An Investigation of Methods to Measure the Effectiveness Of Behavior-based Safety Programs In the XYZ Company

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ABSTRACT

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This study was an investigation of determining methods to measure the effectiveness of a behavior-based safety (BBS) program in the XYZ Company. BBS was a proactive process for managing the safety of employees through the use of observations, measurement, feedback, and reinforcement. The objective of BBS was continuous improvement in safety results based on the measurement of operationally defined critical behaviors by employees. Critical behaviors and conditions were defined to identify “ safe behaviors” by employees and “at risk” behaviors that could lead to employee illness and injury.

This research considered determining reliable methods of measuring the effectiveness of BBS in improving safety performance. Effectiveness was measured in terms of improvements of "down stream" indicators such as the reduction in the frequency and severity of illness and injuries (OSHA incident rates) and worker compensation incurred costs. "Upstream" indicators measured were % safe behaviors observed compared to OSHA incident rates and improvements in employee perceptions of safety.

Statistical methods identified to measure the effectiveness of the BBS process included statistical process control charting (SPC) of incident rates and incurred medical costs, linear and step change trending of incident rates and incurred costs using control charts, analysis of variance, regression analysis, and correlation analysis of the data.

Statistically significant changes in OSHA frequency rates were found in 37% of the BBS locations of XYZ Company after process implementation. Forty six percent of the BBS locations had significant downward changes in the OSHA severity rate. Nineteen percent of the BBS locations had statistically significant changes in worker compensation incurred costs after BBS implementation. There was little statistical difference in OSHA incident rates between BBS and selected non-BBS locations for the year 2000 and 2001.

There was a strong inverse relationship between percent safe behaviors observed and the OSHA frequency rate (OSHA IR) (correlation coefficient = - .822, p = 0.023). As percent safe observations increased, the corresponding OSHA frequency rate decreased.

A safety perception survey was given to a Wisconsin location of the XYZ Company. There were statistically significant differences in seven of eight categories designed to measure the effectiveness of the BBS process between two work groups at the location. One work group had been exposed to the BBS process for two years, while the majority of the plant population was just being introduced to the process.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Statement of the Problem

Introduction to the Study

Behavior based safety (BBS) is a proactive process for managing the safety of employees through the use of observations, measurement, feedback, and reinforcement. As Dennis (1997) wrote "the objective of behavior-based safety is continuous, statistically significant improvement based on the measurement of operationally defined critical behaviors" (p. 114). Critical behaviors and conditions are defined to identify " safe behaviors" by employees and "at risk" behaviors that could lead to employee illness and injury. Feedback and positive reinforcement are given for "safe behaviors" and actions are taken by management to eliminate barriers that cause "at risk" behaviors.

Company XYZ has 19 facilities in the US and Europe that had implemented some form of BBS to improve safety performance in the workplace over the past 10 years. Several of these facilities had implemented these systems with the assistance of outside consultants, such as Behavioral Science Technology, Inc. (BST, 2002) and Safety Performance Solutions (SPS, 2002) who specialize in the implementation of the BBS process. Other sites have or are conducting self-implementation of BBS based on current BBS theories and principles (see Appendix A). One Wisconsin facility of Company XYZ had implemented a BBS program in one of their major operating departments (about one fourth of the employees at the site), two years ago. The remainder of the plant was just beginning implementation of the BBS process. There has been limited research conducted within XYZ Company to determine the effectiveness of BBS alone towards safety performance improvement.

Purpose of the Study

The focus of this study was the determination of reliable methods to measure the effectiveness of the behavior-based safety process in the XYZ Company.

Goals of the Study

The primary goals of this study were:

1. To identify statistically valid techniques that measured the effectiveness of BBS alone as a management tool to improve safety performance.
2. To determine if the behavior-based safety process worked? In a company where existing EHS management systems were relatively identical from facility to facility, was it shown that BBS alone had improved overall safety performance in those plants that had implemented this process?

Background and Significance of the Study

Background. The BBS process had become a popular choice for many organizations in the past 10 years to manage their safety performance (Peterson, 1998). The XYZ Company has had 15 U.S. locations implement the process, with the earliest implementation beginning in approximately 1995 (refer to Appendix A). Research on the effectiveness of the behavior-based safety process in improving safety performance had not been extensively conducted in the XYZ Company. BST had provided XYZ management with some measured results in facilities that initially installed the process through their consulting firm in 1998 (BST, 1998). An internal study conducted in 1999 attempted to correlate the percentage of safe observations observed with a decrease in OSHA recordable incident rates (Bond, 1999). As with any process or management system, methods to effectively measure improvement must be a consideration before an organization fully embraces the program. Therefore, this remained the main purpose and significance of this study.

Significance of study. The significance of this study:

1. Provided information to XYZ Company management on the effectiveness of BBS by determining reliable methods of measurement. Was it effective to implement a BBS program over other traditional safety management approaches?
2. Verified or disproved previous research conducted within XYZ Company on BBS effectiveness.
3. Contributed to the knowledge base of other researchers in the support of determining statistically reliable methods of measuring the effectiveness of BBS in improving safety performance.

Limitations and Assumptions of the Study

Limitations. This study included the following limitations:

1. This study was limited to Company XYZ and those XYZ facilities that had implemented the behavior-based safety process.
2. No comparisons were made to the European facilities that have implemented the process.
3. Access to worker compensation information was limited.
4. There was a time constraint of three months to complete the study.

Assumptions. The following assumptions were made concerning this study:

1. Previous research conducted in this area may have been bias since considerable research in measuring BBS effectiveness had been conducted

by consultants that marketed the BBS process to clients (i.e. BST and SPS).

2. Since BBS was a long term cultural change in an organization, the relatively short duration of time where BBS had been implemented in some facilities may not have been shown in indices such as a reduction in OSHA incident rates. It was assumed that if employees believed in the BBS process, their perception (attitude) of EHS issues should have been more positive than those employees not engaged with the process. A perception survey was conducted in only one facility – the Wisconsin facility where one major department implemented BBS two years ago, while the remainder of the plant had just started implementation of a BBS program.
3. Changes in incident rates were due primarily to the introduction of the BBS process into the organization. Outside factors that may have also contributed to changes in incident rates could have been more proactive activity in return–to-work programs, ergonomic initiatives, management allocation of additional resources and emphasis of the safety activity in the plants, internal OSHA record keeping audits, voluntary OSHA VPP STAR certification programs, and other factors related to these changes.

Definitions.

Illnesses. Illnesses were anything other than an instantaneous event in the work environment (XYZ Company, 2002).

Incidence Rate. The number of injuries, illnesses or lost workdays related to a common exposure base of 100 full-time workers. The common exposure base enabled accurate inter-industry comparisons, trend analysis over time or comparisons among firms regardless of size (XYZ Company, 2002). This rate was calculated as:

$$\text{Incidence Rate} = \frac{\text{\# Cases or Days x 200,000}}{\text{Total Hours Worked}}$$

Injuries. Injuries caused by instantaneous events in the work environment (XYZ Company, 2002).

Lost workdays. The number of workdays, consecutive or not, on which the employee would have worked but could not because of an occupational injury or illness. (XYZ Company, 2002).

Lost workday, cases. Cases which involved a full day away from work or more (XYZ Company, 2002).

Lost workday case incidence rate (LWIR). The number of lost workday cases / 100 workers. It was calculated as follows: (# lost workday cases) x 200,000/ # hours worked (CompWatch, 2002).

OSHA incidence frequency rate (OSHA IR). The number of workers/100 workers who had lost or restricted workdays. It was calculated as follows: (# lost workday and restricted cases) x 200,000/ # hours worked (CompWatch, 2002).

OSHA lost workday severity rate (LWSR). The number of lost workdays / 100 workers. It was calculated as follows: (# lost workdays) x 200,000/ # hours worked (CompWatch, 2002).

OSHA severity rate (OSHA SR). The number of workdays/100 workers who had lost or restricted workdays. It was calculated as follows: (# of lost and restricted workdays) x 200,000/ # hours worked (CompWatch, 2002).

Restricted work only, cases. Cases which the employee, because of the result of a job-related injury or illness, was physically or mentally unable to perform all or any part of his or her normal assignment during all or any part of the workday or shift (XYZ Company, 2002).

Restricted work, days. The number of workdays, consecutive or not, on which, because of injury or illness: (1) the employee was assigned to another job on a temporary basis; or (2) the employee worked at a permanent job less than full time; or (3) the employee worked at a permanently assigned job but could not perform all duties normally connected with it (XYZ Company, 2002).

Total lost workdays. The number of workdays, consecutive or not, beyond the day of injury or onset of illness, the employee was away from work or limited to restricted work activity because of an occupational injury or illness (XYZ Company, 2002).

Total lost workday, cases. Cases which involved days away from work or days of restricted work activity or both (XYZ Company, 2002).

Total recordables. All work-related deaths, illnesses and those work-related injuries, which resulted in: loss of consciousness, restriction of work or motion, transfer to another job or required medical treatment beyond first aid (XYZ Company, 2002).

Total recordable OSHA incident rate (TRIR). The number of workers / 100 workers who had OSHA recordable injury and illnesses (I/I). It was calculated as follows:

(# of OSHA recordable I/I) x 200,000/# hours worked (CompWatch, 2002).

Chapter 2

Review of Literature

Background

Crisis in safety management. There still remains a crisis in safety management in business and industry. According to a report issued by the National Safety Council, in 2000 there were 5,200 workplace fatalities due to unintentional injuries in the United States. This equated to 3.8 deaths per 100,000 workers during that year. On the job, 3.9 million American workers suffered disabling injuries during the same time period. Economically it was estimated that these injuries cost Americans 131.2 billion dollars in 2000. These losses exceeded the combined profits of the top 13 Fortune 500 companies during that year (NSC, 2001). Obviously the reduction in the loss of life, a reduction in disabling injuries, and the associated monetary loss should be the primary goal of the safety management of any firm.

History of safety management. Unfortunately effective safety management has not been a core value business and industry embraced consistently in their strategic planning in the Twentieth Century. Safety is not a new management responsibility. In 1931 H.W. Heinrich, an employee in the insurance industry, developed the domino model of accident causation (Heinrich, Roos, & Petersen, 1980). This theory stated accidents were caused by one of five factors in a sequence: ancestry and social environment, a personal flaw, unsafe acts and conditions, the accident itself, and the resulting injury. By minimizing or removing the “unsafe acts” or “unsafe conditions”, Heinrich believed that accidents could be controlled. This model dominated the thinking of safety management during the remainder of the century. Legislation passed during the century, such as the

Occupational Safety and Health Act (OSHA) in 1970 was based heavily on identifying unsafe conditions in the workplace.

Even companies that developed hazard recognition systems purported to be based on behavioral principles, such as the Dupont STOP (Safety Training Observation Program) program, was largely designed to "correct unsafe acts and conditions". These were actual words written on their website (Dupont, 2002). Geller (2002) stated that this approach lacked perceived ownership by employees, which was a necessary success factor in implementing a BBS process. McSween (1995) described the process as "a process of layered safety audits" by management. Each level of management was required at least weekly to observe their subordinates and "document any unsafe acts they have observed on STOP cards (but not the names of offenders)" (p.7).

From the early 1900s to the present employers and safety practitioners have employed the three Es of safety management – engineering, education, and enforcement (Geller, 1996; Pettinger, Boyce, & Geller, 2002). These three Es of safety focused on (a) engineering that designed safe equipment and work conditions, (b) educating and training employees on engineering interventions, and (c) enforcement of recommended safe work practices. This was consistent with the top down management approach of the traditional safety management model.

Traditional safety management focused on injuries and illnesses, reactive rather than proactive involvement, treated safety as a separate function in the management hierarchy, was not system –oriented, tended to blame workers for accidents, focused on attitudes of workers, relied heavily on rewards and promotions, was based on a top down management model, and placed a strong emphasis on rules and close supervision of workers (Dennis, 1997).

In contrast to the tenets of traditional safety management supported by Heinrich, another major viewpoint of safety management developed during the century. These concepts evolved from quality management theory developed during the times preceding and following World War II. Walter Shewart, a contemporary of Heinrich, found in his empirical research that (a) 85 percent of the causes of error were caused by the system (deemed common causes), and (b) 15 percent of the causes of error originated outside the system, and were therefore special causes (Dennis, 1997). Therefore, since management controlled the system this meant management was responsible for 85 percent of the errors, while the workers were responsible for 15 percent of the errors. Most problems in any operation were systemic, derived from the workplace and work methods created by management. Therefore management was responsible for resolution. The worker was responsible for the small remainder (Manuele, 1998). This was in direct opposition to the theory developed by Heinrich, which placed most of the blame on the worker for accident causation.

After World War II, Japan enlisted two quality experts, Joseph M. Juran and W. Edward Deming, who had studied Shewart's theories of management, to rebuild their economy. These individuals developed management theories based on quality principles. Using statistical process control (SPC) and other management tools that stressed leadership, measurement, and participation, they helped transform the Japan economy into a world industrial power by the 1980s. "Deming's 14 Obligations of Management" applied to any management system, including safety management. When applied to an organization's safety management system, top management must create a constancy of purpose, take responsibility to institute management controls, focus on upstream prevention, measure the quality of the system, and focus on continuous improvements of the system (Salazar, 1989). These systems management principles became the dominant approach advocated by leading safety professionals in the past 25 years (Petersen, 1994).

Whereas the attempt of the traditional safety management approach was to identify factors in the workplace environment (unsafe conditions) and factors with employees (unsafe acts), the BBS effort has focused on defining and managing an employee's behavior to improve safety performance. Since the early 1990's many organizations have embraced this approach to be the "Holy Grail of accident prevention – the 'silver bullet' that will 'slay the werewolves' preventing us from achieving zero accidents" (Ragan, 1997).

Behavior Based Safety Concepts

Development of behavior-based safety. The BBS process was based on a proactive process for managing safety through the use of employee observations, measurement, feedback and reinforcement. The four main elements of a behavioral-based safety process were identifying critical behaviors, observation/data gathering, giving feedback, and removing barriers that cause illness and injury. (Geller, 1996). This process evolved out of research in the behavioral sciences that can be traced back to the early Twentieth century. The concepts stemmed from works from John Watson, a psychologist who wrote about behaviorism as early as 1910, Pavlov who experimented with "classical conditioning" in the 1920s, and B.F. Skinner's "operant conditioning" concepts in the 1940s (Petersen, 2000a). According to behaviorist theory, consequences (reinforcement), which were positive, immediate, and certain (rewards) would keep employees working safely. Negative consequences, which were immediate and certain (punishment), discouraged unsafe behaviors (Smith, 1999).

In 1978 Judi Komaki (Komaki, Barwick, & Scott, 1978) was one of the first applied psychologists to apply BBS principles, referred to at that time as applied behavioral analysis (ABA), in the workplace setting. During that same time period, two employees at Proctor & Gamble were developing the same methodology to be used in an integrated safety management system (known now as the P&G Key Elements model). The P&G employees were believed to be the first safety professionals to use the term "behavior-based safety" to describe the process (Krause, 2001).

Application to safety management. The Komaki study (Komaki, et. al., 1978) applied behavioral psychology to safety problems in a food processing plant. This study (a) defined safety-related behaviors in clear and simple terms, (b) assessed observed behaviors against defined desirable behaviors, (c) introduced the concept of "percent safe" for observed behaviors, and (d) provided feedback to workers based on safety-related behaviors. This became the model upon which the BBS process has been refined.

Application of the BBS process was built around this research approach. The main concept of the BBS process was the antecedent-behavior-consequence (ABC) model. Antecedents (also called activators) were events that triggered or preceded behaviors. Behaviors were observable actions. Consequences were states or events that followed behavior. Consequences, both positive and negative, were the most powerful influence on changing behaviors (Williams & Geller, 2000) . In the BBS process , the identification of key, observable safe behaviors upstream in the process was the first step in establishing the ABC model. Antecedents (activators) that encouraged these safe behaviors were identified or established and those behaviors that caused at-risk behaviors were removed. Concurrently, predictable positive and negative consequences were implemented to reinforce desired behaviors and discourage unsafe behaviors. Therefore, by designing and controlling effective workplace antecedents and consequences, management could increase safe behaviors and discourage at-risk behaviors. Therefore, in theory, the effective management of select critical behaviors upstream in the process in combination with well-planned antecedents and consequences would result in fewer accidents and injuries (Reynolds, 1998).

Implementation of the BBS process. Although a particular consultant or organization may have differed in the methods or steps in the process, these were the basic steps of implementation (Hans, 1996):

1. Identified site –specific critical behaviors and developed a critical behaviors inventory (CBI) relative to the organization.
2. Performed a loss analysis to compare the identified critical behaviors to historical accident and injury data to confirm the CBI.
3. Trained employees in observation and feedback skills to identify safe and at-risk behaviors. Observations were anonymous and non-punitive to all employees.
4. Integrated the observation process into normal organizational activities.
5. Data collected from the observations was collected and analyzed to determine required interventions. The Plan-Do-Check-Act (PDCA) quality model was applied for continuous improvement (Dennis, 1997).

