

Estimating Average University Environmental Health and Safety Program Staffing and Resourcing Using a Series of Iteratively Developed Evidence-Based Models

Robert J. Emery,^{*} Bruce J. Brown, Jing Wang, Seth Parker, Otu Inyang, and Janelle Rios



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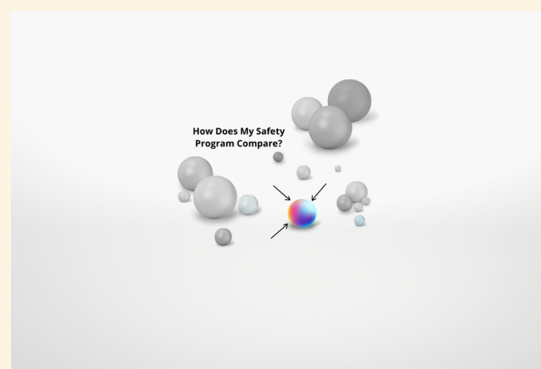
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ABSTRACT: Inherent to the work carried out at institutions of higher education is a set of diverse health and safety risks, which include the use of a variety of potentially hazardous materials. To manage these hazards, colleges and universities typically maintain Environmental Health and Safety (EHS) programs, but objective models for determining the typical amount of organizational resources dedicated to EHS programs are lacking. Summarized here are a series of iterative modeling efforts based on benchmarking data provided by the members of the Campus Safety, Health, and Environmental Management Association (CSHEMA), combined with publicly available institutional data, to produce a series of predictive models for EHS program resourcing. Linear and multiple regression analysis techniques were utilized to develop the models to estimate industry-average college and university EHS program staffing and expenses. Interestingly, the subset of recurrent key predictors identified through these efforts, such as the total net assignable area (TNASF) and the research laboratory area, includes measures that many EHS professionals do not typically have readily available. Although these models do not address the ultimate outcomes achieved by any EHS program, they can assist decision makers with determining a representative level of staffing and resources needed to support university EHS programs.

KEYWORDS: *environmental health and safety resources, program management, financial support, staffing, budget*



1. INTRODUCTION

Inherent to the work carried out at institutions of higher learning is a set of diverse potential health and safety risks, which include the use of various potentially hazardous materials.^{1,2} For example, dormitories and student housing can pose a significant fire risk, as indicated by a history of tragic fire-related fatalities in various types of campus housing.³ Teaching and research laboratories can contain a variety of potential hazards in the form of toxic chemicals, potentially infectious agents, radioactive materials, and fire-related risks.^{2,4} It is not uncommon to encounter three-dimensional (3D) printers, lasers, and robotic equipment in engineering laboratories. University art departments represent a variety of documented hazards, including increased noise levels, volatile and toxic chemicals potentially in excess of occupational exposure limits, respirable silica dust, and other particulates.⁵ Many job-specific hazards faced by workers in custodial services, food service, maintenance, groundskeeping, construction, office ergonomics, and operating motor vehicles exhibit risks similar to those in other industries.⁶

To manage these risks and their associated regulatory compliance requirements, colleges and universities maintain risk financing programs, generally in the form of commercial

insurance policies to provide financial recovery for potential losses such as fires, floods, and electrical power interruptions. Risk control programs, typically in the form of Environmental Health and Safety (EHS) departments, are maintained to protect students, faculty, staff, and the surrounding communities.

To derive the premiums for insurance policies, insurance underwriters rely on a combination of institutional factors including building construction type, occupancy classification, loss exposure, loss history, building size, construction or replacement costs, and facility structural characteristics and protective features.^{7,8} These independent predictive variables are generally referred to as “COPE” data—construction, occupancy, protection, and exposures. Risk financing premiums, in the form of worker’s compensation insurance

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Table 1. Summary of Key Variables Used in University EHS Staffing and Budget Models^a

