Environmental Engineering and Management Journal

March 2019, Vol.18, No. 3, 665-683
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

METHODOLOGIES FOR INVESTIGATING OCCUPATIONAL ACCIDENTS AND THEIR USE IN OCCUPATIONAL HEALTH AND SAFETY RESEARCH. LITERATURE REVIEW

Francisco Salguero-Caparros[1*], Manuel Suarez-Cebador[1], Juan Carlos Rubio-Romero[1], Jesús A. Carrillo-Castrillo[2]

[1]School of Industrial Engineering, University of Málaga, C/ Dr. Ortiz Ramos, s/n 29071 Málaga, Spain
[2]University of Sevilla, C/ Camino de los Descubrimientos s/n, 41092 Seville, Spain

Abstract

The objective of this paper is to review the main studies published on occupational accidents to recognize, classify and describe the scientific methodologies used.
To achieve the objective set we used a method that has already been implemented and validated, consisting of an extensive review of international scientific literature related to the methodologies for investigating accidents in occupational health and safety. Then, to assess the importance of these methodologies, we analyzed the number of times the selected publications are cited and the impact factor of the journal where it was published.
The results of this review show that many different investigation methodologies have been developed over the last few decades. These methodologies cover different areas of application, qualities and limitations, with the understanding that a thorough accident investigation requires a combination of different activities included in these methods. This study describes which methodologies have been used the most in the field of occupational accident investigations. A total of 35 different methodologies were identified. This study reveals that, even to this day, there are not many methodologies available with a single focus on the field of occupational health and safety. On the other hand, in order to develop and advance in the application of occupational accident investigation techniques, it would be advisable to promote studies that verify the proper selection and use of methodologies in real cases of occupational accidents.

Keywords: investigation of occupational accidents, methodologies for accident investigation, occupational accident, review

Received: February, 2016; Revised final: June, 2016; Accepted: July, 2016; Published in final edited form: March, 2019

1. Introduction

An accident investigation determines the facts leading to the accident through research, observation and examination (Harms-Ringdahl, 2004). All of this is followed by an analysis of the facts in order to establish the causes of the accident and the measures that should be adopted to prevent its repetition. This definition clearly shows why an accident investigation is a useful tool for Safety Science.

Accident Investigation is a concept that has been widely applied to specific fields such as civil aviation, maritime and rail transport, hospitals, space industry, construction etc. (Roed-Larsen and Stoop, 2012). Likewise, over the years a great number of specific methodologies for accident investigation have been developed for these industries (Lindberg et al., 2010). However, most of these methodologies (Jacinto et al., 2011) were not developed for the occupational accidents defined by the Encyclopedia of International Safety Organization Part VIII, Chapter 56 (International Labour Organization, 1998), as "an event occurring while at work or in connection with work causing occupational injuries or even death".

*Author to whom all correspondence should be addressed: e-mail: c2613sc@copitima.com; Phone: +34 952282354

In this sense, European Directive 89/391/EEC of the Council, of 12 June (European Council, 1989) related to implementation of measures to promote worker health and safety at work, became an important milestone for all matters related to Occupational Health and Safety (hereinafter OH&S) in Europe. This document, which defines the common legislation requirements for this topic in the European Union countries, establishes in Section D of Article 9 that: "It is an employer's obligation, to draw up, for the responsible authorities and in accordance with national laws and/or practices, reports on occupational accidents suffered by his workers". Given that this Directive 89/391/EEC was transposed to all EU Member States, at different times and with different levels of detail, each EU country developed its own system for reporting accidents and submitting investigation reports.

As advanced by McDevitt and Benner (1981), the concept of "accident investigation methodology" is defined as the system of concepts, principles and procedures to investigate accidents. To initiate an occupational accident investigation, authors such as Lindberg et al. (2010) and Dien et al. (2012), state it is necessary to have a methodology to conduct the investigation process thoroughly. Furthermore, the methodology to be used in the investigation should help identify the direct and the indirect causes, as well as any faults in the organization system or work management (Antao et al., 2008), and naturally the methodology needs to have been validated (Katsakiori et al., 2009).

Similarly, Roed-Larsen and Stoop (2012) expressed that the systematic use of scientific methods structures the investigation process and improves identification of the causes, interpretation of the results and validity of the recommendations.

Moreover, as stated by Katsakiori et al. (2009), the evolution of accident investigation methodology over time reveals a gradual shift from the search for a single immediate cause, to the recognition of multiple basic causes, and ultimately to the identification of weaknesses in the organization system of the occupational activity. That is, as stated by Dien et al. (2004), the accident analysis methodology should not only detect human and technical errors as causes of accidents, but also organization errors.

In spite of these sound arguments showing not only the usefulness but also the need to follow a scientific methodology when conducting occupational accident investigations, as stated by Roed-Larsen and Stoop (2012), currently in Europe there is a worrying lack of standardized and validated methods being used during the analytical phase of the investigation process.

Furthermore, for many years multiple methodologies have been developed to investigate accidents that could be used in the field of occupational accidents, such as: MES (Multi-Linear Event Sequencing) (Benner, 1975), MORT (Management Oversight and Risk Tree) (Johnson, 1980), OARU (Occupational Accident Research Unit) (Kjellen and Larsson, 1981), STEP (Sequentially Timed Events Plotting) (Hendrick and Benner, 1987), FTA (Fault Tree Analysis) (Ferry, 1988), MTO (Man Technology and Organisation) (Rollenhagen, 1995), TRIPOD (Groeneweg, 1994), Acci-Map (Accident Map) (Rasmussen, 1997). Likewise, new methodologies have emerged over the last decade: HFACS (The Human Factors Analysis and Classification System) (Wiegmann and Shappell, 2001), WAIT (Work Accidents Investigation Technique) (Jacinto and Aspinwall, 2002), FRAM (Functional Resonance Accident Model) (Hollnagel, 2004), STAMP (System-Theoric Accident Model and Processes) (Leveson, 2004), ATSB (Australian Transport Safety Bureau) (2008), RIAAT (The Recording, Investigation and Analysis of Accidents at Work process) (Jacinto et al., 2010).

There is also a specific group of articles describing the practical application of scientific methodologies to actual accident investigations. Worthy of note are the case studies by Antao et al. (2008) and Jacinto et al. (2009) implementing the WAIT method and the studies by Schroder-Hinrichs et al. (2011) and Lenné et al. (2012) applying the HFACS method.

On the other hand, we found different administrations and organizations which have developed their own occupational accident investigation manuals, where they have identified, described and, in some cases, assessed different accident investigation methodologies: National Institute for Occupational Health and Safety (Pique, 1997); NRI Foundation (1998); US Department of Energy (DOE,1999); Root Causes Analysis: Literature Review (Livingston et al., 2001); WORM Project (Ale et al., 2006); Esreda, 2009; Accident Analysis Models and Methods: Guidance for Safety Professionals. Loughborough University (Underwood and Waterson, 2013a).

Likewise, over the last few decades, a series of reviews of scientific literature have been carried out that cover the evolution and development of accident investigation methods, compare their specifics features and define their field of application, some of which can be adapted to occupational settings (Benner, 1985; Dien et al., 2012; Hollnagel and Speziali, 2008; Jacinto et al., 2011; Katsakiori et al., 2009; Sklet, 2004; Strömgren et al., 2013; Wagenaar and Van der Schrider, 1997). Moreover, several reviews have been developed about adequate risk assessment of the workplace and specific manufacturing industry methodologies and techniques (Marhavillas et al., 2011; Willquist and Torner, 2003).

There has been, therefore, for almost half a century, a good amount of material published on methodologies for accident investigations, although this data is highly fragmented and divided into different areas of knowledge, such as Engineering, Ergonomics, Economics, Psychology and Organisation.

Therefore, the purpose of this study is, on the one hand, to conduct a review of existing scientific literature that has dealt with the analysis of occupational accidents, as well as studies on occupational accident investigations published by public administrations or institutions. Also, to classify the methodologies used for occupational accident investigations in the literature and studies selected, together with a brief description of the same. Similary, this review will complement previous reviews that left out of scope research analysis of occupational accidents and methodologies used. Therefore, this study becomes the first review of the scientific literature with this scope. This article is aimed at those who in their research or work have the mission of investigating occupational accidents, as it can serve as a guide to the extensive and fragmented literature available.

2. Methodology and search criteria

2.1. Study design

This study includes an international review of publications which have analysed occupational accidents as the basis for identifying the scientific methodologies they used. In order to carry out this review, defined by Fink (2009) as "a systematic, explicit and complete process and a reproducible method to identify, evaluate and synthesize existing materials produced and reported by investigators", we used the techniques defined in the methods applied by Fink (2009), Okoli and Schabram (2011) and Wang et al. (2013) (Fig.1).

