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Since 2003, a project has been underway to analyse the most serious occupational accidents in The Netherlands. All the serious occupational accidents investigated by the Dutch Labour Inspectorate for the 12 years of 1998–2009 inclusive have been entered into a database, a total of 20 030 investigations. This database uses a model of safety barriers supported by barrier tasks and management delivery systems such that, when combined with sector and year information, trends in the data can be analysed for their underlying causes. The trend analyses show that while the number of victims of serious reportable accidents is significantly decreasing, this is due to specific sectors, hazards and underlying causes. The significant results could not easily be directly associated with any specific regulation or action undertaken in The Netherlands although there have been many different approaches to reducing accidents during the period analysed, which could be contributing to the effect.

accident analysis trends safety barriers

1. INTRODUCTION

The collection of accident data and the estimation of people exposed is one way in which safety can be monitored over time. Worldwide estimates based on 2003 data indicated that every day ~960 000 workers per day were injured at work and ~1020 per day died from occupational accidents; the fatality rate per 100 000 workers was 13.8, whereas for The Netherlands it was reported to be 1.3 in 2003 [1]. It was estimated that worldwide accidents were increasing but that in Europe the numbers were decreasing, possibly due to stricter legislation. The evaluation of whether risk is increasing or decreasing and whether numbers of accidents provide reliable information for measuring changes in occupational safety is compounded by factors influencing accident reporting, like the state of the economy [2], reporting requirements, or the extent to which exposure to the risks could be affecting the results [3]. Nonetheless, the measure of accidents over time remains a key safety performance indicator nationally, within work sectors and for individual companies. The European Agency for Safety and Health at Work suggest that other indicators are also necessary, e.g., monitoring of workplace conditions, composition of the workforce, and preventive strategies adopted [4].

This paper has been prepared on the basis of work carried out under contract to the National Institute for Public Health and the Environment (RIVM) in answer to questions posed by the Health & Safety Directorate of the Ministry of Social Affairs and Employment, The Netherlands.

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This paper looks at a database in The Netherlands which is used to monitor and extract causal data from serious occupational accidents. The data have been analysed at a level of detail that enables monitoring trends in underlying causes relating to safety barriers and could give some idea about changes in their quality, use and management over time. There is no common definition of the term "safety barrier" [5] and the concept in general use has been extended to include practically anything that could influence safety, both technical and nontechnical, from physical barriers through to compliance and described as actual objects, signs and signals, performance of functions, or rules and principles [6]. In the modelling described here, a safety barrier performs a technical function like preventing a fall or keeping a person at a distance from the hazard while the human parts of the system are defined as barrier supporting tasks which are resourced by management delivery systems for equipment, competences, procedures and other resource requirements to enable the barrier support tasks to be carried out.

The model components were developed in a project started in 2003 in The Netherlands to build a model for quantifying the risk of occupational accidents given an exposure to accident hazards in the workplace, the first ever such occupational risk model. The model consists of quantified logical bow-ties, which were founded on the analysis of the most serious occupational accidents, together with a survey in 2006 of the population exposure, to provide risk rates for the different occupational accident hazards [7]. The analysed accident data are contained in 36 accident bow-tie models using tailor-made software, which employs a unique approach using a graphical interface for data entry and review [8]. There are 23 030 serious reportable occupational accidents over 1998–2009 entered into the models. Dutch serious reportable accidents constitute an estimated 1% of all occupational accidents in The Netherlands. They are accidents that occur during or as a result of work activities. The accident is reportable if it results in death, permanent injury or admission to a hospital. All serious reportable accidents are investigated by the Labour Inspectorate (I-SZW) of the Ministry of Social Affairs and Employment (SZW) and a report is made of the investigation. These investigation reports are used in the accident analysis.

2. METHODOLOGY

2.1. Database

The accident database is built up from analyses of the investigation reports of the Labour Inspectorate and of the inspectors' findings. The analyst is meant to be objective in this respect and not make guesses or personal judgements. If something cannot be identified, then it is classified as "unknown". The database contains 36 different hazard bow-ties structured as in Figure 1, a very simplified representation of the actual bow-ties, some of which have multiple blocks of safety barriers and all of which contain additional information about activities and equipment involved, for example.

Each hazard bow-tie has a centre event, which is the release of the hazard agent such as *struck by moving vehicle*, *hit by falling object*, *contact with moving parts of a machine*, *explosion* and through which all the accident victims' scenarios of that bow-tie pass. Within each hazard bow-tie, there are a number of safety barriers against the hazard being realized (left-hand side of the bow-tie) and against the effects when the hazard is released (right-hand side of the bow-tie). Each barrier has a success and a failure mode but it is almost always the failure modes which were identified in the accident investigations, and any identified barrier successes are mainly on the right-hand side of the bow-tie in association with emergency actions and first aid.

The safety barriers are attached to human tasks and a management delivery system of resources for doing the task. If there is a failure of the safety barrier, the analyst enters data about the tasks and management deliveries which failed in relation to the barrier, if that information is to be found in the report. These barrier tasks are provide, use, maintain and monitor the barrier. Every barrier has a set of these but any barrier failure has only one barrier task failure associated with it. The barrier tasks are resourced by eight management delivery systems: procedures, equipment, ergonomics, availability, competence, communication, motivation and awareness, and conflict resolution. Up to three of these can be selected as failures contributing to causing the task failure. An accident is represented in the model as failures in these delivery system and task components identified in the investigation as leading to barrier failures connected to loss of control. For successes, the barrier is noted but not further analysed. In total, there are 390 barriers across all the bow-ties.

