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Editorial

It is with my greatest pleasure to summarize three remarkable articles in the 2017 spring issue. The scholars are from three universities across North America, including Embry-Riddle Aeronautical University, the University of Alabama and Ryerson University.

The first article, "Choosing a Career Path: Why Not Safety and Health? Identifying Factors That Influence Students' Choices, Part 1," by Michael F. O'Toole, Kimberly J. Szathmary, Jennifer E. Thropp and Vincent J. Baeri of Embry-Riddle Aeronautical University, focuses on identifying significant influences that shape a student's selection of a college major, specifically in the occupational safety and health area. A survey was developed to identify those factors that were most influential in students' career choices. The surveys were finished by university students who are currently enrolled in an occupational safety and health degree program. The results have shown that one of the major influencing factors was that of conversations with professors at their university.

In the second article, "Site Location Optimization of a Tower Crane Through Building Information Model (BIM)," Xu Shen and Eric Marks from the University of Alabama conducted a study on optimizations of crane location selection based on safety and productivity. The authors created a framework within a BIM to optimize the two-dimensional (2-D) location of a tower crane for a given construction site. According to their research, by optimizing the location of the tower crane in an existing BIM, hazardous conditions can be decreased by identifying and mitigating situations in which a load lifted by the tower crane crosses the travel path of equipment and pedestrians.

For the third article, "Occupational Health and Safety Legislative Gap Analysis of the Food Processing Sector in Ontario, Canada: A Pilot Study," Chun-Yip Hon and Craig Fairclough from Ryerson University in Canada evaluated the occupational health and safety (OHS) hazards within the food processing sector. The study was to determine the level of compliance of that sector with the relevant OHS legislation as well as produce a sector-specific priority list of OHS concerns. The authors utilized an online legislative gap analysis questionnaire. Participants were individuals in a database of alumni OHS students/registrants. The results show several legislative gaps related to inadequate training, lack of relevant OHS policies and insufficient hazard identification activities. Finally the authors summarized the top three concerns: 1) manual material handling; 2) slip, trips and falls; and 3) energized equipment.

I hope that you enjoy these articles. As always, I look forward to hearing from you and welcome your future submissions.

Sincerely,

Sam Wang, Ph.D., P.E., CSP
Managing Editor, JSHER

Choosing a Career Path: Why Not Safety & Health?

Identifying Factors That Influence Students' Choices: Part 1

Michael F. O'Toole, Kimberly J. Szathmary, Jennifer E. Thropp and Vincent J. Baeri

Abstract

This study is the first of a two-part exploratory study that seeks to identify the significant influences that shape a student's selection of a college major, specifically in the area of occupational safety and health. College students across the U.S. completed a survey designed to identify those factors that were most influential in students' career choices. The research focused on university students who are currently enrolled in an occupational safety and health degree program at an accredited college or university in the U.S. The results suggest that one of the major influencing factors for surveyed students was that of conversations with faculty members at their university. The second part of the research was conducted in the latter part of 2016 with a survey of high school students.

Keywords
Career choices, safety degree, safety and health, choice of major

Choosing one's career path is arguably one of the most important decisions a person will make in his or her life. The choosing of a college major is the first major step along that path. A review of relevant literature identified individuals' decision-making processes in arriving at that all-important decision, noting the factors taken into account when choosing an academic major. Knowing what factors are most important when choosing an institution, as well as those significant influential factors that affect the selecting a major, can improve recruitment efforts not only for safety-and-health-related programs, but for all higher education programs. Understanding the impact, if any, of faculty, academic advisors and university-offered career services can help shape efforts to ensure time and resources are spent productively.

A qualitative study by Walmsley, Wilson and Morgan (2010) followed groups of students who either entered their university with an undecided major, or who changed their majors from the one they originally selected, and provided useful insights as to factors that influenced their decisions. Walmsley, et al. (2010) found that personal relationships (family and peers), faculty relationships, and extracurricular experiences such as research opportunities and internships had the greatest impact on students' decisions.

Aside from peers, instructors, many of whom act as student advisors and mentors to students, were found to be one of the greatest sources of positive (and negative) influence toward many majors. Similar findings were also expressed by Edmonds (2012). Generally, students were greatly influenced by faculty who were supportive, enthusiastic and were able to discuss how such majors apply to jobs "in the real world" (Walmsley, et al., 2010). Sharing real-life experiences can help students picture themselves in careers after college. Internships go a step further in helping students validate their career decisions.

As expected, the other factors affecting students' choice of major included their interest in the field, probability of employment, expected earnings and psychological/social benefits (Edmonds, 2012). Job characteristics, fit and interest in the subject, financial considerations and psychological/social benefits were the major influences listed by Gordon and Steele (2015). Researchers agreed that students tend to choose majors in line with their own assessment of their skills and abilities (Edmonds, 2012; Roach, McGaughey & Downey, 2012; Walmsley, et al., 2010). As college students face an uncertain future, the impact of this choice on their future opportunities for employment, job satisfaction and pay should ensure their thoughtful consideration. Choosing a career that students will genuinely find interesting

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Kimberly J. Szathmary, Ph.D., is an assistant professor of aerospace and occupational safety in the College of Aviation at Embry-Riddle Aeronautical University's Daytona Beach campus. She is an FAA-certificated multiengine commercial pilot and flight instructor, a retired U.S. Air Force C-17 pilot and squadron chief of flight and ground safety.

Jennifer E. Thropp, Ph.D., is an assistant professor of graduate studies in the College of Aviation at Embry-Riddle Aeronautical University's Daytona Beach campus. Previously, she supported the safety requirements of the Space Shuttle Program at the Kennedy Space Center.

Vincent J. Baeri, M.S., is a recent graduate of Embry-Riddle Aeronautical University, from which he holds a B.S. in Air Traffic Management and an M.S. in Aeronautics. He is an aviation safety analyst for an aviation consulting group in Washington, DC.

may be the most important factor in choosing a major (Malgwi, Howe & Burnaby, 2005). While students' interests might be the original motive for choosing a specific major, students' perceptions regarding a particular career path of interest might well be too narrow or unrealistic. Researchers found that faculty members and advisors can help students adjust their perspectives of life in their chosen career fields beyond academia (Walmsley, et al., 2010). The professional perspective can be an eye-opener, and can instill confidence in that all-important decision.

Compensation in the form of starting salaries and potential career earnings was important to students when choosing nontechnical majors (Walmsley, et al. 2010). Students look for reinforcement of salary information from those in the field and from career services (Roach, McGaughey, Downey, 2012), especially when they perceive themselves as making heavy investments in their education. Job security ranked high in many works (Gordon & Steele, 2015; Malgwi, et al., 2005; Roach, et al., 2012), each mentioning that some data were collected during times of financial upheaval and heavy unemployment in the U.S.

Method

A 16-item survey instrument was developed to help the authors identify the factors that may have influenced currently enrolled students' decisions to major in an occupational safety and health (OSH)-related degree program. The items in the survey were developed based on the experience of the authors as well as that of full-time faculty members from several colleges and universities, each teaching in an occupational safety degree program. A copy of the survey items is included in Appendix A (p. 329). These items are categorical in nature and therefore lend to descriptive statistics.

Student participants were asked to respond to statements or questions by selecting responses that represented factors that influenced their decision to enroll or transfer into an OSH-related program. The participants were also given the opportunity to cite any other factors that may have helped them make their career choice.

Each survey item was developed to fit into one of four general areas. The first area grouped questions/statements related to factors or issues that initially attracted them to pursue a degree in safety and health. The second group of questions/statements looked to identify factors that influenced their choice to enroll in their current academic institution. The third area assessed current students' understanding of membership in professional societies that support their career choice. Lastly, general demographic data were collected in an attempt to develop a profile of students who are currently enrolled in a safety and health degree program.

A total of 236 students from across the U.S. voluntarily completed the survey, including 142 male and 94 female students. All surveys were completely filled out, eliminating the need to exclude any of the voluntary participants from the pool. The students were enrolled in one of five participating universities or were in attendance at ASSE's Future Safety Leaders Conference (FSLC) held in October 2015.

The FSLC is a multi-day conference attended by students who are nominated by their executive committee and student section advisor from an ASSE student section at their college or university. These student members are generally officers or committee chairs in their student sections and are attending the conference to be exposed to various leadership techniques of volunteer organizations as well as means to prepare for their transition from student to working professional. There were 125 student participants at the conference with 47 completing the survey. Additional demographic or survey data from this population were not gathered in order to keep any analyses consistent across all participants.

The five participating academic institutions were located in Florida, Michigan, Missouri, Pennsylvania and Wisconsin. The Florida school included 58 majors (22 females and 36 males); the school in Michigan had 119 majors (58 females and 61 males); the Missouri safety program included 357 majors (52 females and 305 males); the school in Pennsylvania had 129 majors (22 females and 107 males); and the Wisconsin school included 163 majors (25 females and 138 males).

All of the participants from these universities were currently enrolled and majoring in an OSH-related degree program. The universities and their safety and health programs are believed by the authors to be representative of safety and health degree programs throughout the U.S. No undergraduate safety and health degree programs were identified in the western U.S. Three of the five programs are independently accredited through either ABET or the Aviation Accreditation Board International (AABI), and the Board of Certified Safety Professionals (BCSP) gives their graduates the graduate safety practitioner (GSP) designation.

The survey was produced in SurveyMonkey for ease of delivery to the participants. Each participating group received a separate link for their university to allow for comparison among and between the groups. The survey was available to students attending the ASSE FSLC for a week prior to their arrival and for the 4 days they were in attendance. During the conference, ASSE leaders periodically reminded and encouraged students to participate in the survey.

The survey link was then sent to the five participating universities in early November and was available to students during the months of November and December 2015. All surveys were completed prior to the end of the fall 2015 semester. Each participating university was sent the data tables with the identities of the other participating universities deleted.

The data were imported into SPSS Version 22 to compute the descriptive statistics. Responses to each item were analyzed for their proportion of the total responses.

Results

Not surprisingly, current students responded that the career opportunities presented by a degree in safety and health was an important factor in selecting that degree choice (Table 1, p. 325). Closely associated with that item was their perception of the issue of "daily task variety" as an attractive feature of this profession.

It appears from the survey results that a fair number (45.7%) of the respondents first became aware of safety and health as a career path through their college professors (Table 2, p. 325). Other factors that appear to have influenced students' decisions were family members, friends and neighbors, and current safety and health professionals.

