelessness and distractions are the most common unintentional errors in pipeline construction. Thinking within the workplace is as much a part of the role of employees as is acting or doing; most of what people do at the workplace throughout the day follows this pattern. Checklists and training are shown to aid daily field operations as a tool for verification by the foreman, superintendent, or the crew leader, and are important tools in error management, contributing significantly to reductions in the risk of costly mistakes and improving overall outcomes.

Intentional errors are prevalent in many industries including construction. An intentional error is not intended to harm the system, but its effect on the system may be undesirable. Based on the Question 17-21 survey responses, communication and shared learning are the focus best practices to help combat intentional errors.

Future research should look at the relationship of quality control programs within industry to reducing or eliminating human error at the workplace. Working with construction industry safety experts will assist in more closing defining the specific outcome questions. The future development of set of procedures that can potentially result in a reduction in workplace errors in pipeline construction will be defined for pipeline contractors.

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Appendix A
Survey Questionnaire

Question 1 *– Name of Individual (Optional)*
Question 2 *- Company*
Question 3 **–** What is your current position within your company?
Question 4 **–** How long have you been in your current position?
Question 5 **–** How many years of experience do you have in underground pipeline construction?
Question 6 **–** How many pipeline construction projects have you completed?
Question 7 *- What are the three most common human errors or mistakes (that result in do-over) that occur on your projects in the field? Please list three and briefly describe.*
Question 8 *– How frequently do these mistakes happen?*
Question 9 *– Briefly describe the financial and operational impact of the mistakes on a recent project?*
Question 10 *– (Follow-up to Question 7) How did you or your field personnel come to realize the mistake or mistakes had been made?*
Question 11 *– (Follow-up to Question 7) Were you or your team able to determine the root cause of the human error or why it occurred?*
Question 12 *– Do you have a system of checks and balances in place in your field operations where team members check behind each other to verify the work is installed correctly?*
Question 13 *– Do you have any systems or processes in place to help catch errors and mistakes in the field before they occur or escalate?*
Question 14 *– At what experience level do most errors occur?*
Question 15 *– What are the most common causes of errors? (Select all that apply)*
Question 16 *– How often do you provide training for daily processes (such as using level, laser, figuring grade, checking grade and alignment)?*
Question 17 *– Do you bring company-wide awareness to mistakes made on individual projects or crews so that everyone learns from the error?*
Question 18 *– Does your company use "Lessons Learned Programs" at the end of each project or during the projects?*
Question 19 *- Does you company use "checklists" for daily field operations?*
Question 20 *– Do you think your field personnel effectively communicate when an error or mistake has occurred on the project or do they try to hide them from management?*
Question 21 *– Does your company provide training for employees and management to help prevent human error?*
Question 22 *– What would you estimate as the annual cost of workplace errors within your organization?*
Question 23 *– Would your organization be open to trying process changes that had the potential to reduce errors?*