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DEVELOPMENT OF DIRECT TO INDIRECT COST RATIO OF OCCUPATIONAL ACCIDENT FOR MANUFACTURING INDUSTRY

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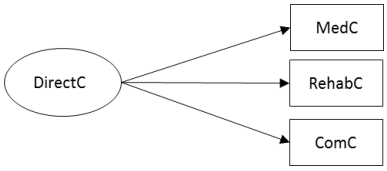
Graphical abstract



Abstract

Occupational injury would certainly give an impact not just to the victim but also to the organization and society at large. The impact would be in term of victim suffering, bad company reputation, low working moral among fellow workers and economic costs to the company. However, most of the aspects are difficult to quantify except for economics costs. The objective of this paper is to validate relationship accident direct cost model towards its observable cost components. Besides, this paper also proposes direct to indirect cost ratio based on accident cost range, accident scenario and impact of accident. Basically, accident cost can be categorized into two distinct categories which are direct and indirect cost. A total of 342 cases have been acquired for this study and recorded cases only cover temporary disability with more than one day of MC. Data is gathered from six types of sectors from manufacturing industry in Malaysia by using local specific method. The validity of direct cost model is tested by using confirmatory factor analysis (CFA) while indirect to indirect cost ratio is developed based on following aspects: (1) Accident cost range; (2) Accident scenario; and (3) Impact of accident. Proven direct cost model and direct to indirect cost ratio proposed would give a better insight to the relevant stakeholder in quantifying the occupational accident cost which may assist them in making necessary changes in order to avoid occurrence of similar accident in the future.

Keywords: Confirmatory factor analysis, direct cost, indirect cost, direct to indirect cost ratio, local specific, accident cost estimation

Abstrak

Kemalangan di tempat kerja akan memberikan impact bukan sekadar kepada mangsa tetapi juga kepada organisasi dan masyarakat secara keseluruhan. Antara impak tersebut ialah penderitaan mangsa, kejatuhan reputasi syarikat, moral pekerja yang semakin menurun dan implikasi kewangan kepada syarikat. Objektif kajian ini adalah untuk mengesahkan hubungan antara jumlah kos langsung kemalangan dan kos komponen yang terlibat. Selain itu, kajian ini juga mencadangkan nisbah kos langsung kepada kos tidak langsung berdasarkan julat kos kemalangan, scenario kemalangan dan impak kemalangan. Sejumlah 342 kes telah direkodkan dan hanya merangkumi kes hilang upaya sementara sahaja dengan bilangan hari cuti sakit melebihi sehari. Data kemalangan juga diperolehi daripada 3 sektor yang berbeza dalam industry pembuatan melalui kaedah data spesifik. Kesahihan model kos langsung ini diuji dengan menggunakan kaedah pengesahan analisis faktor. Sementara itu nisbah kos langsung kepada kos tidak langsung dibangunkan berdasarkan julat kos kemalangan, scenario kemalangan dan impak kemalangan. Model kos langsung yang telah ditentukan akan memberikan kefahaman yang lebih baik kepada pihak berkepentingan dalam menentukan kos kemalangan. Tambahan itu, ia akan membantu mereka dalam membuat perubahan yang diperlukan terutamanya dalam aspek keselamatan di tempat kerja bagi mengelakkan kejadian kemalangan berulang di masa akan datang.

Kata kunci: Analisis pengesahan faktor, kos langsung, kos tidak langsung, nisbah kos langsung kepada tidak langsung, anggaran kos kemalangan

1.0 INTRODUCTION

Accident cost estimation study has been started since 1920s which is pioneered by Heinrich [1]. He also has proposed direct to indirect cost ratio of 1:4 and this ratio has been widely used around the world especially on safety management field [2]. This kind of study has gained traction from last few decades due to growing concern on occupational accident among organizations management and safety practitioners especially on cost viewpoint. Presenting workplace accident statistics to the management is no longer working since number of cases does not translate into high accident cost. Researchers claimed that it is important to address workplace safety issues by expressing it in the term understood by managers-dollar and cents [3].

2.0 LITERATURE REVIEW

Generally, accident cost can be divided into two components which are direct and indirect cost [4, 5]. Gosselin stated that the distinction of those two cost categories is the one most often use in quantifying the accident cost and this terminology being used by Heinrich, Leopold and Leonard, Brody *et al*. and Hinze [6-11]. Other researchers such as Sun *et al*.; Simonds and Grimaldi use insured and uninsured cost in their study. Nevertheless, researchers fail to come into agreement on the cost definition and categorization [12, 13].