6. Regular feedback to employees was given to influence behavioral change. Safe behaviors were reinforced and became habits.
7. Removal of barriers that caused at-risk behaviors. These barriers could have been a lack of employee training, failure in the management system (lack of procedures), lack of engineering controls or safeguards, or organizational culture.

Comparison of BBS methods. Three leading consultants evolved out of the BBS research that was conducted beginning in the late 1970s in the United States: (a) Thomas R. Krause, founder of BST, (b), E. Scott Geller, founder of SPS, and (c) Terry McSween, an independent BBS consultant, writer, and colleague of Geller.

Krause referred to his BST process mostly as behavior-based safety (BBS) methods (Krause, Hidley, & Hodson, 1990). E. Scott Geller took a more psychological and humanistic approach and referred to his process as “Actively Caring in a Total Safety Culture” (Geller, 1996). Terry McSween called his approach “Values Based Safety” (VBS) methods since this concept promoted making safe behavior a value that would endure in the culture of an organization and not be another program that dwindled away (McSween, 1995). Both Geller and McSween believed that the BBS process must be a core value in the organization rather than just habitual. All these processes were based on sound social and psychological principles backed by peer-reviewed research. All three systems used a form of operant conditioning to modify behavior toward the desired end. Krause and McSween described this conditioning as Antecedent-Behavior-Consequence. Geller interchanged Activator with Antecedent.

All consultants used the terminology "safe" and "unsafe behavior" for the observable behaviors and the data collectors were called either observers or coaches (Geller, 1996). All consultants agreed that an assessment of the existing safety programs and organizational culture was necessary to identify potential barriers and help plan implementation strategy. The observation record was called the Critical Behavior Inventory (CBI) by Krause, the Safety Checklist by McSween, and the Critical Behaviors Checklist (CBC) by Geller. Each consultant used a slightly different format, but the results were the same.

All consultants stressed the power and advantage of the BBS process to empower the rank and file worker. McSween developed this further into team building and individual skills development. Geller stressed teams, but also emphasized the individual psychological processes involved with the BBS process. Krause, through his BST resources, offered other organizational applications based on the BBS process such as Total Quality Management (TQM), Statistical Process Control (SPC), and Continuous Process Improvement (CPI) (BST, 2002). Krause utilized proprietary data management software to track the results of the BBS data. Geller, through his SPS organization, offered similar data management software (SPS, 2002). McSween did not offer this service.

Geller promoted humanistic behavior of individuals within organizations to "actively care" for the safety of their coworkers, not just themselves. Geller introduced the concept of the safety triad (person-behavior-environment). He also advocated the new three "E"s of safety: ergonomics, empowerment, and evaluation. Geller recommended a redirection of safety incentives/awards to "celebrate" the accomplishments of the BBS process and to sustain the interest in the program (Geller, 1996).

McSween's approach to the BBS process was more employee–driven and team-oriented that worked within the existing framework of the organization. McSween recommended a redirection of incentive/rewards from the traditional approach (results-oriented) to activity–based rewards and recognition (McSween, 1995).

Krause 's approach to the BBS process appeared to be the most regimented. It was employee-driven and attempted to change the organizational culture. Krause appeared to be against awards and incentives and only passed judgment that these alternatives were ineffective and needed to be replaced (Krause, et. al., 1990).

Advantages of BBS. According to the proponents of the BBS process, the concept had several advantages over other traditional safety management approaches. BBS identified systems causes of illness and injuries, enhanced traditional safety systems, and were based on sound behavioral analysis principles (Blair, 1999). The process was administered to individuals with minimal professional training, reached employees at the problem, was cost effective, and intervention was easily applied by indigenous personnel monitoring target behaviors (Geller, Boyce, Williams, Pettinger, DePasquale, & Clarke,1998).

The BBS process functioned well in the employee feedback/communication loop needed to continually improve the process. The observation and feedback cycle reinforced the "relaxed awareness" (optimal state of safe and productive performance) of employees, and especially kept veteran employees from "going on automatic pilot" with the increased risk of suffering an accident. (Dennis, 1997). As noted earlier, traditional thought stated 88% of accidents were caused by unsafe acts by employees (Heinrich, et al, 1980). By identifying the critical behaviors and controlling their antecedents and consequences, the frequency of at-risk behaviors and the potential for accidents were reduced. The cooperative problem solving between employees created an atmosphere of trust among employees and fostered changes in the organizational culture (Dennis, 1997). By identifying subtle employee behaviors that caused accidents, the BBS process was an opportunity for organizations with exemplary safety records to move to the next level of safety performance (Loafmann, 1998).

Disadvantages of BBS. Just as there have been many safety professionals that have supported the claim that BBS was the paradigm shift needed to move safety management to the next level, there have also been as many doubters of the process. Opponents of the process claimed BBS placed responsibility for safety on the employee and not management, could not be a substitute for the lack of other solid safety programs required in the work place, and has been proliferated with consultants with a “sell mentality”(Atkinson, 2000).

Organized labor has also voiced opposition to the process. In an article published by the UAW, Jim Howe , union representative, stated,**”** Victim blaming” is at the heart of behavior-based safety programs.” (Blair, 1999). According to Howe,” Behavior-based safety programs appeal to many companies because they make health and safety seem simple , do not require management change, focus on workers, and seem cheaper than correcting health and safety hazards.” (Karr, 2000). Even Charles Jeffress, former head of OSHA, had reservations on how BBS could be applied in organizations that tried to correct unsafe behaviors by employees but shirked their management responsibility to provide a safe workplace. Jeffress stated, "I'm troubled by programs that use behavior-based safety as a basis for the program" (Karr, 2000).

Other opponents say success has been measured and conclusions drawn based on causal relationships. In an article published by the National Safety Council, one writer suggested that the research that has been conducted have been only case studies and anecdotal stories, and not predicated on rigorous scientific research. (Karr, 2000). No studies have taken into account the influence of other programs that may have influenced the results. Some companies have chosen to scrap the BBS process when it did not produce the desired outcomes. One safety professional that worked in an organization where BBS was tried but abandoned said that BBS would be "an excellent tool in an ideal world." "Its good for getting employees to take ownership for their own well-being and a lot of employers think it's the be-all and end all…But people run into trouble when they try to substitute it for engineering controls." (Karr, 2000).

According to Dr. Richard D. Fulwiler, former corporate director of health and safety for Proctor & Gamble-worldwide, and key contributor to the development of the P&G key elements process, BBS has had its shortcomings when implemented by some management. He blamed too many programs have been implemented where there has been a lack of focus from management. Management had introduced it as a "program" and not integrated into the overall management system or worse yet, according to Fulwiler, it had become the main delivery system for safety management in the organization. (Fulwiler, 2000).

Another disadvantage of BBS seen by some is the long length of time and resources needed to implement the program. The National Safety Council regarded BBS as a useful tool but cautioned that it was not a “magic bullet” for organizations. As Don Ostrander, NSC director of the organization’s consulting division, stated, “We endorse any concept that stimulates an organization to make safety and health a priority. But behavior-based programs are only effective in the long run if companies maintain the interest and if there’s sufficient internal support to let the system thrive”(Hans, 1996). The cultural change required for the process may be too long for some organizations to endure, who give up, and go back to their old ways. Acceptance by foreign companies, where the culture of the society may have problems with the observation and feedback process, such as in the Orient, has not been extensively studied (Hans, 1996).

Lastly, some opponents, such as T. A. Smith, have argued the roots of the BBS process are based too much on behaviorism (the human element) and have not fit well with the new integrated management systems that required systems thinking by employees. Smith contended the BBS has fit well with the command –and-control style of management , but not within the quality/integrated management model. The quality model dictated that the cause of accidents was the system and not the employees. “When management discovers this is a better way to manage their safety, then they will give up the BBS concepts and take aim at managing the system” (Smith 1999).

Safety Performance Measurements

Measurement criteria. A common management proverb has stated, “What gets measured gets done.” (Source unknown). In terms of the measurement of safety performance the questions become: what is measured and how is it measured? Safety performance has been measured to (a) determine benchmarks to sense improvement, (b) measure and determine accountability, (c) measure communication/feedback in the management system, and (d) measure costs (Dennis, 1997).

Downstream measurement. The traditional method of measuring safety performance has been downstream or after-the-fact accident rates. The OSHA frequency, severity, and total recordable incident rates (refer to Chapter 1 definitions) have been used since the inception of OSHA in 1970 to measure the success of any organization's safety performance. There has been much discussion on how incident rates should be used to measure safety performance. Even Heinrich recognized the need to measure the results of accidents during the 1930s. In *Industrial Accident Prevention,* Heinrich states "The most valued methods in accident prevention are analogous with the methods for the control of quality, cost, and quantity of production" (Heinrich 13-16)(O'Brien, 1998).

Industry has typically measured safety by one single number – OSHA recordables. Geller contended that this was the wrong standard to be used to measure safety success. Geller argued that this has been the only indices that some companies have used to evaluate their success and for determining promotions and pay raises. According to Geller, other drawbacks of using the incident rate for measuring success has been the manipulation of the numbers for company advantage by under-reporting employee injuries and illnesses to make the company look good. (Geller, 2002).

O'Brien (1998) discussed the inadequacies of results oriented metrics, but also stated that downstream metrics must also be used for internal and external safety measurements such as benchmarking and industry comparisons. He stated,

> The focus is on constant improvement of leading edge indicators that will ultimately improve the trailing edge indicators. Lagging indicators that should be

used are OSHA recordable incident rate, severity rate, and insurance reserves. Leading indicators should be measuring activities: safety suggestions, safety meetings, safety audits, contractor measurement, housekeeping, documentation, and management involvement. Safety performance must be measured in the same way that other business sectors are measured.

Dan Petersen, noted safety management consultant, has also realized the drawbacks of downstream indicators to measure safety success. If incident rates were to be used they required statistical validity consistent with the other quality management systems in the organization. Petersen advocated replacing traditional measures (incident rates) with valid meaningful upstream measures such as process improvements achieved or through measured improvements through safety perception surveys. (Petersen, 1997). Petersen further stated that the incident rates were false benchmarks for organizations. Insurance companies used them to set rates and organizations used them internally to measure safety system effectiveness. Peterson contended that this information is used wrongly to punish or reward management, determined which organizations were best in safety, set unrealistic goals, and was the determining factor for management action or inaction. “Results measures nearly always measure only luck and do not diagnose problems”, said Petersen (Petersen, 1998b).

Other safety professionals (Salazar, 1989) have equated incident rates in terms of quality metrics: the measurement of the number of defects in the system. Deming advocated the measurement of the quality of the system and not the quality of results. Salazar contended that incident rates were an unreliable metric based on chance if there was no intervention by management. The reporting of incident rates has been subject to under reporting and bias by organizations.

Stricoff (2000) contended there were two types of safety measures used in industry – accountability indicators and performance indicators. The safety profession has historically relied on retrospective indicators (accountability indicators) – injury frequency rates. Management has been reactive when the frequency rate exceeded the upper limit of the norm and management acted to drive the rate down. When the rate fell below the limit, management tended to ignore safety and the recordable rate increased again. Injury rate outcomes were after-the-fact indicators and not suited for proactive safety management efforts. With emphasis on the rates, these measurements have been more suspect to manipulation to "make the numbers" come out right by organizations. Stricoff explained, "This rate is the ultimate outcome for the safety process and is analogous to the business measuring profit".

In summary, use of the incident rate to measure safety performance has been applied extensively in industry. However the incident rate-focused approach to safety concentrated on the outcomes of the safety process. Management became reactive when the incident rate exceeded their comfort level and became complacent when the incident rate dropped below their lower comfort level. The fallacy of this approach was that incident rates may reflect no more than random variation rather that a valid indication of safety performance improvement. Incident rates may plateau with no efforts given by management to improve the safety process even though losses occurred. Upstream measurement was more desirable. Incident rates can be used as sound benchmarks over a span of time for large companies who have tracked their progress after a program has been implemented (such as this study). Incident rates can be "bottom line" measures and therefore can be used to track long-range trends in the organization. As with BBS, the organization should use statistically valid incident rates as an indicator on how well the process was affecting safety performance (Dial,1992).

Upstream measurement. As has been indicated in the literature review thus far, down stream measurements, such as incident rates, should only be considered for the measurement of long-term results and trends in the safety management system. The measurement of upstream or before-the-fact metrics was argued to be the most effective way to manage the system. Upstream metrics included safety perception surveys, safety audits, critical behavior checklists, and the tracking of safety activities in organizations.

Perception surveys. Perception surveys can be used to measure the effectiveness of the safety management system (Krause, Hidley, & Hodson, 1991). Dan Petersen (Petersen, 2000b) stated that perception surveys can be a means of measuring the safety "health" in an organization. Perception surveys measured what employees thought about safety management as opposed to benchmarking against safety programs. Benchmarking or "best practices" asked management what was working or not working, but not how employees felt about their safety. Peterson recommended the Minnesota Perception Survey to be one instrument that has been statistically validated. It measured perceptions in 20 categories of a safety management system. The results were presented in % positive responses. Responses below 60% positive were considered to be "red flags" for management. "Surveys reveal where performance levels actually are", stated Petersen.

Safety audits. Safety audits can be another upstream metric to indicate safety performance. Dan Petersen (Petersen, 2000b) proposed audits should be used only when the organization has validated that the audit items have correlated to its accident record over a period of years to identify problem areas. He stated that audits were developed to define upstream measures – elements of the safety system that were in place to prevent accidents. However, Petersen argued that there has been little effort to correlate audit results to the accident record. Research conducted by various organizations and individuals show mixed results that accident rates could be reduced by improving safety audit scores. Only if audits are constructed to correlate accident records in large enough numbers to show validity would they be considered to be effective (Petersen, 1998b).

Measuring behavioral indicators. Krause, et al (1991) advocated that the "most valid method of achieving sustainable, long-term results is to steer a facility's safety efforts by a variety of behavior-based indicators, in judicious combination to accident frequency". Measuring safe behaviors against a predetermined critical behavior checklist or inventory has been the preferred upstream method of evaluating the effectiveness of the BBS process. The authors advocated upstream measures based on the quality improvement cycle: specify standards, measure compliance, and provide feedback. The standards related to an inventory of critical safety-related behaviors and the measure of compliance compared the ratio of safe to unsafe critical behaviors. Feedback on improvement provided employees with reports and charts on their progress on the inventory of behaviors. The analysis of persistent unsafe behaviors highlighted management system issues. According to the authors there were five safety management indicators: accident frequency, frequency of observation, percentage of actions that rated as "safe", safety-related maintenance information, and involvement indicators and surveys. "In a number of informal studies, frequency of observations per 100 employees has been shown to be a consistent predictor of accident frequency rates", stated the authors. There was found to be an inverse relationship to these variables – when observations increased, the frequency of accidents decreased.

Other safety professionals have supported the idea that leading behavioral indicators were the preferred method of measuring and managing safety performance. Loafmann supported the concept that upstream behavioral indicators could be used to uncover root-cause barriers likely to cause injuries in the future (Loafmann, 1998). Stricoff, president and principal consultant with BST, also supported the idea that behavioral indicators were valid upstream measures. He stated, "Measuring exposures is a highly valid prospective measure of injury exposure. At-risk behaviors are indicative of exposures, thus measuring them can be used to develop a good upstream indicator" (Stricoff, 2000).

Stricoff went on further to state that the BBS process allowed an organization to track and report upstream parameters directly related to exposures. He stated, "Because BBS generates data at the exposure stage – directly upstream from injuries – they can be harnessed as a foundation for improved upstream measurement". (Stricoff, 2000). If properly employed, valid measured data (observations) correlated "percent safe behaviors" to injury rates. To produce data predictive of this performance a site selected behaviors indicative of exposures that produced injuries at the facilities, and developed risk-based, well-defined observation criteria, together with valid and consistent sampling procedures.

Measurement of BBS Effectiveness

Downstream measurement. There has been numerous case studies and research conducted on how the BBS process has reduced accident incident rates. Beth Sulzer-Azaroff and John Austin, both university behavioral psychologists, conducted a comprehensive literature review of this topic. A review of literature of 83 databased evaluations of behavioral safety programs identified 33 studies that reported data on changes in incident rates. (See appendix D). Of the 33 studies reviewed, 32 reported reductions in injuries. However, the format of reported changes varied widely. Some studies reported incident rates, lost workdays, percent improvement from a baseline, or numbers of accidents. There was not a consistent measure between studies. In addition, some accident rates were reported on miles driven instead of hours worked, the standard denominator to measure OSHA incident rates. Other factors that may have influenced the results of this study were reporting validity and the ranges of baseline injury rates reported. Sites that had initially high injury rates have a larger potential of improvement than those sites with low rates (Sulzer-Azaroff & Austin, 2000). In a similar study conducted earlier, a systematic review of 53 OSH studies since 1977 indicated that BBS had the highest average injury rate reduction (59.6%) (Gaustello, 1993).

Incident rates. Much of the major research conducted on the effectiveness of the BBS process to reduce accident/illness incident rates have been conducted by the major consultants in the industry (BST and SPS).