Just more than one-half of the students identified manufacturing as the industry segment to which they will likely seek employment after graduation (Table 3). The construction industry was another significant industry segment identified by current students as a desired career path (44.5%). Consulting (33.9%) and government (34.9%) were also identified as appealing by students completing the survey. These results may be due to the potential variety of experiences these career paths present. Transportation was selected by 27.1% of the respondents with further divisions selected within that category (Table 3). Student respondents were asked to select up to three choices related to a desired or appealing industry segment for employment as a safety and health professional, which explains why the totals are greater than 100% for this factor.

Question 7 asked participants whether they switched into their safety major from another degree program (Table 4). Of the respondents, 45.7% indicated they had switched into the OSH-related degree program at their current university. In addition, Question 8 asked participants if they transferred to their current institution form another college or university. About one-third of students reported having transferred to their current academic program from another college or university (either 2-year or 4-year).

The training and education that a student receives is only a means to an end, that of securing meaningful employment in their chosen field. Question 5 sought students' perceptions on how long after graduation they expect to secure meaningful employment (Table 5, p. 327). The vast majority of students reported that they expect to secure employment in their field within three months of graduation.

Once enrolled in a safety and health degree program, students are encouraged to join the student section or chapter (if one is available) of one of the professional societies such as ASSE, American Industrial Hygiene Association (AIHA) or International Society of Air Safety Investigators (ISASI). When responding to Question 12, 71% of students indicated they belong to one of these student organizations (Table 6, p. 327).

Factor	Percentage
Career opportunities	70.5%
Making a difference	66.4%
Daily task variety	65.4%
Save lives	63.4%
Expected career stability	52.0%
Expected starting salary	47.5%
Accident investigations	41.5%
Interaction with people	38.2%
Technical aspects	33.2%
Significant challenges	27.2%
Not math intensive	19.8%

Table 1: Factors that attracted students to consider safety as a degree program

Factor	Percentage
College professor	45.7%
Family member	33.3%
Safety professional	31.1%
Friend/neighbor	26.9%
Job Fair	15.1%
Alumni	12.3%
Current/previous employer	11.9%
Websites	8.7%
Other	7.8%
Industry expo	5.0%
TV show/movie	4.6%
High school teacher or guidance counselor	4.1%
Social media	1.4%

Table 2: Factors that increased participant awareness of safety as a career path

In response to a follow-up question (Question 10), 81.7% students indicated they would pursue the certified safety professional (CSP) certification as soon as they were eligible. Of those students who reported that they would not pursue the CSP certification, 16.7% indicated it was because they did not see the value in the CSP certification (Question 11).

Question 7 sought students' consideration of pursuing an advance degree such as an M.S. or MBA. Response to this item showed 27.1% of undergraduates intend to pursue an advanced degree immediately after graduation (Table 7, p. 328). The vast majority of respondents indicated that they intend to pursue an advanced degree within 5 years of graduation.

The balance of the questions attempted to better characterize those students currently enrolled in safety related degree programs. Question 13 sought to identify the distance from their hometown students commuted or relocated to attend their current institution. Responses revealed that 21.9% relocated or commuted less than 25 miles from their hometown to attend their current college or university (Table 8, p. 328).

Question 15 identified the age of respondents within four age groupings (Table 9, p. 328). Only 2.3% were 17 to 18 years old at the time of the survey. Question 14 sought to identify the gender of respondents. Not surprisingly, 64.8% respondents identified themselves as male. Lastly, Question 16 sought the class rank of students' responding to the survey. Super seniors, who are students who did not graduate within the traditional 4 years of an undergraduate degree, made up 19.8% of respondents. In the authors' experience, many of those super seniors were likely students who transferred into the safety degree program from another program or college.

Factor	Percentage
Manufacturing/production	50.5%
Construction	44.5%
Consulting	33.9%
Government	34.9%
Transportation	27.1%
- Aviation	33.0%
- Rail	14.7%
- Maritime	9.6%
- Trucking	4.1%
Insurance	26.6%
Petrochemical	18.3%
Academic	16.5%
Mining	14.7%
Utilities	14.7%
Service industries	12.8%
Religion/charitable	5.0%

Table 3: Factors participants found appealing regarding safety as a career path

Did you transfer into the safety-related degree program from another degree program?

Factor	Percentage
Yes	50.7%
No	49.3%

Did you transfer to your current college/university from another academic institution (2year or 4 year?)

Factor	Percentage
Yes	37.9%
No	62.1%

Table 4: Percentage of students transferring into a safety-related degree program

Discussion

The results of the survey were not particularly revealing to the research team or other faculty members teaching within safety and health degree programs. Safety as a "found degree" at most institutions is supported by commonly accepted anecdotal data. What this study accomplished is providing objective data that clearly affirms the anecdotal data. More than 50% of the respondents indicated that they transferred into the safety and health program from another degree program at their college or university. Adjunct to that data is the 37.9% of students who reported that they transferred into a safety and health-related degree from another college.

The results of this preliminary study and those of previous limited research in this area suggest there is a lack of information available for high school students that inform them about potential career opportunities as a safety and health professional. There is also a lack of information related to the value-added aspects this career field presents to employers in most any industry. This lack of information precludes most students from ever considering a safety and health degree program or seeing it as a viable and desirable career path. The results of this research suggest that, once some students learn about the opportunities and details of safety and health careers, they switch degree programs. Being able to identify with a career that "makes a difference" or helps to "save lives" appears to be factors that strongly influenced current students' decision to change their major.

It has been the experience of the authors and many of their colleagues that students "discover" the safety and health degree program at their university after taking an introductory safety and health course. The students identified other factors such as "making a difference" and "saving lives," which appears consistent with anecdotal observations from faculty members at institutions with undergraduate safety and health degrees (T. Loushine and H. Fonooni, personal communication, June 8, 2014; J. Ogutu, personal communication, March 10, 2015).

A second path that current students follow to a degree in safety and health is a change of major after a semester or two in their initial degree program, discovering it is not a good fit for them for any number of reasons. It has been the experience of the authors that students in other degree programs often are required to take an introductory course in safety and health as part of their degree program. Once exposed to the profession, it is not unusual to have several students change degree programs or at least add safety as a minor to their degree. Nationwide, approximately 80% of students change their majors in college, according to the National Center for Education Statistics, which also indicated that many students will change their major an average of three times.

Conclusions

It is imperative that those institutions offering an undergraduate degree in safety and health work with those school districts that are primary sources of incoming students. Only through a concentrated effort will appropriate information get into the hands of students, parents and guidance counselors so that informed decisions can be made.

Additionally, professional societies such as ASSE, American Industrial Hygiene Association (AIHA), International Systems Safety Society (ISSS) and International Society of Air Safety Investigators (ISASI) need to work with those colleges and universities that prepare students to enter their associated profession. The authors believe that joining and participating in these professional societies that support their future profession may have an influence in their retention in that program. Graduates from these programs often become full members in the allied society. Therefore, these professional societies have a vested interest in attracting new students into related degree programs. According to an BCSP salary survey (Readex Research, 2015), those in safety and health careers with advanced degrees earn $9,000 more annually than those with a bachelor's degree.

This research was a preliminary study and was intended to gather and examine information related to factors that may have influenced a currently enrolled student's decision to pursue a safety and health-related career path. There is a need to extend this preliminary study to high school juniors and seniors to examine the degree to which they are aware of OSH-related degree programs and career paths. The results of that research will hopefully provide more specific guidance to colleges and universities that offer environmental, health, and safety degrees, and prove valuable information for enhancing their recruitment efforts. It should also provide similar value to allied professional societies in their quest to promote the profession.

How long after graduation do you expect it will take to find a suitable safety-related position?

Factor	Percentage
Offer before graduation	38.8%
Within three months of graduation	48.3%
Within six to eight months of graduation	12.9%

Table 5: Employment expectations

Are you currently a member of a student safety organization such as the American Society of Safety Engineers (ASSE), the International Society of Air Safety Investigators (ISASI), or the American Industrial Hygiene Society (AIHA)?

Factor	Percentage
Yes	71%
No	29%

If you plan to pursue the Certified Safety Professional (CSP) certification, when will that likely occur?

Factor	Percentage
As soon as I am eligible	81.7%
Within 10 years	10.0%
Do not plan to pursue the CSP	8.3%

If you do not plan to pursue the Certified Safety Professional (CSP) certification, why not?

Factor	Percentage
I don't see the value in the CSP certification	16.7%
I don't know about the CSP eligibility requirements	31.3%
I have heard of the CSP but I do not feel I know enough about it	52.1%

Table 6: Student membership in safety-related professional society

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Upon completion of your undergraduate degree, do you plan to continue your education and attain an advanced degree such as a Master of Science or MBA?

Factor	Percentage
Immediately upon graduation	27.1%
Shortly after securing employment	33.7%
Within 5 years of graduation	36.1%
No source of funding	1.8%
I do not see the benefit of an advanced degree	1.2%

Table 7: Pursuit of advanced degree

The distance between your "hometown" and the location of your college/university is…

Factor	Percentage
Less than 25 miles	21.9%
26 – 50 miles	24.7%
15 – 100 miles	15.5%
101 – 500 miles	20.1%
Greater than 500 miles	17.8%

Table 8: Distance from hometown and current college/university

Age of those students completing the survey

Factor	Percentage
17 – 18 years old	2.3%
19 – 21 years old	35.6%
22 – 25 years old	31.1%
More than 25 years old	31.1%

Gender

Factor	Percentage
Male	64.8%
Female	34.2%
Did not answer	0.9%

Rank of class

Factor	Percentage
Freshman	6.3%
Sophomore	10.6%
Junior	25.1%
Senior	38.2%
Super Senior	19.8%

Table 9: Participants' age, gender and class rank

APPENDIX A

When did you first become aware of safety (including health, environmental, industrial hygiene, fire science, etc.) as a potential career path? (Select one)

❏ Elementary School
❏ Middle School
❏ High School
❏ Military Service
❏ After enrollment in a college or university
❏ Exposure to a working professional during a summer job or internship
❏ Family member or neighbor
❏ Other ____________________________

Through which of the following sources did you become aware of safety as a potential career path? (Select all that apply)

❏ TV show or movie
•Which one?
❏ High school teacher or guidance counselor
❏ College professor
❏ Job or career fair
❏ Industry Expo
•Which one?
❏ Safety professional
❏ Other industry professional
❏ Family member
❏ Friend or neighbor
❏ Alumni
❏ Current or previous employer
❏ Magazine
•Which one?
❏ Website
•Which one?
❏ Social Media
•Which one?

