

6th International Conference on Industrial Engineering and Industrial Management.  
XVI Congreso de Ingeniería de Organización. Vigo, July 18-20, 2012

## Organizational causes of accidents in manufacturing sector.

Carrillo JA<sup>1</sup>, Onieva L<sup>2</sup>

**Abstract:** Occupational safety is an important issue. Industrial engineering and management plays an important role in a socio-technical view of accident causation. This paper analyzes 418 official investigation reports of non-slight accidents in the Andalusian manufacturing sector from 2004 to 2008. Investigation reports include 1,311 causes identified and coded, of which 669 causes are directly related to safety management and work organization. This paper shows how different scenarios are related to specific causes of accidents and the association between organizational and management causes and the mechanism of the accidents and their immediate causes. In order to prevent, both severe and fatal accidents, managers and safety experts should take into account these results in order to include the most frequent causes as inputs for safety assessments.

**Keywords:** Occupational Safety, Safety Management, Accident Investigation, Industrial Organization.

### 1.1 Introduction

According to The Encyclopaedia of Occupational Health and Safety (Saari et al. 1998), causes of accidents can be classified as immediate causes like unsafe acts and unsafe conditions or as contributing causes like safety management performance, mental condition of worker and physical condition of worker.

---

<sup>1</sup>Jesús A. Carrillo Castrillo (✉)

Junta de Andalucía

Dirección General de Seguridad y Salud Laboral, Avda. Hytasa, 14 P-1, 41006 Sevilla, Spain

e-mail: [jarcas@gmail.com](mailto:jarcas@gmail.com)

<sup>2</sup>Luis Onieva Giménez

Grupo de Investigación de Ingeniería de Organización, Universidad de Sevilla.

Camino de los Descubrimientos s/n Isla de la Cartuja 41092 Sevilla, Spain

e-mail: [onieva@us.es](mailto:onieva@us.es)

Many studies have attempted the characterization of safety management and the relationship between management practices and safety performance (Arocena et al. 2008) (Fernández-Muñiz et al. 2009). The underlying hypothesis is that some management practices can be protective measures (barriers) of accidents. On the other hand, other management practices, or the lack of them, can be contributing causes of accidents.

Although this line of research is useful, safety is a complex and multicausal matter and analyzing accidents as single cases can provide a deeper insight in the mechanism of the accident causation. Our purpose is to study how those management causes contribute to accident causation and their relation with accident scenarios and accident mechanism.

Accident investigation examines at least four different levels: work and technological system, staff, management and company level (Sklet 2004). Accident investigation methods need to be aligned to an accident causation model (Katsakiori et al. 2009).

There is a huge challenge for research. Each accident is in some way unique and any attempt to group or categorize different accidents together implies the loss of important pieces of information. Nevertheless, safety engineers need to know why accidents are occurring and what can be improved.

Most of quantitative studies have proposed or used a coding system for causes and most of Health and Safety Public Authorities have their own system. In narrative analysis, researchers use a coding system performed in a second step using previous accident report submissions so they are coded by a person who did not have direct information about the accident (McKenzie et al. 2010).

Although we gathered every year a large number of accidents with narrative description, we have discarded them for this study due to the lack of accuracy and the limited information provided by accident reports. Therefore we chose accident investigation reports as they have a more accurate information and because the main causes were coded at the same time the accident were being investigated.

## **1.2 Conceptual model**

According to the latest studies, both latent and active failures need to be taken into account in order to explain accident causation (Reason 2000). Accident investigations joint both immediate and non environmental causes in order to explain both accident physical event and the latent conditions that contributed to the accident occurrence.

Accident mechanism and pattern determine most of the possible causes. This is because active failures in manufacturing sector are commonly related to physical barriers. The simplest way to take into account this issue is to build ideal accident scenarios. Although every single accident is unique, a group of accidents from the

compare differential causes.

Phase III of European Statistics on Accidents at Work –ESAW- (European Commission 2001) covers other harmonized variables and classifications of the causes and circumstances of accidents at work which will help establish the situation and conditions prevailing at the time of the accident. The results of these analyses will provide useful information which will assist in the development of new and carefully targeted prevention policies.

According to phase III of ESAW, there is an implicit identification of accident scenarios as a combination of work in process, physical activity, deviation and agent of deviation (Jacinto and Aspinwall 2009). From the preventive point of view what constitutes the scenario of the accident is that combination of variables as they define the previous conditions existing when the accident took place.