BST conducted an extensive study of five years of injury data from 73 companies, drawn from a target population of 229 companies that had implemented a BBS process (Krause, Seymour, & Sloat, 1998). Comparisons of pre–to-post incident rates across the group indicated a significant decrease in incident rates following BBS implementation. The average years since BBS observations began for the survey companies were 3.11 years. The average reduction from baseline amounted to 26% in the first year increasing to 69% by the fifth year. Tests of internal and external validity were conducted as part of the study. Limitations of the study were (a) voiced concern by the researchers that only successful sites (i.e. those that showed incident rate improvement) submitted data, (b) the researchers did not consider other alternative treatments to explain safety improvements other than the BBS process, and (c) companies considered in the survey used the consulting services of a BBS firm.

A review of individual case studies, primarily led by BBS consultants, has resulted in similar reductions in the incident rates. Contrary to some union opposition to the process, implementation of the BBS process in large unionized facilities has resulted in reduction in incident rates after implementation. Implementation of a BBS process in some ARCO oil refineries over a span of seven years reduced the OSHA TRIR from 8.0 in 1990 to 0.39 by the end of 1996 (Barton, Caldwell, & Hodson, 1997). A BST-led process installed in a Weyerhaeuser pulp mill in 1995 showed a 57% step-change improvement in the OSHA incident rater (TRIR). There were 265 union workers at this site. Union and management worked closely together to implement the process. This supported the evidence that management commitment was a key factor in program success. The 47-month baseline TRIR was 8.12 (1992-1995). The TRIR was reduced to

3.53 (1995-1999). The plant manager credited the BBS process as the major reason for the safety performance improvement and that it had been a positive shift in the safety culture of the plant work force (Hidley & Airhart, 1999). In another BST implementation, the Tennessee Eastman maintenance organization, a 1000 person unionized department, reduced their TRIR 88% from 20.5 in 1990 to 2.5 in 1998. This was particular noteworthy for a large maintenance staff working in a highly hazardous chemical plant where the potential for serious injury was present. As the process matured, special focus was placed on cumulative trauma disorder (CTD) injuries. The CTD-related TRIR rate decreased from a mid-1993 rate of 4.40 to a 1998 rate of 0.41 (Hodson & Hall, 1999).

The review of literature did not find extensive research of the BBS process applied in the construction industry. However, one case study was reviewed involving a major construction firm. The M.W. Kellogg Company, an international construction firm, noted the following reductions in OSHA incident rates in an extensive construction project over two years: TRIR of 1.27 by the end of the project, LWIR of 0.11 and LWSR of 0.7. The observations per worker per month was tracked against the TRIR and appeared to indicate that as observations increased, the incident rate slightly decreased during the same time period (Hodson, Groover, & Ray, 1999).

Worker compensation costs. The literature review revealed limited research has been conducted on the impact of the BBS process on worker compensation costs. M.W. Kellogg Company reduced baseline worker compensation costs from $0.75-$0.99 cents per hour worked to $0.18 per hour worked in a major construction project over 2 years (Hodson, et. al, 1999). The result of a one-year BBS intervention study in an engine bearing manufacturing produced an estimated $200,000 savings in worker compensation costs (Pettinger, et. al, 2002). A significant reduction in costs occurred in a pork slaughterhouse that implemented a form of a BBS program to reduce worker compensation costs from 1.8 million to $400,000. However, since the injury rate at this company was so high, almost any intervention would have worked to reduce costs and injury rates according to a former corporate safety director. Before BBS the TRIR was a staggering 119 (30 was the industry average) and that was lowered to 40. However, since the results were still too high, the company decided that any further gains were not worth the efforts expended through the BBS process (Karr, 2000).

Upstream measurement. The predominant research conducted on the upstream measurement of the effectiveness of the BBS process has been conducted in the area of perception surveys concerning the implementation and sustainment of the BBS process and the relationship of observed safe behaviors and the resulting incident rates. BST has developed a BST Culture Factors survey that measured statistically validated organizational characteristics that underlie safety performance. The survey measured organizational factors such as perceived management support and credibility, teamwork, workgroup relations, organizational values of safety, safety communication, and approaching others to discuss safety performance (Stricoff, 2001).

Research studies on perceptions. E. Scott Geller and Jason P. DePasquale conducted research concerning perception surveys that were administered in twenty different organizations to measure the interpersonal trust, management support, and employee participation/involvement with BBS programs. The results indicated five factors that influenced the success of a sustainable program – perceptions that BBS training was effective, trust in management abilities, accountability for BBS through performance reviews, education in the BBS process, and tenure with the organization. Organizations that made BBS involvement mandatory saw higher levels of involvement, trust in management, trust in coworkers, and satisfaction with BBS training than organizations that made it voluntary (DePasquale & Geller, 1999).

In other research studies, Geller, Roberts, and Gilmore (1996) applied a 154 item Safety Culture Survey (SCS) that showed support of the Antecedent –Consequence model to prove workers "actively cared" for the safety of their coworkers who had been trained and implemented a BBS. Another study constructed and validated a 50-item instrument entitled the Work Safety Scale (WSS) to assess five distinct areas necessary to support a BBS process: (a) job safety, (b) coworker safety, (c) supervisor safety, (d) management safety practices, and (e) satisfaction with the safety program. The purpose of the instrument was to show correlation between worker's perceptions of safety on the job with variables related to industrial accident rates. The strongest correlation between employee compliance with safe behaviors was found to be coworker safety and supervisor safety (Hayes, Perander, Smecko, & Trask, 1998).

Two foreign studies used perception surveys to determine the acceptability of behavior-based safety in their industrial cultures. An Australian study (Harper, Cordery, de Klerk, Sevastos, Geelhoed, Gunson, Robinson, Sutherland, Osborn, & Colquhoun, 1996) conducted a qualitative analysis of observed managerial behavior in relation to program effectiveness in seven Australian companies. Effectiveness was measured in terms of a statistical significance of changes in safe work practice rates and good housekeeping rates between a base line period and the intervention period. Nine parameters of management behavior were found to be associated with BBS effectiveness: active managerial involvement in safety, delegation of authority for safety to employees, effective organizational communication, consistency of management safety practices, managerial safety leadership, positive safety role models, equal priority for safety vs. production, and cooperation of management with the research team. The study also concluded that even in companies that were considered to have strong management commitment to safety, the probability of BBS being effective in promoting safe behaviors was found to be only 50% compared to other studies cited in the research. The study reaffirmed that management commitment and support must be in place for the BBS process to be effective and that BBS only appeared effective in companies with recognizable managerial styles.

The second foreign study involved a Finnish study of the safety culture in the wood processing industry in that country. A questionnaire measured the safety climate in eight wood processing companies in Finland. The conclusions reached in the study indicated that the more favorable the safety climate in the company, the lower the accident rates. When comparisons were made, four companies with an accident rate below the average for the wood-processing industry had a better safety climate than four similar companies with accident rates above the average (Varonen & Mattila, 2000).

Research studies on safe behaviors. Many research studies have indicated direct relationships between observed safe behaviors and accident incident rates. Krause's implementation of the BBS process in his client firms has indicated that as observed percent safe performance increased, recordable rates decreased. Likewise his research has suggested that as contact rate (the average number of times per month that a full-time employee is observed) increased, recordable rates decreased (Krause, 1998).

Since Komaki et al's (1978) research on the correlation of safe work behaviors to incident rates was conducted, many other research studies have attempted to validate this relationship. The behavior safety performance index (BSI), a ratio of the number of observations safe divided by the number of safe and unsafe , (Komaki, et al., 1978) was used to measure the degree of safety in the organization. Research conducted since that time has appeared to validate an inverse relationship between the BSI index and the incident rate. That is, as the BSI index increased, the incident rate decreased.

Research conducted by Ray and Frey (1999) substantiated this relationship. During a six-month study the BSI index was calculated against the OSHA recordable (TRIR) rate and lost time injury rates (LWIR). Visual inspection of graphical data (BSI index and incident rates) appeared to indicate this inverse relationship. The findings supported the hypothesis that the frequency of safe behavior was inversely related to the frequency of injuries in the workplace. A statistical test of correlation between these variables was applied to determine whether this inverse relationship was significant. The following results were shown:

> The correlation (rho) between recordable incident rates and mean safety indexes for each group was found to be – 0.77, which indicates a moderate-to-strong inverse relationship between the two samples. The correlation between lost-time injury rates and the mean safety indexes was found to be - 0.63, which indicates a moderately strong inverse relationship between the two samples. As these results show, the statistical test provided evidence that a statistically significant

inverse relationship exists between the BSI and injury rate, and, thus supports the findings depicted in the visual graphic analysis.

Review of Effectiveness at XYZ Company

BST evaluation. BST furnished a management report to the director of corporate safety for XYZ Company on the status of the locations that had implemented their BAPP® (Behavioral Accident Prevention Process) in May 1998 (BST, 1998). BST identified five "Success Factors" that were needed to assure successful implementation at the eight sites identified in the report. These factors were (a) management support, (b) frequency and quality of observations, (c) sharing data and problem solving, (d) communication, and (e) accountability. BST concluded the following at the close of the report:

> Evaluating the above XYZ Company implementations of the BAPP® technology in relation to BST® overall client base, it is our judgment that the factor differentiating the most successful from the least successful processes is leadership on the part of site management. For those processes that are not doing as well as one would expect, systematic attention to leadership practices are indicated.

An evaluation of the status, results, and opportunities for improvement for each facility as reported by BST was included in Table 1.

Table 1

Results of BAPP® Implementations at XYZ Company

Location	Results
Knoxville	Began observations in 1995. Showed a 27% reduction in TRIR in first year, 50% by the third year using a four-year baseline prior to implementation. Participation at all levels. Strong facilitator/steering team. Opportunities: declining observations & weak follow up by management on action items.
Brookings	Began observations in October 1996. Data through April 1998 indicated a 25% reduction from baseline TRIR. Strong commitment from plant manager and steering team. Opportunities: lack of strong supervisor support and feedback of observations was poor.
Northridge	Began observations in January 1997. No indication of TRIR reduction at this point. Quantity of observations was high. Opportunities: process was management driven and not employee driven. Poor observations quality – "air sampling" to meet quotas, competition for time and resources with other facility goals.
Greenville	Began observations in March 1996. As of March 1998, a 59% reduction in the TRIR from baseline. Strong management and steering team commitment. Opportunities: lack of supervisor support in some areas and follow up on action items identified from the data.

Decatur film / chemical plants	Began observations in the fall of 1995. TRIR in the film plant has decreased 32% from baseline period. TRIR in the chemical plant showed a 60% increase from the baseline period. Strong management sponsorship in film plant. Data is used effectively to remove barriers. Has become engrained into the organizational culture. Opportunities: more management commitment from plant manager in the chemical plant. More frequent and quality observations were needed.
Cordova	Began observations in 1996. Supervisors performed observations. Strong facilitator and management sponsor. Average observations were 160/month. Opportunities: top down approach has created problems with employees and steering team in accepting process.
Petaluma	Implemented directly by BST facilitator. Small operation (50 employees) has resulted in limited resources for planning, training, and follow up.

XYZ Company BBS research study. An internal study by a XYZ Company safety engineer was conducted in 1999 to determine the effect that percent safe observations had on the TRIR for eight locations that had implemented the BBS process (Bond, 1999). Descriptive and analytical statistical methods were used to determine valid correlations between the percent safe behaviors observed and the OSHA recordable (TRIR) incident rate. The hypothesis was that as safe behaviors increased, there would be a resultant decline in the TRIR rate. An analysis of variance (ANOVA) was used to test the correlation between the observed percent safe behaviors and the OSHA incident rates.

Correlations were low between all locations tested. Bond (1999) concluded, "there is no evidence of any downward trend in incident rates once a behavior-based safety process is implemented" (p. 171). Individual /moving range (I/MR) statistical process control charts were also applied in this study to track individual facility incident rates over time. Four locations showed a downward trend in incident rates, however this downward trend was occurring before the implementation of the BBS process. Three locations showed no trend in incident rate change before or after BBS implementation. Recommendations from this research included (a) more research on incident rates at other locations to support or reject the study findings, (b) a corporate database to track and assess the process corporate wide, and (c) networking between locations to further promote and validate the process.

Conclusion

The literature review has examined the origins of safety management, behavior-based safety concepts, safety performance measurements, and research conducted to measure the effectiveness of behavior-based processes in organizations. The review indicated that both upstream and downstream metrics should be used to evaluate the effectiveness of the BBS process. Downstream indicators, such as accident incident rates and worker compensation costs, should be used for long-range verification of the process and for benchmarking between facilities and industries. Upstream or proactive indicators, such as safety perception surveys and percent safe behaviors should be used to manage the process, remove barriers that could cause loss, and serve as verification that the process is working. Previous studies conducted within XYZ Company differed in their interpretation of the effectiveness and measurement of the process. Thus, it is the conclusion of this review that this remains the main purpose of this study.

Chapter 3

Methods and Procedures

Introduction

The methods and procedures used in this study are explained in this chapter under the headings of (1) method of study, (2) population and sample, (3) instrumentation, and (4) method of analysis.

This research considered determining reliable methods of measuring the effectiveness of BBS in improving safety performance. Effectiveness could be measured in terms of statistically valid "down stream" indicators such as the reduction in the frequency and severity of illness and injuries (OSHA incident rates) and worker compensation incurred costs. "Upstream measurements" that could be measured included percent safe behaviors observed, improvements in employee perceptions of safety, number of corrective actions (barriers) identified and resolved, number of workplace environmental hazards eliminated, and safety work orders or suggestions submitted.

The review of literature has indicated measurement of statistically valid downstream indicators such as changes in incident rates can be a valid measurement of BBS effectiveness (Barton, et al., 1997; Hodson & Hall, 1999; Krause, et al., 1998). Perception surveys and the correlation of observed safe behaviors to changes in incident rates have also been shown to be valid upstream indicators of BBS performance (DePasquale & Geller, 1999; Geller, et al., 1996; Hayes, et al., 1998; Komaki, et al., 1978; Ray & Frey, 1999).

Method of study

Therefore, these methods were chosen for the design of this study:

1. Statistical analysis of OSHA incident frequency rates (OSHA IR), severity rates (OSHA SR), and worker compensation incurred costs in BBS facilities of XYZ Company before and after intervention with the BBS process.
2. Statistical comparison between BBS and non-BBS facilities for the periods of 2000 and 2001 in terms of OSHA incident rates.
3. Correlation between % safe behaviors observed and OSHA incident rates (OSHA IR) in BBS facilities of XYZ Company.
4. Correlation of safety perceptions between work groups in the same facility of the XYZ Company. One work group implemented the BBS process two years ago, while the remainder of the plant had not been exposed to the process.

Incident rates. It has been suggested that many occupational injuries go unreported (Weddle, 1996). Therefore using safety metrics that are difficult to mask or hide, such as lost-time or restricted work injuries, provided a more accurate depiction of the impact of a safety process improvement than a record of minor or OSHA recordables. Therefore, the OSHA severity rate (OSHA SR), which indicated the severity (# of days of lost or restricted work/100 workers) and the OSHA frequency rate (OSHA IR), which indicated how often restricted or lost workday cases occurred, was the basis for measurement of the effectiveness of the BBS process in the XYZ Company.

As the literature review has indicated, one method that determined the effectiveness of behavior-based safety was the examination of the effect the process had on OSHA incident rates. A statistical analysis was performed on each XYZ Company facility that had implemented the process. OSHA severity (OSHA SR) and OSHA frequency rates (OSHA IR) were examined for linear trends and statistical differences before and after the application of the BBS process. The same process was used to examine worker compensation incurred costs in the same facilities.

A comparison of BBS and non-BBS facilities was made using the same indices during the two most recent reporting years. Statistical tests were performed between these groups to examine any differences in the measured criteria.

An examination of percent safe behaviors compared to incident rate was conducted similar to the studies conducted by Ray and Frey (Ray & Frey, 1999) and Bond (Bond, 1999) to confirm or disprove the hypotheses that as percent safe behaviors observed increases the incident rate decreases.

Perception survey. A survey instrument that measured safety perceptions of the BBS process was given voluntarily to the entire production employee population in one of the Wisconsin facilities of the XYZ Company. Since a portion of the facilities employees had been operating with the BBS process for two years, an analysis was performed on the responses from this group to determine if any statistical differences existed in this group compared to the plant general population.

Population and sample

For the purpose of this study three distinct populations were identified for analysis. The 15 locations of the XYZ Company that had installed behavior-based safety programs beginning in 1995 were examined for changes in incident rate and worker compensation costs. The relationship of percent safe behaviors observed and incident rate was also examined. Four locations were excluded from this analysis due to the short time duration that the facility had operated with the BBS process. These locations included: Columbia, Guin, the Wisconsin location, and Hutchinson. All locations selected represented medium to large manufacturing facilities within the XYZ Company. A variety of plants were selected intentionally in order to represent a full spectrum of different business groups, manufacturing and employee diversity, geographic locations, and cultures. Plant locations varied from the east coast, west coast, and southern locations, with a majority of the plants located in the central United States. Refer to Appendix A for these locations.