Model name by the primary analyst	Variables in the original dataset used for analysis	Variables identified as statistically significant in the model for the predicted EHS:	
		Staffing	Budget
Wang	Original CSHEMA Benchmarking data (<i>n</i> = 110, each with more than 50 data fields from respondents)	TNASF, RNASF, Med/Vet, BSL3	N/A
Emery	EHS rounders reported total EHS budget and TNASF (<i>n</i> = 35)	TNASF	TNASF research expenditures
Brown(all)	CSHEMA vital statistics survey: number of students and number of employees; total institutional expenditures and research expenditures; TNASF and RNASF (<i>n</i> = 118)	TNASF, total institutional expenditures	TNASF, total Institutional Expenditures
Brown(AAHC)	CSHEMA vital statistics survey: number of students and number of employees; total institutional expenditures and research expenditures; TNASF and RNASF (<i>n</i> = 31)	TNASF	TNASF
Parker	CSHEMA vital statistics survey re-analysis: number of students and number of employees; total institutional expenditures and research expenditures; TNASF and RNASF (<i>n</i> = 118)	TNASF, number of institutional employees, research expenditures	RNASF, number of institutional Employees, research expenditures
Inyang	CSHEMA vital statistics survey: total institutional expenditures and research expenditures; TNASF and RNASF (<i>n</i> = 55)	Total institutional expenditures, research expenditures	Total institutional expenditures, research expenditures

^aTNASF: total net assignable square footage. RNASF: research net assignable square footage. Med/Vet: do you have a medical school of a veterinary school? (yes = 1, no = 0). BSL3: do you have a biosafety level 3 or higher laboratory at your institution? (yes = 1, no = 0). CSHEMA: Campus Safety, Health, and Environmental Management Association. AAHC: Association of Academic Health Centers. Note: Each model exhibits certain clear commonalities and also some subtle differences. These differences are due to (1) the variation in the way the data were assembled for each model and (2) the assumptions used by the researcher.

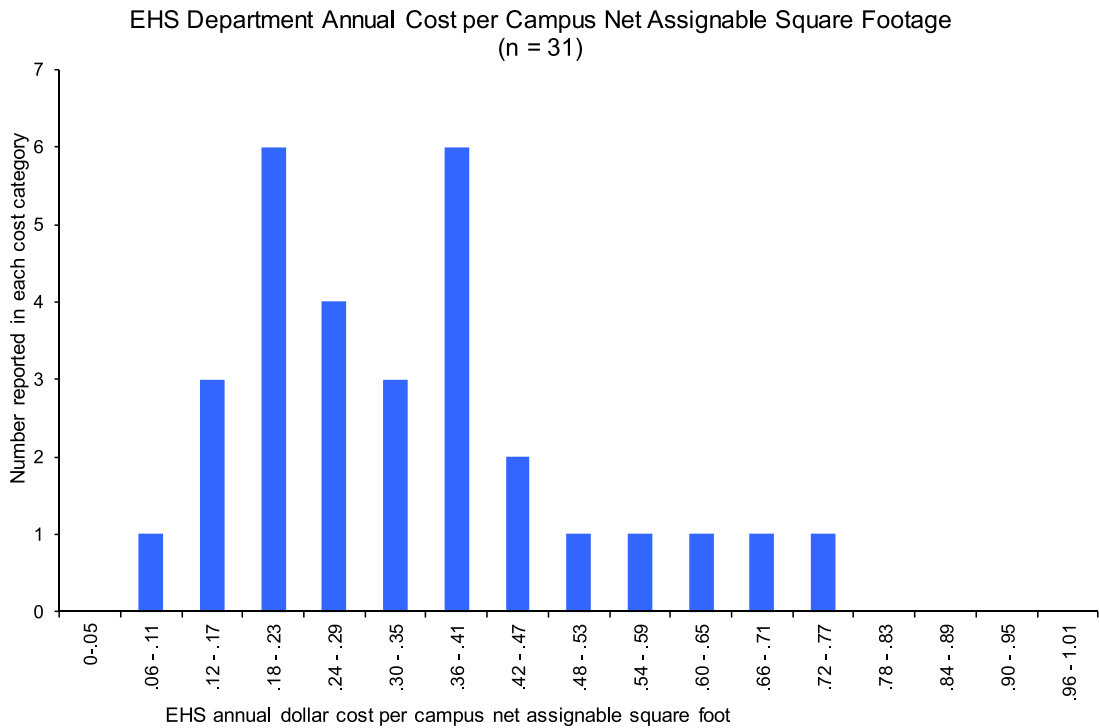


Figure 1. EHS department annual cost per campus net assignable square footage.

