REMODELING HEINRICH

An Application for Modern Safety Management

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HERBERT WILLIAM HEINRICH was an employee of the engineering and inspection division of Travelers Insurance Co. He collected data from insurance claims and analyzed it to form a theory that he outlined in the first edition of *Industrial Accident Prevention: A Scientific Approach*, which was first published in 1931. His findings have served as the foundation of much of the teachings in modern safety management. He was a pioneer in his era of occupational safety in that he sought to establish a model that would predict incidents and the ratios in which they would occur based on the data he examined.

As presented in the literature review, Heinrich's theory has become the object of much recent criticism. Heinrich used data based on a spectrum of industries insured by his employer. Some critics have indicated through research that his model is inaccurate and that not enough information is available through his methodology to replicate his research. Critics allege that minor incidents cannot be used to predict the volume of serious injuries and fatalities (SIFs), which has given rise to a body of literature on SIFs. The criticism is also based on macro-level Bureau of Labor Statistic (BLS) data that indicate a reduction in other recordable, restricted-work and lost-time injuries, while fatalities have not experienced the same improvement (Krause, 2011). Figure 1 presents incident rate data from 2003, the year in which the Standard Industrial Classification (SIC) changed to the North American Industry Classification System (NAICS), through 2014, the most recent year for which BLS data are available.

The BLS data could present a potential issue with Heinrich's theory. Other recordable, restricted-work and lost-time rates have decreased over time with no year-to-year increase. However, the fatality rate did increase between 2003 and 2004; 2005 and 2006; 2009 and 2010; and 2013 and 2014. This cursory analysis could support criticism of Heinrich's theory, but a deeper analysis is needed through an exploration of various industrial sectors. Of note, prior to a deeper analysis and considering the year-to-year fluctuations in fatality rates, the following percentages of improvement exist over the period presented in Figure 1:

- other recordable rate, 33%;
- restricted-work rate, 34%;
- lost-time rate, 27%;
- fatality rate, 15%.

The research presented in this article is not intended to be an exact comparison to Heinrich's model. Instead, BLS data were analyzed to determine whether the spirit of Heinrich's model has a space in contemporary safety management by evaluating the degree to which minor incidents (i.e., recordable injury rates) can predict the occurrence of more severe incidents (i.e., restricted-work, lost-time and fatality rates). The authors did not include near-hits in the current research due to lack of available data within the context of the BLS data, although near-hits were a component of Heinrich's model. Due to BLS data being utilized at the industry sector level, the authors acknowledge that they did not analyze unique variables within each industry sector and organizations contained in each sector that can influence incident occurrence. Such variables affecting safety culture could include organizational policies, management philosophies, number of workers in the organization, level of diversity, tasks per-

KEY TAKEAWAYS

- **This article presents the authors' analysis of current Bureau of Labor Statistics data at the national and industry sector levels to determine whether simple revisions to Heinrich's theory are in order rather than dispensing with it entirely, as has been recently suggested.**
- **The authors determine that Heinrich's theory has merit in contemporary safety management through an analysis of recordable, restricted work, lost-time and fatality data at the national and industry sector levels.**
- **The authors determine that instead of a singular model, multiple models are in order as evidenced by the "house" models presented in the research findings.**

formed, exposure to risks, condition and type of equipment and tools available, and pay scales.

Literature Review

Research related to Heinrich's theory has been mixed. Seward and Kestle (2014) performed a study on the relevance of Heinrich's theory in modern reconstruction projects by reviewing incident data from rebuilding projects in Christchurch, New Zealand. Seward and Kestle felt that Heinrich's safety pyramid was still relevant to the safety practices on construction sites, as they found a ratio of 20-5-1, which is at least in the spirit of Heinrich's model.

Radvanska (2010) states that the focus must be a more balanced approach and that focusing too heavily on major incidents is also cause for concern when there are many more significant opportunities to provide a better basis and better control of major incidents at the bottom of the pyramid. They say collected data reveal that the triangle model presented by Heinrich may not actually be an equilateral triangle, depending on the safety culture of the individual company in which it is used.

Johnson (2011) states that still under debate is whether the influence of Heinrich is good or bad. She says that many safety professionals are calling for the debunking of Heinrich's theory and for its removal from all safety language and training, citing its age and the continual question of whether his research would hold up to modern methods and peer review. She cites Manuele, who notes that Heinrich revisited his 300-29-1 ratio in subsequent editions of his work but failed to explain it outside of his 1931 first edition.

Johnson (2011) says that critics of Heinrich's work note that focusing on "man-failure," as is supposed by Heinrich (1931) suggesting that 88% of accidents occur due to the unsafe acts of man, lead safety professionals to focus too heavily on workers rather than on the systems in which they operate. Accidents often have multiple causes, Johnson notes, not solely the failure of one person or piece of equipment, and should be investigated more diligently by safety professionals.

The research presented in this article is intended to extend the dialogue and present potential modifications that can be made to the foundation that Heinrich established.

Dislodging the long-held beliefs that Heinrich's theory is law is a daunting challenge for modern safety professionals. Heinrich's work should serve as a guideline for planning safety initiatives, but should not be the sole focus, as it leaves out an entire realm of possible hazards, including system design and overall culture. The belief that the majority of incidents are the fault of the worker enables upper-level management to simply insure against major losses as a result of an inevitable incident, and further keeps the safety profession from better ensuring the safety of the worker. Because of this, many professionals call for the complete removal of Heinrich's ideas. Some professionals, however, feel that more research is needed, using Heinrich as a litmus test but striving to advance the profession through professional research (Johnson, 2011).