The non-BBS plants were selected similarly in terms of geographic location, similar manufacturing technologies, and employee and cultural diversity. Facilities that matched well included: Nevada and Cynthiana; Irvine, Monrovia and Northridge; Springfield and Cordova; Columbia and New Ulm; and Valley, Aberdeen, and Brookings. Additional non-BBS plant locations selected included: Alexandria, Ames, Bristol, Brownwood, Menomonie, Monrovia, Stillwater, and Wausau. These plants were selected for similar geographic, technological, and cultural similarities to the BBS locations. All plants within XYZ Company were subject to adherence to the corporation's Global, Safety, and Health Plan (GSHP) which defined the major requirements of the safety management system in the company (refer to Appendix B). Therefore, the risks inherent with the workplace environment (physical and chemical hazards) in each plant were assumed to be managed similarly.

The third population of this study was the production employees at one of the Wisconsin locations of the XYZ Company. Since this group was most involved with the implementation of a site-wide BBS process, this group was surveyed with the safety perception survey. There were 437 employees at this location at the end of 2001. Of this population, 338 were considered to be in manufacturing and administrative positions that would be involved with the process. The manufacturing group, Optical Systems Division, that implemented the BBS process two years ago, comprised a subset of 70 employees of the identified manufacturing and administrative employees. The remaining employees were in supervisory or management positions that would be supporting the BBS process.

Instrumentation and materials

Perception survey. A 32-question safety perception survey was administered to the general manufacturing population of the Wisconsin facility (refer to Appendix C). Its content was based from the Safety Culture Survey available from Safety Performance Solutions (SPS, 2002). The intent of the survey was to gain a baseline measurement of employee perceptions about their safety attitudes prior to the implementation of a behavior-based safety (BBS) process.

The second purpose related to the application of this survey, and a major goal of this study, was a measurement of the perceptions of a specific work group at the facility that implemented the BBS process two years ago. This group's results would be compared to the general plant population. It was assumed that the effectiveness of the process would be shown with statistical differences in the responses compared to the remaining plant population.

The 32-question survey related to perceptions concerning these areas: accident reporting, peer feedback, safety rules and regulations, employee safety involvement and inititative, job "short cuts", supervisory and mangement support for safety, peer relationships and trust, and safety environment. Responses were analyzed to determine barriers that were present in the system that would impede the process.

A Lickert scale was used to quantify the survey questions from each participant. The scale was designed as follows: (1) highly disagree, (2) disagree, (3) agree, and (4) highly agree. Each question in the survey had a desired positive or negative response. This data was structured to statistically measure these responses. The BBS implementation team at the facility decided not to include a scale factor for “no opinion” since they wanted the participants to have a definite opinion on each question.

Incident rates and worker compensation costs. Various sources were utilized to analyze the data concerning incident rates, worker compensation costs, and percent safe behaviors. Injury and illness data and worker compensation costs were analyzed for the period 1991 through 2001. Information for the years 1996 through 2001 was obtained through the corporate safety web site (XYZ Company, 2002a). Reports from 1991 through 1995 were obtained in hard copy from the corporate safety staff contact that compiled these reports. Worker compensation incurred costs were obtained from the corporate safety department.

Spreadsheets were developed for each BBS and non-BBS location for the years 1991 through 2001. Data included on the spreadsheet included the OSHA I/I data and worker compensation incurred costs. Refer to Table 2 for an example of these spreadsheets.

Table 2

Brookings, S.D. I/I rates and incurred costs

Year	TRIR	LWIR	OSHA IR	LWSR	OSHA SR	Incurred costs ($1000)
1991	13.29	3.12	5.43	4.48	169.68	116.2
1992	11.55	3.23	4.97	19	214.75	145.4
1993	11.32	2.64	3.77	38.36	119.62	153.7
1994	7.95	1.3	3.78	20.85	89.77	167.2
1995	7.36	0.4	2.54	7.49	43.89	151.3
1996	6.3	0.84	2.1	7.28	38.52	47.3
1997	6.55	0.66	2.23	3.93	31.86	77.4
1998	3.76	0.39	0.91	15.04	44.85	56.8
1999	4.15	0.54	1.07	2.54	29.57	178
2000	4.16	0.38	1.26	1.51	9.07	39.6
2001	6.62	0.36	2.41	4.45	50.28	270

Statistical analysis of each BBS location will be discussed in the *Method of analysis* section.

% Safe behaviors vs. incident rates. Information about observed percent safe behaviors was collected from the BBS facilitators at the individual plant locations. Requests were made to each BBS facility to provide the total percent safe behavior observations from the years 2000 and 2001. Analysis of the data is discussed in the *Method of Analysis* section.

Perception survey. The 32 question survey instrument was given to 338 production and administrative employees at the Wisconsin facility beginning in February, 2002. Subjects had the survey distributed by their supervisor asking them to voluntarily complete the survey. Completed surveys were returned anonymously to their supervisor or to the plant BBS coordinator. Employees had sufficient time to complete the survey during their work time. No deadlines or completion dates were attached to the survey. The employee participation in the survey was strictly voluntary and the only identifier associated with the survey was the employee's assigned department. By the end of March, 2002, 218 surveys were returned for a completion rate of 64%. The Optical Systems Division returned 37 of 70 surveys for a participation rate of 53%.

Method of analysis

Incident rates and worker compensation costs. Since behavior-based safety is a process, statistical process control techniques can be applied to evaluate its effect on the system. Process charts show historical patterns of variation to provide a better understanding of where the process is headed. Process charting provided information to show short term or "common cause" variation of the process and identified whether unusual or "special cause" variation had occurred. Common causes were variations that belong to the system and constitute, according to Deming, about 94 percent of the variation of the process. Special causes, or variation from causes outside the system, made up 6% of the variation in a system (Dennis, 1997). If special cause variation was shown this indicated that a change had occurred in the process. Therefore, in this study, these charts were examined before and after the implementation of a behavior-based safety system on selected incident rates for the BBS locations of the XYZ Company.

The statistical software packages used for data analysis included BPChart, Version 4.0 (BPChart, 2001) and Minitab, Version 13.3. BPChart was customized statistical software designed within the XYZ Company for business and process charting. It used Microsoft Excel software with macros developed to easily build and apply statistical process control (SPC) techniques. Minitab was used for statistical analysis of variance and correlation.

To analyze any statistical differences in the OSHA IR, OSHA SR, and worker compensation incurred costs in the BBS locations before and after implementation, control charts were constructed for each facility. A Run chart was first constructed to view the overall process so that trends or patterns could be easily identified on the graph. Next an "I Chart" was plotted for each facility. An "I Chart" or Individual chart was a time series plot with a calculated mean centerline and process limits. Special cause indicators based on sound control chart theory (Wheeler, 1993) were built into the graph. The I chart indicated that the process average was stable. Next a MR chart, or moving range chart was constructed. A MR chart, a chart that plotted the moving range, indicated the process variation.

BPChart was also capable of linear trending of the process. This was applied to the three indices (OSHA IR, OSHA SR, and incurred costs) after the BBS implementation in each facility. The confidence level or "P-value" associated with the linear fit should be within the range of 0.0 to 0.05 range to be accepted as strong statistical validity.

BPChart also has the capability of evaluating step changes in the process. The step change model was the best trending model to be used in this study since it was known when the BBS process was implemented in each facility. The year that the process began was excluded from the analysis to allow the process to stabilize. A step change chart was generated and the difference (if any) was analyzed with a one-way analysis of variance (ANOVA) in Minitab.

Comparison of BBS and non-BBS facilities. A statistical comparison of BBS and non-BBS facilities in terms of the accident incident rates defined in this study was conducted. A one-way ANOVA test of the OSHA incident rates was conducted for the period of 2000 and 2001 from the available data.

% Safe behaviors vs. incident rates. Data was analyzed similar to the study conducted by Ray and Frey (Ray & Frey, 1999). Results were analyzed in two ways (1) visual inspection of graphical data plotted for percent safe behaviors and incident rate (OSHA IR) and (2) statistical testing using a rank difference correlation (Spearman rho) between facility incident rates and the corresponding facility percent safe behaviors.

Perception survey. The data from the survey was compiled into an Microsoft Excel spreadsheet. Participant response to each question was tabulated into the spreadsheet by department location. The participants from the Optical Systems Division were separated from the remainder of the plant surveys since it was a goal of the survey to prove that there could be a statistical difference in their responses.

A one-way analysis of variance (ANOVA) using Minitab was conducted for each question that compared the plant response to the response from the Optical Systems division. This test indicated any statistical difference to the response to the question. For example, the ANOVA of question six (Q6) is shown in Figure 1.

```
Source     DF      SS      MS      F      P
Process     1   3.749   3.749   8.26  0.004
Error     211  95.800   0.454
Total     212  99.549
                               Individual 95% CIs For Mean
                               Based on Pooled StDev
Level       N    Mean   StDev  --+---------+---------+---------+----
Optical    33  2.0000  0.5000  (-----------*-----------)
Plant     180  2.3667  0.7004                   (----*----)
                               --+---------+---------+---------+----
Pooled StDev =  0.6738        1.80      2.00      2.20      2.40
```

Figure 1. Analysis of Variance for Question number 6

This type of analysis would indicate a statistical difference between the means of the two samples in the population (p= 0.004). Results were compiled for each question and discussed in Chapter 4, Results and Discussion.

Results of the survey were also submitted to the statistical and research consultant at the University of Wisconsin – Stout Computer Education and User Services for additional analysis. Independent group t-tests using Levene's test for equality of variances were used in this analysis. Independent group t-tests were performed on the 32-question survey using the Optical Systems Department and the remaining plant population for comparison. The eight specific perception areas specified in the survey were also analyzed using this test. Results of this analysis are discussed in Chapter 4.

Summary

This chapter identified methods and procedures to be used in the study to identify ways to measure BBS effectiveness. SPC techniques along with descriptive statistics were implemented to evaluate downstream metrics of measurement. Techniques to analyze results from perception surveys related to BBS concepts were also explained.

Finally, percent safe behaviors observed, an upstream metric, were correlated with injury rates to validate a method of measurement.

Chapter 4

Results and Discussion

The purpose of this study was to determine methods to measure the effectiveness of behavior-based safety in the XYZ Company. The objectives of this study were to (1) identify statistically valid methods to measure the BBS process, and (2) determine if the BBS process improved safety performance in the XYZ Company facilities that implemented the process. The literature review showed both upstream and downstream measures could be used to determine BBS effectiveness. The methods used in this study included (1) statistical analysis of accident and injury rates and worker compensation costs for both BBS and non-BBS plants using SPC, trending, and analysis of variance, (2) an examination of the relationship between percent safe observations and OSHA IR, and (3) measurement of differences in safety perceptions between employees that had been exposed to the BBS process and those who had no exposure to the process.

Results and Discussion

Objective 1: Determine statistically reliable methods to measure BBS effectiveness.

Results. Using the methodology established in Chapter 3, Methods and Procedures, each BBS location within the XYZ Company was examined for the effects that the BBS process had on downstream measures such as incident rates and incurred costs. Upstream evaluation included an analysis of how percent safe behaviors influenced incident rates. Linear regression and correlation analysis was used for this analysis. Statistical analysis of group responses to a safety perception survey, an upstream measure, was also conducted to determine the effectiveness of the process.

OSHA incident rate (OSHA IR), OSHA severity rate (OSHA SR), and worker compensation incurred costs were analyzed using SPC charting, trending, and analysis of variance for each BBS facility. For the purpose of this discussion, the results of the analysis of the OSHA IR for the Cynthiana location are shown in this section. For the complete analysis of the remaining indices (OSHA SR and incurred costs) for this location refer to Appendix E.

Discussion. Incident rates and incurred costs were examined before and after the introduction of the BBS process at each XYZ Company BBS location. The locations at Hutchinson, Columbia, and Guin were not included in this analysis. Guin tried the process through BST for two years, but decided not to continue the program. Hutchinson and Columbia just began formal site observations in the fourth quarter, 2001 and therefore were not be included in the analysis.

Run charts, I charts, and MR charts for the OSHA IR were constructed using BPChart. These charts are shown in Figure 2, Figure 3, and Figure 4 respectively. Special cause indications were discussed with each chart when applicable.

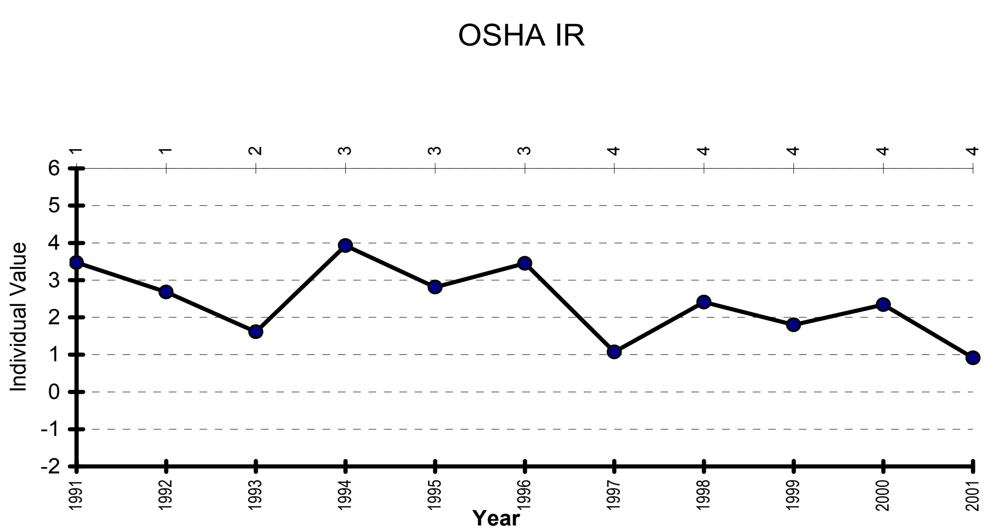
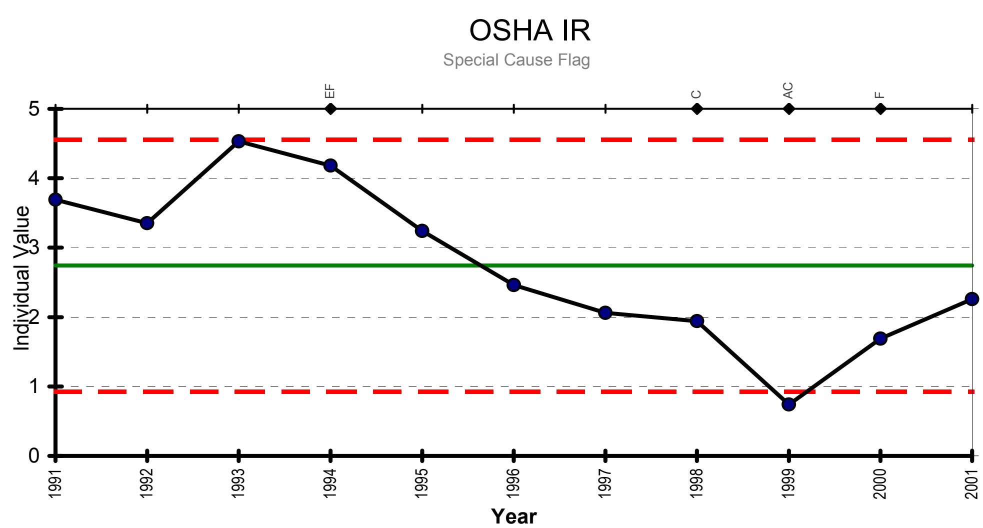


Figure 2. Run Chart: Cynthiana OSHA IR (1991-2001)

Figure 3, the I Chart, indicated a special cause flag when two out of three incident rates were beyond two standard deviations (sigma) of the incident rate average in 1992 through 1994 (special cause flag E). Another special cause flag revealed four out of five incident rates were beyond one sigma from 1991 through 1995 (special cause flag F). Beginning in 1993 there was a seven-year downward trend in the incident rate beginning in 1993 and ending in 1999 (special cause flag C). In 1999 the incident rate dropped below the incident rate mean lower control limit (obviously the lower control limit for accidents should be theoretically zero) to 0.074.