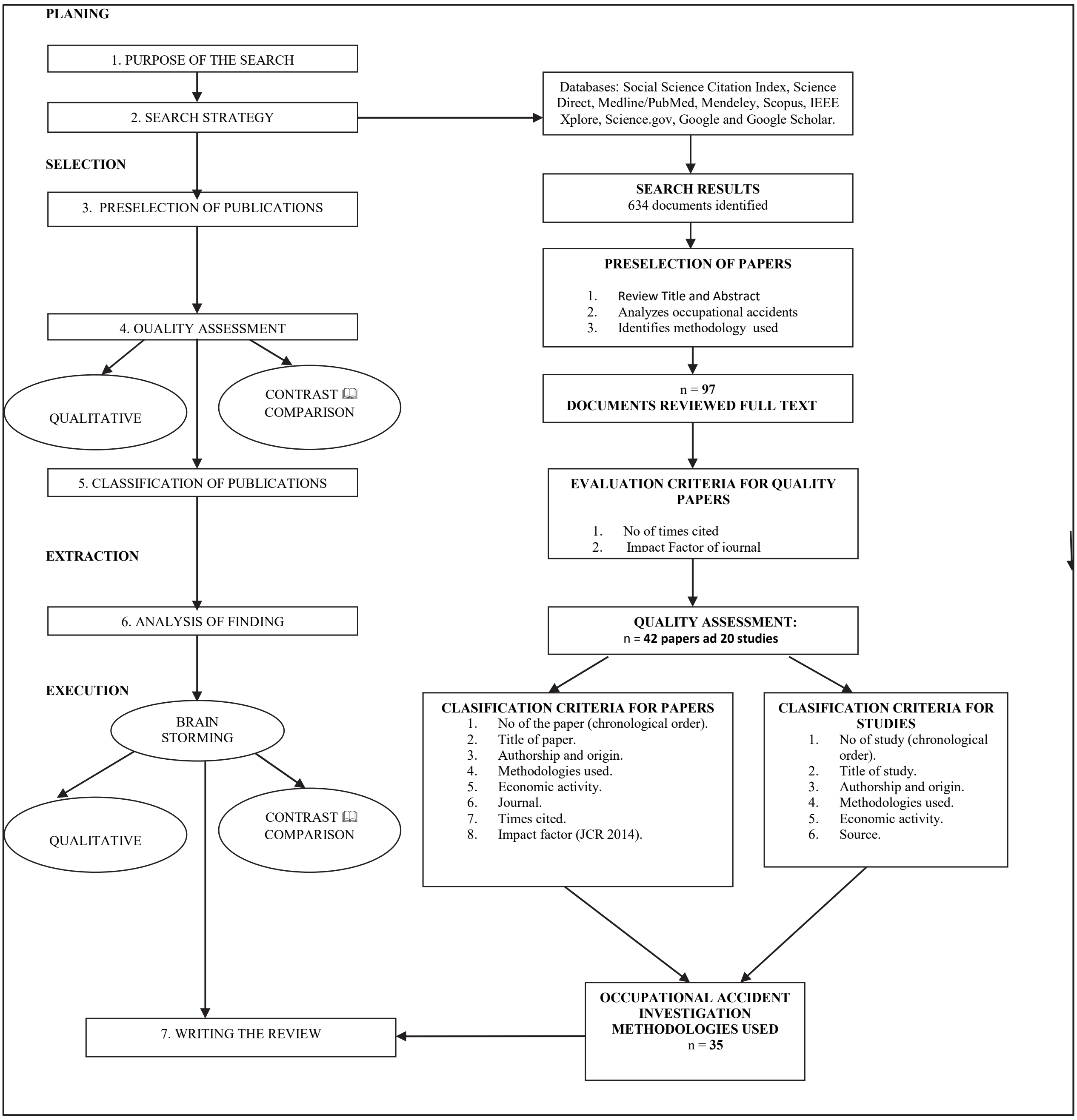

Fig. 1. Research process of systematic literature review and structuring content analysis, Wang et al. (2013)

On the other hand, in order to determine the impact and importance of the methodologies identified, this study also assessed the literature based on the number of times the publications identified are cited, and the impact factor of the journals they are published in (Liu et al., 2013).

This literature review therefore aims to explore some useful findings and identify knowledge gaps regarding the investigation of occupational accidents in order to establish an agenda for future research

2.2. Literature search

The bibliographic search was limited to the last three decades so that the results are current and aligned with recent scientific community trends. The search was restricted to scientific papers, and studies conducted by public administrations or institutions in any country published mainly in Spanish or English.

In the case of public administrations and institutions, we used the following Science Search Engines: IEEE Xplore, Science.gov, Google and Google Scholar. As for papers, we looked in five international bibliographic databases: Social Science Citation Index, Science Direct, Medline/PubMed, Mendeley and Scopus. To find papers we used The Social Science Citation Index as the main bibliographic source, conducting an advanced search, using free text expressions and full text searches.

The Keywords used were adapted to the type of search and web tool used in each case. For the initial search sweep we used the key words "accident investigation" combined (AND) with "methodology". Next we looked for the terms "accident investigation" and "accident investigation methodologies" AND "occupational". The article search continued by using the long phrase "occupational accident investigation methodologies" AND "application". All of these were also accompanied by the word "Review". The final search sweep was carried out by combining the name of the known scientific methodologies AND "occupational".

2.3. Literature selection. Inclusion and exclusion criteria

By applying the search strategy exposed and because of the use of databases with overlays information, the appearance of duplicate publications was inevitable. Therefore, after excluding repetitions, a total of 634 results were obtained. The relevance of the references was determined by analysing the title and abstract. The inclusion criteria for the articles were those analysing a sample of actual occupational accident investigations which then identified the scientific methodology used. The full text of the 97 articles chosen in this initial selection were studied before deciding whether to include them or not.

Next, from the selected articles, we assessed the quality and clarity of the investigation and its contribution to the scientific community.

We also analysed the publications which had cited them, in order to find new articles that could be relevant to our study. Special attention was paid to articles reviewing methods analysing who cited them, to see whether they also used some of the methodologies reviewed in the occupational accident investigation analysis. Then we excluded articles which either did not cover the topic clearly, or had bibliographic and/or documentation flaws.

To assess the quality of the selected articles we used ISI Web of Science (WOS) as the source of data for this study. We extracted the number of author citations and the impact factor of the journal that had published the article in the Thomson Reuters Journal Citation Reports. After this final analysis, we ended up with a selection of 42 articles and 20 studies published by public administrations or institutions.

2.4. Literature coding

The final articles chosen were classified according to 8 criteria: number of the paper in chronological order of publication, title, author or authors and country of origin, accident investigation methodologies used, economic activity of the sample studied according to NACE Rev.2 (European classification of economic activities), journal or publication, total number of times this article is cited and impact factor of the publication according to the Journal Citation Reports 2014 (JCR 2014).

The manuals, studies or guides prepared by the public administrations or institutions selected were in turn classified according to 6 criteria: number of publication by chronological order, title, author and country of origin, occupational accident investigation methodologies used, economic activity of the sample investigated and source. Finally, we analysed the results of the literature selected and classified them in the abovementioned categories and looked at the state-of-the-art for the identified occupational accident investigation methodologies.

3. Results

3.1. Classification of quality articles selected

The first objective of this paper was to identify the main studies published that have analysed a sample of investigated occupational accidents, and in turn to identify the scientific methodology used to analyse the accidents. Based on the methodology applied, we identified 634 publications, of which 97 were preselected for a more detailed analysis. We ended up with a selection of 42 publications (Table 1).

As shown in Table 1, this is a very heterogeneous sample as far as the origin of the articles selected, since it includes studies from 4 continents (Europe, America, Asia and Oceania). In this selection, we identified 25 different methodologies to investigate occupational accidents.

Table 1. Summary of selected publications with the methodology used

No.	*Title*	*Authorship and Origin*	*Methodologies used*	*Economic activities (NACE Rev. 2)*	*Journals*	*Times cited*	*Impact factor JCR 2014*
1	A classification system for causes of occupational accidents for use in preventive strategies	Feyer and Williamson (1991). Australia	MORT	Several Workplaces	SJWEH	35	3.454
2	Accident analysis the goal, and how to get there	Wagenaar and Van der Schrider (1997) The Netherlands	TRIPOD	Mining and Quarrying	SS	14	1.831
3	Identifying root causes of construction injuries	Hinze et al. (1998). USA	OSHA	Construction	JCEM	67	0.842
4	A comparison of accident analysis technique for safety-critical man-machine systems	Kontogiannis et al., (2000) Greece	FTA, STEP, Petri nets	Mining and Quarrying	IJIE	22	1.070
5	Identifying root causes of construction accidents	Abdelhamid and Everett (2000). USA	ARCTM	Construction	JCEM	75	0.842
6	WAIT- a new method for the investigation and Analysis of accidents al work	Jacinto and Aspinwall (2002) Portugal	WAIT	Manufacturing	PPHS	4	No record
7	Work accidents investigation Technique (WAIT)-Part I	Jacinto and Aspinwall (2003) Portugal	WAIT	Construction	SSM	25	No record
8	Organisational accidents investigation methodology and lessons learned	Dien et al. (2004) France	Event tree Analysis.	Electricity, gas. Steam and air conditioning supply	JHM	23	4.529
9	WAIT (Part II)-Results of application in real accidents	Jacinto and Aspinwall (2004a) Portugal and UK	WAIT	Manufacturing and construction	SSM	2	No record
10	WAIT (Part III)- Preliminary validation studies	Jacinto and Aspinwall (2004b) Portugal and UK	WAIT, PFA	Manufacturing and construction	SSM	3	No record
11	Contributing factors in construction accidents	Haslam et al. (2005). UK	HSE	Construction	AE	117	2.023
12	Accident patterns and prevention measures for fatal occupational falls in the construction industry	Chi et al. (2005). Taiwan	MES	Construction	AE	71	2.023
13	Occupational accident models. Where have we been and where are we going?	Attwood et al. (2006). UK and Canada	MORT and HSE	Mining and Quarrying	JLPPI	21	1.406
14	Storybuilder - A tool for the analysis of accident reports	Bellamy et al. (2007). The Netherlands	MORT	Construction	RESS	30	2.410
15	Modeling accidents for prioritizing prevention	Hale et al. (2007). The Netherlands and Greece	STAMP	Several Workplaces	RESS	28	2.410
16	Types and sources of fatal and severe non-fatal accidents in industrial maintenance	Lind (2008). Finland	Swiss Cheese Model	Manufacturing	IJIE	17	1.070
17	Causes of occupational accidents in the fishing sector in Portugal	Antão et al. (2008). Portugal	WAIT	Agriculture, forestry and fishing	SS	15	1.831
18	The software tool storybuilder and the analysis of the horrible stories of occupational accidents	Bellamy et al. (2008). The Netherlands and Greece	FTA	Several Workplaces	SS	15	1.831
19	Analysis of safety functions and barriers in accidents	Harms-Ringdahl (2009) Sweden	SFs	Electricity, gas, steam and air conditioning supply	SS	16	1.831
20	Workplace and organizational factors in accident analysis within the food industry	Jacinto et al. (2009). Portugal	WAIT	Manufacturing	SS	13	1.831
21	In-depth accident analysis of electrical fatalities in the construction industry	Chi et al. (2009) Taiwan	MES	Construction	IJIE	27	1.070
22	Risk assessment tools incorporating human error probabilities in the Japanese small-sized establishment.	Moriyama and Ohtani (2009) Japan	FTA	Manufacturing	SS	6	1.831
23	Industrial accidents triggered by flood events: Analysis of past accidents	Cozzani et al. (2010) Italy	FTA	Several Workplaces	JHM	32	4.529