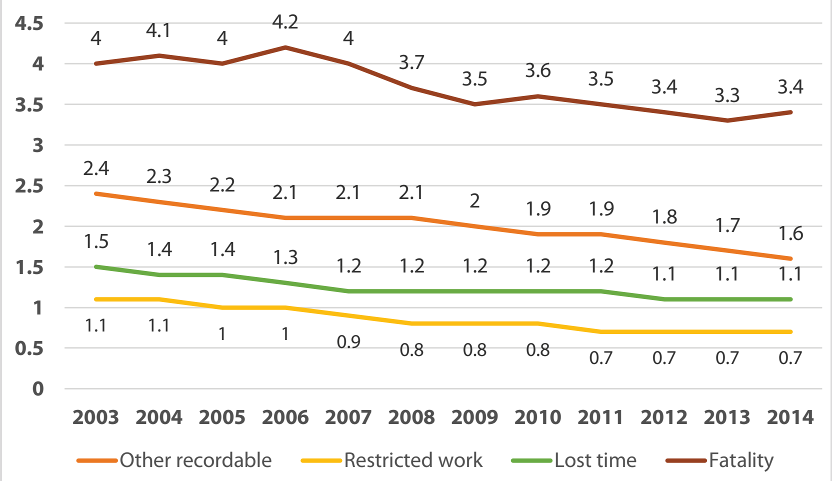
Executives often rely solely on OSHA injury rates or large penalties to assess their overall safety performance. When something catastrophic occurs, especially at a location with a low overall injury rate, many executives are caught off-guard and chalk it up to chance (Krause, 2011). Companies often cite that they were operating under the premise of Heinrich's theory, that by reducing the number of minor incidents the company would be able to eliminate or at least drastically reduce the occurrence of major incidents.

Krause (2011) states the root cause for major incidents lies not in Heinrich's theory that frequency breeds severity, but rather in the entire metric by which safety is measured as a whole. Heinrich's theories have been debunked by current BLS data, which has shown a decrease in the number of minor incidents, but the more serious injuries and fatality rates have remained constant, even showing increases in some cases (Krause).

Krause (2011) also notes that proper identification of factors leading to SIFs must be a priority. He says that many SIFs have identifiable precursors and assuming the conditions that led to the SIF have never previously occurred is a fatal flaw in safety professionals' thought processes. According to Krause, safety professionals

FIGURE 1

U.S. BLS RATE DATA, 2002-2014



Note. Data from "Injuries, Illnesses and Fatalities," by Bureau of Labor Statistics (BLS), 2015, retrieved from www.bls.gov/iif/oshsum.htm; and "Census of Fatal Occupational Injuries (CFOI): Current and Revised Data," by BLS, 2016, retrieved from www.bls.gov/iif/oshcfoi1.htm#rates.

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TABLE 1
RESULTS USING RECORDABLE CASES TO PREDICT FATALITY CASES

Simple linear regression model results using recordable cases to predict fatality cases for each industry sector.

Sector	n	Estimated regression line	R^2	Slope P-value	95% CI for average fatalities for 1 recordable case per 100	
					Lower limit	Upper limit
Agriculture, forestry, fishing and hunting (11)	41	$\hat{y} = 63.59 - 9.75\ x$	0.07	0.10	35.28	72.4
Mining (21)	22	$\hat{y} = 11.04 + 6.65\ x$	0.16	0.07	15.53	19.84
Construction (23)	8†	$\hat{y} = 8.0 + 0.98\ x$	0.45	0.08	7.89	10.14
Manufacturing (31-33)	85	$\hat{y} = 0.94 + 1.28\ x$	0.10	0.00	0.88	3.57
Wholesale trade (42)	19	$\hat{y} = 6.9 - 1.3\ x$	0.14	0.11	4.80	6.36
Retail trade (44-45)	56	$\hat{y} = 5.48 - 0.88\ x$	0.02	0.18	3.30	5.91
Transportation and warehousing (48-49)	63	$\hat{y} = 12.31 - 0.46\ x$	0.00	0.80	8.90	14.80
Utilities (22)	10†	$\hat{y} = -2.0 + 3.7\ x$	0.66	0.00	0.55	2.90
Information (51)	8†	$\hat{y} = 0.89 + 0.92\ x$	0.16	0.33	1.24	2.37
Finance and insurance (52)	10†	$\hat{y} = -0.0 + 0.9\ x$	0.34	0.08	0.38	1.32
Real estate, and rental and leasing (53)	14	$\hat{y} = -3.8 + 5.5\ x$	0.52	0.00	0.09	3.19
Professional, scientific and technical services (54)	10†	$\hat{y} = 0.5 + 0.6\ x$	0.19	0.20	0.71*	1.36*
Management of companies and enterprises (55)	0	--	--	--	--	--
Administrative and support, and waste management and remediation services (56)	10†	$\hat{y} = 3.68 + 2.03\ x$	0.32	0.09	4.98	6.44
Educational services (61)	10†	$\hat{y} = 0.6 + 0.3\ x$	0.03	0.64	0.42	1.28
Healthcare and social assistance (62)	33	$\hat{y} = 1.18 - 0.14\ x$	0.34	0.00	0.89	1.19
Arts, entertainment and recreation (71)	17	$\hat{y} = -1.6 + 2.07\ x$	0.66	< .0001	-1.16	2.06
Accommodation and food services (72)	18	$\hat{y} = 0.6 + 0.58\ x$	0.17	0.09	0.21	2.19
Other services, except public administration (81)	27	$\hat{y} = -1.25 + 3.05\ x$	0.24	0.01	0.90	2.71

Note. *Extrapolation of the model; † Level 2 analysis.

should look beyond the numbers, realize that Heinrich was wrong, and work to develop new and better methods of prevention. Process safety must be better understood, and the organization's culture should reflect the desire for top leadership to do more to prevent SIFs (Krause).