Database Column

Special Cause Detected **Chart Type: Chart for Individuals**

Centerline: 2.740 Process Limits: Lower: 0.9235 Upper: 4.556 3

Avg of Data Shown 2.74 A. 1 Beyond Control Limit E. 2 of 3 Beyond 2 Sigma

Median Data Shown 2.46 B. 9 On One Side of Average F. 4 of 5 Beyond 1 Sigma

Sigma for Limits 0.6055 C. 6 Trending Up or Down G. 15 Within 1 Sigma

Base for Limits Average MR D. 14 Alternating Up & Down H. 8 Outside 1 Sigma

X. Excluded or Missing Data

Figure 3. Individual Chart: Cynthiana OSHA IR (1991-2001)

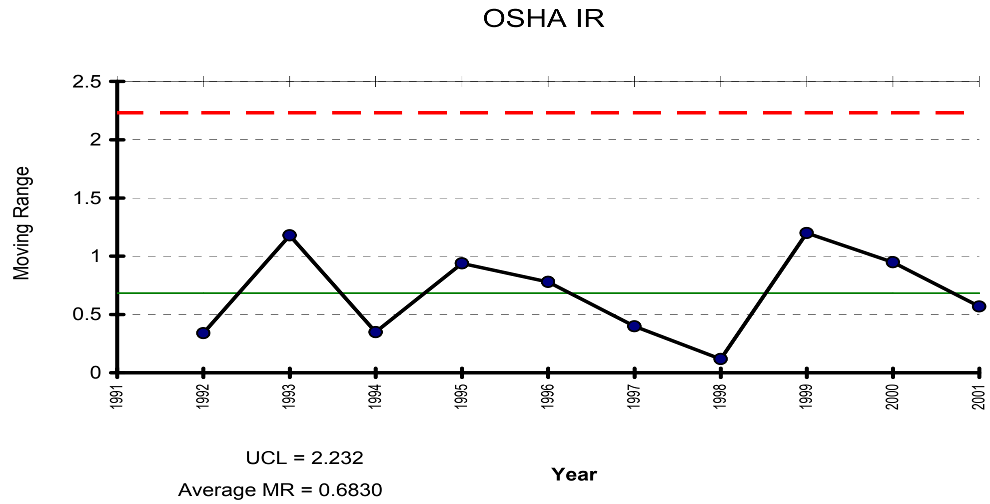


Figure 4. Moving Range Chart: Cynthiana OSHA IR (1991-2001)

Trend charts were produced to visually examine the evidence of trends in the process. Linear trending charts were constructed for the three indices from 1991 through 2001. In Figure 5, the Cynthiana location indicated a downward trend in the OSHA IR (p= 0.003). However, from 1996, the year the BBS process was implemented, through 2001, there was no statistical evidence to support a downward trend in the incident rate (p = 0.576). This is indicated by Figure 6.

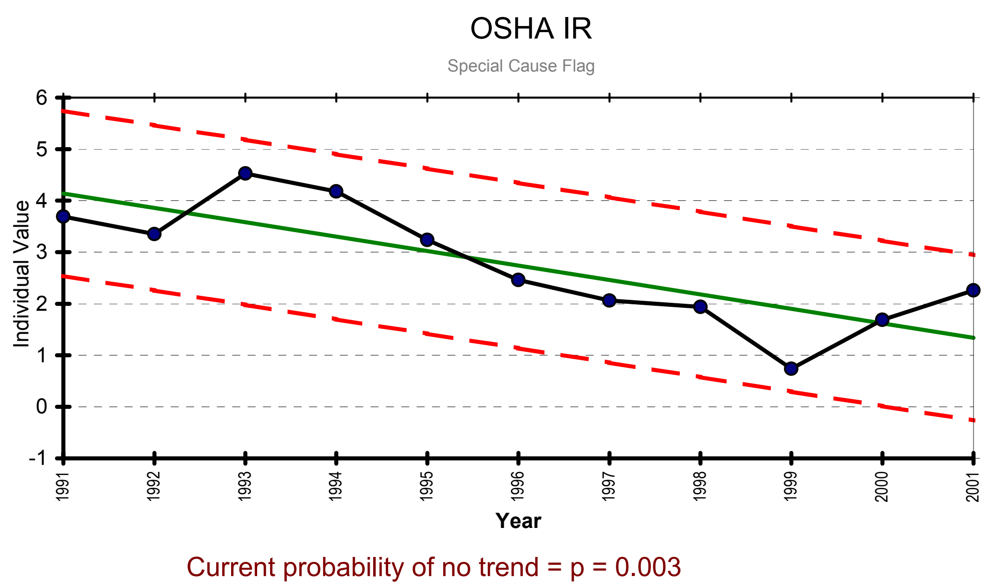


Figure 5. Linear trend chart: Cynthiana OSHA IR (1991-2001)

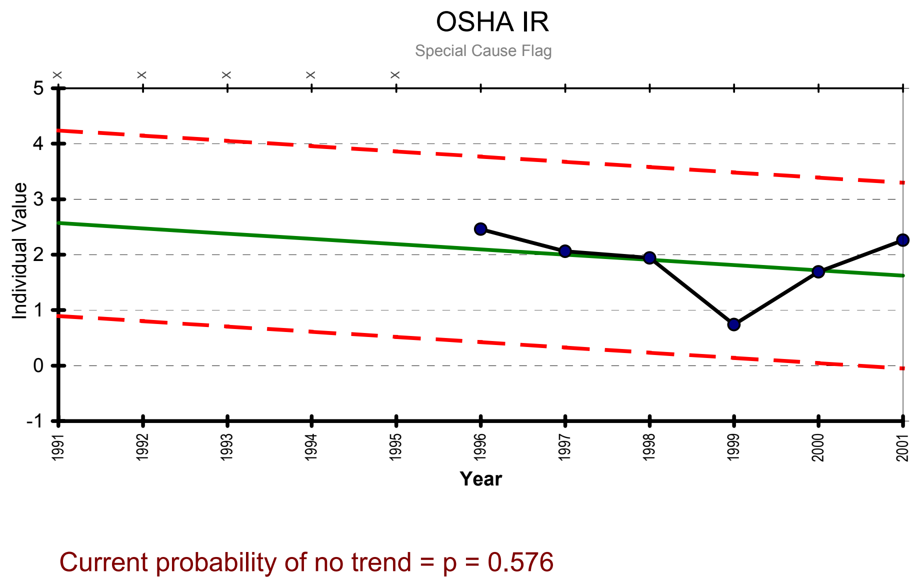


Figure 6. Linear trend chart: Cynthiana OSHA IR (1997-2001)

Step change modeling was applied to this example to indicate changes in the incident rate means before and after the BBS process was installed. In Cynthiana, the BBS process was implemented in 1996. This year was excluded from the modeling to allow the BBS process to stabilize in the facility. The result of the step change modeling is shown in Figure 7. The p value was equal to 0.005, which indicated the change in the OSHA IR mean was statistically significant.

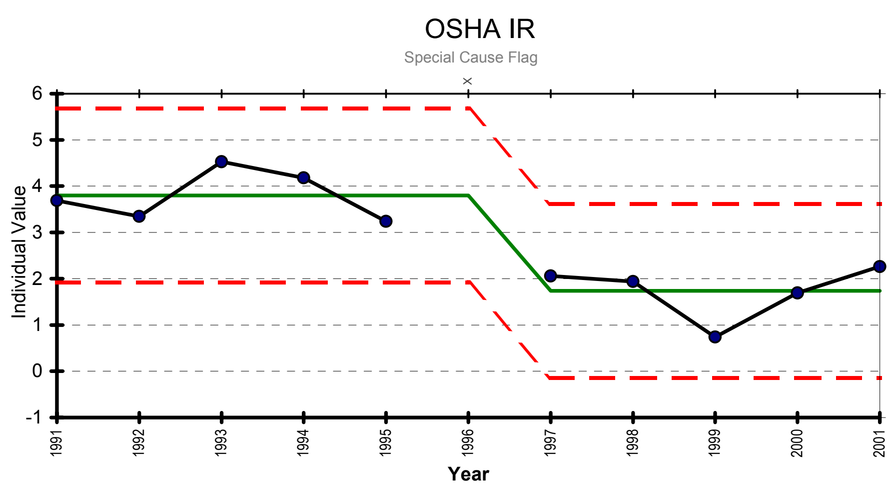


Figure 7. Step Change Chart: Cynthiana OSHA IR after BBS implementation

To further test the significance in the change of the OSHA IR in Cynthiana, a one –way ANOVA test was performed using Minitab. The results are indicated in Figure 8 below.

```
Analysis of Variance for OSHA IR
Source    DF       SS       MS       F       P
Status     1   10.609   10.609   32.38   0.000
Error      8    2.621    0.328
Total      9   13.230
                               Individual 95% CIs For Mean
                               Based on Pooled StDev
Level       N    Mean    StDev  ---------+---------+---------+-------
After BB    5   1.7380  0.5948  (-----*-----)
Before B    5   3.7980  0.5490               (-----*-----)
                                ---------+---------+---------+-------
Pooled StDev =   0.5724                  2.0       3.0       4.0
```

Figure 8. ANOVA for OSHA IR at Cynthiana from Minitab

The results showed a clear statistical difference in the OSHA IR means for the Cynthiana location after the implementation of the BBS process in 1996. Similar analyses were performed with the OSHA severity rate and worker compensation incurred costs. The results of this analysis are shown in Appendix E.

The application of statistical process control charting, linear trending, step change trending, and analysis of variance for the incident rates and incurred costs were done for the remaining BBS locations. This fulfilled the first objective of this study.

Objective 2: Did BBS work in the BBS locations of the XYZ Company? By applying the statistical analysis methods discussed in the first objective of the study, a determination could be made on how effective the BBS process was in decreasing incident rates and incurred costs at the BBS locations of the XYZ Company.

Results. Table 3 shows the results of the statistical analysis performed in BPChart for the OSHA IR, OSHA SR, and worker compensation incurred costs using the step-change modeling in the program. The results of the one-way analysis of variance using the Minitab statistical program for the same indices are shown in Table 4. A summary of the linear trending before and after the implementation of BBS at each location is shown in Table 5. A comparison of incident rates between BBS locations and selected non-BBS locations for the years 2000 and 2001 are shown in Table 6. The correlation between the OSHA IR rate and percent safe observations is shown in Figure 9. The results of the perception survey are shown in Table 7.

Table 3

Summary of Step Change Analysis of BBS Locations of XYZ Company

Location	OSHA IR p value	OSHA SR p value	WC Incurred Costs p value
Austin	0.08*	0.008**	0.634
Brookings	0.001**	0.002**	0.808
Cordova	0.346	0.472	0.376
Cynthiana	0.005**	0.011**	0.024**
Decatur - Chemical	0.53	0.315	0.064*
Decatur - Film	0.873	0.537	0.451
Greenville - Film	0.181	0.212	0.814
Greenville - Tape	0.148	0.281	0.454
Knoxville	0.922	0.189	0.966
New Ulm	0.164	0.389	0.857
Northridge	0.688	0.122	0.122

Note. $*p < 0.10$ $**p < 0.05$

Table 4

Summary of One-way ANOVA of BBS Locations in XYZ Company

Location	OSHA IR p value	OSHA SR p value	WC Incurred Costs p value
Austin	0.054*	0.031**	0.936
Brookings	0.003**	0.015**	0.74
Cordova	0.185	0.579	0.25
Cynthiana	0**	0.003**	0.041**
Decatur - Chemical	0.288	0.114	0.059*
Decatur - Film	0.75	0.429	0.959
Greenville - Film	0.041*	0.297	0.529
Greenville - Tape	0.421	0.1*	0.345
Knoxville	0.476	0.088*	0.866
New Ulm	0.214	0.418	0.63
Northridge	0.989	0.114	0.187

Note. *$p < 0.10$ **$p < 0.05$

Table 5

Summary of Linear Trends of Indices in BBS Locations of XYZ Company

Location	OSHA IR p value		OSHA SR p value		WC Incurred Costs p value	
	Trend	After BBS	Trend	After BBS	Trend	After BBS
Austin	0.074*	0.262	0.012**	0.921	0.603	0.116
Brookings	0.001**	0.1196	0.002**	0.987	0.792	0.3251
Cordova	0.318	0.63	0.445	0.735	0.36	0.818
Cynthiana	0.003**	0.576	0.007*	0.759	0.019**	0.473
Decatur - Chemical	0.47	0.977	0.277	0.774	0.046	0.789
Decatur - Film	0.852	0.994	0.488	0.706	0.87	0.87
Greenville - Film	0.15	0.83	0.175	0.1*	0.803	0.4
Greenville - Tape	0.103	0.192	0.346	0.294	0.187	0.441
Knoxville	0.934	0.153	0.221	0.357	0.979	0.767
New Ulm	0.085*	NA	0.241	NA	0.612	NA
Northridge	0.645	0.673	0.096*	0.545	0.124	0.775

Note. $*p < 0.10$ $**p < 0.05$

Table 6

Analysis of Variance of Incident Rates for BBS and Non-BBS Locations

Year	TRIR p value	LWIR p value	OSHA IR p value	LWSR p value	OSHA SR p value
2001	0.912	0.091*	0.260	0.043**	0.312
2000	0.764	0.204	0.777	0.584	0.969

Note. *p <0.10 **p < 0.05

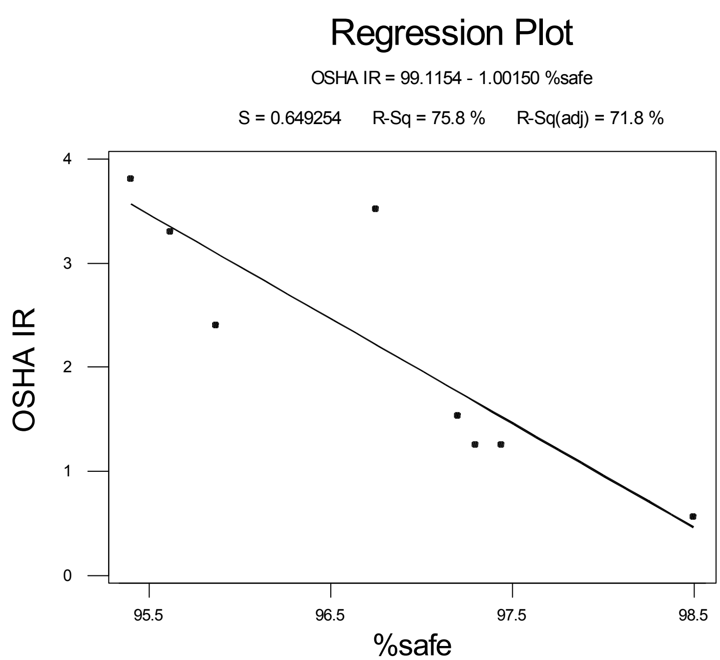


Figure 9. OSHA IR vs. % Safe Observations

Table 7

T-test for Equality of Means between Plant and Optical Systems Employees for Eight Safety Perceptions Measured

Perception	F	Sig.	t	df	Sig. (2-tailed)
Peer feedback	3.895	.50	5.472	69.814	0.001**
Rules	3.215	0.074	2.167	212	0.031**
Initiative	2.517	.114	1.697	212	0.091*
Shortcuts	0.16	.898	1.281	206	.202
Management	5.688	.018	3.792	74.855	0.001**
Peer trust	.379	.539	2.219	208	0.028**
Safety environment	.238	.626	1.854	209	.065*
Caring for others	.532	.466	2.301	213	.0.022**

Note. **p <0.10 **p < 0.05*

Discussion.

Changes in incident rates. In Table 3 three of the 11 locations had changes in the OSHA IR rate that were statistically significant. Two of the three of these locations had statistically significant changes at the 95% confidence level ($p < 0.05$), while the remaining location had a statistically significant change at the 90% confidence level ($p < 0.10$). The same three locations, Austin, Brookings, and Cynthiana had statistically significant changes in the OHSA SR ($p < .05$). Two locations had a statistically significant change in their worker compensation incurred costs.

The results of the one-way analysis of variance using Minitab for OSHA IR, OSHA SR, and worker compensation incurred costs were shown in Table 4. Using this method, four of 11 locations had statistically significant changes in their OSHA IR rate. Two of the four facilities had changes significant at the 95% confidence level ($p < .05$), while two facilities had changes at the 90% confidence level ($p < 0.10$). Five of the eleven facilities had statistically significant changes in their OSHA SR – three facilities at the 95% confidence level and two facilities at the 90% confidence level. Two of the 11 facilities had statistically significant changes in their worker compensation incurred costs. This calculation method increased the number of facilities that had statistically significant changes in indices. This was caused by the way the software calculated the population means. By using the ANOVA method, one additional facility achieved a statistical difference in the OSHA IR and OSHA SR. The facilities that showed a significant change in incurred costs remained the same using either method.

Linear trends in indices. Table 5 showed the results of linear trending before and after the intervention of BBS at each facility. Four of 11 facilities showed a downward linear trend in OSHA IR rate for the 10-year period that was statistically significant. Two facilities were significant at the 95% confidence level and two at the 90% level. However, no facilities showed a statistically significant trend after the implementation of the BBS process. Four facilities also showed a significant change in the OSHA SR rate for the period. One facility showed a statistically significant change in the OSHA SR after implementation (Greenville-Film). Only one facility, Cynthiana, showed a statistically significant linear trend in the reduction of worker compensation incurred costs from 1991 through 2001. However, no trend was indicated in any facility after BBS implementation.

Comparison of BBS and non-BBS facilities. In Table 6, a one-way ANOVA was conducted in Minitab comparing statistical differences in all of the I/I rates (TRIR, LWIR, OSHA, IR, LWSR, and OSHA SR) between the plant locations that have employed the BBS process and selected non-BBS locations in the XYZ Company. Comparisons were made for the years 2000 and 2001.