24	Analysis of work related accidents in the Spanish mining sector from 1982-2006	Sanmiquel et al. (2010). Spain	FTA	Mining and Quarrying	JSR	11	1.870
25	Workplace and organizational accident causation factors in the manufacturing industry	Katsakiori et al. (2010) Greece	MILI	Manufacturing	HFEM SI	4	0.862
26	Constructing "core stories" for contributing practical safety actions in industrial units	Rajala and Väyrynen (2010) Finland	MES	Manufacturing	SS	5	1.831
27	Accident in a French dynamite factory: An example of an organizational investigation.	Le Coze (2010) France	MORT and STAMP	Manufacturing	SS	6	1.831
28	Accident investigation reporting deficiencies related to organizational factors in machinery space fires and explosions	Schröder-Hinrichs et al. (2011) Sweden	HFACS	Transportation and Storage	AAP	8	2.070
29	SHIPP methodology: Predictive accident modeling approach. Part II. Validation with case study	Rathanayaka et al. (2011) Canada	FTA, Event tree Analysis.	Electricity, gas, steam and air conditioning supply	PSEP	19	2.551
30	A systems approach to accident causation in mining: An application of the HFACS method	Lenné et al. (2012) Australia	HFACS	Mining and Quarrying	AAP	13	2.070
31	Accident investigation in the Norwegian petroleum industry–Common features and future challenges	Okstad et al. (2012) Norway	MTO	Mining and Quarrying	SS	9	1.831
32	Developing the understanding of underlying causes of construction fatal accidents	Hale et al. (2012). The Netherlands and UK	HFACS	Construction	SS	8	1.831
33	FTA vs. Tripod-Beta, which seems better for the analysis of mayor accidents in process industries?	Mohammadfam and Nikoomaram (2013) Iran	FTA, TRIPOD-BETA.	Manufacturing	JLPPI	2	1.406
34	Systemic accident analysis: Examining the gap between research and practice	Underwood, and Waterson (2013b) UK	STAMP, FRAM, AcciMap, Swiss Cheese Model, FTA.	Manufacturing	AAP	11	2.070
35	Causation of severe and fatal accidents in the manufacturing sector.	Carrillo-Castrillo et al. (2013). Spain	FTA	Manufacturing	JOSE	4	0.312
36	Texas city refinery accident: Case study in breakdown of defense-in-depth and violation of the safety–diagnosability principle in design	Saleh et al. (2014). USA	STAMP	Mining and Quarrying	EFA	5	1.028
37	Graphical fault tree analysis for fatal falls in the construction industry	Chi et al (2014) Taiwan	FTA	Construction	AAP	0	2.070
38	A study of maintenance-related major accident cases in the 21st century	Okoh and Haugen (2014) Norway	FMEA	Manufacturing	PSEP	3	2.551
39	Electrical deaths in the US construction: An analysis of fatality investigations	Zhao et al. (2014). USA	OSHA	Electricity, gas, steam and air conditioning supply	IJICSP	2	0.707
40	Comparison of different methods for work accidents investigation in hospitals: A Portuguese case study	Nunes et al. (2015) Portugal.	FTA, CTM, Swiss Cheese Model, FM, WAIT, RIAAT	Human Health and Social work activities	WORK	0	0.320
41	Analysis of investigation reports on occupational accidents.	Salguero-Caparros et al. (2015) Spain	RIAAT	Several Workplaces	SS	1	1.831
42	A STAMP-based causal analysis of the korean sewol ferry accident.	Kim et al. (2016) Norway	STAMP	Transportation and Storage	SS	0	1.831

Thus, considering the relative frequency percentage of use of each methodology in the publications selected, we highlighted eleven of them. First is the FTA method, found in 26.19% of the publications selected. Second is the WAIT method, present in 16.66% of the publications. Third is the STAMP method, found in 11.90% of the publications. Fourth is the MORT method, found in 9.52% of the publications. Fifth are the HFACS, MES and SCM (Swiss Cheese Model) methods, which are present in 7.14% of the publications. Sixth are the OSHA (Occupational Safety and Health Administration Data Collection Forms), HSE (Health and Safety Executive), ETA (Event Tree Analysis) and RIAAT methods, which are present in 4.76% of the publications selected. The rest were identified only in one of the articles selected (2.38%).

Because is a selection of articles analyzing accident investigations in the field of Occupational Health and Safety (OHS), it is considered essential (Carrillo-Castrillo et al., 2015) to quantify them in terms of activity sector of the sample used. As for the economic activity conducted in the publications selected, according to the European Statistical

Classification of Economical Activities (NACE Rev. 2 hereinafter), we found that the activities reporting the highest number of analyzed accident investigations in the selected publications were:

- Manufacturing: 11 publications, 26.19%
- Construction: 9 publications, 21.42%
- Mining and Quarrying: 7 publications, 16.66%
- Several Workplaces: 5 publications, 11.90%
- Electricity, gas, steam and air conditioning supply: 4 publications, 9.52%
- Manufacturing and Construction simultaneously: 2 publications, 4.76%
- Transportation and Storage: 2 publications, 4.76%
- Agriculture, forestry and fishing: 1 publication, 2.38%
- Human Health and Social work activities: 1 publication, 2.38%.

With relation to the journals where the 42 papers were published, Table 2 shows a classification of these according to their impact factor (JCR 2014). The last column shows the numbers of the articles according to the numerical order assigned in Table 1. Safety Science (SS) had the highest number of articles selected as most relevant, followed by Accident Analysis and Prevention (AAP), Safety Science Monitor (SSM) and International Journal of Industrial Ergonomics (IJIE). More than 50% of the selected papers were published in these four journals, demonstrating the significance of them in the area of investigation on occupational accidents.

As for the results obtained from the analysis of the number of citations of the publications selected according to data extracted from WOS (Web of Science). First is the publication by Haslam et al. (2005), which has been cited 117 times. In this study, conducted by scientists from Loughborough University and UMIST, they analysed a sample of 100 accident investigations occurring in the construction industry in Great Britain using the HSE method.

Table 2. Scientific research journals where the papers selected as most relevant were published

Acronym	*Journal*	*Ranking by Impact Factor JCR 2014*	*Impact factor JCR 2014*	*Ranking by number of publications selected in Table 1*	*Number assigned to the paper selected in Table 1*
JHM	Journal of Hazardous Materials	1	4.529	5	[8, 23]
SJWEH	Scandinavian Journal of Work, Environment & Health	2	3.454	11	[1]
PSEP	Process Safety and Environmental Protection	3	2.551	10	[29, 38]
RESS	Reliability Engineering and System Safety	4	2.410	6	[14, 15]
AAP	Accident Analysis and Prevention	5	2.070	2	[28, 30, 34, 37]
AE	Applied Ergonomics	6	2.023	8	[11, 12]
JSR	Journal of Safety Research	7	1.870	12	[24]
SS	Safety Science	8	1.831	1	[2, 17, 18, 19, 20, 22, 26, 27, 31, 32, 41, 42]
JLPPI	Journal of loss prevention in the process industries	9	1.406	7	[13, 33]
IJIE	International Journal of Industrial Ergonomics	10	1.070	3	[4, 16, 21]
EFA	Engineering Failure Analysis	11	1.028	13	[36]
HFEMSI	Human Factors and Ergonomics Manufacturing and Services Industries	12	0.862	14	[25]
JCEM	Journal of Construction Engineering and Management	13	0.842	9	[3, 5]
IJICSP	International Journal of Injury Control and Safety Promotion	14	0.707	15	[39]
WORK	WORK	15	0.320	17	[40]
JOSE	International Journal of Occupational Safety and Ergonomics	16	0.310	16	[35]
SSM	Safety Science Monitor	17	No record	4	[7, 9, 10]
PPHS	Policy and Practice in Health and Safety	18	No record	18	[6]

Note: journals were sorted according to their Impact Factor followed by the total articles selected for this study.

Next is publication by Abdelhamid and Everet (2000), which has been cited 75 times. This study presented the ARCTM (Accident Root Causes Tracing Model) method, developed by members of the ASCE research group from the University of Michigan in the USA. In this study they analysed 3 severe occupational accidents in the construction industry, selected from the Michigan Department of Transportation (MDOT). The objective of the ARCTM method was to complement occupational accident investigation techniques in the construction industry with contemporary techniques in 2000 related to the causes of accidents and human error.

Third is the publication by Chi et al. (2005), cited 71 times. This study analyzed a sample of 621 fatal accidents at work in the construction industry between 1994 and 1997. The accident investigation reports analyzed were taken from the Council of Labour Affairs of Taiwan. The analysis of this sample used a MES methodology in order to determine potential causes and propose preventive measures.

Then, there is a publication by Hinze et al. (1998), cited a total of 67 times. This study examined 1,082 accidents which were investigated between 1994 and 1995 in the construction industry in the USA using the OSHA methodology. This study provides recommendations to improve the methodology used.

In fifth place is the publication by Feyer and Williamson (1991) cited 35 times. This study analyzed a sample of 1,020 investigated accidents corresponding to different work sectors between 1982 and 1984. The reports handled were extracted from the National Institute of Occupational Health and Safety in Australia. This study used the MORT method to analyze the accidents investigated.

Also noteworthy are the publications by Bellamy et al. (2007) cited 30 times and Hale et al. (2007) cited 28 times. These studies were conducted within the WORM (Workgroup Occupational Risk Model) project financed by the Ministry of Social Affairs and Employment of the Netherlands. This workgroup created a tool called "Storybuilder" to analyse the causes of accidents documented by the Dutch Labour Inspectorate.

Also notable are the publications by Jacinto and Aspinwall (2004b); Kontogiannis et al. (2000); Le Coze (2010); Nunes et al. (2015). Each one of these studies analyzed the same sample of occupational accidents in each case, but using two or more different scientific methodologies. Finally, we would like to refer to two atypical publications. The first one is by Katsakiori et al. (2010), which analyzed a sample of 40 accidents occurring between 2000 and 2008 in the manufacturing industry. The sample used was obtained from the database of reports at the East Attica Risk Prevention Centre in Greece. The interesting contribution of this study is that it uses a method called MILI (Method of Investigation for Labor Inspectors), developed to investigate accidents by the Labour Inspectorate, which not only identifies the causal factors, but also detects legal breaches leading to the accidents. The second notable atypical publication is the one by Nunes et al. (2015). This study analyzed a very broad sample of 4,593 accidents occurring in 2007 in a little-studied work environment, that of hospitals. In addition, the sample selected was analyzed using up to 6 different methods: FTA, Causal Tree Method, Swiss Cheese Model, Failure Matrix, WAIT and RIAAT.

3.2. Classification of studies selected

The first objective of this paper also included identifying studies published by public administrations or institutions that had also analysed occupational accident investigations using a scientific methodology. Therefore, Table 3 shows the list of 20 studies on occupational accident investigations published by international public administrations and institutions.