2.2. Victim and Accident Counts

The accident data are built into the graphical bow-tie model by clicking through events in the model which are part of the accident scenario and saving the result. A victim record is counted as a path through events in a single bow-tie. This record may be a single-victim accident or a victim of a multiple-victim accident. A victim may have more than one record if the scenario traverses more than one bow-tie, e.g., the victim is hit by a falling object, is knocked off the ladder they are working on and falls into a canal. This would constitute three records. However, a victim only receives one outcome: death, permanent injury, recoverable injury or unknown. In the current analysis, victims are counted as one scenario and not as a number of bow-tie records. The current database (1998–2009) holds 23 030 accidents with 23 799 victims across the 36 bow-ties.

2.3. Full Time Equivalent (FTE)

Any change in accidents and victims per year could be related to the exposure to the risks in terms of the number of jobs and the hours worked. For this reason, the measure of FTE jobs was used from the figures of the Dutch Central Bureau of Statistics [9]. The FTE is a measure of the volume of work, which is calculated by adding all jobs (full-time and part-time) to convert to full-time jobs. The total number of FTEs (both fixed-contract and self-employed workers) for each year of the 12-year period was used. The important point is to identify whether there is a decrease in the number of victims of serious occupational accidents over the years examined or whether it is simply due to a decrease in the working population. The Labour Inspectorate do not investigate accidents in all sectors, in particular where these are handled by other inspectorates: offshore, railway related accidents (not strict), accidents on sea going ships, accidents related to air traffic, accidents with radiation/nuclear accidents. Also accidents with owners of one-person businesses are not investigated, when the work is not performed under the supervision and responsibility of a company involved in the work. The total FTEs used are representative of the

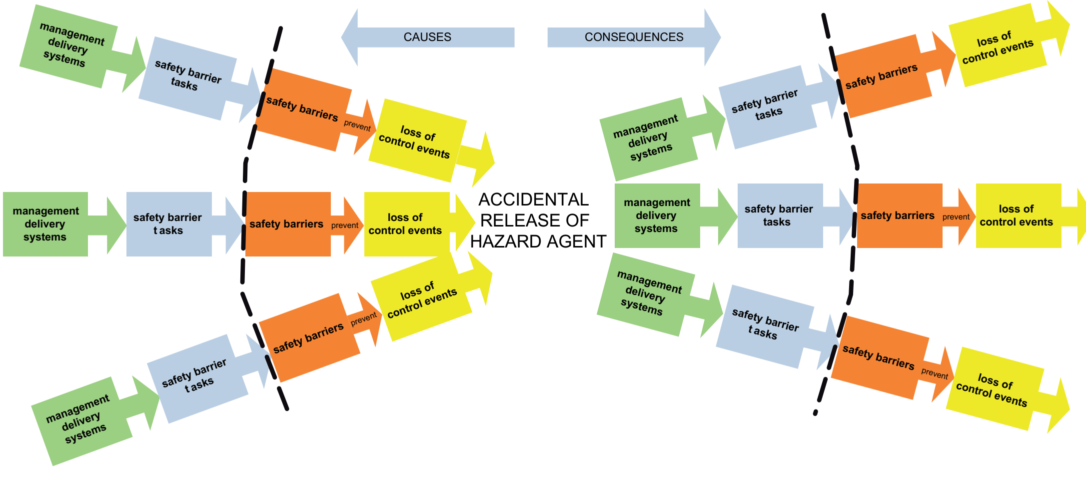

Figure 1. Model of an accident bow-tie composed of safety barriers with front line and management tasks attached. *Notes.* The release of the hazard agent is the centre event of the bow-tie, this being the agent of harm.

general change in work volume in the sectors investigated but are not subject to any fine-tuning.

2.4. Sectors

The data are divided into sectors that broadly follow the divisions given in Dutch annual monitors of working conditions, diseases and accidents [10, 11]. The sectors used in this study are based on the Dutch Central Bureau of Statistics classification of economic activity, the so-called SBI (Standaard Bedrijfs Indeling) code [12]: industry (06–33); construction (41–43); trade (45–47); transport, warehousing and communications (49–53, 58–61); public administration (84); agriculture and forestry (01–02); health and welfare (86–88); education (85); finance (64–66); hotels, restaurants and catering (55–56); other (35–39, 62–63, 68–82, 90–99, and unknown), which comprises various services including supply of utilities, financial and legal services, facility management, waste collection, consultancy, and sport and recreation.

2.5. Trends

Trends are explored with a linear regression of y (victims) on x (years), where $y = \mathrm{a} + bx$, a = intercept or constant, b = slope, which is either positive (increase) or negative (decrease). The calculations are made with the Excel LINEST function. The trend is deemed significant if a slope of zero does not fall within the 95% confidence intervals (CI) calculated as $b \pm t_{0.05,n\text{-}2} \times SE_b$, where SE = standard error. Since there are 12 years, $df = 10$. The linear relationship is tested with the Pearson correlation coefficient and the two-tailed probability calculated to determine the level of significance.

3. RESULTS

3.1. Overall Trends

There were 909 deaths, 8326 permanent injuries, 9300 recoverable injuries and 5215 unknowns in the Dutch serious reportable occupational accidents in 1998–2009. Figure 2 shows the total victim figures (including deaths) per year; there was a significant downward trend over that period. Figure 3 shows the data for fatal accidents alone; there is a significant downward trend, too. Table 1 provides the regression coefficients for all victims and deaths.

There are on average 1979 victims of serious reportable occupational accidents per year. The overall trend in number of victims is a decrease of 49 victims per year ($p < .001$). The number of victims per 100 000 FTE jobs averages ~30 victims per 100 000 FTEs with a yearly decrease of ~1 victim per 100 000 FTEs ($p < .001$). Over the 12 years, the changes in the number of victims and the number of victims per 100 000 FTEs, shown as the two lines in Figure 2, correlate almost perfectly at .98. This correlation is further investigated in sector trends. For fatalities shown in Figure 3, there are on average 76 deaths from serious reportable occupational accidents per year and 1.15 deaths per 100 000 FTEs. The overall trend in number of deaths is a decrease of 3 deaths per year ($p < .005$) and a yearly decrease of –0.05 deaths per 100 000 FTEs ($p < .001$). The value in 2003 of 1.30 deaths per 100 000 FTEs corresponds with the value Hämäläinen, Saarela and Takala reported [1]. The two trends in Figure 3 have an almost perfect correlation of .99, too.