What factor attracted you to major in safety? (Select all that apply)

❏ It is not math intensive
❏ I am interested in accident investigation
❏ The technical aspects of the profession
❏ Potential career opportunities
❏ The opportunity to make a difference within an organization
❏ Expected starting salaries
❏ To have a career where I don't do the same thing every day
❏ To save lives
❏ Work in a technical field and still deal with people
❏ Expected career stability
❏ Significant challenges
❏ Other__________________________

Which of the following potential career paths do you find most appealing? (Select up to three)

❏ Insurance
❏ Manufacturing and production
❏ Transportation
❏ Trucking ❏ Aviation ❏ Maritime ❏ Rail
❏ Utilities
❏ Mining
❏ Construction
❏ Service
❏ Consulting
❏ Government
❏ Petrochemical
❏ Academic
❏ Religious or charitable organization
❏ Other ___________________________________

Upon completion of your undergraduate degree, do you plan to continue your education and attain an advanced degree such as a Master of Science or MBA?

❏ Yes
If yes, when?
❏ Immediately after completing my BA/BS degree
❏ Shortly after securing employment in the field
❏ Within 5 years of graduation
❏ No
If no, why not?
❏ Cannot afford additional debt
❏ No source of funding
❏ I do not see the benefit of an advanced degree

Did you transfer into the safety or safety-related degree program from another degree program at your current college/ university?

If yes, what was your previous degree program?

How long after graduation do you expect it will take to find a suitable safety-related position?

❏ Offer before graduation
❏ Within 3 months of graduation
❏ Within 6-8 months of graduation

Do you plan to pursue the Certified Safety Professional (CSP) certification?

If yes, when?
❏ As soon as I am eligible
❏ Within 10 years after graduation
If no, why not?
❏ I don't see the value in the CSP certification
❏ I don't know the CSP eligibility requirements
❏ I don't know what the CSP certification is

Are you currently a member of a student safety organization such ASSE, International Society of Air Safety Investigators (ISASI) or American Industrial Hygiene Association (AIHA)?

❏ Yes ❏ No

The distance between your hometown and the location of your college/university is . . .

❏ Less than 25 miles ❏ 26-50 miles
❏ 51-100 miles ❏ 101-500 miles
❏ > 500 miles

Gender

❏ Male ❏ Female

Age

❏ 17-18 ❏ 19-21 ❏ 22-25 ❏ 26 or older

Rank in school

❏ Freshman ❏ Sophomore ❏ Junior ❏ Senior

Site Location Optimization of a Tower Crane Through Building Information Modeling (BIM)

Xu Shen and Eric Marks

Abstract

Construction site layout planning can be described as a multi-criteria optimization problem that is traditionally resolved using two-dimensional project data. Although construction researchers have investigated construction site layout methods, few studies have identified methods of optimization for crane location selection based on safety and productivity. This research creates a framework within a building information model (BIM) to optimize the two-dimensional location of a tower crane for a given construction site. The created algorithms optimize the tower crane's location based on safety and productivity constraints specifically that 1) the tower crane must access the majority of material in the lay down area and the structure and 2) the crane boom coverage radius over a travel pathway is minimized. By optimizing the location of the tower crane in an existing BIM, hazardous conditions can be decreased by identifying and mitigating situations in which a load lifted by the tower crane crosses the travel path of equipment and pedestrians. The contribution of this research is an implementable framework in BIM that can automatically identify the optimal location of a tower crane for productivity and safety applications as well as scientific evaluation data of this framework on an active construction site.

Keywords
BIM, construction productivity, construction safety, tower crane optimization, site layout planning

Site layout of construction resources can have a significant impact on construction productivity (Zhang, Harris & Olomalaiye, 1996), safety (Neitzel, Seixas & Ren, 2001), environmental issues (Sanad, Ammar & Ibrahim, 2008) and overall cost (Anumba & Bishop, 1997). Members of the construction industry have identified the locational placement of construction equipment, including a tower crane, has a significant impact on the overall success of a project including increased productivity and safety (Sadeghpour & Andayesh, 2015). Because of its significant impact, considerable time and effort should be allocated during the pre-planning phase of a construction project to determine the location of a tower crane.

There are approximately 125,000 tower cranes throughout various construction projects in the U.S. Tower cranes are a useful piece of construction equipment because they provide overhead lifting capacity to transport materials and equipment to various locations on the construction site. Efficient and safe operation of tower cranes is the utmost importance in project safety, schedule and overall success (Kang, Chi & Miranda, 2009).

These tower cranes present multiple safety challenges for construction site personnel including 1) crane boom contact with energized power lines; 2) overturned cranes; 3) dropped loads from height; 4) crushing or falling of counterweights; 5) boom collapse; and 6) rigging failures (OSHA, 1996). Tower cranes are a central component of many construction operations and are associated with a large fraction of construction deaths (Neitzel, Seixas & Ren, 2001). As many as one-third of all construction and maintenance fatalities and injuries were contributed by cranes (English, 1994).

This research creates and implements a tower crane location optimization tool using building information modeling (BIM) software as a platform. BIM allows designers and contractor personnel to manage a project through the whole building life cycle including planning, designing (Penttila, 2007), construction (Kymmell, 2008) and operation (Akcamete, Burcu & Garret, 2010). The optimization framework integrates commonly used computing software (MATLAB) with an open API interface within a commonly used BIM software (Revit) to find the optimal location for a tower crane in a simulated construction site. Constraints implemented for the locating of the two-dimensional (2-D) optimum location for a tower crane include 1) maximizing the crane's accessibility to lay down yard and the structure and 2) minimizing the crane boom sweep area over the pathway. In this article, crane boom sweep area was defined as the area of circle with a radius equal to the crane boom's length. A construction site layout including multiple tower cranes, multiple travel paths, a material staging area and building was created for experimental trials. Internal and external techniques were deployed to validate the feasibility of using the created framework.

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Literature Review

Construction site layout is composed of the existence, positioning and schedule of construction resources required to complete a construction project (Mawdesley, Al-Jibouri & Yang, et al., 2002). Due to its immense impact on construction productivity, project schedules and safety, a significant amount of research has focused on construction site planning (Tam, Tong, Leung, et al., 2002). The following review discusses the effects of tower crane location on construction productivity and safety. Additionally, the review examines benefits of BIM for construction site layout planning. This section concludes by deriving a research needs statement based on the findings of this review.

Tower Crane Location for Productivity

Construction site layout planning has a major impact on construction productivity of operations, especially in limited site space situations (Elbeltagi, Hegazy, Hosny, et al., 2001). The accessibility of constructed structures plays a significant role in productivity. Specifically, the location of tower cranes, material staging areas and travel pathways have a meaningful impact on construction productivity (Elbeltagi, et al., 2001). The total operation cost of transporting heavy materials can be minimized by locating the tower crane and associated material supply points (e.g., material staging area) in desired positions (Huang, Wong & Tam, 2011).

The distance between facilities and a tower crane has been found to be essential to construction productivity (Rodriguez-Ramos & Francis, 1983). Once located, it is typically not desirable to relocate a tower crane due to impracticality or a significant cost and time required to relocate (El-Rayes & Said, 2009). It is estimated that the optimal positioning of a tower crane can eliminate 20% to 40% of a crane hook's travel time (Zhang, et al., 1996). To increase production, a crane's jib should reach and access any part of the constructed structure (Huang, et al., 2011). The optimization of a tower crane's location at the onset of a construction project can drastically impact productivity throughout a project's duration.

Tower Crane Safety

In 2013, cranes on construction sites contributed to 590 injuries and 21 fatalities including 11 fatalities that were directly caused by a pedestrian being struck by objects or equipment associated with cranes (BLS, 2013). Cranes were the direct cause of 18% of construction-related fatalities between 1992 and 2006 (McCann & Gittleman, 2009). Consequently, the proximity of pedestrian workers to cranes is regarded as a severe safety issue (Teizer, Venugopal & Walia, 2008). The positioning and reach of a crane with respect to construction equipment travel paths and pedestrian worker walking paths should be considered.

Tower Crane Location Optimization

A wide variety of best practices are implemented when selecting the location for a tower crane on a construction site. A given location can be selected based on demand locations (i.e., locations the crane is most needed), site layout, structural design of the constructed structure, spatial constraints, capabilities of the tower crane and supply locations (Tork, 2013). Researchers have implemented stochastic simulation models to optimize the location for a single and multiple tower cranes, but included only work schedule as the single input parameter (Zhang, et al., 1996; Zhang, Harris, Olomolaiye, et al., 1999). Another study developed a genetic algorithm to identify optimal supply point locations for a single tower crane in an attempt to minimize transportation time (Tam, et al., 2001; Tam & Tong, 2003). Apart from the identified research, most construction companies implement their company-specific tower crane location decision making process which includes assessing productivity parameters and overall feasibility (Tork, 2013).

BIM for Cranes

Capabilities of BIM have positively contributed many elements of construction management including construction site planning (Eastman, Teicholz, Sacks, et al., 2011). Researchers found that site layout planning for safety and productivity were enhanced when integrated with BIM (Elbeltagi, Hegazy & Eldosouky, 2004; Hallowell, Hinze, Baud, et al., 2013). With regard to site layout, a navigation system was created within a BIM platform to better support crane operators during lifts (Lee, Cho, Ham, et al., 2012) and to mitigate congested construction sites (Kumar & Cheng, 2015). BIM was also used to generate and visualize the optimum location of a tower crane through the integration with geographic information system (GIS) (Irizarry & Karan, 2012). This research orients a tower crane based on productivity constraints based on existing GIS data.

Research Needs Statement

From the literature review, it can be concluded that construction site layout, specifically the placement of tower cranes, can significantly affect the overall productivity and safety of a construction project. Due to BIM's popularity and usefulness among construction managers, interfaces and algorithms functioning within BIM take advantage of an existing platform for communication and decision-making (Azhar, 2011). A framework and optimization tool is needed within an existing BIM to locate the optimal position for placing a tower crane on a construction site. Realization of an optimized location for a tower crane in BIM can be useful for productivity and safety applications for construction management personnel.

Methodology

A simulated construction site was designed in Autodesk Revit software to create the tower crane optimization tool. The designed construction site included one building under construction, one material staging area, single and multiple travel pathways for construction equipment and pedestrian workers. All components on the construction site were simplified to represent orthogonal 3-D rectangular spaces. The radius of the tower crane boom was assumed to be 70 m (200 ft). The 2-D planar surface areas of each construction site component is shown in Table 1.

