Reliability Engineering and System Safety 133 (2015) 106–118

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

journal homepage: www.elsevier.com/locate/ress

Risk horoscopes: Predicting the number and type of serious occupational accidents in The Netherlands for sectors and jobs

Linda J. Bellamy [a,*], Martin Damen [b], Henk Jan Manuel [c], Olga N. Aneziris [d], Ioannis A. Papazoglou [d], Joy I.H. Oh [e]

[a] White Queen Safety Strategies, P.O. Box 712, 2130 AS Hoofddorp, The Netherlands
[b] RIGO Research & Advies, P.O. Box 2805, 1000 CV Amsterdam, The Netherlands
[c] National Institute for Public Health & Environment (RIVM), Centre for Safety, P.O. Box 1, 3720 BA Bilthoven, The Netherlands
[d] National Center for Scientific Research, "DEMOKRITOS", Aghia Paraskevi 15310, Greece
[e] Ministry of Social Affairs & Employment (SZW), P.O. Box 90801, 2509 LV The Hague, The Netherlands

ARTICLE INFO

Article history:
Received 27 March 2014
Received in revised form
31 August 2014
Accepted 1 September 2014
Available online 11 September 2014

Keywords:
Exposure
Occupational accidents
QRA
Risk rates
Survey

ABSTRACT

The risk of a serious occupational accident per hour exposure was calculated in a project to develop an occupational risk model in the Netherlands (WebORCA). To obtain risk rates, the numbers of victims of serious occupational accidents investigated by the Dutch Labour inspectorate 1998–Feb 2004 were divided by the number of hours exposure for each of 64 different types of hazards, such as contact with moving parts of machines and falls from various types of height. The exposures to the occupational accident hazards were calculated from a survey of a panel of 30,000 from the Dutch working population. Sixty risk rates were then used to predict serious accidents for activity sectors and jobs in the Netherlands where exposures to the hazards for sectors or jobs could be estimated from the survey. Such predictions have been called "horoscopes" because the idea is to provide a quick look-up of predicted accidents for a particular sector or job. Predictions compared favourably with actual data. It is concluded that predictive data can help provide information about accidents in cases where there is a lack of data, such as for smaller sub groups of the working population.

1. Introduction and background[1]

The objective of this paper is to describe how Dutch occupational accident risk rates per hour combined with estimated hours of exposure in specific sectors and jobs have been used to predict numbers and types of accidents for workers in these specific groups. This is done in the form of look-up graphs and tables, which are termed "risk horoscopes", in order to help these groups get a quick sector or job risk assessment instead of having to do it themselves. This has been made possible through the so-called Workgroup Occupational Risk Model (WORM) project in the Netherlands [21] for the Ministry of Social Affairs and Employment and involving an international multi-disciplinary group of experts. This idea of quantitatively assessing the occupational risks of workers based on workers' exposure to accident risks in the workplace is quite new [1,20].

Occupational risk can be measured as the chance of having an occupational accident of a particular severity per unit of exposure. For an individual or group of individuals, such as type of job like a carpenter or activity sector like construction, risk is a function of the exposure to the different accident hazards to which those individuals, groups or sectors are exposed. A carpenter is exposed to the hazard of falling off a ladder while a forklift truck driver is exposed to hazards associated with moving vehicles. Risk contains a probability component such as the probability of a fatal accident per hour of exposure. The duration of exposure can vary during the working period and there can be simultaneous exposure to multiple hazards. Jobs risks may vary because of the variability of the situations that can realise the hazards and determine their effects. Aneziris et al. [2] ranked the risks of different job positions associated with the different phases of construction and operation of wind farms. Risk was calculated from a composite model of the activities performed and the hazards present in those activities together with the amount of time exposed to them. As a result of the calculations, multiplying risk rates by exposures, it was found that fitters had higher accident probabilities than crane operators who were higher than electricians.

* Corresponding author. Tel.: +31 235651353.
E-mail address: linda.bellamy@whitequeen.nl (L.J. Bellamy).

[1] Abbreviations: DNA Dutch National Average, EBB Enquête Beroeps Bevolking (Labour Force Survey), NEA Nationale Enquête Arbeidsomstandigheden (National Working Conditions Survey), LIS Letsel Informatie Systeem (Injury Information System), ORCA Occupational Risk Calculator, WORM Workgroup Occupational Risk Model.

http://dx.doi.org/10.1016/j.ress.2014.09.012
0951-8320/

There is a difference between conducting a quantitative risk assessment of occupational accident hazards and that of major accident hazards. Occupational accidents involve many different hazards such as falls, being trapped, being hit by objects, human aggression, electricity, fire, release of a hazardous substance and so on and many different situations in which they can occur; major hazard accidents involve only fire, explosion or toxic chemical release. There is also a difference in the approach to occupational risk assessment, which focuses on analysing activities, compared with that for major hazards, which focuses on equipment failures leading to loss of containment such as from vessels and pipes and which is location specific [12].