TABLE 1. Linear Regression (y = a + bx) of Victims (y) per Year (x) and Victims per 100 000 FTEs (y) per Year (x) for Investigated Serious Occupational Accidents in The Netherlands, 1998–2009

Data Group	$M^{\dagger}$	a	b	95% CI	r	Significance‡
All victims	1979	2299.3 (65.6)	–49.26 (8.91)	[–69.1, –29.4]	–.87	↓ < .001
All victims/100 000 FTE	30	36.1 (0.9)	–0.91 (0.12)	[–1.2, –0.6]	–.93	↓ < .001
Deaths	76	95.36 (4.98)	–3.02 (0.68)	[–4.52, –1.51]	–.82	↓ < .005
Deaths/100 000 FTE	1.15	1.49 (0.07)	–0.05 (0.01)	[–0.07, –0.03]	–.87	↓ < .001

Notes. FTE = full time equivalent; † = victims per year; ‡ = df = 10, two-tailed; a = constant (SE); b = slope (SE), change in victims per year; CI = confidence interval; r = coefficient of correlation; ↓ = significant decrease.

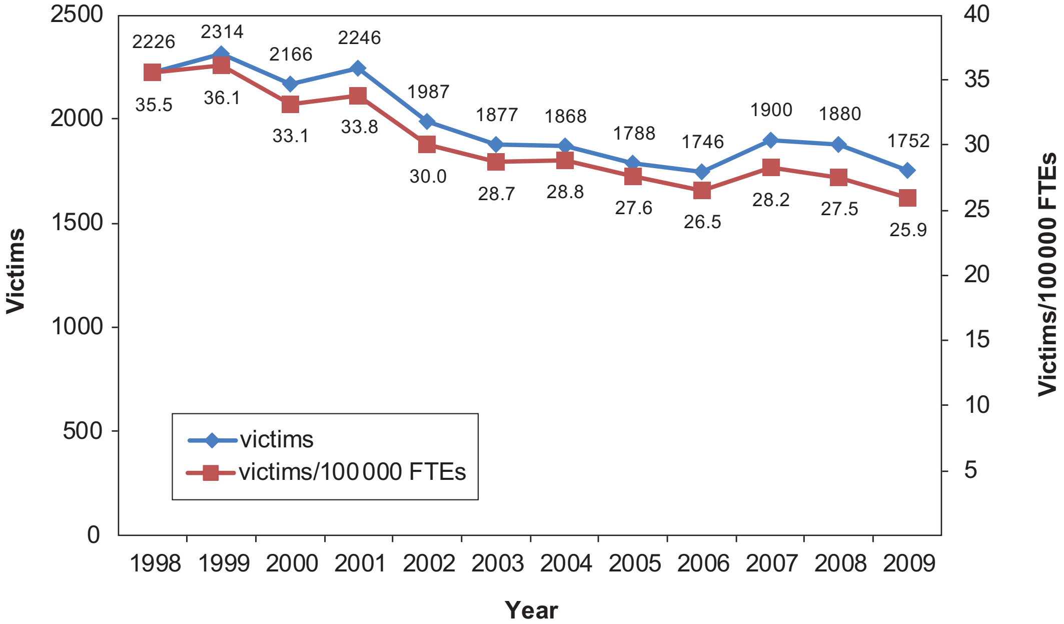

Figure 2. Number of victims per year (including deaths) of investigated serious occupational accidents in The Netherlands, 1998–2009, and the same data expressed as victims per 100 000 full time equivalents (FTEs).

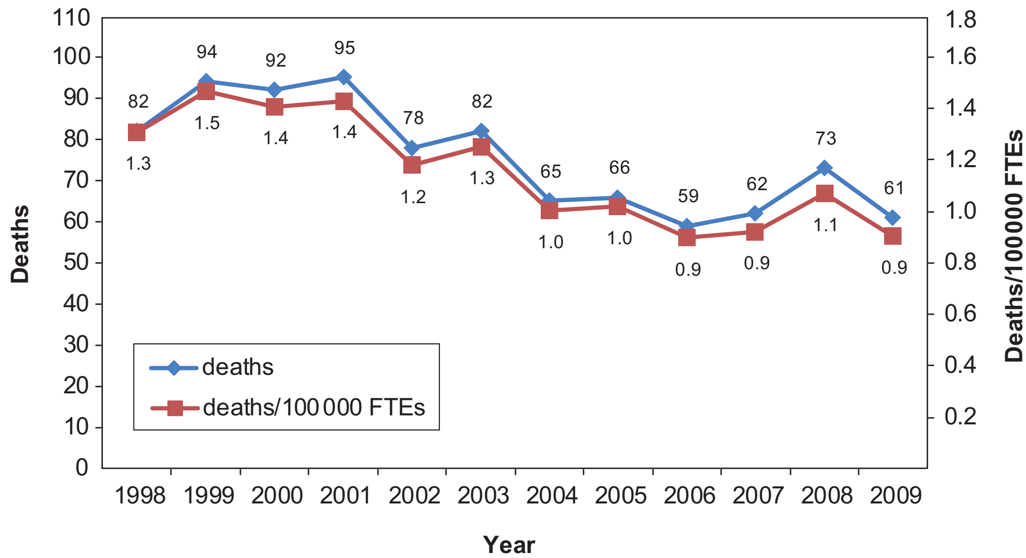

Figure 3. Number of deaths per year within investigated serious occupational accidents in The Netherlands, 1998–2009, and the same data expressed as deaths per 100 000 full time equivalents (FTEs).