Two indices, lost work incident rate and lost work severity rate, were statistically significant for the year 2001 in the BBS locations as compared to the non-BBS locations at the 90 % and 95% confidence levels respectively. The mean LWIR was 0.87 for the BBS locations compared to 1.70 for the non-BBS locations. The mean LWSR for BBS locations was 11.17 compared to 26.91 for non-BBS locations. There were no statistically significant differences between any of the OSHA I/I rates for the year 2000.

Correlation of percent safe to incident rate. In Figure 9 the OSHA IR rates for the individual BBS plants were visually graphed against their corresponding percent safe behaviors observed. Percent safe observations were collected from individual locations for the years 2000 and 2001 when available. Locations at Cynthiana and Northridge did not track this information. Hutchinson began tracking this information during fourth quarter, 2001 and was not included in this analysis. Data was received from the locations at Brookings, both Decatur plants, New Ulm, the Columbia Plant Engineering group, and Knoxville. Contact was made at both Greenville plants and the Decatur location. No information or contact was received from the Austin location. When the Decatur information is excluded, a strong inverse relationship (Pearson coefficient = - 0.822, $p = 0.023$) was evident. When the Decatur chemical plant information was included for the years 2000 and 2001, a rather low positive relationship developed between percent safe observations and the incident rate (Pearson coefficient = 0.345, $p = 0.363$).

Results of the perception survey. Analysis of the perception survey indicated differences between the Optical Systems Division employees and the remaining plant population on individual questions in the survey. Questions that were statistically significant ($p < 0.05$) between groups were questions: 2, 3, 6, 7, 8, 9, 10, 13, 16, 17, 18, 19, 20, 23, 24, 25, and 30 (refer to Appendix C for the survey questions).

Independent group t-tests were performed on the eight perception areas to be evaluated between the work groups. Perception areas measured were: (1) peer feedback, (2) conformance to safety rules, (3) safety involvement/initiative, (4) job “shortcuts”, (5) management support of safety, (6) peer relationships/ trust, (7) safety environment, and (8) propensity to actively care for peers. The t-test for equality of means between the two work groups is summarized in Table 7.

In the group t-test comparisons, the Optical Systems employees had statistically significant differences in seven out of eight perception areas measured. The Optical Systems employee’s responses to seven of the eight perception areas were more positive (the preferred ideal responses) than the plant group. Five of the seven groups measured were to the 95% confidence level , while the remaining two areas where at the 90% confidence level. Job “shortcuts” was the only perception category measured where there was no significant difference between the plant group and the Optical Systems Division employees.

Summary

The identification and application of statistical methods to determine ways to measure and evaluate the effectiveness of the BBS process in the XYZ Company were the prime objectives of this study. Use of SPC, trending, analysis of variance, regression analysis, correlation analysis, perception surveys, and the analysis of the perception survey using individual and group t-tests were used in this chapter to measure the effectiveness of the BBS process. Results of the analysis of the upstream and downstream indicators in the BBS locations revealed the effectiveness of the process within the company. The conclusions and recommendations of this study will be discussed in the next chapter.

Chapter 5

Summary, Conclusions and Recommendations

Introduction

This chapter contains: (1) a review of the study, (2) final conclusions based on the results of the study, (3) recommendations drawn from this study, and (4) recommendations for future study.

Summary

In was revealed in this study that the behavior-based safety process is not the "silver bullet" that can cure all an organization's safety ills, but rather another tool in the safety toolbox to be used to improve safety performance. The summary of this research includes a restatement of the problem, a review of the primary objectives of the study, methods and procedures employed, and a discussion of the major findings of the research.

Restatement of the problem. The focus of this study was the determination of reliable methods to measure the effectiveness of the behavior-based safety process in the XYZ Company. The major objectives of the study were: (1) an identification of statistically valid techniques that measured the effectiveness of BBS, and (2) an evaluation of the behavior-based safety process in the improvement of safety performance in facilities of the XYZ Company that subscribed to the process.

Methods and procedures. The methods and procedures used in this study involved various statistical analyses of OSHA accident incident rates and worker compensation incurred costs in XYZ Company facilities that implemented the BBS process. Other methods used to meet the objectives of the study were a comparison of BBS and selected non-BBS facilities in terms of OSHA I/I rates for the past two years, correlation of

OSHA IR and percent safe observations in BBS facilities, and a measurement of safety perceptions in groups of employees that were familiar and not familiar with the BBS process.

Statistical analysis of OSHA incident frequency rates (OSHA IR), severity rates (OSHA SR), and worker compensation incurred costs in BBS facilities of XYZ Company were examined before and after intervention of the BBS process in these facilities. Statistical methods applied included control charting of these indices using statistical process control techniques. Linear trends before and after the application of BBS in each facility were also reviewed using control chart methods. Statistical significance was determined for each indices for each BBS facility using a one-way analysis of variance that examined statistical significance before and after the application of the BBS process. The same process was used to examine worker compensation incurred costs.

A statistical comparison between BBS and selected non-BBS facilities in terms of OSHA incident rates was performed for the periods of 2000 and 2001. A one-way ANOVA was performed between these groups for the past two years to determine any statistically significant difference in the OSHA I/I rates between the BBS and non-BBS locations.

The correlation between percent safe behaviors observed and OSHA incident rates (OSHA IR) were evaluated for reporting BBS facilities of the XYZ Company. Results were analyzed in two ways: (1) visual inspection of graphical data plotted for percent safe behaviors and incident rate (OSHA IR) and (2) statistical testing that determined correlation between facility incident rates and the corresponding facility percent safe behaviors.

The last method employed to measure the effectiveness of the BBS process was a safety perception survey. A 32-question safety perception survey was given to production and administrative employees at one of the Wisconsin locations of the XYZ Company. Two distinct work groups were statistically compared from results of the survey: one work group implemented the BBS process two years ago, while the remainder of the plant had not been exposed to the process. Statistically significant differences of safety perceptions between these work groups were determined using individual and group t-tests.

Major findings. Major findings from this study supported the purpose and objectives of this research. Findings were reported for (1) statistical measurement of BBS, (2) incident rates and incurred costs in BBS facilities, (3) comparison of incident rates in BBS and non-BBS facilities, (4) correlation of percent safe behavior and OSHA IR rates, and (5) results of the safety perception survey towards the BBS process.

Statistical measurement of BBS. It was shown in this study that the effectiveness of the BBS process can be measured using statistically valid process control charting techniques and other statistical analysis tools that can evaluate process changes. Custom control charting software (BPChart) that was uniformly available and applied throughout the XYZ Company for process control was used for this analysis. Trending of the measured indices were tracked and statistically significant changes noted. Other statistical tools used in the study included analysis of variance, correlation and regression analysis, and individual and group t-tests.

Incident rates and incurred costs in BBS facilities. Four of the 11 BBS locations (37%) had statistically significant downward changes in their OSHA IR rate after BBS implementation. These locations were Austin, Brookings, Cynthiana, and the Greenville film plant. Five locations (46%) had statistically significant downward changes in their OSHA SR rate. These locations were Austin, Brookings, Cynthiana, Greenville tape plant, and the Knoxville location. Two plants (19%) had statistically significant downward changes in their worker compensation incurred costs: Cynthiana and the Decatur chemical plant location. Only the Cynthiana location had statistically significant changes in all three indices after BBS implementation.

A downward linear trend was shown in four of the 11 locations for the OSHA incident rate during the ten –year period 1991-2001. These locations were Austin, Brookings, Cynthiana, and New Ulm. There was no indication of a downward trend in the OSHA IR for any facility after the implementation of the BBS process. Four facilities (Austin, Brookings, Cynthiana, and Northridge) also showed a significant change in the OSHA SR rate for the 10-year period. Only one facility showed a statistically significant change in the OSHA SR after BBS implementation (Greenville-Film). One facility, Cynthiana, showed a statistically significant downward trend in the reduction of worker compensation incurred costs from 1991 through 2001. However, no downward trend was indicated in any facility after BBS implementation.

Incident rates in BBS and non-BBS facilities. All the OSHA incident rates were compared for the year 2000 and 2001 between the BBS and selected non-BBS locations in the XYZ Company. Two indices, lost work incident rate (LWIR) and lost work severity rate (LWSR), were statistically significant for the year 2001 in the BBS locations as compared to the non-BBS locations. The mean LWIR was 0.87 for the BBS locations compared to 1.70 for the non-BBS locations. The mean LWSR for BBS locations was 11.17 compared to 26.91 for non-BBS locations. There were no statistically significant differences between any of the OSHA I/I rates for the year 2000.

Correlation of percent safe behaviors and OSHA IR rates. The OSHA IR rates for the individual BBS plants were visually graphed against their corresponding percent safe behaviors observed. Excluding the Decatur plant information, a strong inverse relationship (correlation coefficient = - 0.822, p = 0.023) was evident. This supported the hypothesis that as percent observed safe behaviors increased, the accident incident rate decreased.

Safety perception survey. In the 32-question safety perception survey, a work group (Optical Systems employees) within the plant that had been exposed to the BBS process for the past two years, had statistically significant differences in seven out of eight perception areas measured compared to plant employees that had not been exposed to the process. The Optical Systems employee's responses to seven of the eight perception areas were more positive (the preferred ideal responses) than the plant group.

Conclusions

Several conclusions may be drawn from the results of this study. Conclusions to be made about ways to measure and evaluate the effectiveness of the behavior – based safety process are discussed under (1) statistical methods, (2) incident rates, (3) percent safe behaviors, and (4) safety perception surveys.

Statistical methods. In was shown in this study that employing statistical process charting methods was a valid method to measure and track the effectiveness of the BBS process. By measuring incident rates over a period of time and using modeling such as linear and step-change trending, the process could be measured and predictions made about which way the process was headed. As Dial (1992) stated, "the organization should use statistically valid incident rates as an indicator on how well the process was affecting safety performance." By listening to the "voice of the process", the SPC methods evaluated in this study could be used to determine the effectiveness of the BBS process. The methods used in this research satisfied one of the objectives of this study: to determine statistically reliable methods to measure the effectiveness of the BBS process. Although this was measurement of "end of the pipe" results of the process, the information can be used for tracking the process and providing feedback to management on how well the process was working and what direction it was heading.

Incident rates. Another major objective of this study was to determine the effectiveness of the BBS process within the XYZ Company. Simply stated, did BBS work? There was not convincing evidence that BBS alone improved the OSHA frequency rates (OSHA IR), severity rates (OSHA SR) or worker compensation incurred costs in BBS locations of the XYZ Company. Only a minority of the locations showed improvements in any of these areas after they implemented the BBS process. Only one facility, Cynthiana, showed a significant downward improvement in all three areas. It was also evident that in most BBS locations was there was already a downward trend in these indices prior to the implementation of the BBS process at their locations.

The comparison of the OSHA incident rates between selected non-BBS locations and BBS locations for the past two years showed no significant differences in these rates. The exception was the LWIR and the LWSR rates for the year 2001 in the BBS locations. These rates were statistically lower than the non-BBS locations. This indicated the frequency and severity of lost–time injuries were lower that year in the BBS locations.

Other factors that may have influenced these results must be considered. During the first part of the review period (1990-1995), the corporation set safety goals for plants that may have encouraged under-reporting to meet these objectives. Programs that promoted recognition based on incident rates and obtaining the “Million Hour Club” award (one million worked hours without an OSHA recordable incident) may have caused reporting bias by plant locations. Later in the decade, similar programs, such as the “50-in 4” program (a 50% reduction in illness and injury rates over four years) may have caused similar effects on incident reporting. Since this study considered only “hard case” incident rates – those cases that had restricted work days or lost –time days, it was assumed that these rates would be more reliable than the minor or OSHA recordable-only cases for analysis.

Other influences on incident rates that may have affected the outcome were more proactive back-to-work programs, ergonomic initiatives, corporate–wide nip guard, machine guarding, and process safety audits, the development of the GSHP, introduction of workplace safety performance correction guidelines (progressive discipline for safety violations), and OSHA record keeping audits. These factors and not solely the effects of implementing the BBS process could have had an influence on the study results.

Percent safe behaviors. Results supported previous research that percent safe behaviors observed are inversely proportional to the accident rate. That is, as the percent safe observations increased, the accident rate decreased. Results reported from the Decatur chemical plant were not included in the analysis, since these results did not support the hypothesis found by other research (Ray & Fry, 1999). This hypothesis was supported by the strong inverse correlation found in this study and the reliability of the data. Additional validity of the hypothesis could have been proven if more BBS locations within the XYZ Company had reported this data.

Perception survey. The results of the perception survey indicated this may be the most valid method to determine if the BBS process is working in the organization. Seven of eight categories measured between the two work groups had statistically significant differences in responses.

Recommendations

Recommendations related to this study. These are the recommendations related to this study:

1. Continue to use the control charting process and other statistical tools identified in this study to measure the downstream effects of the process. The techniques used in this study can be used to track safety performance regardless if the location is involved with the BBS process.
2. The use of frequency rates, severity rates, worker compensation incurred costs, and other downstream safety measures should be used if these indicators are properly interpreted and used together with upstream indicators such as behavior data. It was shown in this study that there is a strong relationship between percent safe observations and the incident rates.
3. More data is needed to further verify the relationship of percent safe behaviors and incident rates. Several BBS locations had just started collecting this information or did not track it. Some BBS systems, such as the BST approach, made it easier to track this information with their

software than the SPS system. Locations with self-implemented BBS processes should consider using these systems or developing their own. The Hutchinson location has developed their own tracking system that could be shared with other locations.

4. Establish a BBS-user group between locations. When interviewing locations about their BBS process, the common issues occurring in BBS plants were (1) keeping the process "fresh" to their employees, and (2) getting or maintaining management support for the process. Although an environmental, health, and safety (EHS) forum database exists for sharing ideas and programs across the company, the BBS discussion topic area in the database has been largely unused in the past two years. This database should be used more extensively to share ideas between BBS locations.
5. Further develop the use of the safety perception survey to measure employee attitudes about the BBS process and identify barriers that may exist. The survey given at the Wisconsin location should be administered again in two years to evaluate the effects the BBS process has had on the plant population. Consideration should be given to expanding the survey with questions designed to measure additional process criteria as the process evolves in the organization.
6. The findings of this study should be distributed to the BBS locations that assisted with this study. This information can also be shared with other facilities of the XYZ Company who have not developed methods or a process of determining BBS effectiveness. There have been requests from

the corporate XYZ Company safety management to review the results of this study. This study can also be posted to the EHS database forum previously mentioned in this discussion.

Recommendations for further study. These are recommendations for further study based on the results of this research:

1. Perform additional research on the BBS process or safety management system that has been implemented at the Cynthiana location. This location had statistically significant changes in all measured criteria in the study. Interestingly, Cynthiana no longer tracks percent safe behaviors, but has focused their activities on identifying and eliminating barriers in the process.
2. Further research could be conducted on determining the "critical mass" of at-risk behaviors in a facility (Krause, et al, 1991). When at-risk behaviors reach a critical mass at a location, accidents occur. An important risk management activity would be to determine the location's critical mass percent at-risk and percent safe baseline. The closer the facility 's baseline percent safe comes to the at-risk critical mass, the greater the risk of accidents occurring.
3. Focus further research on identifying valid upstream indicators of the BBS process. Indicators that could be considered are: number of barriers identified and eliminated, number of observations completed, employee participation in observations, number of behaviors targeted per month/quarter, or a variety of other indicators.

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Appendix A

XYZ Company BBS Locations

Facility Location	BBS Source*	Year Implemented
Austin, TX	BST	1997
Brookings, SD	BST	1996
Columbia, MO	SPS	1999
Cordova, IL	BST	1996
Cynthiana, KY	SPS	1996
Decatur, Al – Chemical	BST	1995
Decatur, Al – Film	BST	1995
Greenville, SC – Film	BST	1996
Greenville SC,– Tape	SPS	1998
Guin, Al	BST	1998
Hutchinson, MN	Self-implementation	1999
Knoxville, IA	BST	1995
Menomonie, WI – Optical Systems	SPS	1998
New Ulm, MN	SPS	1999
Northridge, CA.	BST	1997

*Note: BST is Behavioral Science Technology Inc; SPS is Safety Performance Solutions

Appendix B

XYZ Company Global Safety and Health Plan (GSHP)

1. Management System Elements

1.1 Location Safety and Health Plan

A written location-specific Safety and Health Plan is designed to outline the location's safety and health needs. The plan lists the required safety and health elements and the action plans to initiate, implement, or improve each element

1.2 Safety and Health in the Performance Appraisal System

A system must be in place to ensure that safe and healthy work practices are expected and recognized as an integral part of the performance appraisal process.

1.3 Safety and Health Committee

An established and active safety and health committee is necessary to assist in the implementation of the Safety and Health Plan. The committee helps to oversee that safety and health systems and procedures are followed, promoted, and continuously improved.

1.4 Safety and Health Staffing and Qualifications

Each location must provide qualified staffing to support the required safety and health programs. Specific coordinator needs are based on the size and complexity of the location involved. The coordinators must receive appropriate training, time, and support to serve as a vital resource and effectively oversee safety and health-related activities.

1.5 Safety and Health Orientation and Training

A written Safety and Health Orientation and Training Program is required to properly train employees in the safe and healthful performance of their jobs.