Nash (2008) communicates a similar message regarding BLS data, stating that those who are skeptical of the validity of Heinrich's theory may believe that the data shown by BLS refutes it. He notes that BLS data show an increase in the number of fatal work injuries between 2005 and 2006 but show a fatality rate that remained constant for the same period. Based on Heinrich's model, one would expect the rate to increase along with the number of fatalities (Nash). Because of this discrepancy, it is important for safety professionals to change their view on incident investigations and subsequent corrective actions, employee behavior and risk management, and engineering controls.

Manuele (2011) says Heinrich's original sources have been lost to time and only the first four editions of his book remain; there is no way to determine how Heinrich gathered his data, the quality of the data he obtained, or how effective his data analytics were. Manuele says that Heinrich's work would not stand up to modern peer review and that much of the terminology he used would be considered sexist by today's standards. Manuele notes that Heinrich's work is focused heavily on applied psychology and that many safety practitioners could not effectively apply the psychological emphasis of Heinrich in their daily incident prevention efforts.

Heinrich attributes 88% of the causes of accidents to "man-failure," and believed that psychology was an important element in remedying those problems. Heinrich advocated for prevention of the first proximate cause of an incident, which was generally the easiest to correct. Manuele (2011) states this

TABLE 2

RESULTS USING RECORDABLE CASES TO PREDICT LOST-TIME CASES

Simple linear regression model results using recordable cases to predict lost-time cases for each industry sector.

Sector	*n*	Estimated regression line	R^2	Slope P-value	95% CI for average lost time for 1 recordable case per 100	
					Lower limit	Upper limit
Agriculture, forestry, fishing and hunting (11)	46	$\hat{y} = 1.24 + 0.29$ x	0.22	0.00	1.28	1.78
Mining (21)	30	$\hat{y} = -0.02 + 1.19$ x	0.59	0.00	1.04	1.30
Construction (23)	29	$\hat{y} = 0.27 + 0.67$ x	0.80	0.00	0.81	1.06
Manufacturing (31-33)	210	$\hat{y} = 0.14 + 0.51$ x	0.71	0.00	0.59	0.70
Wholesale trade (42)	26	$\hat{y} = 0.13 + 0.80$ x	0.48	0.00	0.77	1.07
Retail trade (44-45)	117	$\hat{y} = 0.26 + 0.46$ x	0.33	0.00	0.61	0.83
Transportation and warehousing (48-49)	98	$\hat{y} = 0.45 + 1.06$ x	0.35	0.00	1.29	1.75
Utilities (22)	10	$\hat{y} = 0.09 + 0.59$ x	0.85	0.00	0.57	0.78
Information (51)	55	$\hat{y} = 0.46 + 0.10$ x	0.02	0.29	0.47	0.66
Finance and insurance (52)	43	$\hat{y} = 0.06 + 0.38$ x	0.21	0.00	0.32*	0.56*
Real estate, and rental and leasing (53)	29	$\hat{y} = 0.01 + 0.76$ x	0.71	0.00	0.67	0.87
Professional, scientific and technical services (54)	10	$\hat{y} = 0.08 + 0.28$ x	0.24	0.15	0.22*	0.51*
Management of companies and enterprises (55)	10†	$\hat{y} = 0.11 + 0.38$ x	0.81	0.00	0.44	0.54
Administrative and support, and waste management and remediation services (56)	20	$\hat{y} = -0.05 + 1.02$ x	0.65	0.00	0.71	1.24
Educational services (61)	10	$\hat{y} = 0.34 + 0.22$ x	0.42	0.04	0.49	0.63
Healthcare and social assistance (62)	40	$\hat{y} = 0.45 + 0.37$ x	0.39	0.00	0.52	1.13
Arts, entertainment and recreation (71)	29	$\hat{y} = 0.57 + 0.29$ x	0.48	0.00	0.64*	1.07*
Accommodation and food services (72)	20	$\hat{y} = 0.25 + 0.39$ x	0.14	0.11	-0.04	1.32
Other services, except public administration (81)	30	$\hat{y} = 0.24 + 0.48$ x	0.36	0.00	0.60	0.84

Note. *Extrapolation of the model; † Level 2 analysis.

focus does not account for the dynamic, complex environment in which incidents occur, and that focusing only on the first cause does a disservice to those affected by the incident, citing the complex natures of both the 2003 Space Shuttle *Columbia* disaster and the 2010 *Deepwater Horizon* explosion.

According to Manuele (2011), when the focus is placed too heavily on the failures of workers as a root cause of an incident, management is often excused as a causal factor, as blaming the workers is the path of least resistance. There are often several causal factors of an incident, he says, including cultural factors within the organization that are not often accounted for by a superficial investigation. While human error at the worker level accounts for a large portion of the incident causes, what is not often considered are the failures of management that have allowed both unsafe environments and unsafe practices to continue. Maintenance and design factors also must be accounted for, and a comprehensive incident investigation is the only way to uncover all of these causes, not just "man-failures" (Manuele, 2011).