Other research suggested that direct cost is something that can be known at the time of accident whereas indirect cost is something that needs to be quantified after the accident event [14]. In separate study, direct cost is defined as costs which are aware by employers and indirect cost is regarded as hidden costs that employers tend to overlooked and underestimated [15]. Accident direct cost shall include injured worker's compensation, medical treatment and hospitalization cost, ambulance service and rehabilitation cost. As for indirect cost, the examples can be referred as following: replacement cost, productivity cost, accident investigation cost and legal and administrative cost [12]. Less quantifiable cost such as tarnished corporate image, reduced employee engagement, motivation and morale can also be included in the indirect cost when necessary [11, 16].

There are several different approaches that being used by researchers in order to estimate the accident cost namely local specific, bottom-up approach and top-down approach. Local specific approach is focused on examining past internal accident record directly from a company. Cost estimation also limited to that particular company and the findings may not reflect to other type of industry due to different business nature. However, this approach provides accurate cost estimates since OHS issues appeared in that organization represent a significant cost [15].

In other hand, top-down approach utilizes statistics that has been provided by the government for cost analysis. Results of existing studies are being used to estimate average accident costs rather than using company's local data [17]. The validity of this approach is questionable due to disregarded variations in accident cost distributions. Besides, there are high level of uncertainty on the accident cost data which may force researcher to use rough estimation rather than estimating the cost accurately [18]. Thus, it will pose significant variations to the cost distribution.

Relevant data should be gathered from project level rather than national level. Last but not least is bottom-up approach which use data collected from limited sample size. The data would be in the form of survey, questionnaires or face-to-face interview. The advantage of this approach is it provides more detail than top-down approach and information provided can be used to make a refinement on the accident cost. The cost can be based on severity or type of industry. Nevertheless, this should be noted that bottom-up approach has an issues in term of data quality [19]. In other hand, only companies that have well developed occupational safety and health system can contribute useful cost information. Small number of quality data available would pose difficulties in making general conclusion on that particular industry [20, 21].

Direct to indirect cost ratio has been widely used in scientific research to shows the impact between these two cost categories towards total accident cost [6, 15]. This ratio is beneficial to safety practitioner in order to assist them in estimating the indirect cost since the cost components in this cost category are not easy to quantify and the calculation is time consuming [9, 10]. Therefore, the existence of this ratio method will allow them to make initial estimation in short period of time during accident event by multiplying the direct cost with direct to indirect cost ratio. Swift accident cost notification to the company management will permit informed decision making in term of financial resource allocation and strategic approach in dealing with that situation [19]. In addition, accident cost ratio also has been used to achieve improvements in managing workplace safety [2].

There are various studies that have been done in determining the direct-indirect cost ratio and the pioneer of ratio study is Heinrich and followed by other researchers [1, 14, 22]. Researchers are more focus on two topics which are costs that need to be bear by the employer and costs which is due to impact to the society. However the latter one is harder to quantify since it involved society rather than dealing with costs that incurred inside the company.

It can be concluded that the ratio of direct to indirect is not always constant and largely depending on the area of study. There is no consensus among researchers on accepted ratio between direct and indirect cost of accidents. Some of the referred sources mentioned about reliable estimates done by

experts. However, none of the experts or researches are cited [23].

Confirmatory factor analysis (CFA) is a method to evaluate the relationship between observed variables and its underlying latent construct. In addition, it allows analyst to measure whether the hypothesized model proposed can be consistent with available data. Although CFA method is quite famous for social science study, it has not been exploited in safety management study [24].

In addition, CFA is already embedded in theories and priori model specification is needed. Besides, number of factors involved also need to be determined as well as the loading magnitude for each factor. CFA can be regarded as part of Structural Equation Model (SEM) which supports the investigation of causal relationship among latent variables. Combinations of several CFA models including its latent constructs will form the general SEM framework which will assist us in analyzing covariance structure. Nevertheless, CFA has different role compared to exploratory factor analysis [25]. In addition, the number of parameters in CFA is assumed to be known. It allows an indicator to load on multiple factor [26].