premiums, are also calculated for possible personnel losses. These premiums are derived based on the number of workers and the associated total payroll, along with the frequency and severity of reported injury or illness events.⁹

While models exist to aid in the development of institutional risk financing vehicles for workers and property, models for estimating the appropriate level of risk control are lacking. This issue is not unique to colleges and universities, as many who oversee prevention and compliance operations in a variety of job sectors encounter difficulties when quantifying or estimating necessary resources.¹⁰

Quantitative statistical approaches, such as regression modeling, have been used to assess optimal resources for specific safety interventions, but efforts to quantitatively

identify resource predictors for an entire safety program are absent.^{11,12}

In 1982, Fine undertook one of the earliest documented efforts to develop a staffing formula for EHS programs.¹³ Fine based his calculations on the total number of employees, plus a number of qualitative factors including the degree of hazards, the degree of EHS responsibility at the operating level, the degree of responsibility for safety assigned to line supervisors, and the degree of responsibility for developing and establishing policies. In 2010, the American Society of Safety Engineers Council on Practices and Standards (ASSE CoPS) considered Fine's work to be inappropriate, in part because it did not involve empirical data. The ASSE CoPS issued a white paper concluding that a staffing formula across industries was not

Model 1 – Wang UT SPH Practica EHS Staffing in FTE:

- Staffing = $e^{[(0.516 \times \text{Med/Vet School Presence}) + (0.357 \times (\# \text{ sq ft LAB})) + (0.398 \times (\# \text{ sq ft NOT LAB})) + (0.371 \times \text{BSL3 Presence})] - 8.618}$

Model 2a – Emery TNASF EHS staffing estimator in FTE:

- Staffing = $(3 \text{ to } 4 \text{ FTE} / 1,000,000 \text{ TNASF}) \times \text{TNASF}$

Model 2b – Emery TNASF EHS Budget Estimators:

- Budget = TNASF $\times$ \$0.30/square foot for average campus
- Budget = TNASF $\times$ \$0.45/square foot for high lab density campus
- Budget = 0.8% of Total Research Expenditures

Model 3a – Brown UT SPH Dissertation EHS “AIP” models:

- Staffing = $e^{(-19.6877 + 0.49324 \times \ln(\text{total institutional assignable sf}) + 0.72440 \times \ln(\text{total institutional expenditures}))}$
- Budget = $e^{(-7.8093 + 0.50506 \times \ln(\text{total institutional assignable sf}) + 0.69283 \times \ln(\text{total institutional expenditures}))}$

Model 3b – Brown UT SPH Dissertation EHS AAHC models:

- Staffing = $e^{(-9.039 + 0.7899 \times \ln(\text{total institutional assignable sf}))}$
- Budget = $e^{(1.587 + 0.8397 \times \ln(\text{total institutional assignable sf}))}$

Model 4a – Parker UT SPH Dissertation staffing in FTE:

- Staffing = $e^{[-20.3919 + (0.6437 \times (\ln(\text{total institutional assignable sf})) + (1.0039 \times (\ln(\text{Institutional full-time employees})) + (0.3368 \times (\ln(\text{Institutional research expenditures})))^2]}$

Model 4b – Parker UT SPH Dissertation EHS Budget:

- Budget = $e^{([4.6236 + (0.1583 \times (\ln(\text{research net assignable sf})) + (0.4891 \times (\ln(\text{full-time employees})) + (0.1805 \times (\ln(\text{institutional Research Expenditures})))])}$

Model 5a – Inyang UT SPH Dissertation EHS Staffing in FTE:

- Staffing = $e^{[-8.793154 + 0.51573 \times \ln(\text{Institutional Expenditure}) + 0.000036 \times \sqrt{\text{R\&D Expenditures}}]}$

Model 5b – Inyang UT SPH Dissertation EHS Budget:

- Budget = $e^{[3.826151 + 0.0469662 \times \ln(\text{Institutional Expenditure}) + 0.000046 \times \sqrt{\text{R\&D expenditures}}]}$

Figure 2. Model formulae.

feasible,¹⁴ but the paper did not address the creation of an industry-specific staffing benchmark.