Due to the varying perspectives regarding the relevancy of Heinrich's theory in contemporary safety management, additional research is needed. The research presented in this article is intended to extend the dialogue and present potential modifications that can be made to the foundation Heinrich established.

Methodology

Building on information presented in the literature review, the authors used a 9-year history of BLS data to analyze trends related to other recordable injuries, restricted-work injuries, lost-time injuries and fatalities. To present a more accurate understanding of trends accounting for hours worked, the authors used rates rather than volume of cases.

TABLE 3

RESULTS USING RECORDABLE CASES TO PREDICT RESTRICTED-WORK CASES

Simple linear regression model results using recordable cases to predict restricted-work cases for each industry sector.

Sector	*n*	Estimated regression line	R^2	Slope P-value	95% CI for average restricted work for 1 recordable case per 100	
					Lower limit	Upper limit
Agriculture, forestry, fishing and hunting (11)	41	$\hat{y} = 0.369 + 0.31$ x	0.14	0.01	0.31	1.02
Mining (21)	30	$\hat{y} = -0.03 + 0.53\,x$	0.63	0.00	0.45	0.56
Construction (23)	29	$\hat{y} = 0.27 + 0.24$ x	0.41	0.00	0.40	0.61
Manufacturing (31-33)	211	$\hat{y} = 0.19 + 0.60$ x	0.56	0.00	0.70	0.88
Wholesale trade (42)	24	$\hat{y} = -0.01 + 0.76$ x	0.35	0.00	0.55	0.96
Retail trade (44-45)	114	$\hat{y} = -0.20 + 0.61$ x	0.30	0.00	0.25	0.56
Transportation and warehousing (48-49)	98	$\hat{y} = -0.47 + 1.02$ x	0.51	0.00	0.38	0.70
Utilities (22)	10	$\hat{y} = 0.03 + 0.49$ x	0.89	0.00	0.44	0.59
Information (51)	49	$\hat{y} = 0.23 + 0.04$ x	0.02	0.35	0.22	0.31
Finance and insurance (52)	28	$\hat{y} = 0.06 + 0.19$ x	0.04	0.29	0.09*	0.42*
Real estate, and rental and leasing (53)	21	$\hat{y} = -0.13 + 0.60$ x	0.55	0.00	0.34	0.60
Professional, scientific and technical services (54)	10	$\hat{y} = -0.03 + 0.25$ x	0.17	0.24	0.07*	0.38*
Management of companies and enterprises (55)	10†	$\hat{y} = -0.05 + 0.44$ x	0.79	0.00	0.34	0.45
Administrative and support, and waste management and remediation services (56)	20	$\hat{y} = -0.35 + 0.78$ x	0.66	0.00	0.23	0.63
Educational services (61)	10	$\hat{y} = 0.26 + 0.00$ x	0.00	1.00	0.16	0.36
Healthcare and social assistance (62)	40	$\hat{y} = -0.08 + 0.45$ x	0.34	0.00	-0.05	0.78
Arts, entertainment and recreation (71)	27	$\hat{y} = 0.90 + 0.02$ x	0.00	0.76	0.70*	1.14*
Accommodation and food services (72)	20	$\hat{y} = -0.51 + 0.56$ x	0.12	0.14	-1.04*	1.14*
Other services, except public administration (81)	30	$\hat{y} = 0.50 - 0.05$ x	0.02	0.46	0.37	0.51

Note. *Extrapolation of the model; † Level 2 analysis.

This study departs somewhat from the context of Heinrich's theory in that it excludes near-hit and first-aid cases, which do not appear in BLS data. Using BLS data provides a degree of reliability, although it is open to critique due to the system through which information is reported for inclusion. BLS data provide an opportunity to remain within the spirit of Heinrich's theory by evaluating cases that are minor (other recordable cases) and that are severe (lost time and fatalities). BLS data also support extending the research-based dialogue regarding Heinrich's contribution to occupational safety management in that this data has been used to refute Heinrich's theory (Krause, 2011; Nash, 2008).

BLS injury data (BLS, 2015) and fatality data (BLS, 2016) were analyzed for the 9-year period from 2006 through 2014. Although 2003 could have served as the initial year for evaluation because that was when industrial classification codes changed from SIC to NAICS, thus allowing continuity of industry sector comparison between years, uniform specific categorization of the NAICS natural resources and mining sector, and the trade, transportation and utilities sector first appeared within the fatality data tables in 2006. The creation of these two data categories in the 2006 fatality data established a starting point from which fatality data could be analyzed, along with the precise list of industry sector categories presented in the BLS injury and illness tables. The final year of analysis was 2014 because it was the most recent year of data provided at the time the research was conducted. In addition to national data, the authors also analyzed data at the primary industrial sector level, advancing one step beyond national level data. These industry sectors included:

- agriculture, forestry, fishing and hunting (NAICS 11)
- mining (NAICS 21);