1.6 Safety and Health Self-Surveys and Evaluations

A plan for conducting regular safety and health self-surveys and evaluations is required for each location. Self-surveys and evaluations help to ensure that safe and healthful practices are maintained. They provide early opportunities for identifying areas for improvement before they become a safety or health issue. They can also be used to measure progress on identified issues.

1.7 Record Keeping, Reporting, and Follow-Up

A system with written procedures for record keeping, reporting, and follow-up is required. Also, the location is required to maintain accurate and complete records of all safety and health-related activities and incidents. Records must be kept in compliance with XYZ Company standards and government regulations.

1.8 Employee Involvement and Ownership

The location Safety and Health Plan shall promote employee involvement, ownership, and accountability at all levels. This involvement is critical to achieving effective, proactive solutions to safety and health issues. Just as employees are more involved in production and product quality, increasing employee ownership in safety and health will help provide a safer, healthier work place. Emphasis should be placed on a cooperative effort between management and employees in achieving these goals.

1.9 Proactive Evaluation and Control of Hazards

Written procedures are required to anticipate and address work place safety and health hazards in a proactive manner. This program includes procedures to identify potential hazards in materials, processes, and equipment and to establish and implement appropriate controls. These issues should be identified early in the life of a product or project in order to achieve the best and most cost-effective solutions.

1.10 Policies, Standards, Guidelines, and Programs

Locations must comply with all applicable government regulations and XYZ Company safety and health policies and standards. XYZ Company guidelines and programs are available to assist locations in addressing safety and health issues.

2. Process Elements

2.1 Chemical Exposure Assessment and Management

A written Exposure Assessment Program is necessary at each manufacturing location where there is potential for significant chemical exposure to employees. This program is intended to provide an understanding of what chemicals are used, in what processes, and the potential for employee exposures. Other locations, such as R&D laboratories, should evaluate exposure assessment needs individually.

2.2 Process Safety Management

A written Process Safety Management (PSM) program is required for hazardous processes where releases of hazardous materials could result in fire, explosion, or toxic exposures. Effective PSM protects XYZ Company employees, property, the environment, and the surrounding community from potential toxic, reactive, or flammable chemical releases.

2.3 Ergonomics

A written Ergonomics Program is required at each manufacturing location. Other locations, such as R&D laboratories, administration, and engineering, should assess ergonomic program needs individually. Good work place design is the best way to prevent or control ergonomic-related hazards, which may result in injuries and illnesses. This can often help improve productivity, reduce costs, and boost product quality.

3. Procedural Elements

3.1 Emergency Preparedness

A written location-specific emergency plan is required to adequately prepare and practice for quick and effective emergency response when needed.

3.2 Incident and Potential Hazard Reporting, Record Keeping, Investigation, and Follow-Up

A system to report, record, and investigate incidents and potential hazards is required to ensure that root causes are identified and appropriate corrective action is implemented

3.3 Job Hazard Analysis

A written Job Hazard Analysis Program is required. This program includes established standard operating procedures that provide a consistent method to assess potential safety and health job hazards and to identify and implement appropriate control measures.

3.4 Contractor Safety and Health

A written Contractor Safety and Health Program is required to ensure that contractors are informed and comply with XYZ Company safety and health policies and procedures while working on XYZ Company premises.

4. Medical Elements

4.1 Medical Management

Medical management systems are required to assess employees' initial health status and to monitor the continued health of affected employees, as necessary. These systems may include pre-placement exams, medical surveillance, and handling of disability cases.

4.2 Biosafety

Exposure control plans are required to protect employees from potential exposure to biohazardous material. Any employee who may reasonably anticipate having skin, eye, mucous membrane, or other contact with blood or other biohazardous material in job-related duties must be a part of this program.

5. Chemical Hazard Elements

5.1 Hazard Communication

A written program, available to all employees, is required and must inform employees who work with hazardous chemicals how to obtain information on how those chemicals can affect their health, what precautions to take, and what to do in an emergency.

5.2 Respirators

A written Respiratory Protection Program is required to promote safe respirator use in environments containing airborne contaminants. Only employees who have been certified through a program of medical evaluation, training, and fit- testing shall use respiratory protection.

6. Physical Hazard Elements

6.1 Electrical Safety

Electrical safety procedures are required for the safe operation and maintenance of equipment to minimize the effects of electrical hazards in the work place.

6.2 Ionizing Radiation

All locations that utilize radioactive materials or other ionizing radiation sources are required to have a written Radiation Protection Program. This program is designed to ensure that good safety practices minimize employee exposure to ionizing radiation and that exposures are within the radiological health standards of regulatory agencies.

6.3 Non-Ionizing Radiation

Precautionary and protective measures must be routinely taken to minimize employee exposure to non-ionizing radiation sources.

6.4 Powered Industrial Vehicles

A written safety program covering the safety rating, safe operation, and maintenance of powered industrial vehicles is required where this type of equipment is being used.

6.5 Fire Protection and Prevention

A written Fire Protection and Prevention Program are required which includes fire protection systems and equipment, procedures for fire hazard control, and fire protection and prevention training. Careful planning, training, and use of fire protection systems and equipment help prevent fires and casualty losses.

6.6 Fleet Safety

A written Fleet Safety Program, designed for the safe operation of XYZ Company vehicles, is required where XYZ Company owned and leased vehicles are used by XYZ Company employees.

6.7 Lockout/Tagout

Written lockout/tagout procedures are required to isolate all types of energy in order to prevent an unexpected release of stored energy that could cause injury. This applies to equipment during installation, repair, maintenance, removal, and non-routine operations.

6.8 Machine Guarding

A system is required for compliance with XYZ Company's machine guarding specifications and procedures to protect operators and other employees from hazards in machine areas.

6.9 Noise Control and Hearing Conservation

A system is necessary to identify, evaluate, and control potentially harmful noise. The control of noise exposures helps prevent workplace noise-induced hearing loss. If any employee has the potential for noise exposures greater than or equal to 85 dBA averaged over eight hours, the location is required to have a written Hearing Conservation Program.

6.10 Hoist Systems for Overhead Material Handling

A system is required for compliance with XYZ Company's specifications for hoist systems for overhead material handling. This applies to the design, purchase, installation, labeling, operation and maintenance of these devices.

7. Combined Chemical and Physical Related Elements

7.1 Confined Space Entry

A written program is required for all locations with confined spaces. Confined spaces must be identified, evaluated, and designated in compliance with XYZ Company standards. Entry permits, proper equipment, and training are necessary for safe entry and work in potentially hazardous environments.

7.2 Flammable Liquid Handling and Storage

Flammable liquid handling and storage procedures must be established and implemented wherever flammable liquids are used and/or stored. Requirements primarily depend on the liquid's fire characteristics, particularly the flash point, which is the basis for liquid classification. Where Class H or Class IH liquids are heated above their flashpoints during use or storage, additional requirements may be necessary.

7.3 Personal Protective Equipment

A written Personal Protective Equipment (PPE) Program is required for every location where PPE is used. Personal protective equipment is one of the methods for controlling employees' exposure to hazards in the work place. It should be considered the last choice among control strategies because it may be ineffective if used improperly

Appendix C

Safety Culture Survey

Please check (√) your assigned department:

CMS&O		SRW		PE		TFTR	
E-Beam		PCRP		TPTC		TCM	
LSD		Fuel Cell		SWP/Zippy		OSD	
SF&C							

Please circle the number that reflects your feelings for each particular question within this survey. Highly Agree – **4**Agree – **3**Disagree – **2**Highly Disagree - **1**

1.	Reporting minor injuries is usually a waste of time because most can't be prevented anyway	1	2	3	4
2.	Employees appreciate feedback from their coworkers about their safe behaviors	1	2	3	4
3.	I am willing to put forth a little extra effort to improve workplace safety	1	2	3	4
4.	I feel pressure from my co-workers to "short cut" safe work practices	1	2	3	4
5.	Employees in my work area caution each other about unsafe behaviors	1	2	3	4
6.	If I approach my coworkers about their unsafe behaviors, they will react negatively	1	2	3	4
7.	Supervisors regularly discuss safety improvement goals and efforts with employees	1	2	3	4
8.	I enjoy being with my coworkers	1	2	3	4
9.	I don't give safety feedback to my coworkers because I'm not sure I can do it well	1	2	3	4
10.	Supervisors routinely acknowledge employees for safe behaviors	1	2	3	4
11.	I sometimes overlook hazards to get the job done	1	2	3	4
12.	In the past 12 months, I have been asked to perform a task which I thought was unsafe	1	2	3	4
13.	When employees in my group are cautioned about working unsafely, they begin working more safely	1	2	3	4
14.	I am encouraged to stop a job if a safety hazard is identified	1	2	3	4
15.	I am willing to caution my coworkers about working unsafely	1	2	3	4
16.	Employees fully understand the potential hazards of their jobs	1	2	3	4
17.	I trust my coworkers	1	2	3	4
18.	Most employees would feel uncomfortable if their work practices were observed and recorded by a coworker	1	2	3	4
19.	Work stress affects my ability to do my job safely	1	2	3	4
20.	I am willing to praise my coworkers for working safely	1	2	3	4
21.	Following all safety rules and regulations needlessly slows down my job	1	2	3	4
22.	I have more respect for my coworkers who work safely than for those who don't	1	2	3	4
23.	Employees in my work group participate in defining safe work practices	1	2	3	4
24.	I am willing to observe the work practices of my coworkers to give them safety feedback	1	2	3	4
25.	Employees should observe the work practices of their coworkers to give them safety feedback	1	2	3	4
26.	Employees here often "short cut" safe work practices	1	2	3	4
27.	When an employee sees a safety hazard, they should correct it themselves if possible	1	2	3	4
28.	It is the responsibility of each employee to seek out opportunities to prevent injury to others	1	2	3	4
29.	Supervisors consistently set a good example for safety through their own safe behavior	1	2	3	4
30.	Work productivity and quality usually have a higher priority than work safety	1	2	3	4
31.	Production demands do not override supervisors' concern for safety	1	2	3	4
32.	I would be willing to have a coworker observe me while I work, to give me feedback about safe and unsafe behaviors observed	1	2	3	4

Appendix D

BBS studies reporting impact on injuries

Study Author(s)	Number of Participants	Setting	Reduction in Accident/Incident Rates
M. Alavosius	5-500	50 small companies	Lost-workdays per 100 workers: 184 pre-intervention; 111 during; 84 post-interventions (six months) and 58 (12 months).
M. D Cooper, et al	540	Construction industry	From 6.33 prior to 3.88 at end; from 3.3 to 0.56 on check listed items.
D. J, Fellner and B. Sulzer-Azaroff	158	Paper mill	Significant difference between pre-and during-feedback- from 6.9 percent to 4.9 percent.
F. Fiedler	500	Mine	Baseline = 226 percent; follow-up two percent over industry average.
D. K. Fox, et al	1754	Coal mine	Range: 15-32 percent.
D. Harshbarger and T. Rose	a) 100 b) 350-400	a) Bedding b) Footwear	Lost-time accidents a) 95 percent; b) 87 percent.
R.S. Haynes, et al	100	Urban transit	24.9 percent.
B.S. Karan and R. F. Kopelman	Not reported	Vehicular and industrial	2.2 percent and 4.0 percent.
J. L. Komaki, et al (1978)	38	Food manufacturing plant	Injuries fell to "…less than 10 lost-time accidents per million hours worked, a relatively low number" (pg. 441).
J. L. Komaki, et al (1980)	55	Vehicle maintenance	Decline from 3.0 lost-time injury rate per month proceeding to 0.4 during and 1.8 following intervention.
T. R. Krause, et al, (1999)	51 to 3,000 per site (39,664 across 73 sites)	73 facilities participating up to five years	Year 1: 26 percent. Year 2: 42 percent. Year 3: 50 percent. Year 4: 60 percent. Year 5: 69 percent.
H. Laitinen, et al	300	Engineering workshop	46 percent reduction in absenteeism.

B. Loafmann	Not reported	Utility company	Treatment group about 78 percent; control group had a 50 percent increase.
L. Lopez-Mena and J.V. Antidrian	914	Forestry (2) and cement factory (1)	62.8 percent; maintained for three years.
L. Lopez-Mena and R. Baynes	41	Electrical distribution system	84.9 percent in one setting; 60.8 percent in a second setting.
L. Lopez – Mena, et al	191	Electrical energy distribution system	34.3 percent.
M. Mattila and M. Hyodynmaa	100	Building construction	Accident rate per 100 workers at control site higher during (166) and after (55) than experimental site – 94 and 47, respectively.
T. McSween	Not reported	Gas pipeline company	35 percent lost-time accidents.
T. McSween	Not reported	Chemical company (union-coordinated)	From four to zero the next 18 months.
R. Montero	Not reported	Industry (general)	"Rate dropped almost to zero".
M. Nasanen and J. Saari	32	Shipyard	50-to-75-percent reduction in accidents.
D. Petersen	Not reported	Railroad	"Experimental groups had fewer injuries than control [groups]."
R. A. Reber, et al (1984)	105	Farm machinery manufacturing	53.83 percent.
R. A. Reber, et al (1990)	44	Manufacturing	50 percent.
K. L. Saarela	2,800	Shipyard	Modest, non-significant reduction in accident frequency. This intervention involved a poster campaign, not a full behavioral program, and feedback to supervisors.
K. L. Saarela	24	Shipyard	20 percent during; about 40 percent after.
K. L. Saarela	> 900	Shipyard	60+ percent.
J. Saari and M. Nasanen	24	Shipyard	25-percent reduction in accidents; 30 percent reduction in injuries.
R. Schwartz	110	Grocery distribution	39.4 percent.

		workers	
M. Smith, et al	44	Shipyard	Average decrease in eye injuries of 7.48 per 100 workers; control group average reduction of 1.16.
B. Sulzer-Azaroff, et al	140	Paper mill	From 19 recordable incidents during baseline to two after feedback given for three behaviors.

Appendix E

BPCharts of Cynthiana

BPChart special cause chart (example)

Database Column

Special Cause Detected **Chart Type: Chart for Individuals**

Centerline: 65.59 Process Limits: Lower: -25.02 Upper: 156.2 6

Avg of Data Shown 65.5875

Median Data Shown 36.4

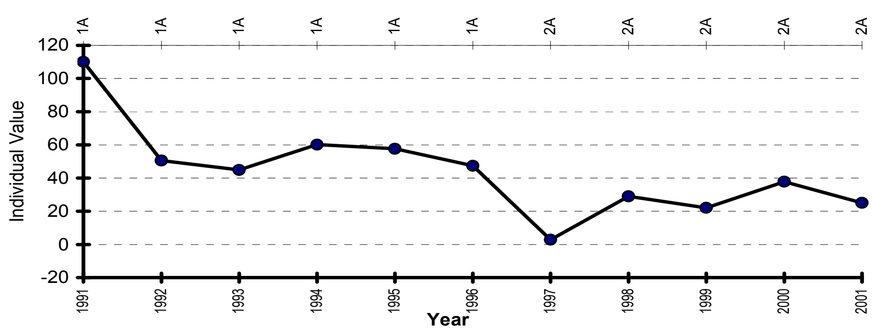
Sigma for Limits 30.20

Base for Limits Average MR

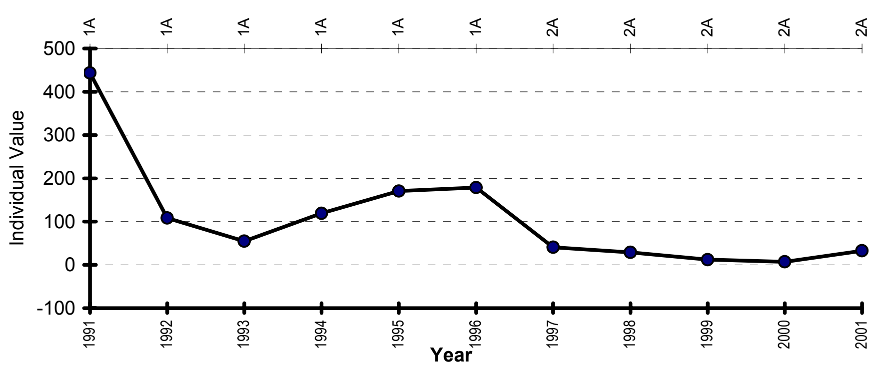
A. 1 Beyond Control Limit
B. 9 On One Side of Average
C. 6 Trending Up or Down
D. 14 Alternating Up & Down
E. 2 of 3 Beyond 2 Sigma
F. 4 of 5 Beyond 1 Sigma
G. 15 Within 1 Sigma
H. 8 Outside 1 Sigma
X. Excluded or Missing Data