Oyewole and Haight noted that a statistical model could better predict the allocation and optimization of resources to risk control efforts, while others identified a need to research the link between EHS characteristics to organizational measures.¹⁵ The objective of these analyses was to determine the key predictors most influential in forecasting institutional EHS program resources and to generate a model to calculate EHS staffing and expenditures.

2. METHODS

The benchmarking and modeling efforts described here represent a sequence of investigator-initiated, self-funded projects that have spanned a period of over 15 years with each building upon the knowledge gained from the previous undertakings (see Table 1).

In 2005, Wang analyzed a set of institutional benchmarking data collected as part of a Campus Safety, Health, and Environmental Management Association (CSHEMA) benchmarking effort. The data represented 102 institutions and included an eclectic set of measurements such as student population, employee population, number of buildings, number of laboratories, number of fume hoods, and so on. Wang performed a series of simple linear regression analyses to determine which independent variable was most closely related to the reported EHS program staffing size. He identified the total net assignable area (TNASF, in the form of square footage) exhibiting an R^2 value of 47.7%, as the most promising predictor. Recognizing that the data describing institutional area was log-normally distributed, he applied a natural log transformation, which improved the model to an R^2

value of 64.9%. Relying on multiple regression analysis, Wang identified three additional significant predictors: the research laboratory net assignable area, the presence of a medical or veterinary school, and the presence of BSL-3 or higher laboratory activities. These predictors are indicative of the size of the institution's research enterprise, which would prove to be important in future models. Wang's final model, shown in Figure 2, Model 1, exhibited an R^2 value of 80%.

To address the difficulties CSHEMA colleagues encounter while trying to obtain research square footage data, Emery launched a focused project with the goal of refining and simplifying Wang's model. Recognizing the primacy of TNASF, he collected two simple data points from 31 academic institutions: the EHS annual operating budget and the institutional net assignable area. After organizing the data into a frequency histogram of \$0.05 per square foot per year increments, Emery noted a data range of \$0.05 to \$0.75 per square foot with two predominant peaks (see Figure 1). The first peak centered around \$0.20 per square foot per year, and the second one centered at \$0.45 per square foot per year. Emery postulated that these two peaks reflect an institution's research activity: \$0.20 was presumed to be low research activity (as indicated by the proportion of the total net area that is designed as the research area) and \$0.45 represented high research activity. In the absence of information about the size of an institution's research space, Emery suggested using a crude estimate of \$0.30 per square foot per year as a good starting point for estimates. Comparing EHS full time equivalent (FTE) staffing to the total assignable area, he derived an estimate of three to four EHS Full Time Equivalent Staffing (EHS FTE) per million TNASF per year (see Figure 2, Model 2). Although these estimates were useful, the actual

impact of research activities remained unclear in this modeling effort.

To simplify this modeling effort, Brown worked with CSHEMA to conduct a new benchmarking survey, dubbed the “Vital Statistics Survey.” Instead of collecting data on parameters that had been previously identified as not predictive, Brown focused on collecting three key institutional parameters that were not publicly available: total institutional net assignable square feet, EHS annual expenditures, and EHS staffing level. The online survey provided links to clear definitions for each variable. The survey paired the three variables with five publicly available institutional measures: total institutional expenditures, research expenditures, research net assignable square feet, the total number of employees, and the total number of students. The publicly available databases used for these five parameters in the Brown study included the following:

1. National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS) Survey required to be completed by federal mandate¹⁶;
2. National Science Foundation, Survey of Science and Engineering Research Facilities¹⁷; and
3. National Science Foundation, Higher Education Research and Development (HERD) Survey—a voluntary survey that boasts a 95.9% participation rate.¹⁸

Brown collected institutional data in 2013, whereas the publicly available datasets ranged from 2010 to 2013. After merging the CSHEMA survey data (representing 118 usable responses) with the publicly available data on university expenditures and characteristics by the institutional name, Brown de-identified the data by removing the institutional name and assigning a unique identifying number.

In the final regression model, with EHS FTE staff as the dependent variable, Brown identified the total institutional net assignable square feet and the total institutional expenditures as the most significant predictors, explaining 72% of the variability in the model (see Figure 2, Model 3a). Brown’s final model indicated that a 1% change in the total institutional net assignable area was associated with a 0.49% change in EHS FTE staffing, while a 1% change in the total institutional expenditures was associated with a 0.73% change in EHS FTE staffing.