FIGURE 2
NATIONAL DATA HOUSE

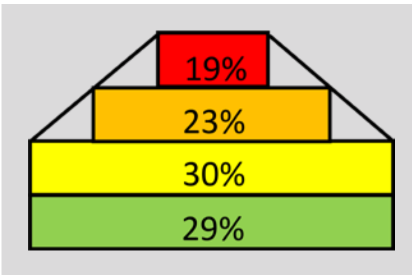


FIGURE 3
CONSTRUCTION DATA HOUSE

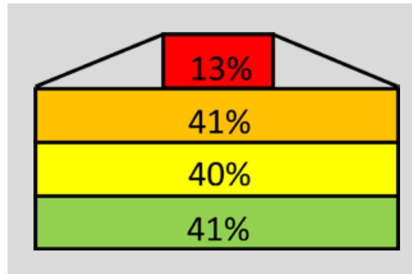


FIGURE 4
MANUFACTURING DATA HOUSE

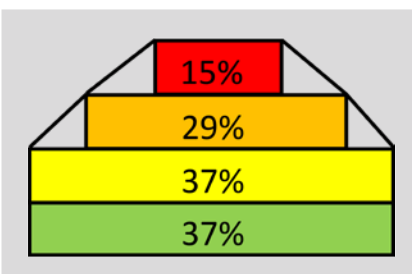
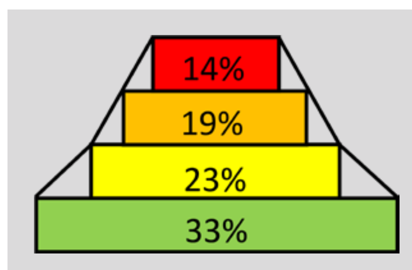


FIGURE 5
TRADE, TRANSPORTATION & UTILITY DATA HOUSE



Figures 2 through 5 show the percentage of improvement in incident rates across the four measured categories of other recordable (green), restricted work (yellow), lost time (orange) and fatality (red).

•construction (NAICS 23);
•manufacturing (NAICS 31-33);
•wholesale trade (NAICS 42);
•retail trade (NAICS 44-45);
•transportation and warehousing (NAICS 48-49);
•utilities (NAICS 22);
•information (NAICS 51);
•finance, insurance and real estate (NAICS 52-53);
•real estate, and rental and leasing (NAICS 53);
•professional scientific and technical services (NAICS 54);
•management of companies and enterprises (NAICS 55);
•administrative and support, and waste management and remediation services (NAICS 56);
•educational services (NAICS 61);
•healthcare and social assistance (NAICS 62);
•arts, entertainment and recreation (NAICS 71);
•accommodation and food services (NAICS 72);
•other services, except public administration (NAICS 81).

Analyzing data at the industry sector level provided a more granular understanding of performance within different industries rather than only analyzing data at the macro level of national performance. This level of analysis provides greater insight into specific issues that can be addressed when applying Heinrich's theory in light of current performance.

In this research, separate simple linear regressions were performed to predict fatality, restricted-work and lost-time cases using the recordable cases as the predictor variable. In addition, the simple linear regression models were used to estimate with 95% confidence the average number of fatalities per 1,000 workers when there was one recordable incident per 100 workers. Three separate linear regression models were used within each industry sector to test the ability of the independent variable recordable rate to predict the occurrence of the three dependent variables: 1) restricted-work rate; 2) lost-time rate; and 3) fatality rate. The corresponding simple linear regression models were used to estimate with 95% confidence the dependent variable on average when there was one recordable incident per 100 workers within each industry sector. The models did not account for variables that might exist within each industry sector or organization that could affect incident occurrence due to such data not being available for inclusion.

The researchers also used descriptive statistics to establish visual models as compared to Heinrich's triangle. The models presented identify the percentage of improvement (or lack thereof) over the 9-year period covered within the scope of this research in other recordable, restricted-work, lost-time and fatality rates.

Research Findings & Analysis

When examining the regression models to predict fatalities across all sectors, we see that NAICS sectors 31-33, 22, 53, 71 and 81 all have significant positive slopes at the 5% significance level, whereas NAICS sector 62 has a negative slope at the 5% significance level (Table 1, p. 46). The regression models used to predict lost-time cases all had significant positive slopes with the exception of sectors 51, 54 and 72 (Table 2, p. 47). The regression models used to predict restricted work cases that had positive slopes were all sectors except 51, 52, 54, 61, 71, 72 and 81 (Table 3).

When examining the regression models within each sector, we see that NAICS sectors 11, 21, 23, 31-33, 22, 53 and 56 all had positive slopes at the 10% significance level. This means that for each recordable incident per 100 workers, the average restricted-work cases per 100 workers increased, the average lost-time cases per 100 workers increased and the average fatalities per 1,000 workers increased by the slopes given in the respective regression model.

When analyzing the percentage of improvement nationally and within industry sectors across the categories of other recordable, restricted-work, lost-time and fatality rates, albeit lagging measures, a revised image appears when utilizing stacked bar graphs (Figures 2 through 12, pp. 49-51). This "house" image provides one aspect of identifying where opportunities exist for improvement in addressing relevant systems issues through proactive safety activities (leading measures).

Following Heinrichian logic, one might expect to see an evenly built block house in which a percentage reduction in lower severity incidents (other recordable incidents building up to recordable incidents) would equate to an equal percentage reduction in greater severity incidents (lost-time incidents building up to fatality incidents). This expectation is somewhat present nationally as well as in the construction, manufacturing, and trade, transport and utility industry sectors. Figures 2 through 5 show the percentage of improvement in incident rates across the four measured categories of other recordable (green), restricted work (yellow), lost time (orange) and fatality (red).