3.2. Sector Trends

The slope coefficient of –49 victims per year was split into the activity sectors (Table 2). Five of the sectors show a significant downward trend. Industry contributes the most at –25 victims per year and construction contributes –9. The correlation between number of victims per 100 000 FTEs and number of victims over the 12 years was examined for the top four sectors with significant trends. This was to evaluate whether it was reasonable to just take the victims figures in further analyses. Figure 4 shows the trends.

The correlations between number of victims and number of victims per 100 000 FTE for

TABLE 2. Linear Regression ($y = a + bx$) per Sector of Victims (y) per Year (x) for Investigated Serious Occupational Accidents in The Netherlands, 1998–2009

Sector	$M^†$	a	b	95% CI	r	Significance‡
Industry	671.33	833.65	–24.97	[–32.11, –17.83]	–.93	↓ < .001
Construction	471.75	529.59	–8.90	[–17.25, –0.55]	–.60	↓ < .05
Trade	230.00	269.05	–6.01	[–11.00, –1.01]	–.65	↓ < .05
Other	220.33	243.97	–3.64	[–7.33, 0.05]	–.57	*ns*
Transport, warehousing and communications	161.92	183.62	–3.34	[–6.73, 0.05]	–.57	*ns*
Public administration	55.75	75.41	–3.02	[–5.67, –0.38]	–.63	↓ < .05
Agriculture and forestry	54.50	66.55	–1.85	[–3.24, –0.47]	–.69	↓ < .05
Health and welfare	37.33	29.42	1.22	[0.34, 2.09]	.70	↑ < .05
Education	29.50	27.68	0.28	[–0.61, 1.17]	.22	*ns*
Finance	28.50	18.91	1.48	[–0.29, 3.24]	.51	*ns*
Hotels, restaurants and catering	18.25	21.50	–0.50	[–1.12, 0.12]	–.49	*ns*
total	1979.17		–49.26			

Notes. † = victims per year; ‡ = $df = 10$, two-tailed; a = constant (*SE*); b = slope, change in victims per year; CI = confidence interval; r = coefficient of correlation; ↓ = significant decrease; ↑ = significant increase.

industry, trade and public administration are each $r = .99$ and for construction $r = .97$. So, as with the overall trends, these are almost perfect correlations. Therefore, it seems reasonable with the further analyses to just examine the trend data using number of victims without having to worry about the FTEs.

3.2. Bow-Tie Hazard Trends

It is not known how exposure to the specific hazards change year on year in The Netherlands although there were two surveys in 2006 and 2011 [13]. Compared to 2006, the number of hours of exposure to the hazards in the workplace was estimated to have dropped by 3.7% in 2011 but this is beyond the range of the years studied. Table 3 shows the trends for number of victims for the 36 accident hazards over 1998–2009. The hazards are listed in order of most to least frequent per year. Some hazards show trends that are significantly decreasing like *contact with moving parts of a machine, fall from height roof/platform/floor*, *fall from height—scaffold*, *in or on moving vehicle with loss of control*, *loss of containment (LoC) from normally closed containments*, *explosion*, *fire*, *LoC from an open containment* and *impact by immersion in liquid*. Together, these 9 of the 36 bow-ties account for 47 of the decrease of 49 victims per year.

Conversely, the bow-tie *trapped between/against* shows a significantly increasing trend. This bow-tie refers to entrapment between a machine (including lifts and moveable platforms) and an object or structure (e.g., wall, ceiling, lift shaft, another machine) or between objects moved by a machine (including sliding doors).

Some accident types with high frequency are not decreasing. These include *contact with falling objects not from cranes/hoists*, *fall from height—ladders* and *struck by moving vehicle*, which together account for over 20% of the serious accidents.

3.3. Underlying Causes

Each bow-tie could be examined in more detail in terms of the individual barrier failure modes. For example, for *LoC from normally closed containments*, there is a very significant negative slope *for personal protective equipment failure* of –5.5 (95% CI [–7.33, –3.7]; $r = –.91$ $df = 10$, $p < .001$), this being a key component of the reduction in the number of victims over the 12-year period. Such an analysis for all the bow-ties would be beyond the scope of this paper, but details of barrier failure modes can be obtained from facts and figures sheets [14].

The deepest level of information available is the management delivery systems (MDS).

