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Occupational Accidents analysis in Food and Drink industry, a contribution to Safety and Risk Management

Lorenzo Comberti*, Micaela Demichela, Gabriele Baldissone

SAfeR, Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, Corso Duca degli Abruzzi, 24 – 10129 Torino, Italia
lorenzo.comberti@polito.it

Food and Drink Industry (FDI) has a strong contribution to EU-28's economy as reported by Eurostat (2014). FDI involves more than 4,25 millions of workers divided in 289000 companies with a relevant degree of diversification. Far away from the common way of thinking the FDI sector has an accident frequency comparable to those of other industrial sectors. Economic and social consequences of occupational accidents affects clearly FDI efficiency and its competitiveness. The accidents investigation is a crucial field for a safety and prevention management system because understanding how an accident occurred can help to avoid the same type of accident in the future. This paper was intended to give a contribution to Safety Management of FDI industry. A large Database of more than 6000 occupational accidents occurred in FDI Industry was analysed with an innovative coupled numerical method named SKM (S.O.M and K-Mean method) able to identify the occupational accident dynamics more critical and frequent. The information acquired by this research can help analysts to better address the measures to be adopted in a work environment, in order to prevent occupational accidents and give a concrete contribution to Risk Management.

1. Introduction

Food and Drink industry (FDI) is a relevant contributor to EU-28's economy.
According to Eurostat (2014), Food and Drink industry (FDI) generated in 2013 a turnover of 1090 billions, 80% of which was spent in input costs for a value added of 212 billion.
This sector collected in 2013 the 15,6% of turnover in EU manufacturing industry and the 1,8% of the whole gross value added of EU economy. In FDI are employed more than 4,25 millions of workers shared in 289000 companies (Eurostat, 2014). Compared to other manufacturing sectors, FDI maintained the characteristics of a stable, resilient sector even during the recent economy crisis (Comberti et al., 2018a).
FDI is a highly diversified sector where bakery and farinaceous products, meat sector, dairy products, drinks represent the 75% of the total turnover and collect more than the 80% of the employees.
FDI sector is strongly characterised by the presence of SMEs (Small and Medium Enterprises) that represent the 99% of the enterprises involving the 62% of the employees and almost the 48% of the Value added of the sector.
These economy data underline the importance of FDI sector for the EU economy, in particular for country as Germany, Italy, France, Spain and Poland that are the largest producers for turnover.
FDI sector have to deal with the occupational accidents that still represent an unsolved problem for the whole world economies. Workers of FDI sector are exposed to several risks (Stave et al., 2007): such as working with sharping tools and working with machinery; as a consequence the number of occupational accidents is high (Evtushenko et al., 2013) and not far from others manufacturing branches (Willquist et al., 2005) as confirmed by HSE official reporting (Health and Safety Executive) for 2011-2012 that in UK the occupational accidents occurred in FDI accounted for a quarter of all manufacturing injuries.
To limit the occupational accidents frequency EU promoted several regulations and the constant monitoring of the problem since 1990, when the European Statistics on Accidents at Work (ESAW) project was launched. On the basis of ESAW standards all occupational accidents are reported to the National Health and Safety