Brown’s final regression model identified the total institutional net assignable square feet and the total institutional expenditures as statistically significant predictors, explaining 73% of the variability in the model (Table 1), and yielded EHS expenditures as the outcome variable. A 1% change in the total institutional net assignable area was associated with a 0.50% change in EHS expenditures.

Brown also performed subanalysis on the data to determine the impact (if any) of institutional differences, such as public versus private, large or small campuses, or location (east coast or west coast), and graduate medical programs. He detected only one statistically significant difference within the dataset: whether or not the institution reported to be a member of the Association of Academic Health Centers. The modeling formula for these institutions is shown in Figure 2, Model 3b.

A critique of Brown’s work discussed how he compared data sets from different time periods. He compared data collected in 2013 to publicly available datasets that dated from as far back as 2010. This situation was unavoidable because the time needed to assemble and validate the data, delays its availability

by a year or two. To address this issue, Parker performed a re-analysis of Brown’s 2013 data in 2016. Supplementing Brown’s data with updated publicly available data, Parker applied other statistical techniques in his modeling and produced the formulas shown in Figure 2, Models 4a and 4b.¹⁹ Although Parker used different statistical methods than Brown, the total institutional net assignable square feet and the total research expenditures remained key predictors along with the total number of institutional employees.

In coordination with CSHEMA, Inyang performed a subsequent benchmarking study in 2020 to investigate the dependence of laboratory density, that is, the research net assignable area (RNASF), as a proportion of the TNASF, on EHS program staffing and expenditure resources for colleges and universities. The three institutional variables and variable definitions used by Brown²⁰ were obtained from the 2020 CSHEMA Vital Statistics II Survey. Inyang merged the survey data (55 usable responses, representing 16% of the surveyed population) with publicly available data on the total institutional expenditures, the institution’s research expenditures, research net assignable square feet, and then de-identified the data. In terms of the level of research activity, the 55 CSHEMA member institutions included in the analysis represented four-year CSHEMA member colleges and universities within the United States.

A high positive correlation existed between EHS FTE staffing and all predictor variables: TNASF, total institutional expenditures, research and development expenditures, and the RNASF. The predictor variables included TNASF ($r = 0.78$), total institutional expenditures ($r = 0.88$), research and development expenditures ($r = 0.92$) and RNASF ($r = 0.85$). Similarly, a high positive correlation existed between the EHS expenditure and the following predictor variables: TNASF ($r = 0.75$), total institutional expenditures ($r = 0.93$), research and development expenditures ($r = 0.94$), and RNASF ($r = 0.81$). The relationship between EHS FTE and laboratory density, that is, the proportion of the RNASF to the TNASF, showed that surveyed institutions average 3.25 FTE for every million square feet of the TNASF and about \$505,000 in EHS expenditure for every million square feet of the TNASF. The multiple regression of EHS FTE with predictor variables using laboratory density ($n = 55$) indicated that 83.29% of the variance in EHS FTE can be predicted from the transformed independent variables and that the model variables reliably predict the dependent variable ($p < 0.0001$). The model indicated that a 1% change in the laboratory density was associated with a 0.85% change in EHS FTE, when all other variables are held constant.

Multiple regression of transformed EHS expenditures with transformed predictor variables using the laboratory density ($n = 55$) was then performed. Results indicated that 71.9% of the variance in EHS expenditures can be predicted from the transformed independent variables and that the model variables reliably predict the dependent variable ($p < 0.0001$). When all other variables are held constant, the model indicated that a 1% change in the laboratory density was associated with a 0.15% change in EHS expenditures, while a 1% change in the total institutional expenditures was associated with a 0.47% change in the EHS expenditure.

Unfortunately, the onset of the COVID-19 pandemic dramatically impacted response rates. (A response of 55 was well below the targeted sample size of 90 valid respondents.)

However, the survey results gleaned some very useful information.

3. RESULTS

The models developed in this project have direct practical applications for estimating the level of staffing and financial resources that may be needed for the EHS department to operate. To assist with this effort, we developed a tool that uses identified key predictors to calculate EHS staffing and expenditures that are reflective of industry averages for colleges and universities based on various benchmarking datasets that were either publicly available or provided by CSHEMA members.