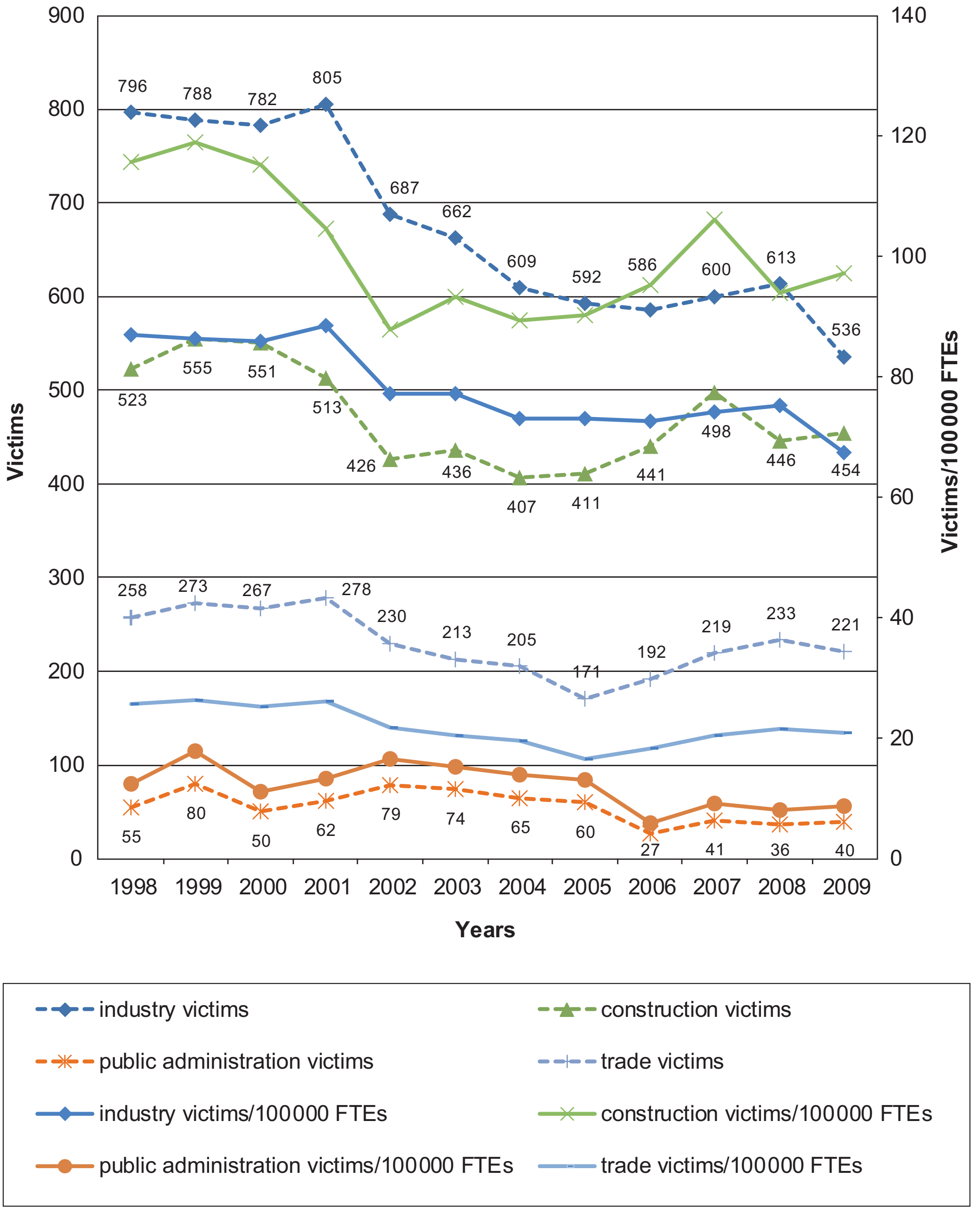

Figure 4. The top 4 significant downward trending sectors of investigated serious occupational accidents in The Netherlands, 1998–2009, showing the number of victims (dotted lines) and the same data expressed as victims per 100 000 full time equivalents (FTEs) for the period (solid lines).

Table 4 shows trend results for the eight MDS. The data are the count of the number of victims with that delivery system failure as a cause occurring at least once in their scenario. In accidents with multiple victims, the barrier failure count will be equal to the number of victims rather than the number of times it failed. It is considered appropriate here to measure accidents as occurring to an individual rather than to a group, which is consistent with the use of victims as the unit for counting in trends and with the occupational risk model [7].

Most accidents (~22 500) were single-victim and a small proportion (~500) was multi-victim, 380 of these having only 2 victims. The highest victim count for a single accident was 17. A victim is only counted once within any one delivery system but, because there can be up to three delivery system failures per victim according to the rules of analysis as well the fact that an accident

TABLE 3. Linear Regression (*y* = a + *bx*) Hazard Bow-Tie of Victims (*y*) per Year (*x*) for Investigated Serious Occupational Accidents in The Netherlands, 1998–2009

