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Identifying Key Factors for an Occupational Health and Safety Risk estimation Tool in Small and Medium-size Enterprises

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Abstract: Small and medium-size enterprise accidents constitute a large proportion of the occupational health and safety accidents recorded in the construction industry. The methods used to tackle occupational health and safety issues in large enterprises do not work most of the time in the small and medium sized enterprises. Therefore a way of tackling occupational health and safety in these enterprises has to incorporate methods and tools specifically designed for them. This can be done by using a risk estimation tool specifically designed for small and medium sized enterprises. In this paper a literature survey supplemented by data collection is used to identify key factors which can be used in the occupational health and safety risk estimation tool. Three sources were used to identify factors by analyzing and comparing the data acquired. Consequently, 9 key factors were chosen in total from the three data sources and literature survey.

Keywords: Key-factors, occupational health and safety, Data Source, risk estimation, small and medium size enterprise, construction

1. INTRODUCTION

Occupational health and safety (OHS) is an area concerned with the development, promotion, and maintenance of workplace environment, policies and programs that ensure the mental, physical, and emotional well-being of employees as well as keeping the workplace environment relatively free from actual or potential hazards that can injure employees. OHS is a concern in industry. It has been shown in many journal papers that the accidents rate in Small and Medium sized Enterprises (SMEs) is higher than in Large Enterprises (LEs) (Micheli and Cagno, 2010). The reasons for the differences in the rates has been attributed to a lack of resources in terms of technology, finances and personnel (Cagno et al., 2011). This lack of resources in some cases has been attributed to financial constraints which lead to the owner-managers handling all functions of management including OHS of which they may not be experts of (Lamm and Centre, 1999). Because the enterprises are small, there are infrequent accidents associated to one particular enterprise and so this brings in complacency when it comes to OHS issues (Champoux and Brun, 2003), (Hasle et al., 2009). A European agency for safety and health at work in a survey of 3600 companies found that the greatest difficulties of companies regardless of size were;

- Lack of resources such as time, staff or money (36%).
- Lack of awareness such as risk identification, laws and policies (26%).
- Lack of expertise in occupational health and safety management (24%).
- Culture within the establishment such as organization and safety towards work (24%).
- Sensitivity of the issue such as complacency to the rules and regulations of OHS (23%)
- Lack of technical support or guidance on the interpretation and implementation of OHS practices (21%) (EASHW, 2010).

The construction industry has the highest number of occupational health related accidents (Azevedo et al., 2014). The industry is regarded amongst the major indicators of economic achievements (Irumba, 2014) which is correlated unfortunately, to an increased number of accidents. In a 2004 study report, in Spain and the United States, it was observed that the construction industry had the highest fatal accident rates per 100, 000 workers (Camino López et al., 2008). SMEs in the construction industry contribute to a significant number of accidents.

A risk estimation tool specifically designed for SMEs can help improve OHS. The methods used to solve OHS problems in LEs are not interchangeable with SMEs (Hasle and Limborg, 2006). SMEs have specificities which need to be considered.

The aim of this paper is to identify key factors which can be used as a guide in the development of tools for OHS risk estimation in SMEs in the construction sector. The key factors identified should give an insight into the events leading to the accident which will be used as inputs to the tool. The tool will help decision makers in identifying hazards and in the choices they make regarding risk reduction. This will lead to much more reliable and efficient manufacturing systems.

2. METHODOLOGY

The method used in this paper was based on a literature survey to examine which factors associated with OHS are common in the construction industry. The scope of the literature survey was limited to SMEs and Construction Industry accidents. Data was also collected from online databases. There are many online databases like the Analysis, Research and Information on Accidents (ARIA), Failure and ACcidents Technical information System (FACTS), National Institute of Research and Security (INRS), Major Accident Reporting System (MARS), Occupational Safety and Health Administration (OSHA) etc. Some of these databases have open access but are predominantly inaccessible to the public unless by subscription only (Mihailidou et al., 2012). In other cases, language was a barrier.