Table 3 shows a sample of studies selected in 3 continents (Europe, America and Oceania). Here we identified 16 different methodologies to investigate occupational accidents in the 20 studies selected. Thus, considering the relative percentage of use of each methodology in the studies selected, we highlighted four of them. First, is the HSE method, which is present in 30% of the studies. Second is FTA method, which is present in 20% of the studies. Third, is MORT found in 15% of the studies, fourth is Change Analysis, found in 10% of the studies. The rest were identified in only one of the studies (5%).

As for the economic activity sector in which the studies took place, according to the NACE Rev. 2 classification, as well as has been performed for selected publications in Table 1, we found that the activities reporting the highest number of accident investigations in the studies selected were:

- Several Workplaces: 13 studies, 65 %.
- Construction: 3 studies, 15%.
- Agriculture, Forestry and Fishing: 1 study, 5%.
- Manufacturing: 1 study, 5%.
- Electricity, gas, steam and air conditioning supply: 1 study, 5%.
- Mining and Quarrying: 1 study, 5%.

Regarding the publications by international public administrations or institutions selected in Table 3, we established two subgroups: electronic databases including actual occupational accident reports which were analyzed by Safety Specialists and manuals or reference books covering the results of the occupational accidents analyzed and the methodologies used. The following are worth mentioning. Among the databases, there is the Fatality Assessment and Control Evaluation (FACE) Program, created in 1982 by The National Institute for Occupational Safety and Health (NIOSH). This is a database with more than 600 occupational accident investigations in any industry. The objective of FACE is to prevent the repetition of occupational accidents by establishing adequate preventive measures.

Table 3. List of studies of occupational accident investigations published by public administrations or institutions, with methodology used

No.	***Title***	***Authorship and Origin***	***Methodologies used***	***Economic activities (NACE Rev. 2)***	***Source***
1	The Fatality Assessment and Control Evaluation (FACE).	The National Institute for Occupational Safety and Health (NIOSH), 1989, USA	Change Analysis	Several workplaces	The National Institute for Occupational Safety and Health (NIOSH).
2	Analysis of construction fatalities	OSHA (1990) USA	OSHA	Construction	Department of labor, Occupational Safety and Health Administration, Washington, D.C.
3	Étude des accidents mortels et graves dans le bâtiment et les travaux publics	Chitoine and Lan (1993) Canada	OARU	Construction	L'Institut de recherche en santé et en sécurité du travail du Québec (IRSST)
4	Encyclopaedia of Occupational Health and Safety	International Labour Organization (1998) Switzerland	STEP	Several workplaces	International Labour Organization
5	NRI Foundation	Noordwijk Risk Initiative Foundation (1998) The Netherlands	MORT, ECFA, 3CA, ETBA	Several workplaces	Noordwijk Risk Initiative Foundation
6	The health and safety of Australia's farming community	Fragar and Franklin (2000) Australia	ATSB	Agriculture, Forestry and Fishing	The Health & Safety of Australia's Farming Community
7	Management and human performance root causes	Myers (2002) USA	MORT	Electricity, gas, steam and air conditioning supply	First Energy Nuclear Operating Corporation (FENOC)
8	Analysis of occupational accident mortality in Spain	The National Institute of Occupational Health and Safety (2002) Spain	FTA	Several workplaces	Observatorio Estatal de Condiciones de Trabajo (OECT)
9	Causal factors in construction accidents	Loughborough University and UMIST. (2003) UK	HSE	Construction	Health and Safety Executive
10	WorkSafe	WorkSafeBC (2003) Canada	HFACS	Several workplaces	Occupational Health and Safety Regulation of British Columbia
11	Investigating accidents and incidents	Health and Safety Executive (HSE) 2004, HSG (245). UK	HSE	Several workplaces	Health and Safety Executive
12	Fatality and catastrophe investigation summaries	US Department of Labor, 2005. USA	FTA	Several workplaces	Occupational Safety and Health Administration, US Department of Labor
13	Identifying human factors associated with slip and trip accidents	Health and Safety Executive (HSE) 2005 UK	HSE	Several workplaces	Health and Safety Executive
14	Storybuilder v2.0.34	The Dutch National Institute for Public Health (RIVM).(2008) The Netherlands	MORT	Several workplaces	The Dutch Labour Inspectorate
15	Reducing error and influencing behaviour	Health and Safety Executive (HSE) 2009 UK	HSE	Several workplaces	Health and Safety Executive

16	Studies of the causes of severe and fatal occupational accidentes in Andalusia	Junta de Andalucía (2009) Spain	FTA	Several workplaces	Regional Government of Andalusia, Spain
17	Safety of offshore oil and gas operation: Lessons from past accident analysis	Christou and Konstantinidou (2012) Italy	HSE	Mining and Quarrying	JRC Scientific and Policy Reports, European Commission, Brussels, Belgium
18	DOE HANDBOOK Accident and Operational Safety Analysis	U.S. Department of Energy (2012) USA	ECFCA, BA, CA, RCA, VA	Several workplaces	U.S. Department of Energy
19	Official accident investigations repository 'This could have been prevented'	Junta de Andalucía (2012) Spain	FTA	Several workplaces	Regional Government of Andalusia, Spain
20	Work-related fatalities associated with unsafe design of machinery, plant and powered tools, 2006 – 2011	Creative commons (2014) Australia	HSE	Manufacturing	Safe Work Australia

Next is WorkSafeBC, a database belonging to the Occupational Health and Safety Regulation of British Columbia in Canada. This database covers a large number of accidents at work occurring in agriculture or manufacturing whose investigations were based on the HFACS method.

In Europe, probably one of the best public programmes for published accident investigations is the one carried out by the Dutch Labour Inspectorate. They have a software tool called Storybuilder which is a large database with over 9,100 accidents investigated by the Labour Inspectorate. The database is made up of over 36 different accident models corresponding to falls from height, confined spaces, explosions etc. Likewise, in Spain, since 2012, there is a database called "This could have been prevented", which was developed by the Department of Finance, Innovation, Science and Employment of the Regional Government of Andalusia. This database includes a significant number of accidents investigated in all work sectors, using the Fault Tree Analysis (FTA) method.

With relation to the manuals or books published by public administrations or institutions, we can highlight the following:

- First, there is the "Analysis of Construction Fatalities". This is a manual prepared by OSHA in 1990, which includes the results of an analysis of 3,496 occupational accidents investigated in the construction industry in the USA between 1985 and 1989. OSHA (The Occupational Safety and Health Administration), belongs to the Department of Labor of the United States.
- Next, is the "The Health and Safety of Australia's Farming Community", which is a study carried out by Fragar and Franklin (2000), financed by the Farm Health and Safety Joint Research Venture and New South Wales Health in Australia. It covers the results of an analysis of occupational accidents occurring in Agriculture between the years 1995 and 1996 using the ATSB method.
- Third, is the "Causal Factors in Construction Accidents", which is a study conducted by specialists from the Departments of Human Sciences and Civil and Building Engineering of Loughborough University and Manchester Centre for Civil and Construction Engineering of UMIST. This study analysed the results of a sample of 100 accident investigations occurring in the construction industry in Great Britain between 1996 and 1999, using the HSE method.

Most remarkable are the manuals and books published by the Health and Safety Executive (HSE), the non-departmental public body of the United Kingdom, based in Liverpool, England. They include "Investigating Accidents and Incidents", a manual for workers, trade unions, prevention representatives and safety professionals. It was prepared in 2004 by the Health and Safety Executive (HSE). This same administration developed a study in 2005 entitled "Identifying Human Factors Associated with Slip and Trip Accidents". This report details the results of an investigation project aimed at analyzing the impact of human factors on the probability and severity of accidental slips and trips in order to develop strategies and practices to control and reduce their incidence.

Moreover, worth mentioning the set of methods and guides available in the NRI Foundation for investigators and investigating organizations regarding the investigation of industrial accidents. The Noordwijk Risk Initiative (NRI) Foundation was founded in 1998 by Delft Technical University of the

Netherlands to improve understanding of risk issues through discussion, research and technology transfer between different domains of risk management.

Similarly, in Spain there are two case studies published with the results of occupational accidents that have been analysed. On the one hand, since 2002 there is a study called "Analysis of Occupational Accident Mortality in Spain". This is a project carried out by the INSHT (Spanish acronym for the National Institute of Occupational Health and Safety). The INSHT is the specialised technical scientific body of the Spanish Government in charge of analysing and studying health and safety conditions at work. This project aims to achieve an accurate understanding of occupational accident profiles and causes.

On the other hand, since 2009 there is a study entitled "Studies of the Causes of Severe and Fatal Occupational Accidents in Andalusia", prepared by the Department of Finance, Innovation, Science and Employment of the Regional Government of Andalusia. These reports present the causes of fatal and severe accidents which have taken place, based on the investigations conducted by safety specialists to the Labour Authorities of Andalusia.

3.3. Methodologies to investigate occupational accidents

Following the analysis of the 42 publications and the 20 studies analyzing occupational accident investigations, we ended up with 35 methodologies to investigate occupational accidents. Table 4 provides a classification in alphabetical order of the methodologies identified, with a brief description of them and a reference to the authors who first presented them. Stand in the description column the common features of the methodologies identified in regard to the process of investigation of occupational accidents (Dien et al., 2012; Lindberg et al., 2010), as well as their academic origin and method from which in turn comes.

In relation to the occupational accident investigation methodologies selected, only 6 of the 35 identified are both in Table 1, which includes the publications that have analysed occupational accident investigations, and in Table 3, covering studies published by public administrations and institutions on occupational accident investigations. These methodologies are: FTA, HFACS, HSE, MORT, OSHA and STEP. The evaluation, comparison or integration of the methodologies described is beyond the scope of this document, therefore not shown.

4. Discussion

One of the purposes of this study was to review the existing scientific literature on occupational accident investigations. As for the limitations of this bibliographic review, finding scientific literature that presents scientific studies analyzing samples of real cases of occupational health and safety accidents that have been investigated, was often complicated. The reason being that most occupational accident investigations reports are carried out by professionals and not by researchers and, therefore, the results have not been published in scientific journals. The situation is similar with studies of occupational accident investigations published by public administrations or institutions. These are manuals, books and electronic databases found only in the websites of these administrations or institutions. Some of them can be freely accessed and others are posted in their native language, as is the case of the Nordic countries (Norway, Sweden, Finland etc.).