Cynthiana run charts

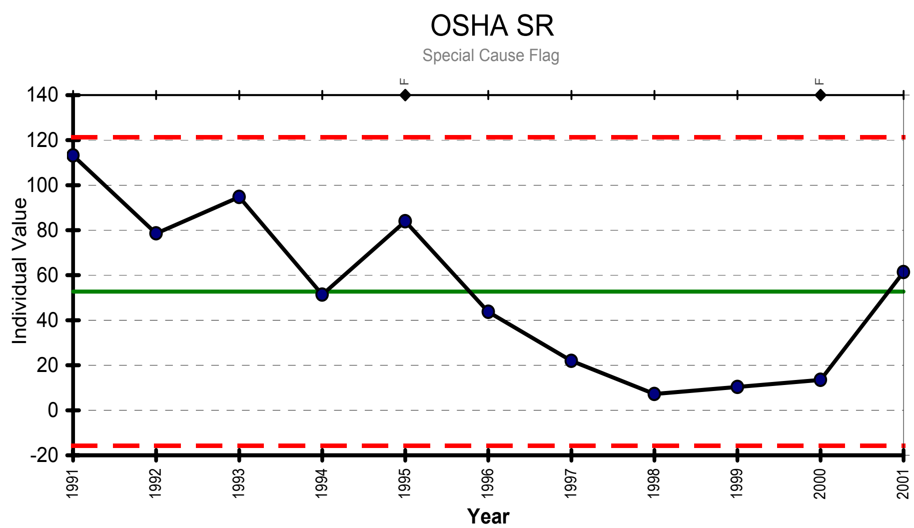
OSHA SR

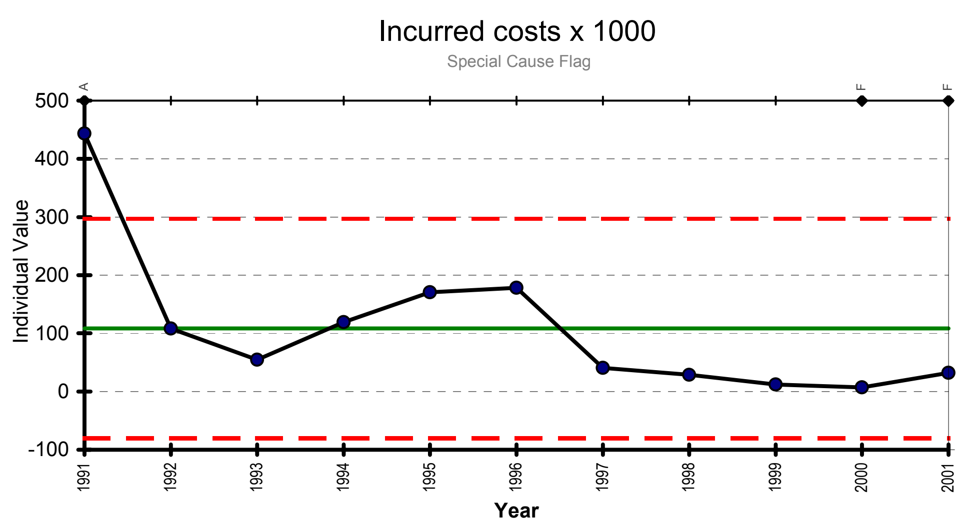


Incurred costs x 1000

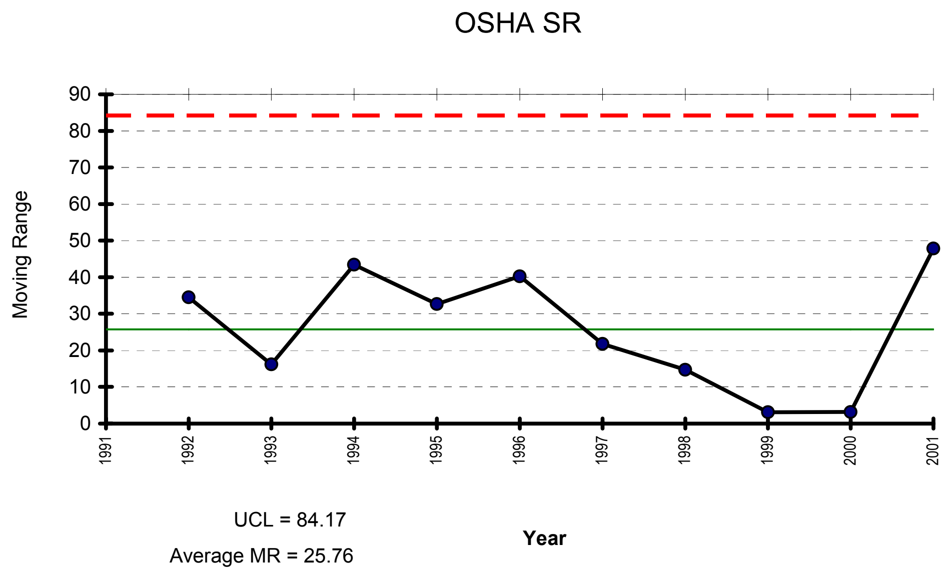


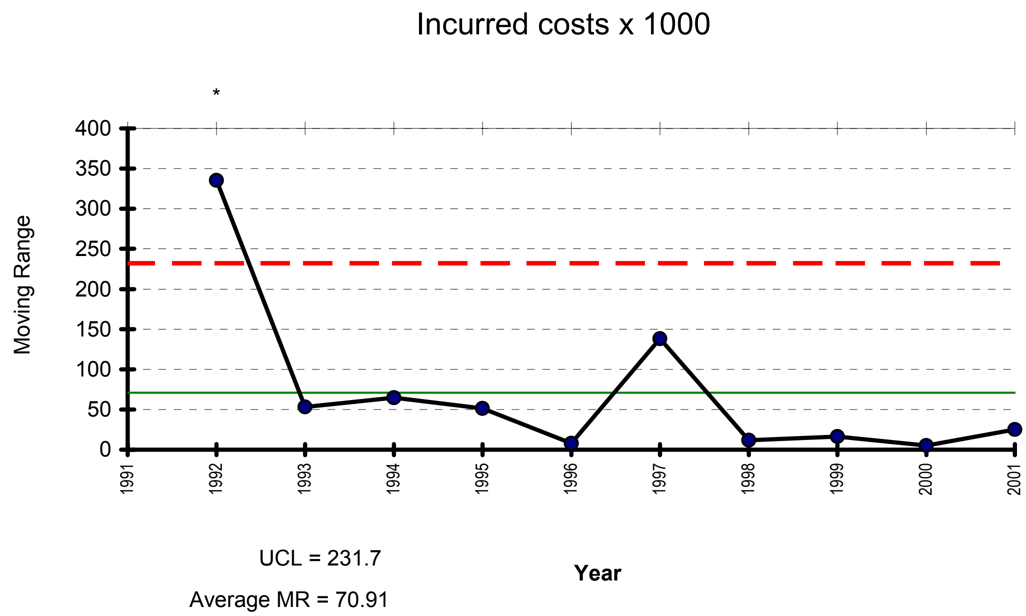
Cynthiana I Charts



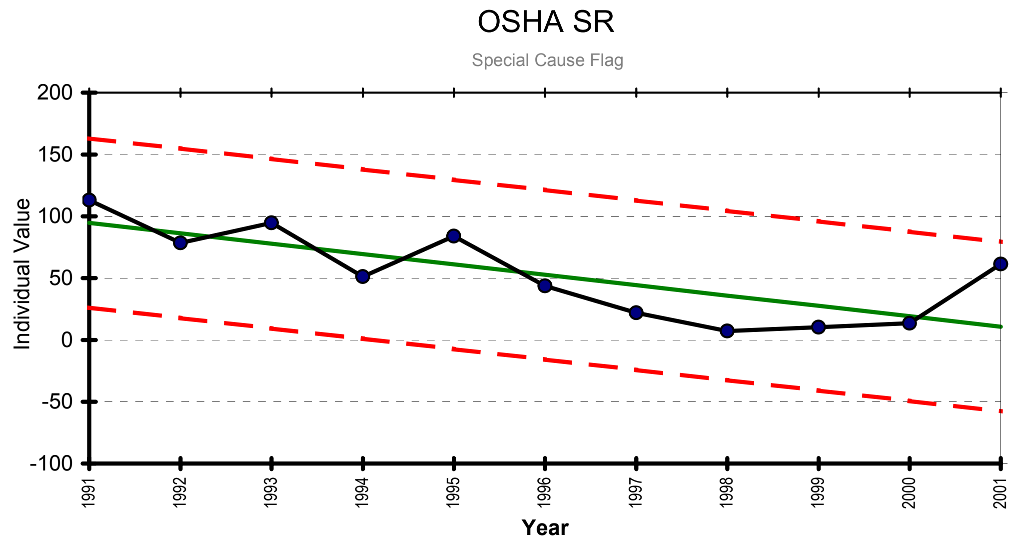


Cynthiana MR Charts

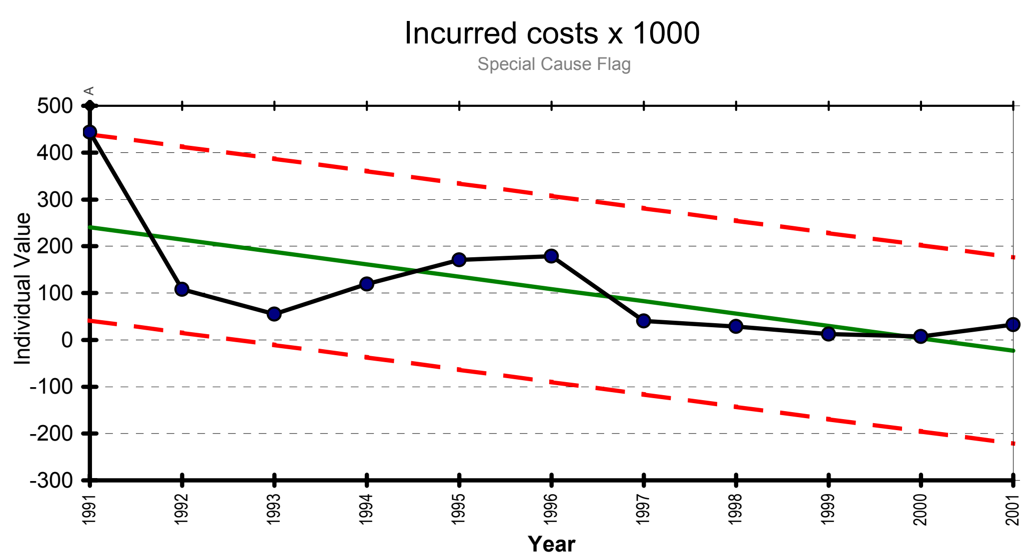




Cynthiana Linear Trend Charts

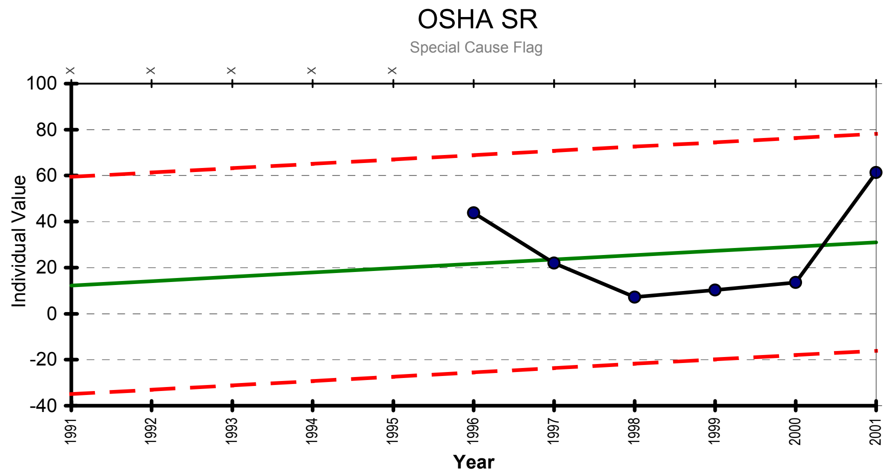


Current probability of no trend = p= 0.007

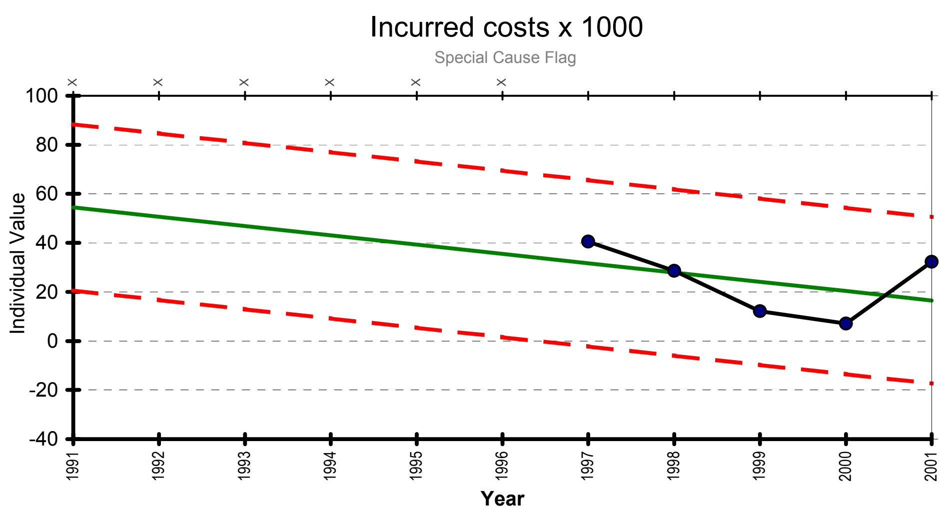


Current probability of no trend = p = 0.019

Cynthiana linear trend after BBS

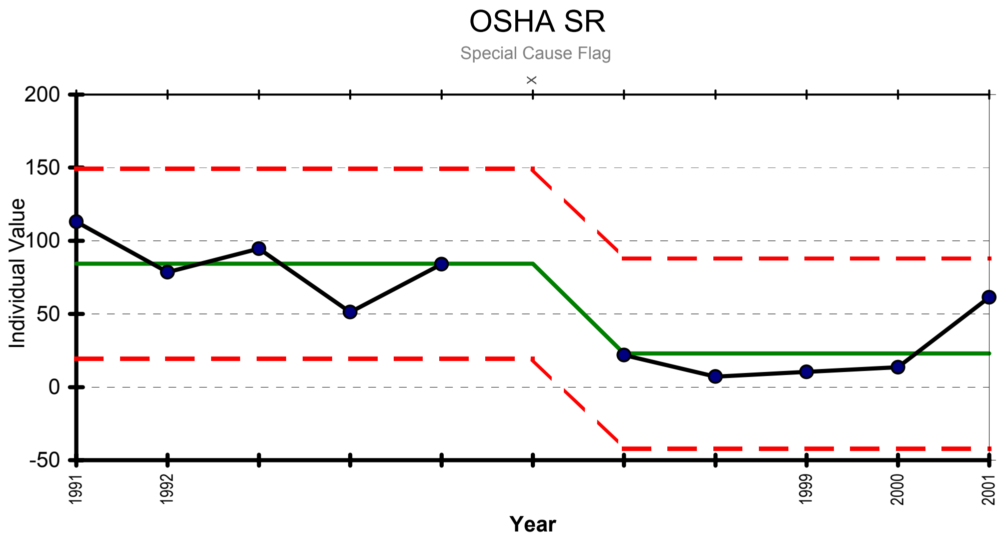


Current probability of no trend = p= 0.759

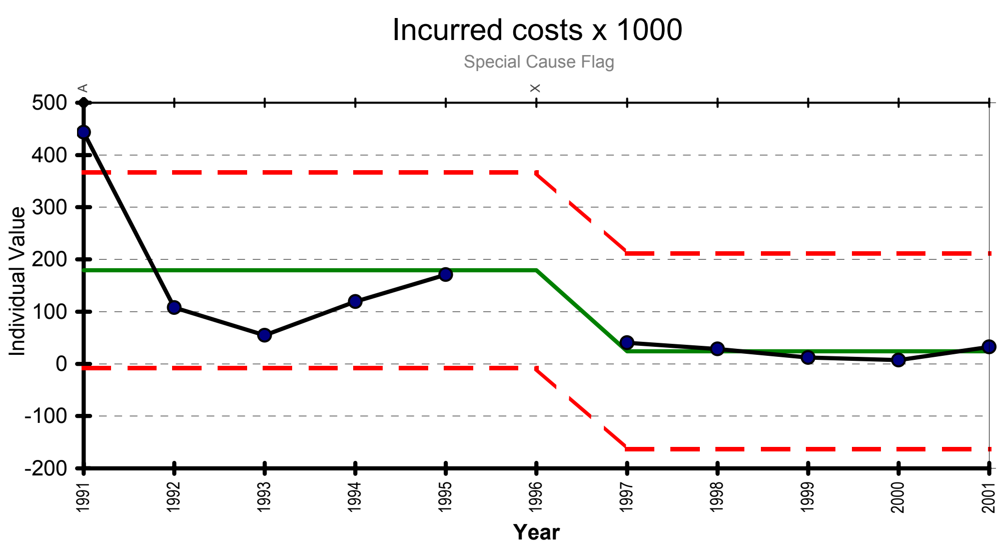


Current probability of no trend = P = 0.473

Cynthiana Step Change Charts



Current probability of no trend = p = 0.011



Current probability of no trend = p = 0.024