Small and Medium-sized Enterprises (SME) have different classifications in different parts of the world as noted by different authors in journal papers (Champoux and Brun, 2003), (Kongtip et al., 2008). These differences in the understanding of what an SME in itself presents a problem and produces challenges especially since the different sized enterprises are all bundled into one group with a seemingly unique feature (Masi and Cagno, 2014). However, in this paper we adopted a standard used by the European Commission (EC) 2003/ 361/ EC recommendation. The classification is shown in Table 2.1.

Table. 2.1: Classification of SMEs based on number of employees and Annual Turnover

Enterprise type	Number of employees	Annual Turnover
Micro	<=10	≤ € 2 Million
Small	11 -50	≤ € 10 Million
Medium Sized	51 – 250	≤ € 50 Million

Data for the analysis was collected from three main sources namely Bureau of Labour Statistics (BLS), EUROSTAT and WorkSafe BC. These data sources were chosen because access to their data did not require registration or subscription and was readily available. The EuroStat database collects its data from most parts of the European Union which covers a wide range of countries (approx. 27) which have a varying range of OHS practices and regulations. More research on OHS regarding SMEs has been done more by Europe than North America (Champoux and Brun, 2003). Therefore analysing the data from both North America and Europe would give a comprehensive view of OHS with regard to SMEs.

- United States Bureau of Labor Statistics (BLS) – this bureau falls under the department of labor which provides data on wages, inflation, productivity, labor, employment, economics and statistics. Data was acquired directly online.
- Eurostat – It is a European organisation under the European commission which provides statistics for most of the European member countries on different topics such as labor, OHS, employment etc. Data was acquired online.
- WorkSafe BC – is a Canadian organisation based in British Columbia which deals with different aspects of occupational health and safety ranging from prevention to compensation issues within the province of British Columbia. Data was sent by mail after making a request by fax specifying what kind of data was needed. The data provided was compiled only from compensation claims that were approved. Worksafe BC provided a total of 45, 609 accident entries from 1980 to 2013 in the construction industry alone.

The purpose of data collection was to identify what meaningful information can be retrieved from each query made from each organization's website and what possible information can be derived from the data collected. The search criteria was based on two important aspects for consideration in the development of a risk estimation tool. These are enterprise size AND/OR sector of industry. It was preferred that the enterprise size be limited to small and medium size while the sector of industry be limited to the construction industry. With this search criteria, all information retained by the search was then analysed to obtain the key factors.

Factors of the OHS risk estimation tool are characteristics of an accident which include events leading to and after the accident. Factors are therefore generalised input and output characteristics of an accident. Key factors were defined as those factors which are directly related to the input of an accident. These key factors should also be classifiable into the parameters which constitute risk analysis. The risk parameters considered are severity and probability of occurrence of harm (Moatari-Kazerouni et al., 2014). Severity is a function of the objective of protection in this case the human being (Moatari-Kazerouni et al., 2014) while probability is the likeliness of occurrence of an accident. Severity of an incident is measured by the number of work days lost due to injury.

In this paper, OHS factors from the literature survey were considered only if they matched with the factors acquired from the data sources. This ensured that the key factors determined matched the available data for analysis. However, additional factors obtained from the literature survey but unavailable on the online database sources can be used as a criteria for additional data type acquisition to be used by these database sources in the future.

3. RESULTS

The data collected from the three online sources was used to create a list of factors which were associated to the accidents in the construction industry. The data covered the accident characteristics leading to and after the accident which were hence defined as the factors. The data collected was divided into 18 factors as shown in Table 3.1. A tick in a cell in table 3.1, shows the availability of data for that particular factor associated with an information sources.

Some of the information obtained from Worksafe BC was analysed. Fig. 3.1 shows the accident rate as it varies with the age (years) of a worker. These results match with the conclusion made by (Salminen, 1993a). The time of day the accident occurred is a factor which also affects accident rates (Camino López et al., 2011).