Table 4. Accident investigation methodologies used

Acronym	*Investigation methodology*	*Short description*	*Source and year*
AcciMap	Accident Map	Accimap is a methodology aiming to address pro-active risk management with a system control approach. The accident is analyzed with reference to different hierarchical levels of society. Identification and analysis of socio-technical context, decision and information flows between different actors.	Rasmussen J., (1997)
ARCTM	Accident Root Causes Tracing Model	ARCTM proposes that accidents occur due to three root causes: (1) failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started; (2) deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and (3) deciding to act unsafe regardless of initial conditions of the work environment.	Abdelhamid, and Everett ,(2000)
ATSB	Australian Transport Safety Bureau	The ATSB model provides a general framework that can be used to guide data collection and analysis activities during an investigation. The ATSB investigation analysis model, it is based on the widely used Reason model of organizational accidents and consists of five levels of safety factors (occurrence events, individual actions, local conditions, risk controls and organizational influences). ATSB include an enhanced ability to combine technical issues into the overall analysis, the use of neutral language and emphasizing the impact of preventative, as well as reactive, risk controls.	Australian Transport Safety Bureau, (2008)
BA	Barrier Analysis	Barrier analysis is used to identify hazards associated with an accident and the barriers that should have been in place to prevent it. A barrier is any means used to control, prevent, or impede the hazard from reaching the target.	DOE, (1999)
CA	Change Analysis	This technique is used to examine an accident by analysing the difference between what has occurred before or was expected and the actual sequence of	Ferry, (1988)

		events. The investigator performing the change analysis identifies specific differences between the accident–free situation and the accident scenario. These differences are evaluated to determine whether the differences caused or contributed to the accident.	
CTM	Causal tree method	CTM belongs to the category of Tree Techniques and the basic idea is that accidents result from variations or deviations in the usual process. There are four classes of variations: those related to the individual, the task, the equipment and the environment, respectively. The tree starts with the end event (the accident) and works backwards. The end event is the starting point and only the facts that contributed to the accident should be selected. The analyst has to identify and list the variations and then display them in the analytic tree, showing causal relations.	Leplat, (1978)
ECFA	Events and Conditional Factors Analysis	Events and Conditional Factors Analysis (ECFA) is a method for creating concise descriptions of incidents. Investigators use ECFA to help them organize facts about what happened and to spot gaps in their data.	Kingston et al., (2004)
ECFCA	Events and Causal Factors Charting and Analysis	The events and causal factors chart may be used to determine the causal factors of an accident. This process is an important first step in later determining the root causes of an accident. Events and causal factors analysis requires deductive reasoning to determine which events and/or conditions that contributed to the accident.	DOE, (1999)
ETA	Event tree Analysis	An event tree is used to analyze event sequences following after an initiating event. An Event tree analysis is primarily a proactive risk analysis method used to identify possible event sequences, but the event tree may also be used to identify and illustrate event sequences and to obtain a qualitative and quantitative representation and assessment.	Villemeur, (1991)
ETBA	Energy Trace and Barrier Analysis	ETBA is integral to applying MORT, but can also be used as a standalone method. ETBA has been characterized as a way of identifying the "*norms, novelties and deviations - NNDs*" that are of relevance to a particular incident or accident.	Frei et al., (2003)
FM	Failure matrix	Failure matrix method (FM) can be applied to any system, or can be adapted to workplace accidents or other cases. The technique identifies the situation, explains the causes, consequential effects, the estimated frequency and severity. On the other hand, this procedure allows the ranking of accidents by level of risk and it might be a way to align priorities of preventive or corrective actions.	Haddon et al., (1968)
FMEA	Failure Mode and Effects Analysis	FMEA refers to a hazard analysis procedure in which component failures are systematically analyzed. The approach takes the form of listing in a table each component and its failure or error modes. Also listed for each failure mode are its frequency, effects on other components, effects on the system as a whole, method of detection, and countermeasures.	Hammer, (1980)
FRAM	Functional Resonance Accident Model	A method for accident investigation as well as risk assessment based on a description of system functions. Non-linear propagation of events are described by means of functional resonance.	Hollnagel, (2004)
FTA	Fault Tree Analysis	In FTA, an undesired event (an accident) is selected and all the possible things that can contribute to the event are diagrammed as a tree in order to show logical connections and causes leading to a specified accident. Safety problems are analyzed based on logical combinations of necessary or alternative/possible causes. FTA is the most widely used of the tree techniques.	Ferry, (1988)
HFACS	The Human Factors Analysis and Classification System	HFACS identifies the human causes of an accident and provides a tool to not only assist in the investigation process, but to target training and prevention efforts. HFACS looks at four levels of human failure, referring to the "Swiss cheese" model. These levels include unsafe acts , preconditions for unsafe acts, unsafe supervision, and organizational influences.	Wiegmann and Shappell, (2001)
HSE	Health and Safety Executive	The HSE was prepared in consultation with industry, unions and health and safety professional bodies in order to provide a workbook for employers, unions, safety representatives and safety professionals. It follows Reason's accident causation model. The starting point is the event and the method provides aids for finding facts with specific structured questions. The aim of the analysis is to set out the reasons why this happened and find immediate, underlying and root causes.	HSE, (2004)
MES	Multilinear events sequencing	MES is a charting technique, which shows events chronologically ordered on a time-line basis. It is based on the view that an accident begins when a stable situation is disturbed. A series of events can then lead to an accident. The method distinguishes between actors, actions and events.	Benner, (1975)
MILI	Method of Investigation for Labor Inspectors	(MILI) was designed to help to identify workplace and organizational factors in addition to immediate factors and legal breaches. This Method was developed with the purpose of helping labor inspectors to investigate and analyze an accident in a specific setting (industrial environment) and in a structured way.	Katsakiori et al., (2010)

MORT	Management Oversight and Risk Tree	The MORT diagram is a logic tree (the accident being the top event). In MORT, the accident is defined as an unwanted energy transfer because of inadequate energy barriers and/or controls. The method follows the energy transfer and deviation concepts. Fact finding aims at identifying hazardous forms of energy and deviations from the planned and normal production process.	Johnson, (1980)
MTO	Man Technology and Organisation	MTO method articulates the events, the causes, the barriers but also presents deviations to normal situation in its diagram. Some checklists are provided to identify fundamental root causes in work organization, work practice, management of work, change procedures, ergonomic deficiencies in the technology, communication, instructions and procedures, education/competence, and work environment.	Rollenhage, (1995)
OARU	Occupational accident research unit	This method has two levels of reasoning: describing the accident sequence, and finding the determining factors. The state of lack of control is characterized by the presence of deviations in the system. The accident sequence has three phases: the initial (when there are deviations from the normal process), the concluding phase (which is characterized by loss of control and ungoverned flow of energy), and the injury phase (where energy meets the human body and causes physical harm). The original model has not survive the test of time (Kjellen and Hovden, 1993) and the main reason for this abandon had to do with lack of input from (human) information-processing theory (Larsson, 1993).	Kjellen and Larsson, (1981)
OSHA	Occupational Safety and Health Administration Data Collection Forms	OSHA relies primarily on employer reporting or coverage by the news media to initiate a fatality investigation. OSHA is used to classify work-related injuries and illnesses and to note the extent and severity of each case.	OSHA, (1990)
Petri nets	Petri nets	Petri Nets is a formal and graphical language which is appropriate for modelling systems with concurrency. The ability to construct models with these properties makes Petri Nets an attractive tool for modeling operator behavior.	Petri, (1962)
PFA	Possible Factors Analysis	This method is applied for identifying both immediate causes and other causal factors (called *Possible Factors*). The tree technique is performed manually, and all people likely to be involved in an investigation have training on its use. From the findings, the investigation team makes recommendations for each possible factor identified. There is not a checklist for the search: investigators will use their own experience and skills.	HSE, (1998)
RCA	Root Cause Analysis	Root cause analysis identifies underlying deficiencies in a safety management system that, if corrected, would prevent the same and similar accidents from occurring. Root cause analysis is a systematic process that uses the facts and results from the core analytic techniques to determine the most important reasons for the accident.	DOE, (1999)
RIAAT	The recording, investigation and analysis of Accidents at work	RIAAT (The Recording, Investigation and Analysis of Accidents at Work process) was chosen a holistic approach to analyze the accident investigation process as a whole. The process covers the full cycle of accident information by recording the event and its main circumstances; carrying out an investigation and causal analysis in a multi-layered fashion; producing a plan of action; and setting out activities required for sharing information and promoting organizational learning.	Jacinto et al., (2011)
SCM	Swiss Cheese Model	The Swiss Cheese model of accident causation is a model used in the risk analysis and risk management of human systems. It likens human systems to multiple slices of Swiss cheese, stacked together, side by side. It was originally propounded by British psychologist James T. Reason in 1990, and has since gained widespread acceptance and use in healthcare, in the aviation safety industry, and in emergency service organizations. It is sometimes called the cumulative act effect.	Reason, (1990, 1997)
SFs	Safety functions	Analysis of various forms of technical, organizational and administrative systems (safety functions), aimed to control and reduce risks.	Harms-Ringdahl, (2009)
STAMP	Systems-Theoric Accident Model and Processes	The hypothesis underlying STAMP is that system theory is a useful way to analyze accidents, particularly system accidents. Accidents occur when external disturbances, component failures, or dysfunctional interactions among system components are not adequately handled by the control system. Safety is viewed as a control problem, and is managed via constraints by a control structure embedded in an adaptive socio-technical system. Understanding why an accident occurred requires determining why the control structure was ineffective.	Leveson, (2004)
STEP	Sequentially Timed Events Plotting	Analysis of the accident sequence by the identification of actors and sub-events in time order, plus their interactions as well as safety problems. The STEP methodology also includes a recommended method for identification of safety problems and development of safety recommendations. Safety problems are marked with diamonds in the STEP worksheet.	Hendrick and Benner, (1987)

TRIPOD	TRIPOD	TRIPOD method is based on James Reason Swiss Cheese model and implemented the idea of latent failures rooted in organization that sets conditions (such as weakened barriers) for later active failures (such as unsafe acts). The latent failures are related to 11 Basic Risk Factors	Groeneweg, (1994)
TRIPOD-BETA	TRIPOD-BETA	Tripod Beta describes incidents in terms of 'objects' e.g. people, equipment being changed by 'agents' (of change i.e. anything with the potential to change an object). Tripod Beta also models 'barriers' showing them as, for example, effective, failed or inadequate barriers. Tripod Beta provides a format and rules for modeling the event and linking each element together and working back ultimately to the underlying causes.	Groeneweg, (1998)
VA	Verification analysis	Verification analysis should be conducted on the draft report after all the analytical techniques are completed. This analysis ensures that all portions of the report are accurate and consistent, and verifies that the conclusions are consistent with the facts, analyses, and Judgments of Need. The verification analysis determines whether the flow from facts to analysis to causal factors is logical.	DOE, (2012)
WAIT	Work accidents investigation technique	This method is based on the theoretical model of “organizational accidents” proposed by Reason (1997) and on that of “human error” by Hollnagel (1998). A particularly important aspect of this method is that it incorporates the variables proposed by Eurostat (2001). The WAIT method is comprised of nine steps grouped into two main stages. The first stage is a simplified investigation process. The second stage is an in-depth analysis, or complete investigation, identifying and analyzing other possible weaknesses and conditions within the organization.	Jacinto and Aspinwall, (2002)
3CA	Control Change Cause Analysis (3CA)	Control Change Cause Analysis (3CA) is a method for analyzing the individual, cultural and management system causes of incidents. Investigators can use 3CA to analyse the root causes of any type incidents of any type. The first step is to identify events that compromise control or increase risks significantly. Each of these significant events can form the subject of a 3CA analysis.	Kingston, (2002)

Although the databases we studied have a significant volume of scientific articles, there is probably scientific information on this matter published in reports or documents (grey literature) or other sources of information not examined here. The next objective for this study was to identify the methodologies used both in scientific literature and in the published studies selected. This objective limited the general purpose of the study even more, given that the occupational accident samples analyzed had to literally, or in a recognizable manner, identify the scientific methodologies used. Also, the methodology identified needed to have been published previously. That is, we did not cover methodologies that are not documented in scientific publications.