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Authorities and collected in official databases and this has been recognised as relevant to prevention policies (Jacinto et. Al., 2004).
This information are analysed with traditional statistical methods according to Regulation 1338/2008 and Regulation 349/2001 on Community statistics on public health and health and safety at work.
Results are regularly published in official reports by National Health and Safety Authorities highlighting useful and general information on occupational accidents trend as: the classes of workers more exposed to accidents, gender effects, the role of educational level, the age and many other different parameters. In addition ESAW data are used, in focus-field studies, with a statistic approach to identify the cause-effect mechanism (Jacinto et al.,2008), to highlight the “typical accident” (Kogler et al., 2015) and the accidents trend (Dzwiarek et al., 2016).
These kind of analysis are only partially useful for enhancing the prevention in the work environment (Comberti et al., 2015) because they did not allow a risk assessment outcome (Carrillo-Castrillo et al., 2016).
Data mining offers an alternative approach to ESAW data analysis, it includes several different techniques of data analysis. Belong them interesting results related to ESAW data have been obtained with Multi Correspondence Analysis (MCA) (Carrillo-Castrillo et al., 2016) and Pattern Identification (Silva et al., 2012) able to allow the identification of most important accidents scenario with a quantification of frequency but without a quantification of associated risk.
A method, named SKM (S.O.M. and K-Means Method) able to combine the accidents scenario identification to the risk assessment was presented in 2015 (Comberti et al., 2015) and successfully applied in occupational accident s analysis of other manufacturing branches as mechanical (Murè et al.,2017) and Wood processing (Comberti et al., 2018b).
The SKM made a quantification of the risk, on the basis of accident scenario identification, allowing the use of the results as a decision making support for prevention purposes.
This work was intended to give a contribution to safety management Food and Drink industry in Italy.
FDI is the third sector in manufacturing for employment with 385000 workers officially involved and generated (Eurostat, 2013) a turnover of 132 billion of euro involving more than 54000 companies.
This research was focused in Piemonte area, a north west region of Italy, where FDI has an historical relevance with the presence of international companies and local brands.
Occupational accidents data collected by regional bureau of INAIL (Italian National Compensation Authority) from 2006 to 2013 were analysed with the using of SKM with the purposes of identifying occupational accidents families with a quantification of their awareness and frequency.
In section 2 a short description of SKM is provided while Section 3 presents the results of the application on the case study. Conclusions and prospects for future work end the paper.

2. Methods

As mentioned in Introduction, this work is intended to analyse and to establish a better understandings of identification of accidents scenario and associated risk in FDI sector.
The methodology used in this study consist of three main stages:

- Data collection of Regional occupational accidents in FDI sector;
- Data sample setting to SKM analysis.
- SKM analysis and results.

The occupational accidents data set was provided by Piemonte-Regional bureau of INAIL (Italian National Compensation Authority).
It covered the period 2006-2013 and it was made of more than 7000 elements including all occupational accidents with at least 4 days of prognosis.
Each accident was recorded according to ESAW standard but unfortunately some reports were inaccurate with a lot of lack of information and consequently the setting for the SKM analysis required a preliminary check of all the available data.
The analysis of the accident database related to FDI sector was characterized as follows:

- firstly the scope of the study was linked to accident scenario identification and risk assessment to support the safety management, consequently between all the variables contained into ESAW description the variables selected were:
    - Activity;
    - Deviation;
    - Material of deviation
    - Contact;
    - Injured body part.
    - Age of worker involved;

First five variables have been selected because they are directly linked to the accident event, the "Age of worker" was selected to investigate is eventual influence into the accident dynamic.

- Secondly It was required that all the first four variables were at the same time present in the accident record to be selected for SKM data set definition.

As a consequence the number of occupational accidents useful for the SKM analysis was of 6483 elements.

2.1 SKM Method

The purpose of this stage was to analyze the occupational accidents domain in FDI sector with the identification of accidents scenario and risk assessment association. SKM is a numerical method based on a two steps of data analysis. Most of the variables are categorical elements, whereas algorithms for SKM calculation require numerical ones. As a consequence a pre-processing phase to adapt the data from occupational accident database to the algorithms characteristic was done according to Comberti et al. (2018).
First step is based on the elaboration of a S.O.M. (Self Organising Map) (Kohonen et al., 2000), a visual map of the data (Figure 1) that is based on their similarity and it is built with a projection process.