Figure 1 shows a screenshot of the construction site modeled in BIM design software.

Figure 2 shows the created interface to input user data concerning the known construction site parameters. The interface

Site Component	Length	Width
Exterior fence	91.4 m (300 ft)	91.4 m (300 ft)
Material staging area	45.7 m (150 ft)	27.4 m (90 ft)
Building boundary	37.2 m (122 ft)	18.9 m (62 ft)
Travel path	61.0 m (200 ft)	3.0 m (10 ft)

Table 1: Dimensions of created construction site

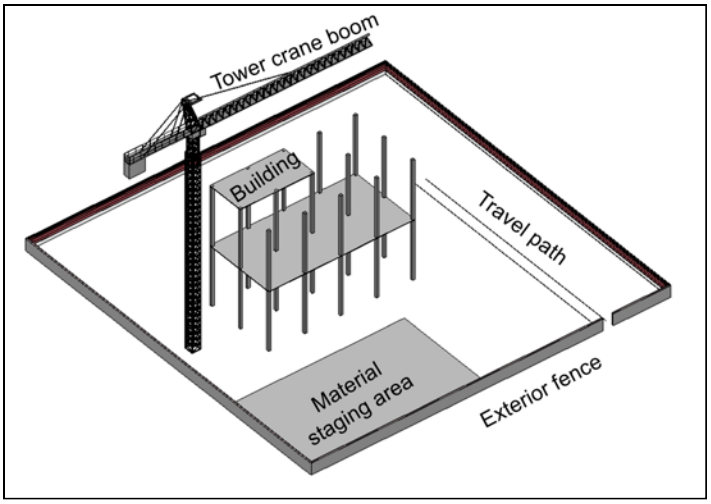


Figure 1: Designed typical construction site layout

Figure 2: Crane location optimization interface

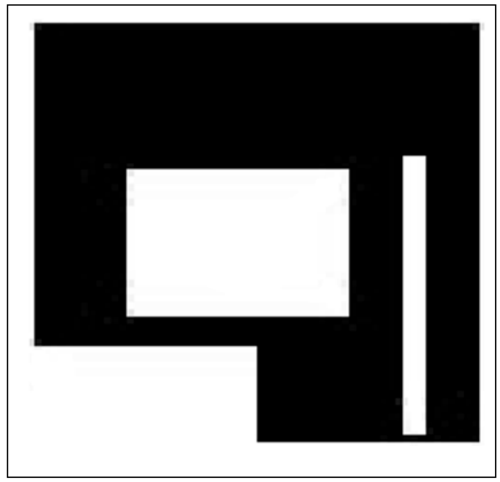


Figure 3: Construction site layout in MATLAB by binary image

enables user to do the following functions: 1) Input coordinates of the construction site components by clicking each intersection point for the shapes that outline the exterior boundary, building in boundary, material staging area and travel path within a model; 2) automatically select the optimal location of the tower crane; 3) visualize the tower crane location in a model; and 4) output site layout coordinates in a text file.

A polygon was created based on the points designated by the user and the intersection points and resulting surface area are exported into a text file that is read by MATLAB to create a binary image of the construction site. The exported binary image of the construction site in MATLAB is shown in Figure 3. The shaded region in Figure 3 denotes locations available to placing the tower crane and the unshaded area shows areas unavailable for placing the tower crane. Each pixel in the Figure 3 represents 1 m in the field.

The goal of the optimization tool is to ensure that the tower crane boom sweep area can cover most of the constructed building and material staging area while minimizing the boom's coverage of the travel pathway. These parameters are typical of decision criteria for management personnel on construction sites and have been identified as performance metrics in previous research. The detailed decision criteria framework used to achieve this optimization solution is shown in Figure 4. The technical computing language and interactive software MATLAB was used to convert the existing site layout with binary images in which one pixel represents 1 m. For a 100 m x 100 m construction site, 10,000 pixels are required. The algorithm identified unavailable pixels including travel paths, buildings and material staging areas for the optimization calculations. This framework details how user input data are collected and analyzed to optimize the two-dimensional location of the tower crane.

Two major constraints are implemented to mediate the optimization of the tower crane location on a construction site. The first and most prioritized constraint implemented by the optimization algorithm is that the tower crane broom must maximize the access to the constructed building and material staging area. An arbitrary threshold of 95% coverage area of constructed building and material staging area by the tower crane was selected for experimental trials. A user can modify this threshold for specialized construction site conditions. As the optimization threshold decreases, the number of available locations for placement of the tower crane increases.

Because projects are unique and have varying criteria for coverage area of a tower crane, management personnel are able and encouraged to modify the coverage area threshold based on their specific project needs using the created user-interface. If this threshold is satisfied, the optimization algorithm implements a secondary constraint based on the available locations that satisfy

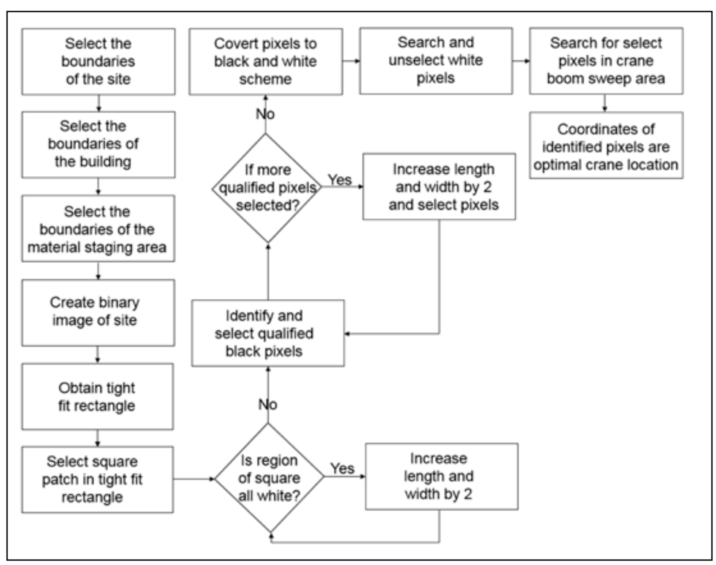


Figure 4: Logic framework for optimized decision criteria

the initial constraint. Figure 5 provides details and prioritizations of each constraint within the tower crane optimization tool. For constraint 1 in Figure 5, the shaded area represents the area that should be accessible by the tower crane boom. The shaded area in constraint 2 in Figure 5 is the area that should be avoided by the tower crane boom.

The two constraints shown in Figure 5 in the algorithm of the tower crane location optimization tool were applied to the modeled construction site shown in Figure 3. After exporting user input data from the tool's interface into MATLAB, the tower crane's 2-D coordinates were computed based on an optimization function and the two defined productivity and safety constraints. Figure 6 shows the resulting tower crane boom coverage area and coordinates for the optimized crane's tower.

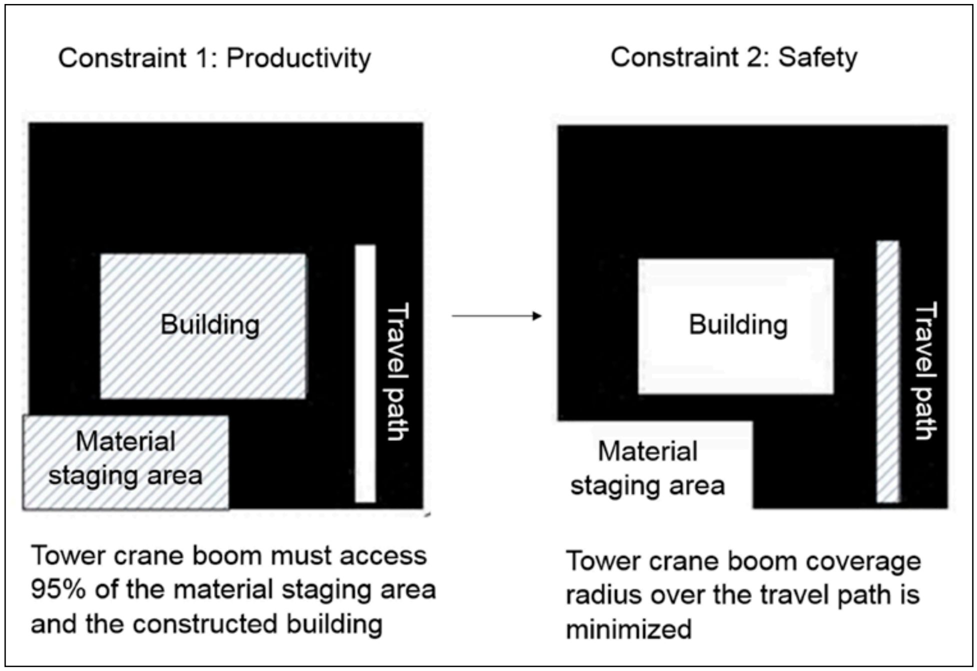


Figure 5: Details and prioritization of constraints within the tower crane optimization tool

The percentage of tower crane boom swing area of the constructed structure, material staging area and travel paths are shown in Equation 1 and 2. The calculated solution of each of these equations is automatically stored in a text file and used to identify the tower crane location in BIM.

$PCBM = (NWP_1/TNWP_1)(100\%)$ Equation 1

where:

PCBM is the percent tower crane boom covers of building and material staging area; NWP_1 is the number of white pixels the tower crane boom overlaps the building and material staging area; and $TNWP_1$ is the number of white pixels that cover the building and material staging area.

$PCT = (NWP_2/TNPW_2)(100\%)$ Equation 2

where:

PCT is the percent tower crane boom covers the travel path; NWP_2 is the number of white pixels the tower crane boom overlaps the travel path; and $TNWP_2$ is the number of white pixels that cover the travel path.

The final step of the interface is for a user to select "show tower crane location." Once this selection as been made, the optimized 2-D location of the tower crane is shown in the BIM model and the (x,y) coordinates of this location are provided as shown in Figure 7. The area inside of the dashed circle and construction site boundary is the area accessible by the tower crane boom. All objects inside of this circular area can be reached by the tower crane boom. The optimized tower crane location shown in Figure 7 provide a 99.3% tower crane boom coverage area of the building and material staging area and a 29.5% coverage of the equipment and pedestrian travel path.