Another aspect to keep in mind and that can be the result of misunderstanding in this analysis is that the terms "Model" and "methodology" are often confused. Both are different, but there are cases in which concepts model and methodology coexists, as are examples of MORT (Johnson, 1980), Swiss Cheese Model (Reason, 1990, 1997) or FRAM (Hollnagel, 2004), which are theoretical conceptual models as well as methodologies for accidents investigation. The objective of this paper was to review the main studies published on occupational accidents to recognize, classify and describe the scientific methodologies used in them.

Therefore, in the scope of this study it has not been the analysis of the influence of conceptual models on methodologies. Despite this we make special mention of the Organizational accidents or "Swiss cheese" Model of Reason (1990, 1997), which is a model that includes organizational and management factors and describe the performance of the whole system as well as the interaction between latent and active failures. Reason had a major impact on OHS thinking and accident causation.

So in terms of influence this model is always very prominent. Therefore, not surprising that in the final selection of methodologies there are 5 methodologies (ATSB, HFACS, HSE, Tripod and WAIT) based on this conceptual model, in addition to Swiss Cheese Model (SCM) considered also methodology. But as well it indicates Katsakiori et al (2009), a methodology of occupational accident investigation is not necessarily linked to a specific accident model.

On the other hand, in this study, we identified six methodologies (CTM, ETA, FTA, MES, MORT and PFA) which employ a "Tree Technique" for its development. As well it also asserts Katsakiori et al (2009), tree techniques are not based in any known theoretical model or accident causation. They simply represent a specific model that can lead the basis for logic interrelationships between causes and events.

Save the abovementioned limitations, the 35 methodologies finally selected in this study are the ones considered ideal for use in occupational accident investigations. However, it would be useful to know whether some of these methodologies are versatile, that is, whether they can be used in different contexts of occupational health and safety, such as in risk analysis or risk assessment.

Of the 35 methodologies identified in this study for accident investigations, we found some coincidences with other studies. For example, when analyzing research such as that conducted by Willquist and Torner (2003), who reviewed literature related to the right methods to analyze hazards in the manufacturing industry, we found 7 coinciding methodologies. These are Change Analysis, MORT, OSHA, Tripod, Event Tree Analysis, FMEA and FTA.

Likewise, when looking at the study by Marhavillas et al. (2011), who analyzed and classified the main methodologies and techniques found in the scientific literature that are suitable for risk analysis and assessment in the work sites, we found that 11 of these methods match those identified in this study. These methodologies are FTA, MORT, MES, OARU, Tripod, WAIT, Petri nets, HFACS, Event Tree Analysis, FMEA and OSHA.

In short, of the 35 the methodologies selected in this study only - MORT, OSHA, Tripod, FMEA and FTA, match those selected in the studies by Willquist and Torner (2003) and Marhavillas et al. (2011), which as stated in the introduction, let out of scope the analysis of occupational accidents and methodologies for investigating them. This could mean that these five methodologies use not only a reactive approach that deals with the faults and hazards already described, but are also proactive, that is, they analyze safety by identifying risks before allowing the accident to take place. Moreover, when exploring the impact these methodologies have on investigation practices, according to the number of times that the selected items are cited that identify them, we saw that there are methodologies to investigate occupational accidents that have a long-standing history in scientific literature. This was observed in methods such as MORT (Johnson, 1980), FTA (Ferry, 1988) or OSHA (OSHA, 1990), which have been used many times to analyse occupational accident samples, as well as being selected in assessment and comparison studies such as in the studies by Benner (1985); Hollnagel and Speziali (2008); Katsakiori et al. (2009); Sklet (2004) or Wagenaar and Van der Schrider (1997). Nonetheless, it should also be noted that some methodologies have been relatively short-lived in the scientific literature in view of the limited number of times they have been cited in studies that analyzed occupational accidents, such as WAIT (Jacinto and Aspinwall, 2002), MILI (Katsakiori et al., 2010) or RIAAT (Jacinto et al., 2011). In some cases, some of their publications have not been included in the WOS database, or they are treated very young methodologies and therefore still underdeveloped and they haven't been extensively used yet. Nevertheless, as suggested by Hollnagel and Speziali (2008), in five or ten years we can expect that the methods developed to date will become partially obsolete, not because the methods themselves will change, but because socio-technical systems will evolve and therefore, the nature of accidents will also.

Moreover, during our work we found that there are very few examples of studies on the use and comparison of various methodologies in the same occupational accident analysed. Consequently, as stated by Lindberg et al. (2010), it is of vital importance to promote this type of studies, not only to be able to compare the various scientific methodologies to investigate occupational accidents, but also to confirm their suitability in different social and work environments.

We also noted certain difficulties regarding the methodology used to investigate occupational accidents. Namely, being able to determine which the best methodology for each labour activity is. In fact, it appears that some of the methodologies selected in this study were developed for well-defined contexts, for example, the OSHA method was designed to be used in the construction industry. However, this study highlights very flexible methods that can be adapted to various work activities, such as the FTA methodology which has been applied to the extractive industry, manufacturing industry, electric power supply industry, construction industry, and even in studies related to healthcare activities and social services. These results, by themselves, confirm the thesis by Katsakiori et al. (2009) that a "good" investigation method should take into account the specific context of the accident. Thus, there are adequate methods for aviation, railways, etc., and others even more suitable for occupational accidents, since the context is different.

This study can also serve as a guide for those doing research on occupational accidents, to know which methodologies are available, how they are used, and even compare them. In practice, as stated by Willquist and Torner (2003), choosing a method is not the first decision made. This may be due to the fact that companies usually have information that is already available, such as reports on previous accidents or even incidents, which have also been analyzed. In this case, the type of information available determines the method chosen, and not the other way around, the method does not determine which information should be used. In any case, to choose a method, the scope of the accident and the complexity of the system in which the investigation is to be carried out, also need to be considered.

In line with this, as already concluded in the study by Strömgren et al. (2013), it is not surprising that methodologies have a strong impact on the accident analysis phase. Methodologies, in general, focus on clarifying the factors and causes of accidents. The purpose of a methodology is often to promote understanding and learning about the occupational accident. Data collection and the initial investigation actions are usually independent of the methodology used, except when the investigating organization follows a certain scientific methodology by default. Only in these cases can the methodology used impact the holistic process of the investigation.

In this sense and as advanced by authors such as Roed-Larsen and Stoop (2012), the modern investigation of accidents faces a series of challenges. These include: improving the training and skills of the experts conducting the investigations, both regarding investigation techniques and methodologies for their application; and creating structural and functional conditions that allow independent investigations, with freedom in relation to what is published and in the monitoring of the proposed preventive measures.

In short, some basic quality criteria that any occupational accident investigation should meet (Salguero-Caparros et al., 2015) is having a methodology for analysis that gradually leads to a thorough diagnosis of the situation that led to the accident. Choosing and using the right methodology will help structure the investigation process, identify the causes, interpret the results and validate the recommendations.

5. Conclusions

The objective of this study was to identify, classify and describe the main methodologies to investigate occupational accidents which have been used in scientific literature or in international public administrations or institutions.

There is a broad range of methodologies to investigate accidents, as indicated in introduction section to this paper, most of which were developed for specific activities, such as the nuclear industry, the aeronautics industry, maritime and rail transport, hospitals, etc. However, there are not many methodologies specifically for occupational accidents, and some have not yet been fully developed or implemented.

This paper reveals the methodologies most frequently used in the field of occupational accident investigations. Each one has advantages and disadvantages, but most authors advocate that using several methodologies is the best choice to investigate a complex occupational accident. For this reason, the expert investigating the accident is the one who should select the methodology or group of methodologies most suitable to each specific context.

Use of each methodology will depend on the analysts' expertise, as well as their experience in implementing the technique in question. If the analysts are not familiar with the methodology, the quality of the results will be limited. Similarly, if the analysts lack specific knowledge of the methodology, it is recommended that they seek expert support. The role of the analyst will be to ensure a systematic and structured investigation is carried out with the support of a validated and recognised methodology.

This paper concludes with three general recommendations which we firmly believe would improve implementation of accident investigation techniques:

1. The methodologies to investigate occupational accidents must be judged based on their performance and results. Therefore, further studies are required to verify the correct selection and use of methodologies in real cases of occupational accidents.
2. Further basic and translational research in several academic disciplines, especially engineering, organisation science and psychology, should be supported and encouraged to face up to the evaluation, comparison and development of methodologies for the analysis of accidents in occupational health and safety and the possible integration between different scientific methodologies.
3. More interaction and collaboration between academia and public and/or private labour sectors is needed with a clear focus on mutual feedback about promoting of continuing education in the practical use of different methodologies for investigating occupational accidents and the dissemination of its findings, recommendations and lessons learned from recent research occupational accidents investigations.

References

Abdelhamid T.S., Everett J.G., (2000), Identifying root causes of construction accidents, *Journal of Construction Engineering and Management*, **126,** 52-60.