### **1.3 Data**

In Spain, accident reports are collected in “Official Workplace Incident Notification Forms” electronically collected. All accidents that result in an absence from work of one or more days must be notified. Medical criteria are applied to classify the accident as slight or non slight, depending on the severity of injuries.

For each accident reported, we have information about worker age, months of experience in the company, occupation, and some technical circumstantial information both from workers and companies.

In certain occasions, as when the accident is non-slight, if it is required by Justice or Labour Inspectors or according to random selection of cases, official safety experts conduct an official accident investigation. The methodology is based on a cause tree model (Ardanuy 1997). These investigations are developed according to internal procedures and an official extended investigation report is submitted.

Since 2003, Instituto Nacional de Seguridad e Higiene that is the Occupational Health and Safety Institute in Spain, has promoted a codification system for causes included in official accident investigation reports in order to facilitate the statistical analysis. There are 255 possible cause codes grouped as workspace conditions, protection and service installations, machines, other equipment, materials and substances, work organization, safety management and personal factors (Instituto Nacional de Seguridad e Higiene 2007).

Accidents included in this study are manufacturing sector accident investigations coded and reported since 2004. Manufacturing sector are activities with NACE from 15 to 27 according to Council Regulation EEC N°3037/1990. We excluded those reported such as traffic accidents, of self-employed worker or occurred in construction sites.

Most slight accidents are not investigated. Only 4% of all the accidents are officially investigated. There is a differential causation between slight and non slight

accidents and 22% of severe and fatal accidents have been investigated. For these reasons we decided to study only severe and fatal accidents accident reports. The final number of accident investigations included is 418 (see Table 1).

**Table 1.** Distribution of severe and fatal accidents investigated in this study.

Group by	Variable	Investigated 2004-2008	Accidents 2004-2008	%
Severity	Severe accidents	397	1,730	23,84%
	Fatal accidents	21	103	20,08%
NACE	15. Food & Beverages	105	327	32,11%
	20. Wood products	48	184	26,09%
	26. Non-metallic mineral products	67	221	30,32%
	27. Basic and fabricated metal products	47	145	32,41%
	28. Metal products	122	340	35,88%
	29. Machinery	23	81	28,40%
	36. Furniture and n.e.c.	59	120	49,17%
Most frequent scenarios (activity +agent+ deviation)	Production + Machines + Control Loss	43	141	30,50%
	Production + Machines + Stepping/Struck/Strike	45	121	37,19%
	Production + Manipulation + Stepping/Struck/Strike	25	80	31,25%
	Production + Movement + Falls	10	66	15,15%
	Production + Manipulation + Loss of Control	17	57	29,82%
	Production + Tools + Loss of Control	14	55	25,45%
	Production + Machines + Other	18	54	33,33%
Company Size	Micro	125	533	23,45%
	Small	189	795	23,77%
	Medium	93	389	23,91%
	Big	11	116	9,48%

## 1.4 Accident scenarios and their most frequent causes.

As previous studies have indicated, accident causation depends on the accident scenario. Scenarios have been defined as a combination of a certain activity, an agent and a deviation.

We have identified nine main scenarios and five causes have been identified as the most frequent (Table 3). In each scenario there are causes that more likely explain severe and fatal accident causation. We have calculated the incidence of each cause as the percentage of accidents where that single cause was identified.

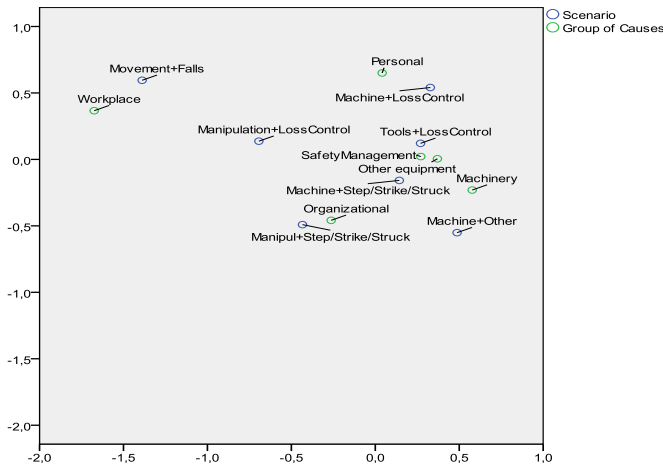
As expected deficient organizational and safety management are directly related in most scenarios through causes as lack of training, inadequate work methods and lack of appropriate preventive measures as personal protective equipment – PPE- and machines safeguards.