These models somewhat depict what might be expected following Heinrich's theory. They also demonstrate an increasing opportunity to apply information produced through a focus on SIFs. While construction has experienced a consistent level of performance improvement in other recordable, restricted-work and lost-time incident rates, a large decrease appears when comparing the level of performance improvement related to fatalities. This analysis could point to the need for an increased level of activity related to risk assessment and follow-up related to high-risk tasks.

When applying the house model to other industries, a much different story is revealed. Industries falling into a category of moderately fitting the house model include information, professional and business services, educational and health services, and leisure, entertainment and hospitality. These industry sectors indicate improvement in each of the four measured categories, although there is no uniform improvement in escalating categories of severity.

The three remaining industries of natural resources and mining, finance, insurance and real estate, and other services fall into a more severe category of complying with the house model in that not only is there incongruity of performance across the four measured categories, but also these industries experienced no improvement in one category.

FIGURE 6
INFORMATION DATA HOUSE

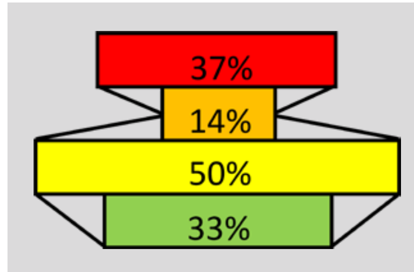


FIGURE 7
PROFESSIONAL & BUSINESS SERVICES DATA HOUSE

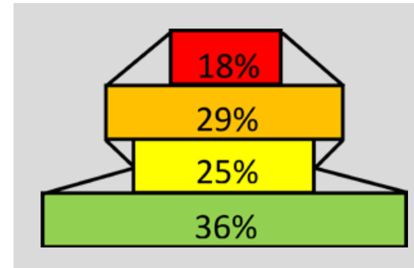


FIGURE 8
EDUCATIONAL & HEALTH SERVICES DATA HOUSE

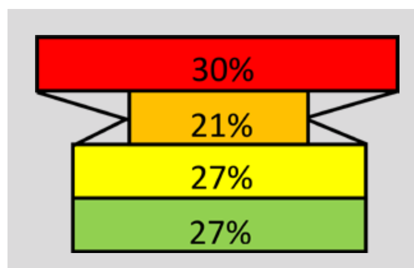
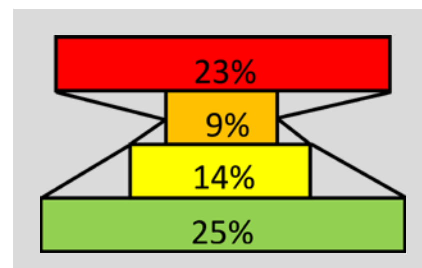


FIGURE 9
LEISURE, ENTERTAINMENT & HOSPITALITY DATA HOUSE



The industry sectors represented in Figures 6 through 9 indicate improvement in each of the four measured categories, although there is no uniform improvement in escalating categories of severity.

Discussion & Implications

Heinrich's theory has come under a great deal of recent criticism for three primary reasons. First, it has been stated that Heinrich's research would not stand up under modern peer-reviewed scrutiny. Although this assumption can be supported utilizing the fact that his data are not available, one could equally assume that it would stand up under modern peer-reviewed scrutiny if his data were available. Context is essential in understanding this dilemma. Heinrich was an independent researcher who collected data from his place of employment to make an impact in an area in which he was passionate: the protection of human life. His model makes intuitive sense when considering statistical probability and human error. For example, a growing body of research exists regarding the risks associated with distracted driving, such as eating or texting while driving. The greater frequency at which a population engages in distracted driving could result in a volume of incidents in which a motorist might swerve or abruptly apply the brakes to avoid a collision (minor events), and the more likely we are to see auto incidents resulting in property damage (moderate events). The more that population experiences the outcome of property damage incidents, the more likely we are to see incidents that involve a fatality (severe event). When applying Heinrich's theory to modern occupational safety issues and unique industries or work environments, we may not find the precise 300-29-1 ratio presented in Heinrich's theory, but we may find a similar ratio, such as the 20-5-1 ratio found by Seward and Kestle (2014).

Second, "frequency breeds severity" is an age-old maxim that has been connected to Heinrich's theory and has been criticized upon various BLS data analyses. This statement holds opportunity for remodeling in the context of linear regression findings and the house depictions of the BLS data presented in this research. Rather than completely dispensing with Heinrich's concept in an attempt to fully embrace an alternative of efforts in the area of SIFs, an option is to evolve the statement to "frequency sometimes breeds severity." This statement accounts for both the value of Heinrich's theory as is evidenced by the BLS data and the need to address SIFs where incidents occur that are uniquely tied to specific industrial risks that are not accounted for in other levels of data analysis, such as other recordable rates and behavior-based observation data. In the house models in which variance appears, opportunity exists to further research these industry sectors to determine the degree to which safety and health management systems have been established. A lack of such systems could be a primary reason for unequal distributions of improvement. In addition to SIFs, focus could also be applied in the area of risk assessment related to incidents that occur in categories in which low performance improvement is indicated.