In spring 2021, members of the CSHEMA Communities of Practice pilot tested the tool for feasibility and function. In summer 2021, we released a beta version of this calculator tool. It is available online, at no cost, on the Prevention, Preparedness, and Response (P2R) Consortium website at

Inputs	
<u>Your Current Key Predictors</u>	
1 Total Institutional Net Assignable Square Footage Square footage of all buildings on and off campus, owned or rented.	Enter Institution Information in Each Box 5,000,000 Square Feet
2 Research Net Assignable Square Footage Also known as research space.	600,000 Square Feet
3 Total Annual Institutional Expenditures Total amount of funds expended by the institution & is published.	\$1,000,000,000 U.S. Dollars
4 Annual Research Expenditures All research and development expenditures from the institution's current operating funds.	\$200,000,000 U.S. Dollars
5 Number of Full-Time Employees at Institution Number of Full-Time Employees at the institution.	4,000
6 Total Annual EHS Expenditures Total amount of funds expended by the EHS department annually.	\$2,500,000 U.S. Dollars
7 Total Number of EHS Staff (FTE) Number of full-time plus part-time employees (converted to full-time basis).	15
8 Specialty Considerations	
- Does your institution have a medical or veterinary school?	YES
- Does your institution have a biosafety level (BSL) 3 or higher facility?	YES
- Is your Institution a member of Association of Academic Health Centers?	YES

Figure 3. Inputs section of the calculator tool at the P2R Consortium website.

<http://p2racademy.org/Calculator.html> (see Figures 3, 4, 5). To use the tool, the following inputs are needed:

1. Total institutional net assignable square footage (TNASF): This measurement includes the square footage of all buildings on and off campus, owned or rented, such as residence halls, nonresidence buildings, and remote research buildings. This total excludes facilities rented to other organizations. An institution's facilities management department typically can provide

this total. In our example, we use a TNASF of 5 million square feet.

2. Research net assignable square footage (RNASF): This is the total research area reported by each institution and is known as "research space" by the National Science Foundation. This number can be found at the National Center for Science and Engineering Statistics (NCSES) Science and Engineering Research Facilities at <https://ncsesdata.nsf.gov/ids/>. In our example, we use a RNASF of 600,000 square feet.
3. Total annual institutional expenditures: This is the total amount of funds expended by the institution and published in the general purpose financial statement. It is available at the Integrated Postsecondary Education Data System (IPEDS) Total Assets at <https://ncsesdata.nsf.gov/ids/>. In our example, we assume a total annual institutional expenditure of \$1 billion.
4. Annual research expenditures: This amount is the total research and development expenditures from the institution's current operating funds. This figure is available from the Higher Education Research and Development (HERD) data source located within the NCSES Interactive tool at <http://nces.ed.gov/ipeds/use-the-data>. In our example, we assume annual research expenditures of \$200 million.
5. Number of full-time employees at the institution: This is the number of full-time equivalent employees at the institution. This number should be available from human resources. Our example institution has 4,000 full-time equivalent employees.
6. Total annual EHS expenditures: This is the total amount of funds expended by the EHS department annually, including salaries and operations and maintenance. This amount does not include capital expenditures or benefits. This figure is likely available from the EHS director or a budgetary support person. In our example, we assume an amount of \$2.5 million in EHS department expenditures each year.
7. Total number of EHS staff, full-time equivalent: This is the sum of full-time EHS employees plus the number of part-time EHS employees converted to a full-time equivalent. This includes technical, managerial, administrative, and contract workers who support EHS functions at least 20 hours per week. Our example institution's EHS department employs 15 full-time equivalent workers.
8. Specialty considerations: In our example institution, we chose "yes" for all specialty consideration from the dropdown menu.

Outputs						
Results:						
Models	Budget Estimate			Workforce Size Estimate		
	\$	% Difference Compared to Actual	Above/Below Industry Average	# FTE	% Difference Compared to Actual	Above/Below Industry Average
Wang Model	N/A	N/A		22.4	▼ 49.03%	Below
Emery TNASF Model	\$2,250,000	▲ 10.00%	Above	20.0	▼ 33.33%	Below
Brown All Model	N/A	N/A	Above	N/A	N/A	Above
Brown AAHC Model	\$2,062,293	▲ 17.51%	Above	23.2	▼ 54.82%	Below
Parker Model	\$1,523,312	▲ 39.07%	Above	18.5	▼ 23.33%	Below
Aggregate Average Prediction*	\$1,458,901	▲ 41.64%	Above	16.8	▼ 12.10%	Below
*Based on all models weighted equally						

Figure 4. Outputs section of the calculator tool at the P2R Consortium website.