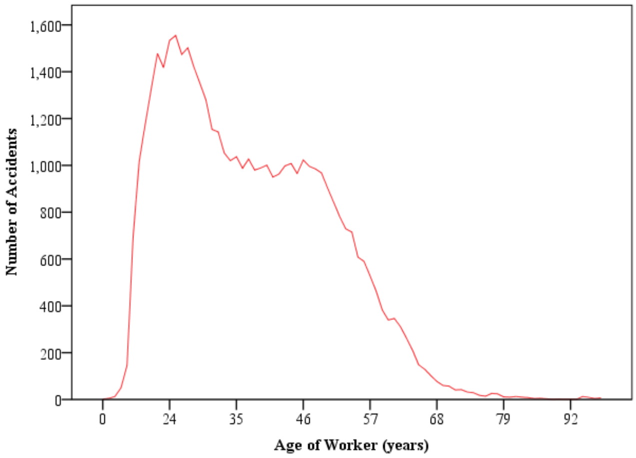

Fig. 3.1: Distribution of Accidents with age in years (WorkSafe BC Statistics: 1980 - 2013).

Fig. 3.2 shows the accident type as a function of number of accidents. The top accident types in the construction industry are overexertion, struck by and fall from elevation. This can be attributed to the fact that in SMEs, there is a general need to save time and lack of caution as noted in (Salminen et al., 1993). Therefore the workers tend to overexert themselves in order to keep up with the schedule and save time.

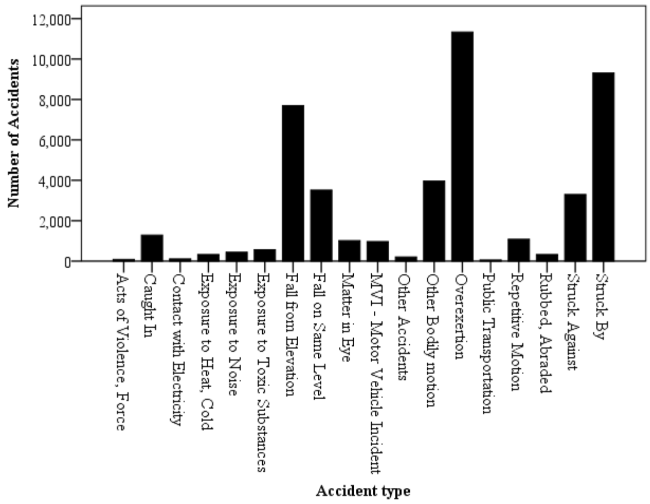

Fig. 3.2: Accident type distribution (WorkSafe BC Statistics: 1980-2013)

4. DISCUSSION

From table 3.1, it is clear that the data sources do not provide information on all the factors. BLS provides statistical data on all factors except the size of enterprise which in this paper is considered to be an important factor for data search. The data obtained from the BLS gives many factors for accident analysis as statistical values but does not provide individual accident analysis. Enterprise size is however explicitly considered from the data obtained from Eurostat, but the missing data is far too large to base a prediction tool on.

Table 3.1: Comparison of Factors obtained from Data sources and literature survey.

Factor	**Information Source**			
	BLS	**Worksafe BC**	**Eurostat**	**Literature survey**
Accident type	✓	✓		✓ (Cheng et al., 2012), (Cheng et al., 2010), (Amiri et al., 2014), (McCall et al., 2009)
Age of the worker	✓	✓		✓ (Cheng et al., 2012), (Haslam et al., 2005), (Cheng et al., 2010), (Chi et al., 2014),(McCall et al., 2009), (Salminen, 1993a)
Day of week accident happened	✓			✓ (Amiri et al., 2014)
Hours worked prior to injury	✓			
Industrial activity of Enterprise		✓		✓ (Cheng et al., 2012), (Cheng et al., 2010)
Industry Sector	✓	✓	✓	✓ (Cheng et al., 2010, Cheng et al., 2012, Haslam et al., 2005) (Chi et al., 2014) (Amiri et al., 2014)