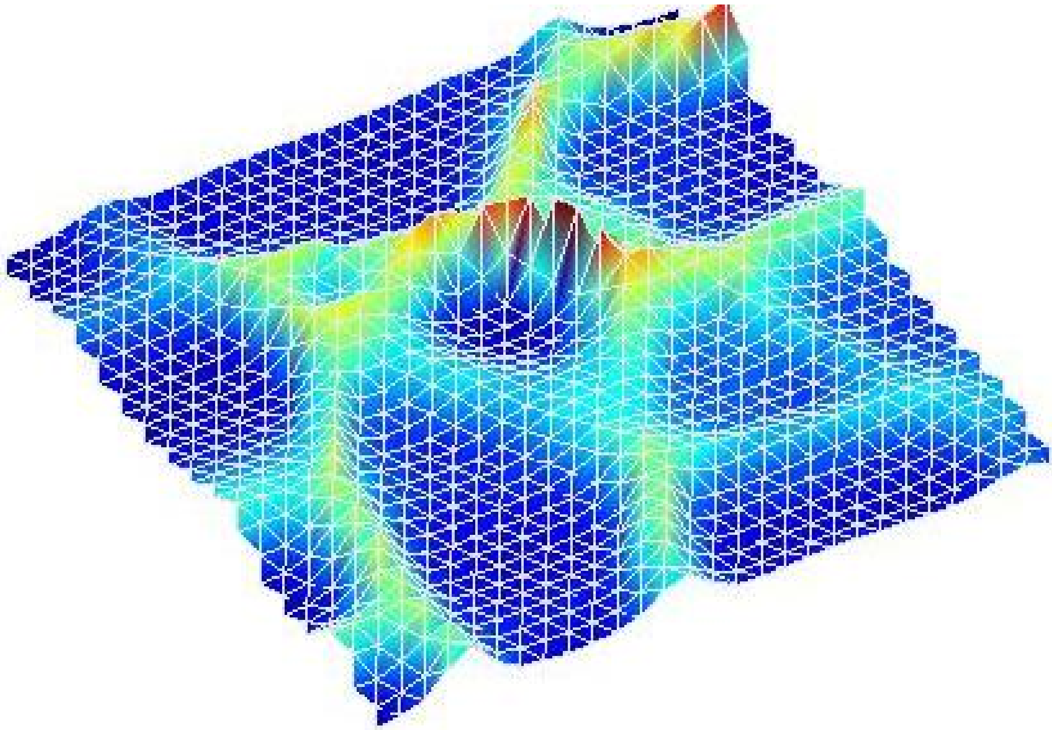

Figure 1: SOM of Occupational accidents data set of FDI elaborated by SKM.

The S.O.M. is a non-metric map made of elementary units, described by different colors. As in Figure 1, the color scale reflects the density of projected data into units, the blue (darker) valleys represent units with a large number of data projected, while red and yellow (lighter) picks represent empty units. The number of the valleys suggests the number of scenarios of similar accidents.
On the basis of this number, the second stage of the method can be applied. The K-Means algorithm (McQueen et al., 1967) is applied to the numerical output deriving from the first phase, and it provides a quantitative partition of the occupational accidents analysed. Accidents are divided into different groups on the basis of their similarity. Each group represent a Scenario of typical accident.

3. Experiments

The method allowed the identification of 13 scenarios of typical accidents that are summarized in Table 1.
For each Scenario a quantification of frequency of occurence, expressed in number of events, and a quantification of seriousness, expressed in term of average days of prognosis, was calculated.
The number of events for scenario had a range of variation from a minimum of 47 element of Scenario 10 to a maximum of 865 elements of Scenario 1.
This highlights the sensitivity of SKM of identifying even small scenario between bigger groups.

The seriousness associated to each scenario had a large range of variation too: from a minimum value of 15 days/event (Scenario 10) to 36 of Scenario 11 and 37 of Scenario 1.
In addition SKM identified all events with an uncomplete information reported and included them into Scenario 5. This Scenario collected the 11% of the whole data examined and it represents a relevant loss of information potentially useful for the full description of the occupational accidents domain (Jacinto et al., 2011).

Table 1: Scenario of typical accidents identification for FDI sector with SKM method.

Scenario	Events	Days of prognosis	Scenario description
Scenario 1	865	37	Driving, Control loosing and Crush.
Scenario 2	621	28	Free Movements and falling down to surface
Scenario 3	897	36	Free movement and Falling down with Body Compression
Scenario 4	288	30	Manual transport, Movements with Efforts and Pain
Scenario 5	718	34	Uncomplete information
Scenario 6	687	31	Working with machinery, Breaking or Contact, Various injuries
Scenario 7	496	29	Working with hand tools , Control losings and body cutting
Scenario 8	739	26	Objects handling, object breaking and cutting
Scenario 9	95	26	Driving and lack of information
Scenario 10	47	15	Object handling, Release and contact with fragment
Scenario 11	715	36	Objects handling, movements and cutting
Scenario 12	82	19	Objects handling, control losing and impact
Scenario 13	233	29	Objects handling, object breaking and impact

With reference to information provided by SKM analysis and resumed in Table 1 a Risk index was calculated according to the following equation:

$$R=F\times S, \quad (1)$$

where R is the risk, F is the frequency of occurrence calculated as number of occupational accidents divided by the period of observation and S is the seriousness calculated as average days of prognosis.
According to equation 1, Figure 2 summarizes the Risk estimation for all scenarios identified.