The tower crane optimization tool provides three categories of output: 1) the visual display of the optimum location for a tower crane; 2) the (x,y) coordinates of the optimized tower crane location; and 3) the tower crane boom coverage area of the building, material staging area and travel path at the optimized location. Figure 8 details the individual objective functions of algorithm to compute the optimized tower crane location through the BIM (Revit), the text file and MATLAB. This data transfer of organizational structure allows for construction safety personnel to receive results simply by navigating the created user interface in an existing BIM.

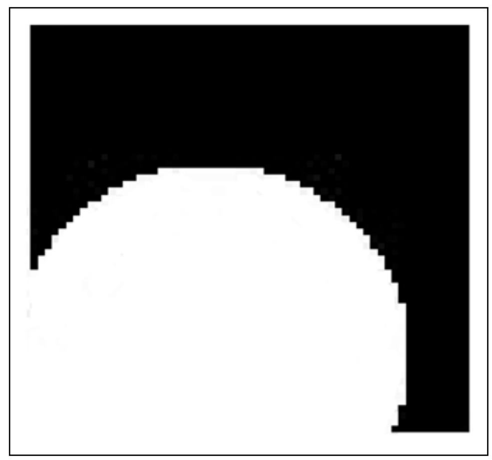


Figure 6: Computed tower crane boom coverage area

Validation

The created tower crane optimization tool for construction sites was validated internally to assess the robustness of the tool and externally through implementation of a case study. Internal validation verifies the robustness of the algorithms and functions of the tower crane optimization tool while external validation implements the created optimization tool on active construction sites to evaluate the feasibility of actual use in the construction industry. Specifically, this validation strategy evaluates the functionality of the created optimization tool; that is, test that verify the algorithms within the tool are capable of calculating and iden-

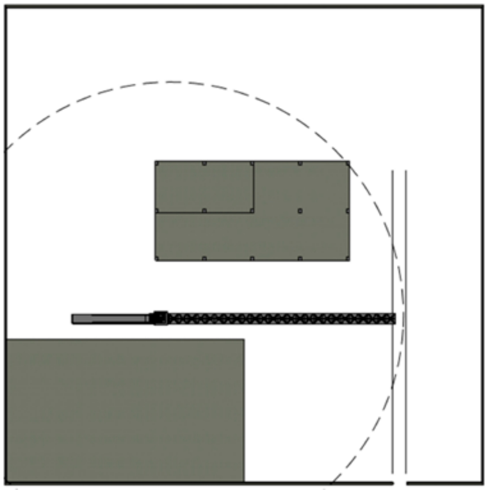


Figure 7: Tower crane optimization location resulting output

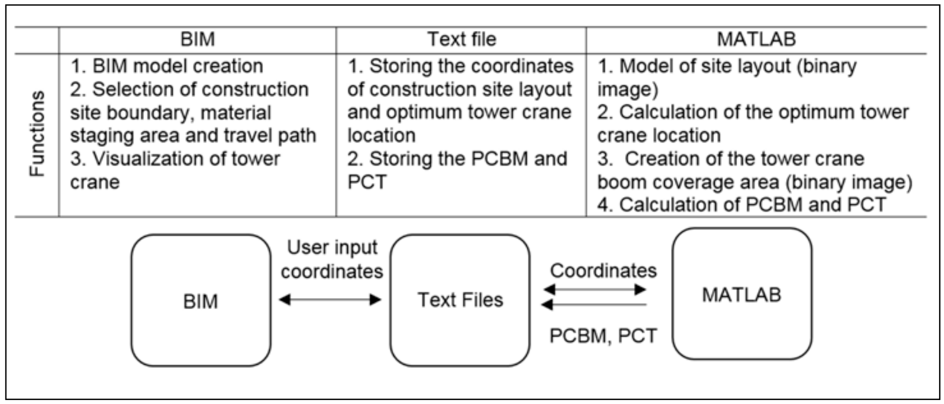


Figure 8: Relationships between optimization tool functions in BIM, text file and MATLAB

tifying the optimal tower crane location based on input parameters. The following section details the methods and results from both validation studies.

Internal Validation

An internal validation effort was completed to assess the functionality of the created tower crane optimization tool. The functionality refers to the ability of the created optimization tool and algorithms to calculate and identify the optimal location of a tower crane based on a set of input parameters. The performance metrics for this validation effort are based on success or failure of the tool to identify the accurate location of the tower crane. The tower crane location optimization tool was internally validated through 50 independent trials. These trials were deemed necessary as an internal validation method for the functionality of the created tower crane location optimization tool.

Each trial consisted of a random and unique construction layout of the constructed building, material staging area and multiple travel paths within the construction site layout shown in Figure 3. The dimensions of the travel paths remain constant, but the dimensions of the constructed building and material staging area vary randomly with each trial. The percent coverage area of the tower crane boom over the constructed building and material staging area and the percent coverage of the tower crane boom over the travel paths are both 1) automatically computed by the created optimization tool and 2) manually calculated through basic geometric tools in BIM design software.

The trial was deemed successful if the automated and manual calculation methods were identical and if both the optimization criteria are met. As noted, the optimization criteria are 1) the percent coverage of the tower crane boom over the constructed building and material staging area is greater than 95% and 2) the percent coverage of the tower crane boom over the travel paths is minimized. In every trial, calculations between the automated and manual calculation were met as well as both optimization constraints were satisfied. Figure 9 presents the results of several sample trials including a plan view of the site layout, a plan view of the tower crane boom coverage area and the optimization constraint metrics.

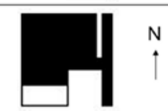
Site Layout View	Tower Crane Sweep Area View	PCBM	PCT
		98.1%	0.0%
		99.0%	0.0%
		95.8%	52.0%
		96.3%	0.0%
		95.0%	41.0%

Figure 9: Results summary of internal validation results

A statistical analysis of the internal validation results was also performed on the two measured optimization constraints. Results of this analysis are shown in Table 2.

Statistical Metric	PCBM	PCT
Average	97.36%	29.45%
Lowest	95.20%	0.00%
Highest	100%	59.71%

Table 2: Statistical summary of internal validation results

External Validation Case Study

Two case studies were performed to implement the created tower crane optimization framework into active construction sites. The existing tower crane locations for both case studies were selected based on judgment and intuition of the general contracting company's project managers.

Simple Construction Site Case Study

The first case study was a new classroom building construction project on a public university campus located in the southeastern U.S. The project started in August 2012 and was completed in May 2015. This construction site was designed in a commonly used BIM software (Autodesk Revit). Construction stakeholders accessed the BIM throughout the design and construction phase of the project to assess and communicate concepts and issues. The tower crane optimization tool was used by an impartial user on the existing BIM to determine the optimal tower crane location based on the input construction site layout polygons and previous stated optimization constraints. Figure 10 shows a picture of the construction site and the BIM model including the current placement of the tower crane. The tower crane's actual location provided 76.5% coverage area for the constructed building and material staging area and covered 24.0% of the equipment and pedestrian travel path.

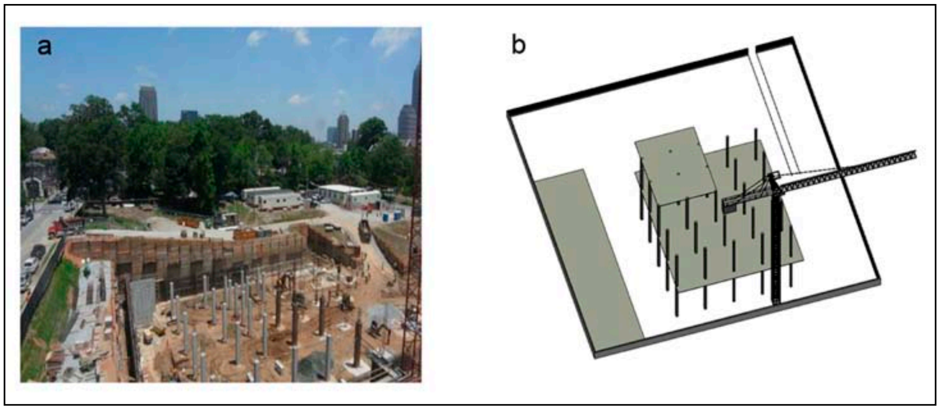


Figure 10: Active construction site (simple case study) for external validation (a) and plan view of the BIM model with the actual tower crane location (b)

Site Component	Length	Width
Exterior fence	106.7 m (350 ft)	106.7 m (350 ft)
Material staging area	30.5 m (100 ft)	27.4 m (100 ft)
Building boundary	65.5 m (215 ft)	32.0 m (105 ft)
Travel path	70.1 m (230 ft)	4.6 m (15 ft)

Table 3: Dimensions of the simple case study construction site

The construction site had one main equipment and pedestrian travel path, one building under construction and one materials staging area. Table 3 provides the dimensions to each element needed for the optimization tool in the actual construction site.

Outputs of the tower crane optimization tool identified a location to position the tower crane which was different that the position selected by site personnel. Although it was impractical to change the tower crane location due to productivity concerns, project management personnel unanimously agreed to implement the tower crane optimization tool for their next construction site layout pre-planning process. The optimization tool's tower crane location increased the percent of coverage area of the tower crane boom over the constructed building and material staging area from 76.5% (actual tower crane location) to 98.4% (calculated optimized tower crane location) and reduced the tower crane boom coverage area over the travel path from 24.0% (actual tower crane location) to 0.0% (calculated optimized tower crane location). The optimal location in regards to the applied productivity and safety constraints is shown in Figure 11.

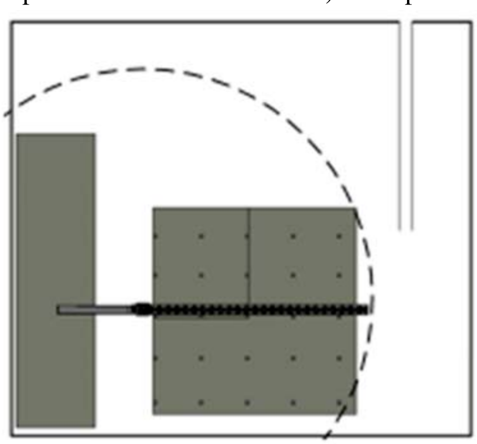


Figure 11: Output of tower crane optimal position tool for external validation construction site (simple case study)

Complex Construction Site Case Study

The second case study was a construction site for a children's hospital located in Akron, OH. The construction project duration was from April 2013 to August 2015. The site consisted of a total of three travel paths for construction equipment and pedestrians, one building and two material staging areas. Table 4 provides the dimensions to each element required for optimization of this active construction site.