Factor	Information Source			
	BLS	**Worksafe BC**	**Eurostat**	**Literature survey**
Length of Service or Experience	✓			✓ (Haslam et al., 2005), (Cheng et al., 2010), (Chi et al., 2014)
Musculoskeletal Disorder	✓			✓ (Schneider, 2001)
Nature of Injury	✓	✓		✓ (McCall et al., 2009)
Occupation of worker	✓	✓		✓ (Haslam et al., 2005), (Cheng et al., 2010)
Part of Body affected	✓	✓		✓ (Amiri et al., 2014)
Primary source of Injury	✓	✓		✓ (Cheng et al., 2012), (Chi et al., 2014), (Amiri et al., 2014)
Race or Ethnic Group	✓			✓ (McCracken et al., 2001)
Secondary source of injury	✓			✓ (Cheng et al., 2012), (Chi et al., 2009), (Chi et al., 2014)
Sex of the worker	✓			✓ (Cheng et al., 2012), (Chi et al., 2014)
Size of the Enterprise		✓	✓	✓ (Cheng et al., 2010), (Chi et al., 2014), (Salminen, 1993b)
Time of day accident occurred	✓			✓ (Camino López et al., 2011)
Work days lost	✓	✓	✓	✓ (Amiri et al., 2014)

Worksafe BC provides a much more relevant set of data based on the search criteria. Worksafe BC data was the closest to an actual accident reports database as it provided individual cases of accidents in the construction sector.

To get the key factors, the factors in table 3.1 were then analysed to determine their risk parameter characteristics, if any. Each factor should answer YES to two main questions and must be an input factor of the tool in order to qualify as a key factor:

1. Is the severity of the accident directly dependent on the factor?
2. Is the probability of occurrence of an accident dependent on the factor?

Using this analogy, the following answers were determined:

- Accident type – depending on the accident type, the severity can vary from minor with zero days lost to fatal or untreatable accidents. Therefore in risk analysis the accident type gives an indicator as to the severity of the accident in terms of number of days lost due to injury. In fig. 3.2, overexertion has the highest number of accident reports, therefore in the construction industry the probability of occurrence of this type of accident is high. Using this analogy, it is clear that accident type answers yes to both questions set as criteria for determining it as a key factor.
- Age of worker - In fig. 3.1, the number of accidents changes with the age of the worker thereby giving an indicator of which age group an accident is likely to occur. In the literature survey it has also been show that the age of the worker affects the severity of harm (Salminen, 1993a). Therefore, this factor also answers yes to both criteria questions for determining it as a key factor.
- Day of week accident happened – from the literature survey, the severity of the accident could not be linked to the day of the week. However, some studies showed that the probability of occurrence of accidents did vary with the day of the week. (López Arquillos et al., 2012), (Camino López et al., 2008). This factor answers yes to question 2 and no to question 1
- Gender of worker – gender satisfies the two question criteria for classification as a key factor. The relationship between gender and severity as well as their probability of occurrence was shown by(Dumrak et al., 2013).
- Length of service of worker – studies have shown that the experience of the worker has an effect on the severity of harm (López Arquillos et al., 2012). The probability of occurrence was also affected by the experience of the worker (Wang et al., 2002). This factor answers yes to both questions.
- Industrial activity of enterprise – Depending on the area of expertise in the construction industry, the severity of accidents varies. Therefore those industries engaged in high risk areas of work have a higher chance of accidents than those working in low risk environments. Severity and probability of occurrence is dependent on the industrial activity of enterprise as shown by (Dumrak et al., 2013). This factor answers yes to both questions.
- Musculoskeletal disorder and Nature of injury – these two factors are loosely grouped together because they represent the end effect of the accident or injury. Nature of injury covers cuts, lacerations, amputation and others. Musculoskeletal disorder covers tendinitis, lower back pain, gout and others. These factors are at the output of the tool or model.
- Occupation of worker –It has been shown that the severity and probability of occurrence of accidents is related to the nature of work done (Dumrak et al., 2013). It therefore answers yes to both questions.