Interpretation	
Based on industry averages:	
- Funding for the institution's EHS department is:	Above Average
- The size of the institution's EHS staff is:	Below Average

Figure 5. Interpretation box within the calculator tool at the P2R Consortium website.

- Does the institution have a medical or veterinary school?
- Does the institution have a biosafety level (BSL) 3 or higher facility?
- Is your institution a member of the Association of Academic Health Centers?

After entering the input information (Figure 3), scroll down to the outputs section (see Figure 4). In this section, the calculator tool estimates budget and workforce sizes, and compares these totals to industry averages. The results are displayed for each model individually and in aggregate. The aggregate results weigh each model equally. Below the outputs section is an interpretation box (see Figure 5). This box clearly states whether the funding and staffing size of the EHS department are *above* or *below* the industry averages. This interpretation can be used in administrative reports to university officials. In our example, the outputs and the interpretation box indicate that the budget for the EHS department is above the industry standard; however, the number of full-time EHS employees is below the industry average.

4. CONCLUSIONS

The power of these iterative models is that each independently identifies a short set of key institutional predictors. Unfortunately, however, many EHS professionals do not have these predictors readily at hand and typically are not trained to collect such information. While there are variations within the models, each provides decision makers and other stakeholders with critical industry average reference points. This is particularly important, given the constant change that occurs in leadership positions within colleges and universities. In some cases, a new leader may have EHS within their management portfolio, but lack specific knowledge related to EHS functions, resource needs, and comparative reference points for estimating costs for those resource needs.

Finally, a note of clarification: these models estimate program “inputs,” such as staffing and budget. The models do not predict “outcomes,” such as injuries, illnesses, deaths, regulatory noncompliance, program costs, and client satisfaction. As future efforts are undertaken in this field, determining relationships between program inputs and outcomes would be very useful for the entire profession.

AUTHOR INFORMATION

Corresponding Author

Robert J. Emery – *UTHealth School of Public Health, Houston, Texas 77030, United States; UTHealth Safety, Health, Environment, and Risk Management (SHERM), Houston, Texas 77054, United States*; orcid.org/0000-0002-6609-237X; Phone: (713) 500-8100; Email: Robert.J.Emery@uth.tmc.edu

Authors

Bruce J. Brown – *The University of Texas Southwestern Medical Center, Safety and Business Continuity, Dallas, Texas 75390, United States*

Jing Wang – *UTHealth, Houston, Texas 77225, United States; AbbVie Inc., North Chicago, IL 60064, United States*

Seth Parker – *UTHealth School of Public Health, Houston, Texas 77030, United States*

Otu Inyang – *Environmental Health & Safety, University of Houston, Houston, Texas 77204, United States*

Janelle Rios – *UTHealth School of Public Health, Houston, Texas 77030, United States*

Complete contact information is available at:

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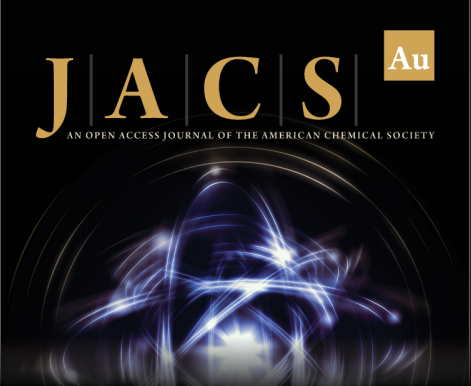
ABBREVIATIONS

ASSE CoPS, American Society of Safety Engineers Community of Practices and Standards; FTE, full time equivalent; TNASF, total net assignable square footage; RNASF, research net assignable square footage; BSL3, biosafety level 3; CSHEMA, Campus Safety Health and Environmental Management Association; AAHC, Association of Academic Health Centers; EHS, Environmental Health and Safety

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