Because the created algorithms were created to optimize the location of one tower crane, the user divided the construction site into two zones depending on the location and desired reach locations of each tower crane. This practice is typical on construction sites largely due to improving productivity and safety between tower cranes. Figure 12 presents a screenshot of the tower crane optimization tool output in BIM (part a) and the actual construction site (part b). In the BIM (part a) of Figure 12, the vertical dotted line denotes the cutting plane line implemented by the created optimization tool. The user can select this cutting plane line, deploy the optimization tool, then combine results of each construction site component.

Site Component	Length	Width
Exterior fence	124.1 m (407 ft)	106.6 m (349 ft)
Material staging area (1)	64 m (210 ft)	33.3 m (108 ft)
Material staging area (2)	60.2 m (196 ft)	45 m (148 ft)
Building boundary	78.2 m (256 ft	68.7m (225 ft)
Travel path (1)	100.5 m (330 ft)	4.6 m (15 ft)
Travel path (2)	80.3 m (263 ft)	4.6 m (15 ft)
Travel path (3)	70 m (230 ft)	4.6 m (15 ft)

Table 4: Dimensions of the complex case study construction site

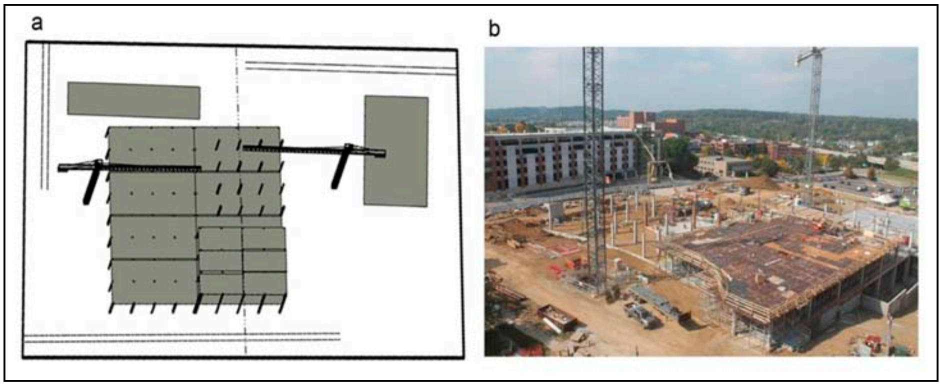


Figure 12: Output of tower crane optimization tool in BIM (a) and screenshot (b) of construction site (complex case study)

When compared to the actual selected locations of the two tower cranes shown in Figure 12, the optimization tool's tower crane location increased the coverage area of the tower crane boom over the constructed building and material staging area by 7.8%. The combined tower crane boom coverage area over the travel paths were reduced by 16.8% when changing the actual location of the tower cranes to the locations selected by the tower crane optimization tool.

Summary of Results

The results identified situations on construction sites in which tower crane placement can be optimized in regard to productivity and safety. An optimization algorithm and tool were created to find the optimal location for a tower crane based on an existing site layout plan from an existing BIM model. This optimal location for a tower crane on a construction site is based both on the crane's best accessibility to the structure under construction and material staging area and the minimized accessibility to the equipment and pedestrian travel path. A user interface allows for construction management personnel to input known locations of a construction site boundary, building under construction, material staging area and travel path. These inputs serve as polygons for the optimization calculations with given productivity and safety constraints. Outputs of the tower crane location optimization tool include percent coverage areas and a visual display of the tower crane location and corresponding accessibility.

It is important to note that the findings of both external case studies are somewhat dependent on the strategy to locate the tower crane for both active construction sites. As discussed in the literature review, many strategies exist for identifying the placement of a tower crane on a given construction site. Various optimization methods and alternatives can be considered when identifying this location of which many are criteria to a specific construction site (Tork, 2013). The various strategies among management personnel for tower crane location can explain the difference between actual construction site tower crane location data and output from the created tower crane optimization tool.

As can be seen in the two performed case studies, construction sites each have a unique size and scope. Because of this and typical construction site characteristics, site-specific constraints unique to each project are not covered by this optimization tool. Site-specific productivity and safety constraints should be prioritized by construction site management personnel and used with the optimization tool to select the best location for placing a tower crane. For example, certain tower crane loads are highly susceptible to movement during wind gusts and require a greater effort for safety intervention.

Conclusion

Tower crane location placement can drastically impact the productivity and safety of a construction project. This research creates an optimization tool capable of locating an optimized location placement for a tower crane given various construction site parameters and governing constraints. The created tool allows designs and construction project managers to locate and optimally position a tower crane through an existing BIM during construction preplanning. The tool assumes management personnel want to place the tower crane one time during the equipment mobilization phase of the project. The tool was implemented successfully in multiple simulation and actual construction site situations. It was validated through an internal robustness verification process and implemented on actual construction sites. Unlike existing site layout strategies, the tower crane location optimization tool implements safety and productivity thresholds as a determining mechanism. The contribution of this research is an implementable framework that can automatically identify the optimal location of a tower crane in BIM for productivity and safety applications as well as scientific evaluation data of this framework on an active construction site.

Some experienced limitations include the integration of only two optimization constraints for the location placement of the tower crane. Future research will explore a multitude of optimization constraints that would be more characteristic of a construction site. The methodology implemented for this research may not be feasible for scaling to larger planning problems mainly due to the increase of complex attributes. Future research can explore the feasibility and effectiveness of implementing additional attributes to the site-layout methodology proposed in this research.

The research results indicate the created tower crane location optimization tool functions can be applied to multiple tower cranes and travel paths. Other functionality such as tower crane relocation during a construction project's duration are made possible through multiple uses of the optimization tool. Additionally, the constraints only address two project controls: productivity and safety. Future work on this optimization tool could address other project controls including quality and environmental considerations. By locating the optimal tower crane position in BIM during the construction pre-planning phase of a project, construction management personnel can more readily anticipate for other project aspects including material transportation schedules, loading and unloading of materials and safety concerns.

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Occupational Health & Safety Legislative Gap Analysis of the Food Processing Sector in Ontario, Canada

Chun-Yip Hon and Craig Fairclough

Abstract

There are many occupational health and safety (OHS) hazards found within the food processing sector. As a result of these hazards, the food processing sector in Ontario, Canada has higher lost time injury rates than other industry sectors traditionally believed to be "unsafe" such as pulp and paper and mining. The purpose of this pilot study was to determine the level of compliance of the food processing sector with the relevant OHS legislation as well as produce a sector-specific priority list of OHS concerns. Adapted from existing resources, an online legislative gap analysis questionnaire was developed for this study. An invitation to participate was sent to individuals in a database of alumni OHS students/registrants. The survey data was analyzed via frequency distributions. We had a response rate of 31% and almost all respondents were OHS managers or coordinators. A number of legislative gaps were identified with key issues related to inadequate training, lack of relevant OHS policies and insufficient hazard identification activities. The top three concerns from this sector were: 1) manual material handling, 2) slip, trips and falls and 3) energized equipment. These findings can facilitate the development of an action plan to improve the OHS performance of this sector.

Keywords
occupational health and safety, food processing, legislative gap analysis, Ontario, hazard prioritization

Generally speaking, the food processing sector employs a substantial percent of the working population in North America and other developed countries. Specifically, the food processing sector in (the province of) Ontario, Canada, is the third largest in North America (OMAFRA, 2015) with an estimated workforce of more than 100,000 and annual sales in excess of $34 billion (OMAFRA, 2016). Those who work in food processing are responsible for transforming agricultural produce and livestock into products that are consumer-ready, such as foods that will be available in grocery stores, restaurants, and households (Bhushan, 2011). These workers are potentially exposed to a variety of occupational hazards including, but not limited to:

•machines and their moving parts due to improper or non-existent guarding;
•manual material handling;
•slipping hazards;
•physical hazards such as noise and radiation;
•chemical and biological agents (Cohen, Connon & Silverstein, 2003; Ontario Ministry of Labour, 2012a).

In fact, it is quite common for food processing workers to be exposed to multiple hazards simultaneously (van Holland, Soer, de Boer, et al., 2015). As a result of these occupational hazards, food processing workers have reported cases of cancer, dermatitis, musculoskeletal disorders, respiratory diseases, infectious diseases as well as acute trauma injuries (Cohen, Connon & Silverstein, 2003; van Holland, et al., 2015). Although the presence of these hazards does not necessarily lead to illness or injury in all instances, they do increase the likelihood of absences as well as a reduction in working ability (Leijten, van den Heuvel, Ybema, et al., 2013).

As a result of the numerous possible workplace hazards, the food processing industry in Ontario has higher lost-time injury rates (0.78 per 100 workers) than other industries traditionally perceived as high risk such as pulp and paper (0.56), mining (0.63) and chemical processing (0.60) (WSIB, 2016). Similar findings have been reported in both the U.S. (Spellman & Bieber, 2008) and the U.K. (Lloyd & James, 2008). In fact, there are several examples of food processing companies that have been fined for violations of the Ontario Occupational Health and Safety (OHS) Act (Ontario Ministry of Labour, 2016a; YOW Canada, 2006).

Work-related incidents not only bear human costs but there are also significant economic costs associated with poor workplace safety and health that negatively affects growth and, in turn, affects the ability of an organization to be competitive (Cagno, Micheli, Jacinto, et al., 2014). Given these consequences, it is essential that the food processing sector in Ontario strive to improve its OHS performance. However, to do so, it is important to initially understand the compliance of these workplaces with respect to the OHS legislation. One means to address this is to conduct a gap analysis, a tool used to highlight the difference between what should be in place and what is in place. In other words, the tool can ascertain

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the current landscape of compliance with the prescribed requirements (Pojasek, 2001). The results of this analysis can subsequently be used to develop a plan of action to fill the identified gaps and, in turn, facilitate compliance with OHS regulatory requirements with the overall goal of improving OHS performance.

Therefore, the purpose of this pilot study was to conduct a gap analysis of the food processing sector in Ontario relative to the province's OHS legislation. In addition, we sought to develop a sector-specific priority list of occupational hazards and associated concerns that will aid in developing a plan of action to address OHS issues. This study is part of a larger research program whose goal is to identify and control OHS hazards within the food processing sector in Ontario, Canada.

Methods

Questionnaire Development

This was a cross-sectional study design and an online questionnaire was developed to collect data. In addition to demographic questions such as size of company and primary type of operation (e.g., meat processing, dairy), the questionnaire also had a section to identify gaps with respect to the OHS legislation and another section to ascertain the type of occupational health hazards.