Hazard Bow-Tie		$M^{\dagger}$	a	*b*	95% CI	*r*	Significance‡
08.1.	Contact with moving parts of machine	424.75	564.09	–21.44	[–29.45, –13.43]	–.88	↓ ≤ .001
03.2.	Contact with falling objects NOT from cranes/ hoists	202.83	233.56	–4.73	[–9.65, 0.19]	–.56	*ns*
01.1.1.	Fall from height—ladders	165.92	177.94	–1.85	[–4.30, 0.60]	–.47	*ns*
01.1.3.	Fall from height—roof/platform/floor	156.50	204.45	–7.38	[–12.32, –2.44]	–.73	↓ ≤ .01
02.	Struck by moving vehicle	86.92	92.21	–0.81	[–2.92, 1.30]	–.26	*ns*
01.1.2.	Fall from height—scaffold	83.58	105.02	–3.30	[–4.46, –2.14]	–.89	↓ ≤ .001
08.3.	Trapped between/against	81.00	42.82	5.87	[2.80, 8.94]	.80	↑ ≤ .005
11.	In or on moving vehicle with loss of control	70.50	99.91	–4.52	[–6.43, –2.61]	–.86	↓ ≤ .001
01.2.	Fall on same level	69.08	59.29	1.51	[–1.16, 4.18]	.37	*ns*
04.	Contact with flying/ejected objects	65.67	68.49	–0.43	[–2.66, 1.80]	–.14	*ns*
01.1.5.3.	Fall from height—working on height unprotected	50.92	49.03	0.29	[–1.75, 2.33]	.10	*ns*
03.1.	Contact with falling objects from cranes/hoists	47.42	46.26	0.18	[–0.91, 1.27]	.11	*ns*
06.	Contact with object used/carried	44.25	40.99	0.49	[–1.18, 2.16]	.20	*ns*
07.	Contact with handheld tools	44.17	38.50	0.88	[–0.10, 1.86]	.54	*ns*
15.	LoC from normally closed containments	40.00	61.96	–3.38	[–5.48, –1.28]	–.75	↓ ≤ .005
01.1.5.2.	Fall from height—nonmoving vehicle	38.50	32.36	0.94	[–0.55, 2.43]	.41	*ns*
01.1.5.1.	Fall from height—moveable platform	34.58	35.92	–0.21	[–1.22, 0.80]	–.14	*ns*
08.2.	Contact with swinging/hanging objects	33.58	40.92	–1.13	[–2.26, 0.00]	–.57	*ns*
12.	Contact with electricity	32.33	38.02	–0.87	[–2.06, 0.32]	–.46	*ns*
27.	Explosion	27.25	42.41	–2.33	[–3.90, –0.76]	–.72	↓ ≤ .01
01.3.	Fall down stairs or ramp	24.00	18.96	0.78	[–0.68, 2.24]	.35	*ns*
17.	Fire	23.33	36.92	–2.09	[–3.57, –0.61]	–.71	↓ ≤ .01
09.	Moving into an object	20.83	25.24	–0.68	[–1.57, 0.21]	–.47	*ns*
14.1.	LoC open containment	20.42	35.35	–2.30	[–3.82, –0.78]	–.73	↓ ≤ .01
14.2.	Contact with hazardous substance without LoC	18.75	28.73	–1.53	[–3.10, 0.04]	–.57	*ns*
05.	Hit by rolling/sliding object	14.75	21.27	–1.00	[–2.03, 0.03]	–.57	*ns*
01.1.4.	Fall from height—hole in the ground	13.17	12.03	0.17	[–1.08, 1.42]	.03	*ns*
20.1.	Victim of human aggression	11.83	12.11	–0.04	[–0.91, 0.83]	–.03	*ns*
22.1.	Contact with hazardous atmosphere in confined space	7.67	8.55	–0.16	[–0.86, 0.54]	–.16	*ns*
25.	Extreme muscular exertion	7.50	6.21	0.22	[–0.46, 0.90]	.23	*ns*
20.2.	Victim of animal behaviour	4.83	4.56	0.04	[–0.52, 0.60]	.05	*ns*
23.	Impact by immersion in liquid	4.50	7.45	–0.45	[–0.78, –0.12]	–.70	↓ ≤ .05
10.	Buried by bulk mass	3.75	4.95	–0.19	[–0.52, 0.14]	–.37	*ns*
13.	Contact with extreme hot or cold surfaces or open flame	2.83	0.52	0.36	[0.01, 0.71]	.58	↑ ≤ .05
22.2.	Contact with hazardous atmosphere through breathing apparatus	0.92	1.60	–0.11	[–0.39, 0.17]	–.26	*ns*
24.	Too rapid (de)compression	0.33	0.74	–0.06	[–0.15, 0.03]	–.46	*ns*
	total	1979.17		–49.26			

Notes. The bow-ties are numbered according to the classification system of the database. LoC = loss of containment; † = victims per year; ‡ = *df* = 10, two-tailed; a = constant; *b* = slope, change in victims per year; CI = confidence interval; *r* = coefficient of correlation; ↓ = significant decrease; ↑ = significant increase.

TABLE 4. Linear Regression (*y* = a + *bx*) of Victims (*y*) per Year (*x*) of Management Delivery System (MDS) Failures Underlying Investigated Serious Occupational Accidents in The Netherlands, 1998–2009

MDS Failure	*M*†	a	*b*	95% CI	*r*	Significance‡
Motivation/awareness	965	930.26	5.41	[–17.35, 28.17]	.16	*ns*
Equipment	535	883.67	–53.58	[–78.89, –28.26]	–.83	↓ < .001
Plans and procedures	466	526.44	–9.27	[–20.15, 1.60]	–.51	*ns*
Competence	427	621.89	–30	[–44.24, –15.75]	–.83	↓ < .001
Conflict resolution	239	401.80	–25.1	[–30.3, –19.9]	–.84	↓ < .001
Communication/collaboration	218	267.17	–7.61	[–16.17, 0.94]	–.53	*ns*
Ergonomics	206	319.62	–17.53	[–25.34, –9.72]	–.85	↓ < .001
Availability of people	60	84.09	–3.63	[–8.13, 0.87]	–.49	*ns*

Notes. A victim is allocated to an MDS by virtue of having a failure of that type at least once in the scenario but can be in more than one MDS category, so these are not independent and are not added up. Unknowns were excluded. † = victims per year; ‡ = *df* = 10, two-tailed; a = constant; *b* = slope, change in victims per year; CI = confidence interval; *r* = coefficient of correlation; ↓ = significant decrease.

may pass through other barriers, the different management deliveries are not independent.

It can be seen that *equipment*, *competence*, *conflict resolution* and *ergonomics* all show significant downward trends. The other four deliveries are not significant, including the biggest yearly contributor to failure, motivation/awareness.

The *equipment* delivery system has the biggest downward trend (–53 victim occurrences per year). It most frequently fails in association with *contact with moving parts of a machine* (37% of equipment delivery system failures) especially in the industry sector (41.5% of equipment delivery system failures). The dominant barrier failure mode here is *physical guarding failure*, most failures being to *provide* (adequate) guarding with a mean of 104 victims a year. The failures in equipment to provide (adequate) physical guarding has a significant negative slope of –15.49 (95% CI [–25.78, –5.21]; $r = -.73$, $df = 10$, $p < .01$), which Figure 5 shows.

Further analysis of the *contact with moving parts of a machine* bow-tie indicates that half the –30 per year of the *competence* delivery system failure victims and one third of the –25 of *conflict resolution* are associated with this machine bow-tie.