3.0 METHODOLOGY

Local specific approach has been adopted for data collection purpose. The data is gathered from six different type of sector within manufacturing industry which includes sawmills and planing, manufacture of furniture and fixture, industries related to printing and publishing, manufacture of plastic products, manufacture of electrical and electronic products and iron and steel basic industry.

Company's previous accident record is reviewed in order to get background of each occupational accident case. Only accident cases occurred between 2008 and 2013 are taken into consideration and it is limited to temporary disability. Besides, first aid cases (which has no medical leave, MC = 0) were excluded from this study. Finally, there are 344 cases available in total after data verification process is completed. For each occupational accident, the site safety officer in charge, human resource and account department officer, supervisor, victim and related co-workers were interviewed in order to estimate the actual cost for each cost component.

The cost components taken into account are medical cost, rehabilitation cost and compensation cost. In contrast, indirect cost comprise of: (a) productivity loss (b) worker replacement cost (c) administration and legal cost (d) investigation cost (e) machine and equipment damage (f) product damage. Data is recorded in SPSS Version 20 software.

After that, confirmatory factor analysis (CFA) is used to validate the direct cost model. The relationship between direct cost and its observed variables are modeled by using AMOS Version 21 software. The conceptual model for direct cost is shown as in Figure 1. CFA can assess the ability of hypothesized model to fit with collected data. The observed variables proposed consists of medical cost (MedC), rehabilitation cost (RehabC) and compensation cost (ComC) whereas direct cost (DirectC) is known as latent construct.

The cost components also known as endogenous variables while latent construct (DirectC) and its residual terms (e1, e2 and e3) known as exogenous variables. The observed variables are assumed to be known and usually embedded in.[24,25] The value inside each observed variable can be determined by collecting appropriate cost data inside the company.

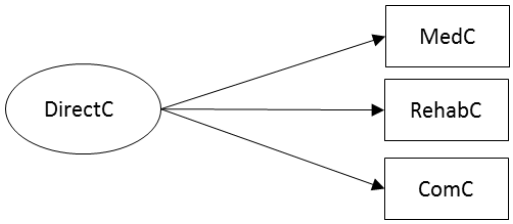


Figure 1 Conceptual of direct cost model

The direct to indirect accident cost ratio is determined by dividing total indirect cost with total direct cost for each case. Both cost categories has been estimated at the earlier phase of this study. The ratio is classified based on direct cost range with increment of RM 1,000 for each range bracket. Then, multiple linear regressions are developed by using Minitab software in order to find regressed ratio value for each respective direct cost bracket. This method also can ensure availability of direct-indirect ratio for various cost range in future study although some of direct cost range is not available in current study. The indirect cost is estimated by multiplying the direct cost with suitable ratio multiplier as stated in Table 2.

In contrast, the ratio is estimated based accident scenario and impact of injury. This classification consists of cause of accident, location of body injury and type of injury. Therefore, the case data is sorted according those categories before the direct to indirect cost ratio is determined.

4.0 RESULTS AND DISCUSSIONS

4.1 Validation of Direct Cost Model

Table 1 shows the output of factor loadings for each observed variables with its squared multiple correlation (SMC). The p-value for each endogenous variable is less than 0.05 ($P < 0.05$) which indicates statistically significant for each cost component. In other words, medical cost, rehabilitation cost and compensation cost will contribute significant impact to the total direct cost estimation. In addition, medical has highest factor loading and followed by rehabilitation and compensation cost. Hence, the result reflects as in practice and in line with direct

accident cost theory suggested by previous study. Steady increase of medical service fees in recent decades proved the finding of this research especially on medical cost.

Table 1 Factor loading estimates and squared multiple correlations

Observed Variables	Factor loading estimates	SMC
MedC	0.947	0.897
RehabC	0.791	0.626
ComC	0.292	0.085

Besides, this model has zero degree of freedom since number of unknown parameters exactly equals to number of known parameters and also called as saturated model. A saturated model indicates ability of the model to reproduce almost the same result as in theory with slight difference. Besides, there is no better model can be done with this data since the model is already saturated.

Several fit indices are used to validate the hypothesis model and those indices had assisted us in decision making process either to reject or accept the hypothesis model proposed. This study uses absolute fit index specifically goodness-of-fit index (GFI) for validation purpose. Praterelli *et al*. has adopted same approach in assessing causal factor of internet use and addiction [27].