This analysis provides very useful information. Every task in manufacturing can be easily classified with both activity and agent so safety assessment can identify easily the most frequent causes of accident.

Correspondence analysis is primarily a technique for representing the rows and columns of a two way contingency table in a joint plot. Although it is only an exploratory technique, it provides a very intuitive tool for managers (see Figure 1).

**Table 3.** Percentage of cases (accidents) of the scenario with each cause.

Scenario	Cause	% Accidents
Prod + Machines + Control Loss	Lack of training	44%
	Inadequate work method	34%
	Other individual factors	30%
	Lack of safeguards	23%
Prod+ Machines + Stepping/Struck/Strike	Inadequate work method	51%
	Lack of training	30%
	Other individual factors	24%
Prod + Manipulation + Stepping/Struck/Strike	Inadequate work method	71%
Prod + Movement + Falls	Other individual factors	30%
Prod + Manipulation + Loss of Control	Inadequate work method	29%
	Inadequate work method	57%
	Other individual factors	43%
	Lack of personal protection	29%
Prod + Tools + Loss of Control	Inadequate work method	39%
	Other individual factors	33%
	Lack of training	28%
	Lack of safe guards	22%



**Fig. 1.** Correspondence plot: group of causes and accident scenarios

Causes are grouped as Workplace (01), Installations (02), Machinery (03), Other Equipment (04), Materials and Substances (05), Organizational (06), Safety Management (07), Personal (08) and Others (09). According to correspondence analysis, each group of causes is near to some specific scenarios. Workplace caus-

es are close to falls accidents. Personal causes and safety management are near to those scenarios with loss of control as deviation. Organizational causes are more likely attributed with strikes and being struck by accidents. As expected correspondence analysis provide similar conclusions to the previous incidence analysis.

## 1.5 Relationship between latent and active causes.

Contingency analysis can give a first insight on how causes are associated. The chi-square test has been performed for all cases using main group of causes (first two digits of the code of each cause) in order to identify relationships.

The cause groups of latent causes as safety management and organization are highly correlated with each other (Chi-square 12.03,  $p=0.001$ , Phi coefficient=0.17). This strong relationship is explained as safety management is part of general management and work organization is one of the management tasks (Shannon et al. 1997).

Contingency analysis also shows that some immediate active causes are highly correlated to latent causes (see Table 2, columns are group of management causes and rows are groups of immediate causes).

This result supports the hypothesis that latent causes such as deficiencies in organizational and safety management explain other immediate causes like lack of appropriate protections or exposures to hazards without proper signaling or training.

**Table 2.** Relation between organizational and safety management causes and others.

Contingency analysis <sup>1</sup>	Work method	Training and instructions	Selection of equipment	Preventive activities	Other organization causes
Physical agents	0.136**	0.182**	--	0.133**	--
Protection installations	--	--	0.150**	--	--
Protection elements	--	--	--	0.102*	--
Signaling	--	--	--	--	0.156**
Other equipment causes	0.147**	--	0.123*	0.118*	--

<sup>1</sup>Phi coefficient is calculated. Chi-square significance is \* if  $p<0.05$  and \*\* if  $p<0.01$

## 1.6 Small and medium companies (SME)

Many studies (Fabiano et al. 2004) have provided evidences of higher injury rates for SME and one of the explanations is a less efficient safety management. European, Spanish and Andalusian strategies for Health and Safety at Work have identified SME as a target for public support.

We have checked if causes identified are related to establishment size (see table 4). Although we only gather establishment size, in Andalusian manufacturing sector more than 92% of companies have only one establishment. In micro and small sites there are more cases with causes like inadequate work method and lack of training. In medium and big sites are more frequent causes as removing safeguards.

**Table 4.** Percentage of cases with each cause vs establishment size (number of workers)

Cause	% Cases	% Cases	% Cases	% Cases
	Micro (1-9)	Small (10-49)	Medium (50-249)	Big (>249)
Inadequate work method	44,8%	36,5%	41,9%	18,2%
Lack of training	20,0%	16,4%	18,3%	9,1%
Lack of safeguards	20,0%	30,7%	23,7%	18,2%
Removing safeguards	15,2%	6,9%	15,1%	27,3%
Not complying safety rules	10,4%	3,7%	4,3%	0,0%
Lack of hazard identification	8,0%	13,2%	12,9%	9,1%
Other safety management causes	8,0%	12,2%	7,5%	0,0%
Not using PPE provided	7,2%	5,3%	7,5%	0,0%
Sharp edges not protected	6,4%	15,9%	4,3%	0,0%

## 1.7 Discussion

We have found a strong relationship between organizational and safety management deficiencies and immediate causes of accidents. According to the accident investigation reports, latent causes are associated to active causes.