Looking at other *competence* contributors and focusing on correlations of –.70 or higher, these are primarily associated with hazardous substances with or without LoC: *LoC open containment*, *contact with hazardous substance without LoC*, *LoC from normally closed containments* and *explosion*. These hazardous substance bow-ties have slopes of decreasing competence

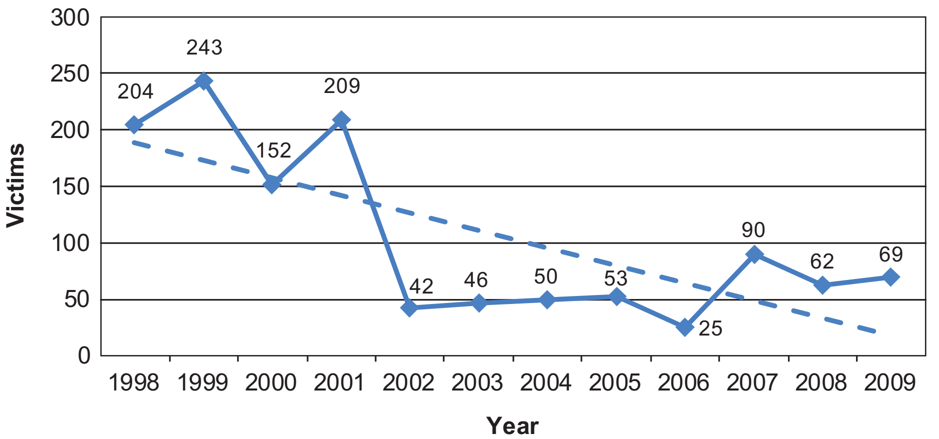

Figure 5. Trend of victims of failure of the management delivery system *equipment* for the barrier task *provide* (adequate) machine guarding leading to *contact with moving parts of a machine* for investigated serious occupational accidents in The Netherlands, 1998–2009.

management delivery system failures which add up to –6. However, there is an increase in competence failures for *trapped between/against objects* mainly explained by barrier failure mode *body (part) position failure*.

Taking *ergonomics* as another example, there are a lot of bow-ties where there are significant contributors to the downward trend especially *LoC from normally closed containments*, *falls from height roof/platform/floor* and *in or on moving vehicle with loss of control*. The latter relate only to vehicle accidents in the workplace. Victims in this vehicle bow-tie with *ergonomics* as a failure decreased significantly by –2.74 per year (95% CI [–3.89, –1.58]; $r = -.86$, $df = 10$, $p < .001$). This can mostly be explained by the barrier failure modes *infrastructure failure* and *failure to control vehicle*, which tend to occur together. Improvements in the barrier *infrastructure* were related to reductions in causes associated with lack of suitable markings, signals and barriers and with obstructions and uneven or slippery surfaces. Improvements in *control of vehicle* were primarily related to reductions in *visual contact failure*.

Finally, Figure 6 and Table 5 show results for the safety barrier task failures across all accidents. Like the failure counts with the delivery systems, the four categories of *provide*, *use*, *maintain* and *monitor* are not independent even though in this case a victim scenario can only pass through one task per barrier failure. Because the victim scenario may pass through multiple barriers, at least one on each side of the bow-tie, the barrier task counts are not independent and so cannot be totalled to match the overall victim count. There are significant downward trends for victims of *provide* barrier and *monitor* barrier failures. The dominant 1243 victims per year of the *use/operate* barrier failures are not trending at all and neither are the *maintain* failures. The implication is that barriers are increasingly being provided or improved in quality but not in their use and maintenance.

4. DISCUSSION

Over the 12-year period of 1998–2009, in The Netherlands there were numerous ways in which the industry and the regulator went about improving safety. This paper only concerns the most serious occupational accidents, a very small percentage (1%) of all the occupational accidents and so any observations of changes over time relate only to these and may not be representative of all accidents in The Netherlands. It is not known what the connection is between the 1% serious reportable and the 99% less serious and whether action taken to reduce accidents would be expected to have similar effects in both categories. It is postulated that the two groups of accidents have the same types of causes for the same types of bow-tie discussed here but the actual distribution of the nonreportable accidents over the bow-ties will be different because the seriousness of an accident is linked to the type of hazard [15]. The dominant types of nonserious occupational accidents in The Netherlands as a whole are more associated with hazards like fall on the same level and extreme muscular exertion [16]. A detailed level of data is not going to be available to be able to compare them on underlying causes. Some data on trends in all occupational accidents are available for 2005–2009; they suggest no significant trends for injury and absence in practically all sectors [11]. The period of 2005–2009 is when, for the investigated serious reportable accident data, the number of accidents is starting to slightly increase again so the results are not incompatible.

Amongst improvement programmes, the Dutch Labour Inspectorate undertakes targeted inspections. For example, in 2004–2005, they focused on forklift trucks [17]. The Ministry of Social Affairs and Employment started a safety improvement project in 2004 focused on improving behaviour [18]. The branch organizations like construction[1], and metalworking[2] offer sector focused information and tools for improving safety in the workplace. The Arbobalans reports

[1] http://www.arbouw.nl
[2] http://www.5xbeter.nl

TABLE 5. Linear Regression (*y* = a + *bx*) of Victims (*y*) per Year (*x*) of Barrier Task Underlying Investigated Serious Occupational Accidents in The Netherlands, 1998–2009

Barrier Task Failure	*M*†	a	*b*	95% CI	*r*	Significance‡
Provide safety barrier	842	1190.14	–53.6	[–69.5, –37.7]	–.92	↓ < .001
Use/operate safety barrier	1243	1205.58	5.78	[–9.96, 21.53]	.25	*ns*
Maintain safety barrier	252	250.33	0.31	[–7.89, 8.5]	.03	*ns*
Monitor safety barrier	147	250.09	–15.94	[–24.29, –7.58]	–.80	↓ < .005

Notes. The data show victim scenarios which have the barrier task failure at least once in the scenario but as there can be more than one barrier failure in a victim scenario, so the task failures are not independent and are not added up. Unknowns were excluded. † = victims per year; ‡ = *df* = 10, two-tailed; a = constant; *b* = slope, change in victims per year; CI = confidence interval; *r* = coefficient of correlation; ↓ = significant decrease.