GFI is considerably better than Chi-square index because the latter is sensitive to sample size and may always reject the properly specified model when the sample size become larger. The range of this fit indices are between 0 and 1 where higher value will reflect better fit [28].

The value of GFI computed by AMOS Version 21 software is 1.0 which indicates perfect model fit. Traditionally, the cut-off point is greater than 0.90 is recommended by various researchers. However, 0.95 is more appropriate if the sample size is small. Perfect fit achieved by direct cost model shows significant relationship between accident total direct cost and those three factors (medical cost, rehabilitation cost and compensation cost).

This finding also validates the theoretical assumption proposed for the direct cost.

4.2 Direct to Indirect Cost Ratio

Direct-indirect cost ratio is important in order to assist relevant stakeholder in estimating indirect cost of an accident after direct cost is already known. It is hard to estimate the cost since some of the workers and SHO themselves not familiar with cost estimation. Therefore, direct-indirect cost method is the best approach in addressing this issue. The indirect cost is divided with direct cost in order to compute the ratio.

(i) Based on direct cost range

Table 2 shows the ratio used for each direct cost range after multiple linear regressions analysis is completed. Then, the ratio is multiplied with actual direct cost in order to predict the indirect cost. From Table 2, it can be said that the direct to indirect cost ratio is decreasing when the direct cost is increased. Eventually, the ratio equal to one before direct cost surpass the indirect cost when direct cost at RM 9,000. Heinrich stated that the ratio is fixed at 1:4 only. However, this study revealed that the ratio can change accordingly based on direct cost. The change of direct to indirect cost ratio also has been found by other researchers. U.S Fish and Wildlife Service stated that the ratio can vary between 1:4 and 1:10 [31]. Study conducted by U.S Department of Labor found that the ratio of indirect cost to direct cost varies widely from as low as 1:1 to high of 20:1 [32].

The ratio is reduced due to increment of direct cost and this condition is reflected to severity of the accident. More severe cases would require accident victim to stay longer in hospital. Therefore, it would incur higher medical and hospitalization cost for recovery purposes. In addition, steady increase of medical service and compensation benefit in last few years has reduced the gap of differences between direct and indirect cost [29].

Ratio of direct to indirect cost published by OSHA also has a decreasing trend when direct cost of claim is increased [32]. The ratio is reduced from 4.5 to 1.1 whenever the direct cost claim reached US$ 10,000. However, that study only considers medical cost and indemnity payments as direct cost while all other related cost are assumed as indirect cost.

In contrast, single ratio number should not be used to make generalization for all occupational accident cases. Sometimes, each case is unique and may have a different kind of scenario and application of single ratio might not appropriate. Thus, this study proposed a more refine ratio which is based on direct cost range and availability of wide ratio range can give better insight and understanding on the accident cost. The accuracy of cost prediction also can be improved further since those ratios can tackle different cost range.

Table 2 Ratio of indirect to direct cost based on regression analysis

Direct Cost Range (RM)	Ratio
0-1,000	2.431
1,000-2,000	2.272
2,000-3,000	2.113
3,000-4,000	1.954
4,000-5,000	1.795
5,000-6,000	1.636
6,000-7,000	1.477
7,000-8,000	1.318
8,000-9,000	1.159
9000-10,000	1
10,000-11,000	0.841
11,000-12,000	0.682
13,000-14,000	0.523
17,000-18,000	0.364

(ii) Based on cause of accident

The highest number of accident recorded is due to striking against moving object with 81 cases. Then it is followed by caught between moving object (67 cases), caught in an object (56 cases), struck by falling object during handling (24 cases) and struck by moving objects (17 cases). These top five cause of accident contributed about 72% of total case recorded. The ratio of direct to indirect cost for each cause of accident as follows: striking against moving object (1:1.93), caught between moving object (1:1.72) cases), caught in an object (1:1.64), struck by falling object during handling (1:1.38) and struck by moving objects (1:2.52).

(iii) Based on location of body injury

The study shows fingers (42%), hand (16%), leg (5.3%), forearm (2.9%) and face (2.6%) contributes 68.8% of overall cases based on location of body injury. Most of the body location can be classified as upper limb body area since the injury occurred at the upper part of our body. The direct to indirect ratio for respective location of body injury can be referred as follows: fingers (1:1.64), hand (1:2.23), leg (1:1.27), forearm (1:2.07) and face (1:1.42).