Any attempt to improve safety should include the appropriate treatment of safety management and organizational causes. In this aspect, adoption of safety management models and audits on safety management are highly recommended. First, because any adequate safety system as preventive activities should help to eliminate active causes. This is the underlying reason of the strong association between organizational and safety management causes and active causes. Second, because latent causes are also contributing risk factors of accident occurrence.

Safety assessment should take into account most frequent causes of severe and fatal accidents in manufacturing sector and their relationship with work scenarios.

Each accident scenario - defined as the combination of activity, deviation and agent - has specific accident causes. This means, in terms of safety assessment, companies with those possible scenarios of accident should concentrate their efforts on eliminating, if possible, the group of causes nearer in terms of correspondence plot and search for the most frequent causes of that scenario.

Finally, we have found strong differences in accident causation depending on establishment size. Micro and small companies have difficulties in adopting safety and health regulation. European, Spanish and Andalusian Strategies on Occupational Health and Safety have identified this issue and propose public assessment

programs. Although big efforts are being done, there is still a huge amount of work to be done with SME.

The main strength of this paper is that all cases are real official accident investigation performed and represent more than 25% of all severe and fatal accidents in the period.

Further research should be done including slight accidents investigations and if possible gathering more information about the safety practices of the companies, in order to identify which safety management practices are sources of latent causes of accidents and which safety practices are protective and effective barriers in preventing accident occurrence. Latent variables are usually related not only with moment previous to the accident but also to permanent safety practices and conditions.

## 1.8 References

- Arocena P, Nuñez I, Villanueva M (2008). The impact of prevention measures and organizational factors on occupational injuries. *Saf Sci* 46(9):1369-1384.
- Ardanuy T (1997). Nota Técnica de Prevención nº442 "Investigación de accidentes-incidentes: Procedimiento". <http://www.insht.es>. Accessed 1 Feb 2012.
- European Commission (2001). European statistics on accidents at work (ESAW): Methodology, edition 2001. Reference: ESTAT/E3/HSW/2001/1130. <http://ec.europa.eu/eurostat/>. Accessed 1 Feb 2012.
- Fabiano B, Currò F, Pastorino R (2004). A study of relationship between occupational injuries and firm size and type in the Italian industry. *Saf Sci* 42(7):587-600.
- Instituto Nacional de Seguridad e Higiene en el Trabajo (2007). Análisis cualitativo de la mortalidad por accidente de trabajo en España 2003-2004. Instituto Nacional de Seguridad e Higiene en el Trabajo. ISBN 978-84-7425-726-7.
- Fernández-Muñiz B, Montes-Peón JM, Vázquez-Ordás CJ (2009). Relation between occupational safety management and firm performance. *Saf Sci* 47(7):980-991.
- Jacinto C, Aspinwall E (2003). Work Accidents Investigation Technique (WAIT) - Part I. *Saf Sci Monit* 7(I) Article IV-2.
- Jacinto C, Canoa M, Guedes Soares C (2009). Workplace and organizational factors in accident analysis within the Food Industry. *Saf Sci* 47(5): 626-635.
- Katsakiori P, Kavvathas A, Athanassiou G et al (2010). Workplace and Organizational Accident Causation Factors in the Manufacturing Industry. *Hum Factors Ergon Manuf Servic Ind* 20(1): 2-9.
- McKenzie K, Scott DA, Campbell MA et al (2010). The use of narrative test for injury surveillance research: A systematic review. *Accid Anal Prev* 42(2): 354-363.
- Reason J (2000). Human errors: models and management. *Br Med J*, 320: 768-770.
- Saari J et al (1998). Part VIII. Chapter 56. Accident Analysis. In: *Encyclopaedia of Occupational Health and Safety*, 4th ed. International Labour Organization, Geneva. [http://www.ilo.org/safework\\_bookshelf/](http://www.ilo.org/safework_bookshelf/). Accessed 1 Feb 2012.
- Shannon HS, Mayr J, Haines, T (1997). Overview of the relationship between organizational and workplace factors and injury rates. *Saf Sci* 26(3):201-217.
- Sklet S (2004). Comparison of some selected methods for accident investigation. *J Hazard Mater* 111(1-3): 29-37.