The legislative gap element of the questionnaire was adapted from the gap analysis tool developed by the Canadian Centre for Occupational Health and Safety. The nature of these questions related to an organization's current practices relative to various OHS legislated requirements such as the duties of employers, duties of supervisors, workers' duties, roles and responsibilities of workplace parties, joint health and safety committee, hazard identification and risk assessment activities, hazard prevention and control programs, OHS documents, and safety inspections.

The occupational health hazards section of the questionnaire consisted of questions with respect to chemical hazards, physical hazards, biological hazards, ergonomics, safety concerns, labour relations at the workplace and general health and safety issues. These questions were created based on health hazard checklists and other related tools from various health and safety agencies (e.g., Cal-OSHA, WorkSafeBC).

The framework for developing the questionnaire was to obtain an understanding of the landscape of compliance with the province's OHS legislation as well as to determine the type of workplace health hazards in this sector and the associated risk of exposure. The questions included in the final survey instrument, from the aforementioned sources, were mutually agreed upon by the two authors who are certified health and safety professionals (each possessing the CIH and CRSP designations) with more than 40 years' combined experience as OHS practitioners. Furthermore, one author (Hon) has been involved with OHS research for a decade and has a history of survey development. In addition, the research team sought an individual with a background in OHS law to review the draft questionnaire.

In total, there were 92 questions on the survey, most of which had yes/no/don't know response options or a Likert scale for questions related to perceptions/opinions (i.e., degree of agreement with a statement). In addition, open-ended questions were made available for a respondent to rank the prevalence of the different types of occupational health hazards within their organization. A draft of the questionnaire was pre-tested by individuals with undergraduate training in OHS (n = 2) as well as by individuals who had worked in the food processing sector (n = 2) and, collectively, represent the study's target respondents. The pre-testers were instructed to complete the survey to the best of their ability. At the same time, they were asked to make note of any questions that they felt were poorly worded, unclear, etc. Once completed, members of the research team recorded the length of time for survey completion and also asked the pre-testers for constructive feedback regarding the survey. Where necessary, changes were made to the questionnaire based on this feedback. Following institutional ethics approval, the questionnaire was hosted on SurveyMonkey. A copy of the final survey is available as a supplemental document.

Subject Recruitment

Electronic invitations to participate in the study were sent to a database of former graduates of Ryerson University's School of Occupational Health and Public Health as well as other individuals who have completed OHS courses offered by the school. The inclusion criteria were occupational health and safety practitioners or a member of the joint health and safety committee affiliated with a food processing facility in Ontario. Invitations were initially sent in July 2015, with two follow-up reminder e-mails, one in September 2015 and another in November 2015. The survey was closed in December 2015.

Data Analysis

Survey results were described using frequency distributions. With regards to ranking the most common occupational health hazards, all survey responses were collated and the top three most frequently reported hazards were recorded. All statistical analyses were performed using Microsoft Excel (Seattle, WA).

Results

Overall, 165 e-mail invitations were sent and 38 e-mails either bounced back or we received a response that the individual was no longer affiliated with a food processing facility. From these sent invitations, we received 48 surveys but nine were deemed substantially incomplete and, therefore, a total of 39 surveys were analyzed (response rate of 31% or 39/127).

Respondents primarily had the job title of OHS manager (59%) or OHS coordinator (33%). A variety of different food processing facilities were represented, with meat and bakeries being the most common, and 80% of all participating workplaces employed more than 200 employees. The proportion of unionized versus. non-unionized workplaces was similar. Ninety percent of the workplaces had a 24-hour operation and most (69%) had three or more work shifts per day (Table 1)

With respect to legal responsibilities of the various workplace parties (Table 2, p. 341), there was 100% agreement that employers provided the prescribed equipment and materials and that they took reasonable precautions to protect their employees. In addition, all but one facility had an updated OHS policy. However, 10% of

Category	Subcategory	N	%
Job title	OHS coordinator/advisor (or similar)	13	33.33
	OHS manager/team lead (or similar)	23	58.97
	Other	3	7.69
Unionized?	Yes	20	51.28
	No	18	46.15
	N/A	1	2.56
Number of employees	50-99	1	2.56
	Between 100-149	3	7.69
	Between 150-200	4	10.26
	More than 200	31	79.49
Primary type of operation	Rate group 207: Meat	7	17.95
	Rate group 210: Poultry products	4	10.26
	Rate group 214: Fruit and vegetable	0	0.00
	Rate group 216: Dairy products	4	10.26
	Rate group number 220: Other bakery products (e.g. buns, bread, cake, donuts etc.)	5	12.82
	Rate group number 222: Confectionery (e.g. chewing gum, sugar and chocolate confectionary etc.)	2	5.13
	Rate group number 223: Biscuits (e.g. cookies, crackers, etc.), snack foods (e.g. chips, pretzels, popcorn etc.) and other products (e.g. dry pasta, jelly powder, cake decorations etc.)	7	17.95
	Rate group number 226: Crushed and ground foods (e.g. cereal grain flour, vegetable oil mills, tea and coffee etc.)	2	5.13
	Rate group number 230: Alcoholic beverages (e.g. distillery products, brewery products, home brewing centers etc.)	5	12.82
	N/A	1	2.56
	Don't know	2	5.13
24-hour operation?	Yes	35	89.74
	No	4	10.26
Number of shifts/day	1 shift	3	7.69
	2 shifts	9	23.08
	3 shifts	17	43.59
	More than 3 shifts	10	25.64

Table 1: Characteristics of respondents

standard operating procedures in place. Regardless, all respondents indicated that their organization had procedures in place to report hazards as well as near-misses and work-related incidents. Of note, 21% of participating organizations reported at least one work refusal in the past year.

Almost all respondents indicated that various policies were available for many different OHS issues such as lockout/tagout (94.87%) and personal protective equipment (97.44%). However, 36% of respondents reported that they did not have a policy for occupational exposure assessments while 46% (12/26) stated that they did not have a policy for designated substances despite indicating that these agents were found in their workplace. In Ontario, designated substances are 11 named chemicals with known chronic health effects (e.g., silica, asbestos, mercury) and for which a specific regulation applies (Ontario Regulation 490/09: Designated Substances; Ontario Ministry of Labour, 2012b). Also, 23% of participants indicated that their organization did not have a policy for ergonomic hazards.

respondents stated that their organization had no written documentation outlining the OHS responsibilities of the various workplace parties and 15% of respondents indicated that supervisors did not receive OHS training. An overwhelming majority agreed that workers in their organization worked in a safe manner (89.74%) and that prescribed protective devices were being used (92.31%). However, OHS was not incorporated into a worker's performance evaluation in 23% of the workplaces. On a positive note, virtually all respondents indicated that their organization had a joint health and safety committee (97.44%) and that the legal requirement of the committee meeting on a regular basis as well as having committee meeting minutes posted was fulfilled (94.87%).

Regarding hazard identification and control activities (Table 3, p. 342), 36% of respondents indicated that jobs and/or tasks with known associated hazards had not been formally identified. Further, the loss potential associated with a hazard was not characterized according to 44% of respondents. In addition, for those work activities that are known to have a major loss potential, 28% of respondents indicated that there were no associated

Lastly, although all respondents had safety orientation training, some workplaces did not have a process for identifying OHS training needs (15%) and even more organizations do not evaluate their OHS training (28%) (Table 3, p. 342).

While all respondents indicated that workplace inspections were routinely performed, when asked if the supervisor/employer instituted corrective measures in a timely manner resulting from these inspections, 10% disagreed with this statement while 13% were neutral (Figure 1, p. 342).

In terms of the different occupational health hazards present within the respondents' facilities, Table 4 (p. 343) summarizes the top three most commonly reported hazards stratified by hazard class. Of these, the overall top three OHS concerns indicated by all respondents were: 1) manual material handling; 2) slips, trips and falls; and 3) energized equipment.

Discussion

The purpose of this pilot study was to conduct an analysis of the gaps within the food processing sector in relation to the

Workplace Party	Requirement	Response	%
Employer	Employer provides equipment & materials as prescribed in OHS legislation	Agree	35.90
		Strongly Agree	64.10
	Employer takes every reasonable precaution for the protection of workforce	Agree	53.85
		Strongly Agree	41.03
		Neutral	5.13
	Performance evaluation includes an OHS component	Yes	76.92
		No	23.08
	OHS policy signed within last 12 months	Yes	97.44
		Don't know	2.56
	Written documentation available which outlines responsibilities of workplace parties	Yes	89.74
		No	10.26
Supervisor	Supervisor trained in general duties per OHS Act	Yes	94.87
		No	5.13
	Supervisor received OHS training	Yes	84.62
		No	15.38
Worker	Uses protective devices as prescribed in the OHS legislation	Agree	56.41
		Strongly Agree	35.90
		Disagree	2.56
		Neutral	5.13
	Works in safe manner	Agree	64.10
		Strongly Agree	25.64
		Disagree	2.56
		Neutral	7.69
Joint Health and Safety Committee	Joint Health and Safety Committee established?	Yes	97.44
		No	2.56
	Joint Health and Safety Committee meets at least every 3 months	Yes	97.44
		N/A	2.56
	Employer is responsive to recommendations of Joint Health and Safety Committee	Agree	38.46
		Strongly Agree	51.28
		Neutral	7.69
		N/A	2.56
	Joint Health and Safety Committee meeting minutes posted in accessible areas	Yes	94.87
		N/A	5.13

Table 2: Participants' response with respect to legal roles and responsibilities of various workplace parties

province of Ontario's OHS legislation. In addition, a prioritized sector-specific list of occupational health hazards was determined. This was undertaken because the workers compensation claims rate for this sector in Ontario is greater than other sectors traditionally known to be unsafe. By improving occupational health and safety in the food processing sector, resources that are currently spent on workers compensation can be diverted to the operational needs of an organization and, in turn, helping to ensure that it remains competitive.

Overall, there were a number of OHS legislative gaps identified in our study. This is consistent with a Business of Safety survey conducted in Australia which also revealed deficiency gaps with respect to the management of workplace health and safety (Ri, Phpehuv, Vxssruw, et al., 2011). The number of participating facilities that failed to comply in critical areas such as supervisory training, availability of OHS policies and thorough hazard identification and control activities lend credence to Haslam, O'Hara, KLazi, et al.'s (2015) conclusion that many organizations do not give OHS the priority it deserves.