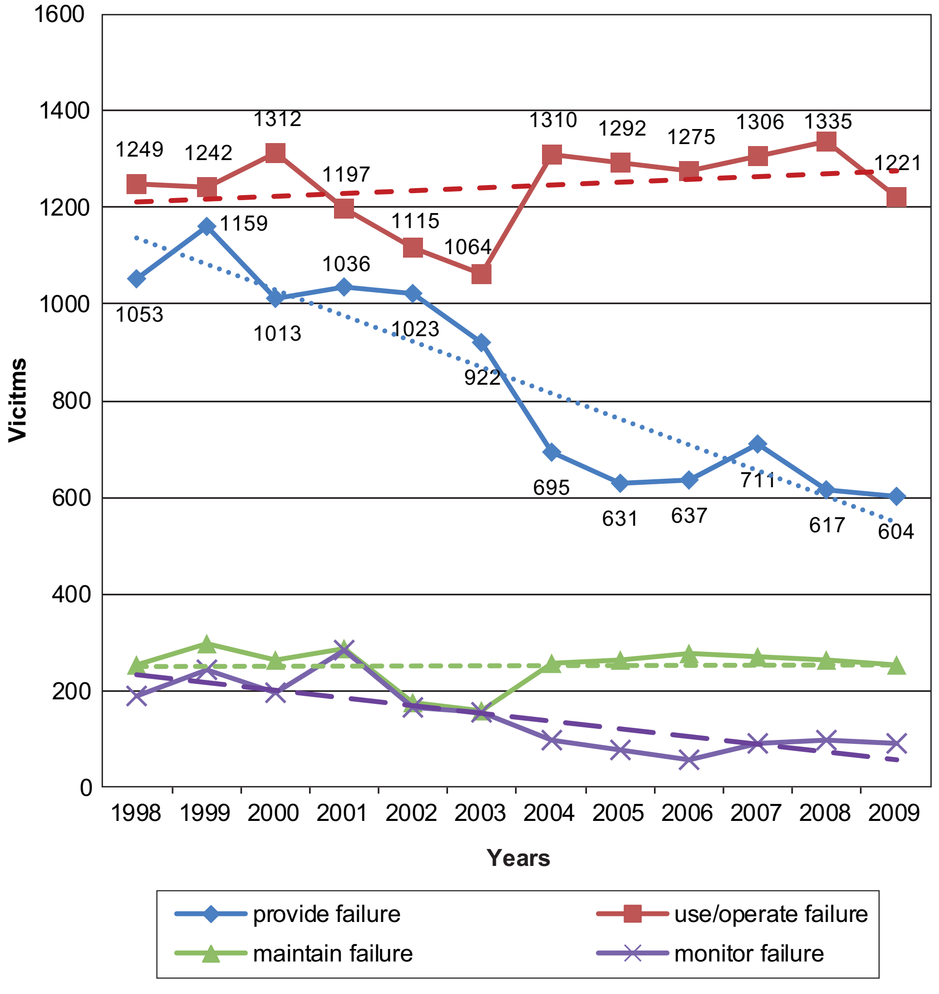

Figure 6. Trends of victims of barrier task failures for investigated serious occupational accidents in The Netherlands, 1998–2009.

indicate no big increase in the number of companies with a risk inventory and evaluation; only 42% of companies were estimated to have a risk inventory and evaluation in 1999 [19], and ~47% in 2008 [16]. However, most of the problem is with the smaller companies: in 2005, it was estimated that 88% of workers came under a risk inventory and evaluation regime [20]. It is difficult to see how the risk inventory and evaluation developments could explain the specific pattern of changes in the serious reportable accidents. The biggest changes are related to a single bow-tie *contact with moving parts of a machine*. This remains the biggest cause of serious accidents and there are still other major contributors which have shown no signs of decreasing. In some cases, like with the health and welfare sector and the bow-tie *trapped between/against objects*, there are even significant increases in victims.

Other questions arising from the analysis include (a) why the delivery of safety *motivation/awareness* has not improved and (b) why there is no improvement in the *use* of safety barriers and keeping them in place, yet such a significant downward trend in providing them? Both the *motivation* and *use* factors together suggest that risk awareness of safety barriers and their proper use are key behavioural aspects of safety barriers that are not being adequately addressed in the prevention of serious accidents. A way of doing this would be to make safety barriers more "visible" by providing appropriate information about what to look for, recognizing what it means, and how to act [21]. As a final question, one can also ask why scaffold safety is significantly improving but not ladder safety. This is quite surprising given Directive 2001/45/EC intended to improve the safety of working at a height, favouring the use of scaffolds and restricting the use of ladders to short duration and low risk tasks [22].

5. CONCLUSIONS

In the Dutch serious accident database, examining the underlying causes to find out what is and what is not getting better can go some way towards helping understand the trends, but it is very difficult to find out which influences have actually been most effective in improving safety for the serious accident risks in The Netherlands and which have not. It can be further speculated that all kinds of biases also exist in the data, including biases of reporting, investigation and analysis. This means that separating the various effects would be quite a challenge.

The number of serious reportable occupational accidents in The Netherlands is decreasing but of the 36 types of occupational accident hazard, only 9 showed a significant decrease. Of the 11 sectors of activity, only 5 had a significant decrease. It is possible to identify what the underlying components of these decreases are and also what is not improving. Significant changes are quite specific, such as the reduction in victims due to not providing (adequate) safety barriers, the significant decrease in victims of equipment delivery system failures but the lack of improvement in the use/operation of safety barriers and in communications, procedures and safety motivation/barrier awareness. This implies that approaches to safety improvement which work are possibly quite targeted and conversely quite blinkered. However, relating safety improvement programmes to the results is too difficult to currently generate any conclusions but it can be said that there are still many areas to focus on for reducing accidents still further. One of these is to understand how the information about the 1% of Dutch accidents reported here relates to the occupational accidents of The Netherlands as a whole and the measures taken to reduce them.

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