Ale B.J.M., Bellamy L.J., Papazoglou I.A., Hale A.R., Goossens L.H.J., Post J., Baksteen H., Mud M.L., Oh J.I.H., Bloemhoff A., Whiston J.Y., (2006), *ORM: Development of an integrated Method to Assess Occupational Risk,* Inter. Conf. on Probabilistic Safety Assessment and Management, May 13-19, 2006, New Orleans, ASME, New York.

Antao P., Almeida T., Jacinto C., Guedes Soares C., (2008), Causes of occupational accidents in the fishing sector in Portugal, *Safety Science*, **46**, 885-899.

Attwood D., Khan F., Veitch B., (2006), Occupational accident models - where have we been and where are we going?, *Journal of Loss Prevention in the Process Industries*, **19**, 664-682.

Australian Transport Safety Bureau (ATSB), (2008), Analysis, causality and proof in safety investigations, Aviation research and analysis report ar-2007-053, Australian Transport Safety Bureau, Canberra City, On line at: https://www.atsb.gov.au/media/27767/ar2007053.pdf.

Bellamy L., Ale B., Whiston J., Mud M., Baksteen H., Hale A.R., Oh J., (2008), The software tool Storybuilder and the analysis of the horrible stories of occupational accidents, *Safety Science*, **46**, 186-197.

Bellamy L., Ale B.J., Geyer T., Goossens L.H., Hale A., Oh J., Whiston J., (2007), Storybuilder - A tool for the analysis of accident reports, *Reliability Engineering & System Safety*, **92**, 735-744.

Benner L., (1975), Accident investigation: multilinear events sequencing method, *Journal of Safety Research*, **7**, 67–73.

Benner L., (1985), Rating accident models and investigation methodologies, *Journal of Safety Research*, **16**, 105-126.

Carrillo-Castrillo J., Guadix J., Rubio-Romero J., Onieva L., (2015), Estimation of the relative risks of musculoskeletal injuries in the Andalusian manufacturing sector, *International Journal of Industrial Ergonomics*, **52**, 69-77.

Carrillo-Castrillo J.A., Rubio-Romero J.C., Onieva L., (2013), Causation of severe and fatal accidents in the manufacturing sector, *International Journal of Occupational Safety and Ergonomics*, **19**, 423-434.

Chi C., Chang T., Ting H., (2005), Accident patterns and prevention measures for fatal occupational falls in the construction industry, *Applied Ergonomics*, **36**, 391-400.

Chi C., Lin S., Dewi R. S., (2014), Graphical fault tree analysis for fatal falls in the construction industry, *Accident Analysis & Prevention*, **72**, 359-369.

Chi C., Yang C., Chen Z., (2009), In-depth accident analysis of electrical fatalities in the construction industry, *International Journal of Industrial Ergonomics*, **39**, 635-644.

Chitoine D., Lan A., (1993), Study of fatal and serious accidents in construction and public works, The Quebec Institute for Research in Occupational Health and Safety (IRSST), (in French), On line at: https://www.irsst.qc.ca/recherche-sst/projets/projet/i/2810/n/etude-des-accidents-graves-ayant-fait-l-objet-d-une-enquete-par-la-csst-dans-le-batiment-et-les-travaux-publics-0086-0210/redirected/1.

Christou M., Konstantinidou M., (2012), Safety of offshore oil and gas operation: Lessons from past accident analysis, JRC Scientific and Policy Reports, European Commission, Brussels, Belgium, On line at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC77767/offshore-accident-analysis-draft-final-report-dec-2012-rev6-online.pdf.

Cozzani V., Campedel M., Renni E., Krausmann E., (2010), Industrial accidents triggered by flood events: Analysis of past accidents, *Journal of Hazardous Materials*, **175**, 501-509.

Dien Y., Decchy N., Guillaume E., (2012), Accident investigation: From searching direct causes to findings in-depth causes- Problem of analysis or/and of Analyst?, *Safety Science*, **50**, 1398-1407.

Dien Y., Llory M., Montmayeul R., (2004), Organisational accidents investigation methodology and lessons learned, *Journal of Hazardous Materials*, **111**, 147-153.

DOE Handbook, (2012), *Accident and Operational Safety Analysis*, Vol. I: Accident Analysis Techniques, On line at: https://www.standards.doe.gov/standards-documents/1200/1208-bhdbk-2012-v1.

DOE, (1999), Conducting Accident Investigations, US Department of Energy, Washington, DC, USA, On line at: http://hss.energy.gov/CSA/CSP/aip/workbook.

EEC, (1990), Council Regulation No 3037/90 of 9 October 1990 on the statistical classification of economic activities in the European Community, L 293/1, 24.10.1990, Brussels.

ESREDA (European Safety, Reliability And Data Associantion), (2009), Guidelines for safety investigations of accidents, On line at: www.esreda.orgwww.esreda.org.

European Council, (1989), European Directive 89/391/EEC of 12 June, Introduction of measures to encourage improvements in the safety and health of workers at work, Official Journal of the European Communities, L32/83, 29 June 1989, Luxembourg.

Ferry T.S., (1988), Modern Accident Investigation and Analysis, John Wiley & Sons, 2th Edition, Canada.

Feyer A., Williamson A. M., (1991), A classification system for causes of occupational accidents for use in preventive strategies, *Scandinavian Journal of Work, Environment & Health*, **17**, 302-311.

Fink A., (2009), *Conducting Research Literature Reviews: from the Internet to Paper*, 3rd Edition, Sage Publications, California, USA.

Fragar L., Franklin R. (2000), The health and safety of Australia's farming community, On line at: http://www.aghealth.org.au/tinymce_fm/uploaded/Research%20Reports/health_safety_aus_farming_community_2000.pdfhttp://www.aghealth.org.au/tinymce_fm/uploaded/Research%20Reports/health_safety_aus_farming_community_2000.pdf.

Frei R., Kingston J., Koornneef F., Schallier P., (2003), Investigation Tools in Context, On line at: http://iprr.orgwww.iprr.org/papers/Frei-Tools-final.pdf.

Groeneweg J., (1994), *Controlling the Controllable: the Management of Safety*, 2nd Edition, DSWO Press, Leiden University, The Netherland.

Groeneweg J., (1998), *Controlling the controllable, The Management of Safety*, 4th Edition, DSWO Press, Leiden University, The Netherland.

Haddon W. Jr., (1968), The changing approach to the epidemiology, prevention, and amelioration of trauma: The transition to approaches etiologically rather than descriptively based, *American Journal of Public Health and the Nation's Health*, **58**, 1431-1438.

Hale A., Ale B.J., Goossens L.H., Heijer T., Bellamy L., Mud M., Papazoglou I.A., (2007), Modelling accidents for prioritizing prevention, *Reliability Engineering & System Safety*, **92**, 1701-1715.

Hale A., Walker D., Walters N., Bolt H., (2012), Developing the understanding of underlying causes of construction fatal accidents, *Safety Science*, **50**, 2020-2027.

Hammer W., (1980), *Product Safety Management and Engineering*, Prentice-Hall, Englewood.

Harms-Ringdahl L., (2004), Relationships between accident investigations, risk analysis, and safety management, *Journal of Hazardous Materials*, **111**, 13-19.

Harms-Ringdahl L., (2009), Analysis of safety functions and barriers in accidents, *Safety Science*, **47**, 353-363.

Haslam R.A., Hide S.A., Gibb A.G.F., Gyi D.E., Pavitt I., Atkinson S., Duff A.R., (2005), Contributing factors in construction accidents, *Applied Ergonomics*, **36**, 401-415.

Health and Safety Executive, (2003), Causal factors in construction accidents, Loughborough University and UMIST, for the Health and Safety Executive, On line at: http://www.hse.gov.uk/researcH/rrpdf/rr156.pdf.

Health and Safety Executive, (2004), HSG (245), Investigating accidents and incidents, HSE-Books, UK, On line at: http://www.hse.gov.uk/pUbns/hsg245.pdf.

Health and Safety Executive (HSE), (2005), Identifying human factors associated with slip and trip accidents, HSE-Books, UK, On line at: http://www.hse.gov.uk/research/rrpdf/rr382.pdf.

Hendrick K., Benner L., (1987), Investigating accidents with STEP, New York.

Hinze J., Pedersen C., Fredley J., (1998), Identifying root causes of construction injuries, *Journal of Construction Engineering and Management*, **124**, 67-71.

Hollnagel E., (2004), *Barriers and Accident Prevention*, Ashgate Publishing Limited, England.

Hollnagel E., Speziali J., (2008), Study on developments in accident investigation methods: a survey of the 'state-of-the-art, On line at: https://hal-mines-paristech.archives-ouvertes.fr/hal-00569424/document.

HSE, (1999), HSG48, Reducing Error and Influencing Behaviour, Published by TSO, On line at: http://www.hse.gov.uk/pUbns/priced/hsg48.pdf.

International Labour Organization, (1998), *Encyclopaedia of Occupational Health and Safety*, International Labour Organization, Geneva.

Jacinto C., Aspinwall E., (2002), WAIT- a new method for the investigation and Analysis of accidents at work, *Institution of Occupational Safety and Health*, **6**, 15-37.

Jacinto C., Aspinwall E., (2003), Work accidents investigation technique (WAIT)- Part I, *Safety Science Monitor*, **7**, 1-17.

Jacinto C., Aspinwall E., (2004a), WAIT (Part II)- Results of application in real accidents, *Safety Science Monitor*, **7**, 5-18.

Jacinto C., Aspinwall E., (2004b), WAIT (Part III)-Preliminary validation studies, *Safety Science Monitor*, **8**, 19-29.

Jacinto C., Canoa M., Guedes Soares C., (2009), Workplace and organizational factors in accident analysis within the food industry, *Safety Science*, **47**, 626-635.

Jacinto C., Guedes Soares C., Fialho T., Silva A.S., (2011), The recording, investigation and analysis of accidents al work (RIAAT) process, *Policy and Practice in Health and Safety*, **9**, 57-77.

Jacinto C., Guedes Soares C., Fialho T., Silva S.A., (2010), RIATT: The recording, investigation an analysis of accidents al work- User's manual, On line at: http://www.mar.ist.utl.pt/captar/riaat.aspx.

Johnson W.G., (1980), *MORT Safety Assurance Systems*, Marcel Dekker Inc, New York.

Junta de Andalucía, (2009), Studies on the causes of Serious and Deadly Accidents in Andalucia (in Spanish), On line at: http://juntadeandalucia.es/organismos/economiainnovacioncienciayempleo/areas/seguridad-salud/riesgos-laborales.