Third, Heinrich clearly presents the notion that the worker is at fault for incidents in his second axiom of industrial safety: "The unsafe acts of persons are responsible for a majority of accidents" (as cited in Petersen, 2001, p. 10). When used as a sound bite, this axiom could lead one to conclude that Heinrich placed too much emphasis on the worker. However,

FIGURE 10
NATURAL RESOURCES & MINING DATA HOUSE

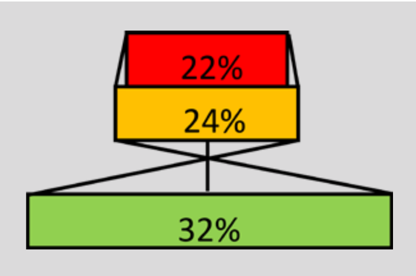


FIGURE 11
FINANCE, INSURANCE & REAL ESTATE DATA HOUSE

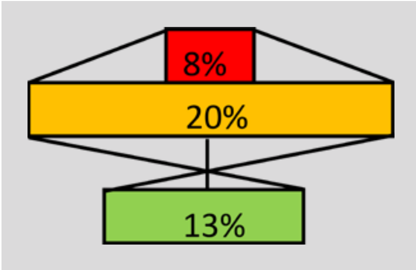
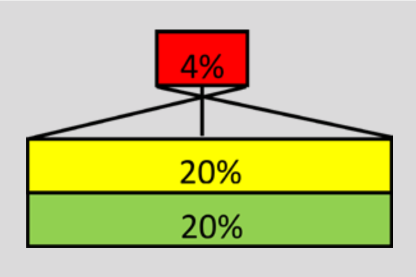


FIGURE 12
OTHER SERVICES DATA HOUSE



For the industry sectors represented in Figures 10 through 12, there is incongruity of performance across the four measured categories. In addition, these industry sectors experienced no improvement in one category.

a further exploration of his fourth and fifth axioms illuminate his multifaceted approach to the system in which the worker exists. Heinrich found reasons for unsafe acts and conditions to include improper attitude, lack of knowledge or skill, physical unsuitability and improper environment. Management and the system at work in an organization can have a direct impact on all four of these issues. Management can impact the culture of an organization, which can in turn have an impact on a worker's attitude. Management is responsible for providing safety training, which impacts the worker's knowledge or skill. Physical unsuitability can be addressed through management consideration of ergonomics. The environment can be impacted by budgetary decisions made by management or the culture it fosters. Heinrich also presented engineering revision, persuasion and appeal, personnel adjustment and discipline as tools that can be used to prevent accidents, all of which are under the control of management. Heinrich does not present workers as a mutually exclusive entity, but rather presents them as having a dynamic relationship with management. It is a both/and proposition in which the conduct of one can impact the other, resulting in an accident (negatively) or the development of a safe work environment (positively).

These axioms should be interpreted in their historical context. They were established in a reactive era that included a cycle of incident occurrence, investigation conducted, and issues addressed. Heinrich's axioms actually underpin much of what was introduced approximately 7 decades later when management systems were first addressed on a large scale through the establishment of ANSI Z10 and, more recently, ISO 45001. Although Heinrich addressed the manifestation of a failure being at the point of worker activity, he did not appear to negate the responsibility of the system in which the error occurred, as is evidenced in a holistic reading of his axioms.

A specific replication of Heinrich's theory is problematic, which is why the research presented in this article uses BLS data. Beginning at the level of near-hit reporting can be challenging due to reporting issues. Even within an organizational context in which an established near-hit reporting process is in place, data collection can be problematic because of the assumption that the volume of near-hit reports gathered during a given period is a quantifiable whole. In an organization in which safety is a significant component of the organizational culture, employees may still fail to report near-hits because they do not want to take the time to do so or because they personally do not see value in the process. This calls into question establishing near-hit incidents in the inclusion of a model that can yield accurate information regarding safety performance and improvement. Rebbitt (2014) identified a similar issue when citing a ConocoPhillips Marine study in which at-risk behaviors and near-hits were qualified as "estimated" in creating a revised pyramid model.

The findings of the research presented in this article do not refute Heinrich's theory, but build upon the concepts he presented and interpret them in light of current available national data. Heinrich's theory should remain as a respected component of the history of safety management and presented within the safety profession in its historical context while continuing to evolve and build upon it, as has been presented here in the form of a house as a way to view the interaction of prevention efforts that result in outcomes among the categories of other recordable, restricted-work, lost-time and fatality rates. Such work can honor the work of a forefather of the profession while striving to adapt relevant principles to modern safety management.

The linear regression results indicate that in a number of cases, minor incidents (quantified within the scope of this research as other recordable injury rates) do indeed predict more severe incidents (quantified within the scope of this research as restricted-work, lost-time and fatality rates). Although the data may not exactly match Heinrich's ratios, these results are precisely within the spirit of what Heinrich was communicating, which makes the concept of dispensing with Heinrich's theory a premature action. Rather, further investigation should be conducted within industries, organizations and local facilities to determine how or whether Heinrich's concepts fit after evaluating the degree to which risk assessments are being conducted and addressed, and the degree to which safety and health management systems are in place (in the spirit of Heinrich's axioms).

An analysis of fatality rates has nationally demonstrated a 15% improvement over the period of 2002 to 2014, which spans the current NAICS industry classification system. Data should be further analyzed to determine the role of SIFs and risk assessment within specific industry sectors or individual operations. For example, the national fatality data are greatly skewed by the large volume of fatalities within the natural resources and mining, and construction industries, with fatality rates of approximately 21 and 10, respectively (accounting for 43% of all fatalities in the U.S. in 2014) compared to all other industries having fatality rates of approximately 5 or below. These two industries present an obvious need to address issues from multiple facets that are leading to the occurrence of fatalities.