Majority of the cases happened at upper limb area because most of production process is being handled by our hands. Hence would directly involve hand, fingers and forearm simultaneously. Bureau of Labor Statistics stated that hand and fingers injury is ranked just after back strain and sprain which contributed to loss of workdays. It is estimated about 110,000 lost time hand injury cases have been recorded annually in U.S. [30].

Therefore, company management can take several precautions in order to prevent the occurrence of this kind of injury in the future which will translate into reduction of number of reported case in the long run. Several steps that can be taken include providing employee with proper training, perform job hazard assessment, improvement of current standard operating procedure (SOP) in manufacturing process, installing guarding on the machine at the risky area and using automation for manufacturing process.

(iv) Based on type of injury

The result of study reveals that other wound (38.8%), superficial injuries (17.5%), fractures (12.3%), contusions and crushing (7.9%) and amputations and enucleations (6%) contributed 80% of total number of cases. The direct to indirect ratio for type of injury is stated as follows: other wound (1:2.12), superficial injuries (1:2.31), fractures (1:1.11), contusions and crushing (1:2.12) and amputations and enucleations (1:2.92).

5.0 CONCLUSIONS

This study proposes theoretical assumption on accident direct cost and validated by using CFA technique. The p-value which stood at less than 0.05 ($p < 0.05$) indicates that each cost components (medical cost, rehabilitation cost, compensation cost) has significant contribution towards accident direct cost. In addition, the direct cost hypothesis model also shows perfect fit since it has GFI value of 1 and having zero degree of freedom at the same time. In other way, theoretical assumptions on accident direct cost made by researchers from earlier studies are valid.

Based on direct cost range, the ratio of direct to indirect has decreasing trend whenever direct cost is start to increase and the ratio can become opposite when the direct cost is exceeding RM 9,000. Eventually, direct cost is seen larger than indirect cost if the accidents become more serious.

Moreover, it is not necessary for the ratio to be fixed at 1:4 across all occupational accident as mentioned by Heinrich and it can be changed depending on situation of that accident itself. The ratio of direct to indirect cost for cause of accident is ranged between 1:1.38 and 1:2.52 while for location of body injury is ranged from 1:1.27 to 1:2.23. For type of injury, direct to indirect cost is recorded between 1:1.11 and 1:2.92.

Despite wide variety of ratio proposed, it is quite difficult to make generalization for all kind of occupational accident case due to different nature of business for each industry.

References

[1] Heinrich, H. W. 1931; 1959. *Industrial Accident Prevention: A Scientific Approach*. 4th ed. New York. McGraw-Hill Book Co.