In the field of occupational accident prevention little if any attention is given to measuring exposure to occupational hazards. Jørgensen et al. [16] describe in the DANWORM project how time consuming it is to actually measure in situ how much time people are exposed to different occupational hazards. Workers had to be followed around for long periods of time to estimate their exposures, in this case 20 carpenters and caretakers for 3 days each. By comparison, in the area of road transport safety, exposure is the important issue in the calculation of risk estimates [18]. The authors discuss the issues of calculating exposures for use in calculating road safety performance, such as the bias caused by having to make estimates from sampling, and the difficulties in making measurements. Proxies may be sought, like fuel consumption to indicate kilometres driven, but attention also has to be given to the level of disaggregation that will be required of the data and whether the exposure measure can be matched to the accident data.

When risk comparisons need to be made between different groups then some standardisation of measurement is required. By identifying the hazards to which workers are exposed and the duration of exposure, the risk to each worker from the exposure to the hazards can be calculated and comparisons made between different groups and with risk criteria. With this in mind the WORM project in the Netherlands has developed an online occupational risk calculation tool called WebORCA [24] to help companies and branch organisations carry out an assessment of the occupational risks faced by the workforce [21]. Using observed serious accident frequencies from the past [4] and a survey of the number of hours to which workers in different sectors and jobs are exposed to the different hazards [7], risk rates for 64 different hazard types were calculated [21]. It was these rates that were used in the studies mentioned above of Aneziris et al. [2] in Greece and Jørgensen et al. [16] in Denmark. The risk rates are representative of the Dutch working population and Dutch workplaces and so are the "Dutch National Average" or DNA. This sets a benchmark with which groups can compare themselves, possibly also in other countries bearing in mind that the risk rates have been calculated on the basis of the quality of Dutch safety barriers and not those of say Denmark or Greece. The WebORCA tool allows the analyst to enter their own barrier quality data and therefore provides for assessing the risks on the basis of such an adjustment. However the risk is the risk of a serious reportable accident according to Dutch law and so results of a risk assessment using these data are expressed in those same units. The Dutch risk rate data are unique and so there are no other data from other countries with which they can be compared. Nonetheless, with these things being understood, their use for providing a risk picture and for establishing risk reduction priorities in other countries is not excluded since these countries could use their own sector and job exposure estimates in making horoscopes.

This paper describes the use of the Dutch hourly risk rates to specify and compare the accident risks of different groups based on hours of exposure in the Netherlands to different hazards estimated from exposure survey data for activity sectors, like construction or trade, or for jobs like carpenters, based upon exposure survey data. These predicted accident profiles for specific sub-groups are called here "risk horoscopes" to distinguish them from actual recorded accident data and to indicate that they can be used as a simple look-up [8]. Risk profiling of sectors and jobs through risk horoscopes is considered of potential value in helping branch organisations, companies, job groups and individuals identify the hazards to which they are most likely to be exposed and the highest accident rates resulting from these exposures by selecting the group of which they are a member. In that way they can benefit from the information in the large data pool of Dutch serious occupational accidents by being able to quickly identify what are the most important risks for them without having to do any exposure calculations.

2. Method and analysis

2.1. Accident hazard

Hale et al. [13] explain that the first task of the WORM project was to devise a mutually exclusive coding of type of accident, so that each accident could be coded uniquely from the incident investigation materials. This approach used a bow-tie concept as basis. The centre of the bow-tie was defined as a loss of control event which is the actual release of the (agent of the) hazard and is the event through which all the accidents of that bow-tie pass.

The bow-tie was also identified by preventive barriers before the centre event and mitigating barriers after the centre event. Functioning preventive barriers could prevent the central loss of control event and functioning mitigation barriers could reduce effect size and consequences of the hazard release. An accident might pass through both failed and successfully functioning barriers; a path through the model is a story of its progress through the bow-tie barriers which begins with an activity and ends with a consequence (harm). These barriers can be of types that are common to one type of accident hazard but not to another e.g. edge protection can prevent falls from height, fire proof clothing can prevent a person catching fire. This hazard specificity is found more in preventive barriers than in mitigating barriers. The latter show more commonality across hazards e.g. wearing personal protective equipment, administering first aid.

Ultimately the coding used the grouping of accident hazards whose barrier failures resulted in the same loss of control event of the release of the hazard (agent). Each of the accident hazard bow-ties were named after this centre event, for example Fall from height – Scaffold. Many of the centre events are either falls (gravity effect is released) or contact with the released hazard (like being hit by a falling object, a flying object, a moving vehicle, being trapped or by walking into something). There are also hazard release events before the contact rather than together with it (like loss of containment of a hazardous substance, fire and explosion).

There were originally 36 bow-ties built in graphic form in the software programme and database Storybuilder (see Section 2.3). The derivation of the 36 bow-ties was initially influenced by a classification of priority issues associated with hazardous work that were identified by the Dutch Labour Inspectorate, including all causes of hazardous work covered by the relevant legislation. These compared well with other classification systems, as used by the UK HSE for RIDDOR [15] and the European ESAW classification [9]. These 36 bow-ties were later further split up on the basis of activity and equipment. They were given an appended name associated with the activity (e.g. while *operating*, while *maintaining*) or with the specific equipment (e.g. *fixed* ladder, *mobile* scaffold) to create 64 bow-ties for which risk rates were calculated.