Incident rate improvement should also be viewed in light of current incident rates within various industrial sectors in which incident rates might be considered as low, thus impacting the amount of incremental improvement that can be expected. For example, the restricted work rate in the finance, insurance and real estate sector in 2014 was 0.2, which could make large percentage of improvement gains challenging to realize, and incremental gains might be typically expected. Over time as rates greatly lessen, the percentage of improvement might tend to lessen, which calls into question the need for a timeline remodeling of Heinrich's theory at a point when a relatively low rate is reached.

Additional research is needed to determine the role of risk assessment, and safety and health management systems within various industries. An underlying assumption of Heinrich's theory might be that organizations are working to manage occupational safety. Such research could verify whether Heinrich's theory indeed holds true due to the reflection of expected data in the house model in the areas of other recordable, restricted-work, lost-time and fatality cases. Research on risk assessment could yield beneficial information as to its impact on all levels of incidents, to include those addressed by a specific emphasis on SIF where applicable rates are high. Research on safety and health management systems could identify best practices, possibly challenging long-held beliefs that have been accepted in the safety profession, and can determine the relationship between management systems activities and incident performance.

Petersen (2001) presents the safety profession as having distinct eras of historical evolution:
- inspection era;
- unsafe act and condition era;
- industrial hygiene era;
- noise era;
- safety management era;
- OSHA era;
- accountability era;
- behavior-based era and human era.

The safety profession is built upon an honorable history as has been chronicled in these eras. There is opportunity to continue in a new data-driven decision era in which incident prevention techniques are not utilized because of their assumed relevance and effectiveness, but one in which past successes and failures can be viewed in their historical contexts and applied with revision, as well as new and emerging methodologies, based on data that is collected and analyzed on a granular level.

The research presented in this article, along with a body of other research and practices, attempts to continue in that direction by focusing on industrial sector performance beyond national level data applied to what might be considered a one-size-fits-all theory. The house model presented here is intended to assess performance from one perspective as a way of knowing where we stand and potential ways to move forward. Lagging measures were used because of the ability to collect usable data published by BLS, yet many opportunities exist to create granular models that can be used through the use of other lagging and leading measures. As Rebbitt (2014) states, "Recognizing that organizations have their own pyramid can help better manage risk and identify trends." **PSJ**

References

Basford, B.P. (2017). The Heinrich model: Determining contemporary relevance. *Online Theses and Dissertations, 474*. Retrieved from https://encompass.eku.edu/etd/474

Bureau of Labor Statistics (BLS). (2015). Injuries, illnesses and fatalities. Retrieved from www.bls.gov/iif/oshsum.htm

BLS. (2016). Census of fatal occupational injuries (CFOI): Current and revised data. Retrieved from www.bls.gov/iif/oshcfoi1.htm#rates

Gallivan, S., Taxis, K., Franklin, B.D., et al. (2008). Is the principle of a stable Heinrich ratio a myth? *Drug Safety, 31*(8), 637-642.

Heinrich, H.W. (1931). *Industrial accident prevention: A scientific approach*. New York, NY: McGraw-Hill.

Heinrich, H.W. (1941). *Industrial accident prevention: A scientific approach* (2nd ed.). New York, NY: McGraw-Hill.

Johnson, A. (2011). Examining the foundation: Were Heinrich's theories valid, and do they still matter? *Safety+Health, 184*(4), 62.

Krause, T. (2011, Oct. 1). Accidents just happen? Leadership can prevent serious injuries and fatalities. *Industrial Safety & Hygiene News*. Retrieved from www.ishn.com/articles/91809-accidents-just-happen

Lander, L., Eisen, E.A., Stentz, T.L., et al. (2011). Near-miss reporting system as an occupational injury preventive intervention in manufacturing. *American Journal of Industrial Medicine, 54*(1), 40-48.

Manuele, F.A. (2011, Oct.). Reviewing Heinrich: Dislodging two myths from the practice of safety. *Professional Safety, 56*(10), 52-61.

Mattis, G.T. (2011). Severity study in reverse: Testing Heinrich's safety pyramid. In *Proceedings of Safety 2011 ASSP's Professional Development Conference and Exposition, Chicago, IL*.

Nash, J. (2008, Nov. 4). EHS worldwide horizons: Preventing death on the job. *Industrial Safety & Hygiene News*. Retrieved from www.ishn.com/articles/87745-ehs-worldwide-horizons-preventing-death-on-the-job

Petersen, D. (2001). *Safety management: A human approach* (3rd ed.). Des Plaines, IL: ASSP.

Radvanska, A. (2010). Accident losses elimination by means of safety pyramid analysis. *Annals of Faculty of Engineering Hunedoara—International Journal of Engineering, 8*(1), 73-76.

Rebbitt, D. (2014, Sept.). Pyramid power: A new view of the great safety pyramid. *Professional Safety, 59*(9), 30-34.

Seward, M. & Kestle, L. (2014). Health and safety practices on Christchurch's post-earthquake rebuild projects: How relevant is Heinrich's safety pyramid? *Proceedings of the 30th Annual Association of Researchers in Construction Management Conference, Portsmouth, U.K.*, Association of Researchers in Construction Management, 361-370.

Smith, T.A. (1999, Sept.). What's wrong with behavior-based safety? *Professional Safety, 44*(9), 37-40.

Ward, R.B. (2012). Revisiting Heinrich's law. In *Chemeca 2012: Quality of life through chemical engineering, Wellington, New Zealand*, 1179-1187.

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