Katsakiori P., Kavvathas A., Athanassiou G., Goutsos S., Manatakis E., (2010), Workplace and organizational accident causation factors in the manufacturing industry, *Human Factors and Ergonomics in Manufacturing & Service Industries*, **20**, 2-9.

Katsakiori P., Sakellaropoulos G., Manatakis E., (2009), Towards an evaluation of accident investigation methods in terms of their alignment with causation models, *Safety Science*, **47**, 1007-1015.

Kim T., Nazir S., Øvergård K. I., (2016), A STAMP-based causal analysis of the Korean Sewol ferry accident, *Safety Science*, **83**, 93-101.

Kingston J., (2002), 3CA – Control Change Cause Analysis Manual. NRI-3 (2002), Pub. Noordwijk Risk Initiative Foundation, The Netherlands, On line at: www.nri.eu.com.

Kingston J., Jager J., Koornneef F., Frei R., Schallier P., (2004), Events and Conditional Factors Analysis Manual, Draft Edition, Pub. Noordwijk Risk Initiative Foundation, The Netherlands.

Kjellen U., Larsson T.J., (1981), Investigating accidents and reducing risks - a dynamic approach, *Journal of Occupational Accidents*, **3**, 129-140.

Kjellén U., Hovden J., (1993), Reducing risks by deviation control – a retrospective into research strategy, *Safety Science*, **16**, 417-438.

Kontogiannis T., Leopoulos V., Marmaras N., (2000), A comparison of accident analysis technique for safety-critical man-machine systems, *International Journal of Industrial Ergonomics*, **25**, 327-347.

Larsson T.J., (1993), Investigating accidents and reducing risks – a dynamic approach (Kjellén and Larsson, 1981) – its relevance for injury prevention, *Safety Science*, **16**, 439–443.

Le Coze J., (2010), Accident in a French dynamite factory: An example of an organisational investigation, *Safety Science*, **48**, 80-90.

Lennè M.G., Salmon P.M., Liu C., Trotter M., (2012), A systems approach to accident causation in mining: an application of the HFACS method, *Accident Analysis and Prevention*, **48**, 111-117.

Leplat J., (1978), Accident analysis and work analysis, *Journal of Occupational Accidents*, **1**, 331–340.

Leveson N., (2004), A new accident model for engineering safer systems, *Safety Science*, **42**, 237-270.

Lind S., (2008), Types and sources of fatal and severe non-fatal accidents in industrial maintenance, *International Journal of Industrial Ergonomics*, **38**, 927-933.

Lindberg A., Ove Hansson S., Rollenhagen C., (2010), Learning from accidents - what more do we need to know, *Safety Science*, **48**, 714-721.

Liu J.S., Lu L.L.L., Lu W.-M., Lin B.J.Y., (2013), Data envelopment analysis 1978-2010: a citation-based literature survey, *Omega*, 41, 3-15.

Livingston A.D., Jackson G., Priestley K., (2001), Root causes analysis - literature review, Contract Research Report 325/2001 for Health and Executive, HSE Books, UK.

LTWA, (2017), List of title Word abbreviations, On line at: http//www.issn.org/2-22661-LTWA-omline.php.

Marhavilas P., Koulouriotis D., Gemeni V., (2011), Risk analysis and assessment methodologies in the work sites: On a review, classification and comparative study of the scientific literature of the period 2000–2009, *Journal of Loss Prevention in the Process Industries*, **24**, 477-523.

McDevitt J., Benner L., (1981), System safety methodology for conference on the state of the art of system safety, *Hazard Prevention*, **18**, 26-31.

Mohammadfam I., Nikoomaram H., (2013), FTA vs. Tripod-Beta, which seems better for the analysis of mayor accidents in process industries?, *Journal of Loss Prevention in the Process Industries*, **26**, 52-58.

Moriyama T., Ohtani H., (2009), Risk assessment tools incorporating human error probabilities in the Japanese small-sized establishment, *Safety Science*, **47**, 1379-1397.

Myers L., (2002), *Management and Human Performance Root Causes*, Davis - Besse Nuclear Power Station, FENOC, Ohio, USA.

Nunes C., Santos J., da Silva M. V., Lourenço I., Carvalhais C., (2015), Comparison of different methods for work accidents investigation in hospitals: A Portuguese case study, *Work: A Journal of Prevention, Assessment and Rehabilitation*, **51**, 601-609.

OECT, (2002), State Observatory of Working Conditions, Analysis of mortality due to work accidents in Spain, On line at: http://www.oect.es/portal/site/Observatorio/menuitem

Okoh P., Haugen S., (2014), A study of maintenance-related major accident cases in the 21st century, *Process Safety and Environmental Protection*, **92**, 346-356.

Okoli C., Schabram K., (2011), A Guide to Conducting a Systematic Literature Review of Information Systems Research, Sprouts Work, On line at: https://pdfs.semanticscholar.org/31dc/753345d5230e421ea817dd7dcdd352e87ea2.pdf

Okstad E., Jersin E., Tinmannsvik R.K., (2012), Accident investigation in the Norwegian petroleum industry – Common features and future challenges, *Safety Science*, **50**, 1408-1414.

OSHA, (1990), The Occupational Safety and Health Administration (OSHA) Data Base 1985-1989 (1990), Analysis of construction fatalities, U.S. Department of Labour, Occupational Safety and Health Administration, Washington D.C., On line at: https://apps.dtic.mil/dtic/tr/fulltext/u2/a400187.pdf.

Petri C.A., (1962), *Kommunikation mit Automaten, Schriften des Rheinisch-Westfälischen Institutes für Instrumentelle Mathematik*, University of Bonn, Germany.

Pique T., (1997), NTP 442: Accident-incident investigation: procedure, Madrid, Spain, National Institute for Safety and Hygiene at Work, On line at:

http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/NTP/Ficheros/401a500/ntp_442.pdf.

Rajala H., Väyrynen S., (2010), Constructing "core stories" for contributing practical safety actions in industrial units, *Safety Science*, **48**, 1393-1401.

Rasmussen J., (1997), Risk management in a dynamic society: a modelling problem, *Safety Science*, **27**, 183-213.

Rathanayaka S., Khan F., Amyotte P., (2011), SHIPP methodology: Predictive accident modelling approach. Part I: Methodology and model description, *Process Safety and Environmental Protection*, **89**, 151-164.

Reason J.T., (1997), Managing the Risks of Organizational Accidents, Ashgate, Aldershot.

Reason J., (1990), *Human Error*, Cambridge University Press.

Roed Larsen S., Stoop J., (2012), Modern accident investigation - four major challenges, *Safety Science*, **50**, 1392-1397.

Rollenhagen C., (1995), MTO - An Introduction, Human Relationship, Technology and Organization, Student Literature, Lund, Sweden, On line at: https://www.diva-portal.org/smash/get/diva2:718405/FULLTEXT01.pdf.

Safe Work Australia, (2014), Work-related fatalities associated with unsafe design of machinery, plant and powered tools, On line at: https://www.safeworkaustralia.gov.au/system/files/documents/1702/work-related-fatalities-unsafe-design.pdf.

Saleh J.H., Haga R.A., Favarò F.M., Bakolas E., (2014), Texas city refinery accident: Case study in breakdown of defense-in-depth and violation of the safety–diagnosability principle in design, *Engineering Failure Analysis*, **36**, 121-133.

Salguero-Caparros F., Suárez-Cebador M., Rubio-Romero J.C., (2015), Analysis of investigation reports on occupational accidents, *Safety Science,* **72**, 329-336.

Sanmiquel L., Freijo M., Edo J., Rossell J.M., (2010), Analysis of work related accidents in the Spanish mining sector from 1982-2006, *Journal of Safety Research*, **41**, 1-7.

Schroder-Hinrichs J., Baldauf M., Ghirxi K., (2011), Accident investigation reporting deficiencies related to organizational factors in machinery space fires and explosions, *Accident Analysis and Prevention*, **43**, 1187-1196.

Sklet S., (2004), Comparison of some selected methods for accident investigation, *Journal of Hazardous Materials*, **111**, 29-37.

Storybuilder, (2008), White Queen BV, The Netherlands, On line at: www.rivm.nl/en/Topics/Topics/S/Storybuilderwww.rivm.nl/en/Topics/Topics/S/Storybuilder.

Strömgren M., Bergqvist A., Andersson R., Harms-Ringdahl L., (2013), A process-oriented evaluation of nine accident investigation methods, *Safety Science Monitor*, **19**, 1-10.

The Dutch Labour Inspectorate, The Dutch National Institute for Public Health (RIVM), On line at: http://www.storybuilder.eu/.

The National Institute for Occupational Safety and Health (NIOSH), (1989), The fatality assessment and control evaluation (FACE), On line at: https://www.cdc.gov/niosh/face/default.html.

Underwood P., Waterson P., (2013a), Accident analysis models and methods: guidance for safety professionals, Loughborough, Loughborough University, On line at: https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/13865/4/Underwood%20and%20Waterson%20.

Underwood P., Waterson P., (2013b), Systemic accident analysis: Examining the gap between research and practice, *Accident Analysis & Prevention*, **55**, 154-164.

US Department of Labor, (2005), Fatal facts accident reports. Occupational Safety and Health Administration, US Department of Labor, On line at: http://www.osha.gov/OshDoc/toc_FatalFacts.html

Villemeur A., (1991), Reliability, Availability, Maintainability and Safety Assessment-Methods and Techniques, vol. 1, Chichester, UK.

Wagenaar W.A., Van der Schrier J., (1997), Accident analysis - the goal, and how to get there, *Safety Science*, **26**, 25-33.

Wang Q., Chen X., YI-Chong X., (2013), Accident like the Fukushima unlikely in a country with effective nuclear regulation: literature review and proposed guidelines, *Renewable and Sustainable Energy Reviews*, **17**, 126-146.

Wiegmann A., Shappell S.A., (2001), Applying Reason: the human factors analysis and classification system (HFACS), *Human Factors and Aerospace Safety*, **1**, 59-86.

Willquist P., Törner M., (2003), Identifying and analysing hazards in manufacturing industry - a review of selected methods and development of a framework for method applicability, *International Journal of Industrial Ergonomics*, **32**, 165-180.

WorkSafeBC, Occupational Health and Safety Regulation, Occupational Health and Safety Regulation of British Columbia, Canada, On line at: www2.worksafebc.com

Zhao D., Thabet W., McCoy A., Kleiner B., (2014), Electrical deaths in the US construction: An analysis of fatality investigations, *International Journal of Injury Control and Safety Promotion*, **21**, 278-288.