- Part of body affected – this factor affects both the severity and probability of occurrence (López Arquillos et al., 2012), (Dumrak et al., 2013). This factor answers yes to both questions.
- Primary sources of injury – this factor relates to the direct cause of injury. The type of tool used in a work environment affects the severity of the accident as well as the probability of occurrence of an accident. In Spain, loss of machine control for example showed much more severe consequences than other sources of injury (López Arquillos et al., 2012). This factor also answers yes to both questions.
- Race or ethnic group – the literature survey could not link ethnicity to severity of an accident. However, the probability of occurrence of an accident was related to the ethnicity in all work related fatalities (McCracken et al., 2001). This factor answers yes to question two only.
- Secondary source of injury – this is an occupational source of injury other than the source that cause an accident. This factor answers yes to question 1 and 2, however this factor is not directly related to the accident.
- Time of day accident happened – past studies have shown that the time of day the accident happened has an effect on the severity and probability of occurrence of an accident.(Camino López et al., 2011) , (Dumrak et al., 2013). This factor satisfies both questions.
- Number of hours worked prior to the accident - no evidence was found to justify the severity and probability of occurrence of an accident as it related to this factor. This factor answers no to both questions.
- Work days lost – It is a consequence of an accident and a measure used to quantify severity. It is therefore not classified as a key factor.

Table 4.1 shows a summary of the classification criteria used to identify the key factors.

Table 4.1 : Factors as functions of risk parameters

Factor	Parameter Classification	
	Severity	Probability
Accident type, Age of the worker, Day of week accident happened, Gender of the worker, Industrial activity of Enterprise, Length of Service or Experience, Musculoskeletal Disorder, Nature of Injury, Occupation of worker, Part of Body affected, Primary source of Injury, Secondary source of injury, Time of day accident occurred	✓	✓
Hours worked prior to injury		
Race or Ethnic Group		✓
Work days lost (severity of harm)	✓	

From table 4.1, thirteen of the factors can be expressed in terms of severity and probability of occurrence of an accident. The other two factors were either severity or probability of occurrence related. Only one factor could not be shown as a function of severity and probability of accident. The nature of injury and musculoskeletal disorder could not be classified as key factors since they were output related factors. Secondary source of injury factor fails to qualify as a key factor since it is not directly related to the accident. Work days lost is more of a measure of severity than a key factor.
The identified key factors to be considered for a risk estimation tool for SMEs in the construction sector are therefore;

1. Accident type
2. Age of the worker
3. Gender of the worker
4. Industrial activity of enterprise
5. Length of service or experience
6. Part of body affected
7. Occupation of worker (in enterprise)
8. Primary sources of injury
9. Time of day accident happened

5. CONCLUSION

Key factors for a risk estimation tool in the construction industry were obtained using three online databases and literature survey. The data collected does not give a complete history of any one particular accident event. This is the biggest problem faced by this method of collecting data for the development of a risk estimation tool. Most of the data is presented statistically, therefore some data for SMEs in the construction industry is lost. Individual accident data was obtained from Worksafe BC. This data can however still be improved by adding more accident details like the number of hours worked prior to injury as they extract information from accident reports.
The number of hours worked prior to the accident can be obtained by looking at the time the accident happened and the time the worker logged in for work. However, most of the data available does not have a log in time for the workers. This makes this factor difficult to obtain. The time for worker log in and log out are obtained mainly from a standardized work day log in, log out time schedule.
The distribution statistics amongst some factors such as accident cause, age, gender in the LEs and SMEs are similar. However, there are likely variations in the secondary source of accident factors since there is likely to be a much more structured OHS management system in LEs than SMEs (Champoux and Brun, 2003, Hasle and Limborg, 2006).
The research was limited by the fact that the key-factors were only retained in the final compilation only if they matched the factors obtained from the data sources. The literature survey has additional factors identified but were not considered because there was no corresponding data found in the online data sources.
More research needs to be carried out to fully understand the effect of day of week accident occurred and number of hours

worked prior to accident, to the severity and probability of occurrence of harm.

Inconsistencies in missing data can be overcome if a standardized accident report system is developed which can incorporate factors raised by researchers in industrial safety engineering. Most risk assessments are carried out using limited historical data (Fung et al., 2012) which may lead to a bad predictor of future events.

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