[2] Manuele, F. 2011. Accident Costs. Rethinking Ratios of Indirect to Direct Costs. *Professional Safety*. Jan 2011: 39-47.
[3] Leigh, J. P., Waehrer, G., Miller, T. R., & Keenan, C. 2004. Costs of Occupational Injury and Illness Across Industries. *Scandinavian Journal of Work Environment and Health*. 30(3): 199-205.
[4] LaBelle, J. E. 2000. What Do Accidents Truly Cost? Determining Total Incident Costs. *Professional Safety*. 45(4): 38-42.
[5] Oxenburgh, M. 1997. Cost-benefit Analysis of Ergonomics Programs. *American Industrial Hygiene Association Journal*. 58(2): 150-156.
[6] Gosselin, M. 2004. *Analyse des avantages et des coûts de la santé et de la sécurité au travail en entreprise: Développement de l'outil d'analyse*. Rapport de recherche R-375. Montréal, QC: IRSST.
[7] Heinrich, H. W. 1959. Industrial Accident Prevention: A Scientific Approach (1931) for the 1st Ed.; 1941 For The 2nd Ed.). 4th Ed. New York, NY: McGraw Hill.
[8] Leopold, E., & Leonard, S. 1987. *Costs of Construction Accidents to Employers*. *Journal of Occupational Accidents*. 8: 273-294.
[9] Brody, B., Létourneau, Y., & Poirier, A. 1990a. *Le coût des accidents de travail: État des connaissances*. Relations Industrielles. 45(1): 94-116.
[10] Brody, B., Létourneau, Y., & Poirier, A. 1990b. *Les coûtsIndirects des accidents du travail. Rapport de recherche R-044*. Montréal, QC: IRSST.
[11] Hinze, J. 1991. *Indirect Costs of Construction Accidents*. The Construction Industry Institute (CII), Source Document 67, Austin, TX.
[12] Sun, L., Paez, O., Lee, D., Salem, S., & Daraiseh, N. 2006. Estimating the Uninsured Costs of Work-related Accidents, Part I: A Systematic Review. *Theoretical Issues In Ergonomics Science*. 7(3): 227-245.
[13] Simonds, R. and Grimaldi, J. 1956. *Safety Management*. Homewood, IL: Richard D. Irwin, Inc.).
[14] Bird, F. 1974. *Management Guide to Loss Control*. Atlanta, GA: Institute Press.
[15] Romain Jallon, Daniel Imbeau, Nathalie de Marcellis-Warin. 2011. Development of an Indirect-Cost Calculation Model Suitable for Workplace Use. *Journal of Safety Research*. 42(3): June 2011, 149-164.
[16] Rikhardsson, P. M., &Impgaard, M. 2004. Corporate Cost of Occupational Accidents: An Activity-Based Analysis. *Accident Analysis & Prevention*. 36(2): 173-182.
[17] Everett, J. G., & Frank, P. B., Jr. 1996. Costs of Accidents and Injuries to the Construction Industry. *Journal of Construction Engineering and Management*. 122(2): 158-164.
[18] Miller, T. R. 1997. Estimating the Costs of Injury to U.S. Employers. *Journal of Safety Research*. 28(1): 1-13.
[19] Grun, R. E. 2006. *Monitoring and evaluation Projects: A step-by-step Primer on Monitoring, Benchmarking, and Impact Evaluation. Health, Nutrition and Population (HNP) Discussion Paper*. Washington, DC: The World Bank
[20] Laufer, A. 1987a. Construction Accident Cost and Management Safety Motivation. *Journal of Occupational Accidents*. 8(4): 295-315.
[21] Laufer, A. 1987b. Construction Safety: Economics, Information and Management Involvement. *Construction Management and Economics*. 5: 73-90.
[22] Leigh, J. P., Markowitz, S. B., Fahs, M., &Landrigan, P. J. 2000. *Costs of Occupational Injuries and Illnesses*. Ann Harbor, MI: University of Michigan Press.
[23] Evelyn Ai-Lin Teo & Yingbin Feng. 2011. Costs of Construction Accidents to Singapore Contractors, *International Journal of Construction Management*. 11(3): 79-92.
[24] Diana, T. 2014. Validating Delay Constructs: An Application of Confirmatory Factor Analysis. *Journal of Air Transport Management*. 35(March 2014): 87-91. ISSN 0969-6997.
[25] Pui-Wa Lei and Qiong Wu. 2007. Introduction to Structural Equation Modeling: Issues and Practical Considerations, *The Instructional Topics in Educational Measurement Series* (ITEMS). 26(3).
[26] Child, D. 1990. *The Essentials of Factor Analysis*. Second Edition. Cassel Educational Limited, London.
[27] Pratarelli, M. E., & Browne, B. L. 2002. Confirmatory Factor Analysis of Internet Use and Addiction. *Cyberpsychology & Behavior: The Impact of the Internet, Multimedia and Virtual Reality on Behavior and Society*. 5(1): 53-64.
[28] Bentler, P. M. and Bonnet, D. C. 1980. Significance Tests and Goodness of Fit in the Analysis of Covariance Structures. *Psychological Bulletin*. 88(3): 588-606.
[29] Manuele, F. (2013). *On the Practice of Safety*, 4th Edition, Wiley-interscience
[30] Bureau of Labor Statistics. 2011. [Online]. From: http://www.dol.gov/wb/stats/stats_data.htm. [Accessed on 15 December 2014].
[31] U.S. Fish and Wildlife Service. 2014. Definitions (undated). Division of Safety and Health. [Online]. From: http://www.fws.gov/safety/definitions.htm. [Accessed on 25 December 2014].
[32] OSHA. 2007. Safety and Health Management System eTool–Costs of Accidents. [Online]. From: https://www.osha.gov/SLTC/etools/safetyhealth/mod1_costs.html. [Accessed on 15 November 2014].