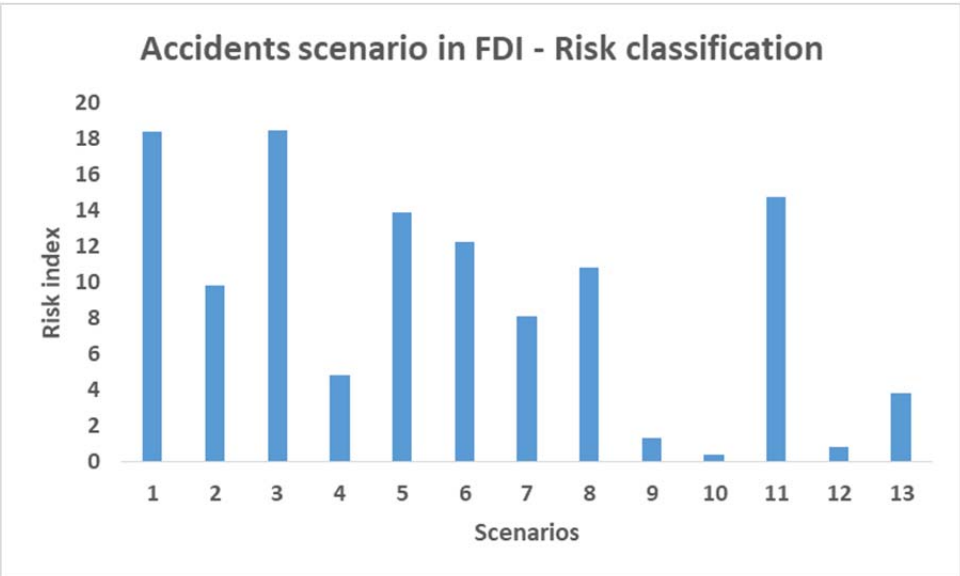

Figure 2: Risk classification for occupational accidents scenarios identified with SKM.

With reference to Figure 2, Risk had a wide range of variation from 0.4 of Scenario 10 to a value of 18 of Scenario 1 and 3.
SKM was able to identify Scenarios of accidents and to rank them in term of minor or greater level of Risk.
As an example the most critical scenario were scenario 1 and 3 that were related to accidents occurred during a vehicle driving (car, forklift…truck) and to falls during free movements.

One of the less critical was Scenario 4 that was related to Manual transport activity. Once this kind of occupational accidents were more critical but probability the most recent National Regulation on Occupational safety, the Dlgs 81/2008, that focused a specific attention to prevention of CTD (Cumulative Trauma Disorder), may had a good contribution in reducing the frequency and the seriousness of this scenario even if evaluating the effectiveness of a Safety Regulation in term of a simple decreasing of occupational accidents (Davies et al, 2009) it remains a controversial topic (De la Fuente et al., 2014).
The association of Risk assessment to each Scenario represents a support to any decision-making process focused to safety policies planning.
In fact any National Authorities involved in occupational safety promotion can use information provided by SKM analysis to plan policies or preventives measures towards those scenarios identified as more critical and having a quantification of their magnitude.

4. Conclusion

This paper was focused on analysis with a numerical methodology of an occupational accidents Data Base (DB) of FDI to support Safety and Risk management.
A data-set of more than 6000 occupational accidents occurred in FDI sector was selected as case study and it was analyzed with SKM method. SKM successfully identified a set of 13 Scenarios of typical accidents.
Furthermore some parameters related to the consequences of each accident (number of days of prognosis) and the number of event (number of accidents) have been calculated and associated to each scenario, this allowed a Risk assessment evaluation.
More in general the SKM can help the Companies' Management and the National Authorities in better addressing the preventive measures and policies toward those scenarios identified as the more critical on the basis of the quantification of risk. This additional information represents a useful knowledge that can be used to support risk based decision making process because it represents a quantification of risk linked to occupational accident groups defined (Comberti et al. 2018,c).
This work can be expanded in the direction of a deeper analysis of each identified Scenario with the aim of highlighting any possible correlation with the distribution of other ESAW information such as: gender effects, company-size effect, age influence, etc.
Furthermore analysis performed with SKM identified a relevant number of occupational accidents not properly reported to INAIL database. This for his magnitude limits the entirety of the whole analysis and it suggests that ESAW project can be improved in term of effectiveness of the reporting system.

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