One of the gaps identified was that OHS training for supervisors was not provided in 15% of the organizations. Under the Ontario OHS Act, every supervisor, defined as "a person who has charge of a workplace or authority over a worker," is required to have, as a minimum, OHS awareness training (Ontario Ministry of Labor, 2016b). Having supervisors engaged in health and safety matters and communicating with workers who are injured at work has proven to be effective in reducing injury claims, with respect to both frequency and severity of injuries, within the food processing sector (Shaw, Robertson, McLellan, et al., 2006). As such, we recommend that the sector recognize the important role that supervisors perform with respect to workplace health and safety and ensure that all supervisors are provided with OHS awareness training.

In addition to training for supervisors, there were deficiencies with respect to OHS training in general. According to the OHS legislation, employers are expected to train workers on hazards in the workplace as well as the means to protect their health and well-being when working with these hazards (Ontario Ministry of Labor, 2016b). Moreover, a systematic review of OHS training found that such training resulted in improved work practices (Robson, Stephenson, Schulte, et al., 2012). Given our findings, it is evident that this sector needs to make improvements with respect to the provision of OHS training to the workforce.

According to 36% of respondents, hazards known to be related to a job and/or tasks have not been formally identified by their organization. This is noteworthy because, without an understanding of the hazards and their associated risks, loss preventions efforts are moot (Izvercian, Ivascu, Miclea, et al., 2012). This is another example of noncompliance in a key area since hazard identification and risk communication are clearly outlined in the Ontario OHS Act as a shared responsibility between the employer, supervisor and the joint health and safety committee (Ontario Ministry of Labor, 2016b). Perhaps this deficiency is a

Requirement	Response	%
Jobs and tasks that present a hazard identified	Yes	61.54
	No	35.90
	Don't know	2.56
Loss potential for each hazard identified	Yes	51.28
	No	43.59
	Don't know	5.13
Safe operating procedures implemented for activities identified as major loss potential	Yes	69.23
	No	28.21
	Don't know	2.56
Procedure for reporting hazards and/or near-misses	Yes	94.87
	No	5.13
Written procedure for workers who wish to exercise right to refuse unsafe work	Yes	87.18
	No	12.82
Workplace has process for identifying OHS training needs?	Yes	84.62
	No	15.38
Workplace regularly evaluates OHS training?	Yes	66.67
	No	28.21
	Don't know	5.13
Workplace has safety orientation program?	Yes	100.00
	No	0.00
Policy or procedure for exposure assessments (e.g., noise, airborne contaminants)?	Yes	64.10
	No	35.90
Policy or procedure for designated substances (e.g., acrylonitrile, arsenic, asbestos, benzene, coke oven emissions, ethylene oxide, isocyanates, lead, mercury, silica, vinyl chloride)?	Yes	35.90
	No	30.77
	Not applicable	33.33
Policy or procedure for ergonomics?	Yes	76.92
	No	23.08

Table 3: Participants' response with respect to select hazard identification and control activities

contributing factor in those organizations which reported at least one work refusal over the past 12 months (n = 8). On a positive note, all respondents reported that their organization's joint health and safety committee meets on a regular basis and, presumably, both known and potential hazards are discussed at these meetings. Regardless, further research is suggested to examine the role and impact of joint health and safety committees regarding OHS performance within the food processing sector.

With respect to OHS-related policies, it appears that most organizations have existing policies associated with safety issues such as lockout/tagout. However, organizations were lacking policies related to occupational hygiene matters such as exposure assessments (in general) and designated substances (i.e., substances with known chronic health effects). The latter is noteworthy because 12 respondents indicated that their organization does not have a policy for designated substances despite the fact that these agents are found in their facility. In Ontario, any workplace that produces, handles or stores one or more of the 11 designated substances is mandated to comply with the Designated Substances Regulation (Ontario Ministry of Labor, 2012b) in addition to the other regulations under the OHS Act. The Designated Substances Regulation has more stringent requirements including the need to have an exposure control plan. Not having proper policies might be attributed to lack of awareness, complacency or indifference and, therefore, warrants further examination.

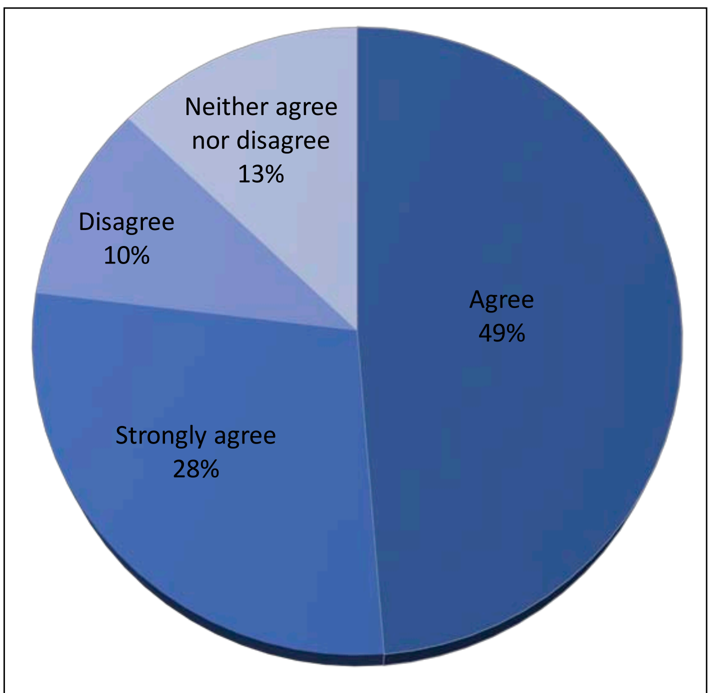

Figure 1: Answers to question: "Are corrective actions addressed in a timely manner by supervisor or employer?"

Although inspections are being performed in workplaces, respondents expressed concern that management is not responding to the reported deficiencies in a timely manner. Granted, the phrase *timely manner* is subjective as there is no indicated timeline in the OHS legislation to respond to inspection reports. Nevertheless, failure to address OHS deficiencies means that the risk(s) will likely remain and can lead to injury, illness, and/or property damage. Lack of appropriate and timely action related to OHS issues reflects a less than ideal safety culture. This is noteworthy as studies have suggested that organizations which develop strategies to improve safety culture will, in turn, have a positive effect on their safety performance (Wu, Chen & Li,

Chemical	Physical	Biological	Ergonomic	Safety
Caustics	Thermal stress	Mould	Manual material handling	Slips, trips, and falls
Ammonia	Noise	Allergens	Repetitive motion	Energized equipment
Cleaning agents	Vibration	Bacteria	Awkward postures	Sharp tools

Table 4: Top three most commonly reported occupational hazards stratified by hazard class

2008). What is likely not well understood by participating organizations is that effective OHS management of accidents, injuries and ill-health is likely to increase profitability (Haslam, et al., 2015). In fact, Veltri, Pagell, Johnston, et al. (2013) argues that it is possible for an organization to improve safety and operating outcomes simultaneously assuming that a culture supportive of safe operations is established and maintained.

With regards to the most prevalent OHS issue facing the sector, respondents indicated that it was manual material handling. This is similar to the conclusions of a study in the United Kingdom which reported that the most glaring issue from food processors in that country were musculoskeletal disorders due to repetitive actions, such as those on packing lines and manual cutting operations, as well as the lifting of heavy or awkward loads (HSE Books, 2005). Given that manual material handling was the most commonly reported concern in our study, it was surprising to find that 23% of respondents did not have an ergonomics policy for their organization.

Perhaps the findings in the current study are reflective of the unique challenges faced by the food processing sector. For example, much of the work in this sector is low skilled with a great deal of repetitive tasks (Dench, Hillage, Reilly, et al., 2000; James & Lloyd, 2008). Also, with retailers dictating costs, this may affect OHS initiatives as the pressure to maintain food quality will always remain at the forefront (Lloyd & James, 2008). Lastly, there are inherent risks associated 24-hr operations, which made up a large majority (90%) of the participating facilities in the current study. For instance, studies have suggested that those working irregular working hours and/or rotating shifts are more likely to experience psychological problems (Papadopoulos, Georgiadou, Papazoglou, et al., 2010).

One limitation of this study was the low response rate despite the fact that there were two follow-up reminder emails. Interestingly, Lloyd and James (2008) also had difficulties securing sites to participate in their study examining OHS issues in food manufacturing in the U.K. The use of our alumni contact database is another possible limitation in that the respondents might have similar perceptions due to having received training from the same institution that may differ from OHS coordinators/directors in this sector who received their training elsewhere.

An additional limitation is that the study was conducted for food processors situated in Ontario, Canada, and may not be representative of similar operators in other jurisdictions. However, based on the fact that lost-time claims from this sector are also relatively high in both the U.S. and the U.K., we believe that the current findings could be argued as relevant to other jurisdictions and, as a minimum, should serve as a starting point for discussion to improve OHS performance in the food processing sector as a whole. Also, we asked the perception of OHS personnel which may not reflect the beliefs of other workers such as processors, cleaners or maintenance personnel in these facilities. We were unable to perform comparative analyses between types of facility as the sample size would have been relatively small when stratified by this variable. Lastly, we did not examine psychosocial hazards that have been reported to affect workers in this sector (Horton & Lipscomb, 2011).

As noted, the results of this pilot study can serve as an impetus for other studies to improve the health and safety performance of the food processing sector. Future related research includes an assessment of the perception of risk and attitudes towards OHS (perhaps such a study can also provide a reason for the poor response rate to the current study and that of others in this sector) as well as an examination of the barriers that prevent compliance with OHS legislative requirements. Furthermore, the current study also provides insight into the most common occupational health hazards faced by the food processing sector. Given this information, control measures to address these most prevalent hazards can be implemented and subsequently evaluated. The latter would be beneficial as there is a dearth of research regarding the effectiveness of occupational health interventions among blue-collar workers (van Holland, et al., 2015).

Conclusions

This pilot study found some key areas where food processing facilities are lacking with respect to the OHS legislation including training, hazard identification and policies. We also obtained a sector-specific priority list of occupational health hazards of which manual material handling was the most prevalent concern. This information is imperative to achieve our goal of improving the OHS performance within the food processing sector in Ontario, Canada. This is an important initiative as current claim numbers from this sector are relatively high and acknowledging OHS matters may also serve to improve the food safety culture within such workplaces (Griffith, Livesey, Clayton, 2010a; Griffith, et al., 2010b). In turn, this will likely lead to an increase in profitability, a benefit to the companies themselves as well as to the province's economy as a whole (Tompa, Dolinschi, de Oliveira, et al., 2009).

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