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COMPARISON OF OCCUPATIONAL ACCIDENT RISKS AND UNDERLYING CAUSES BETWEEN TEMPORARY AND NON-TEMPORARY WORKERS

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ABSTRACT

When a company takes on temporary workers these people are at a higher risk of having an accident than non-temporary workers. Newcomers and temporary workers might be young people who are also considered vulnerable. This paper examines accidents and exposures in the Dutch population that are characteristic of temporary workers. There are 3000+ detailed accident scenarios available on victims in the group temporary workers from a database of 23,000+ Dutch serious reportable reported investigated occupational accidents over a period 1998-2009. Only temporary workers are chosen to be examined because newcomers in the accident population cannot be identified. Estimates of exposures of temporary workers to 62 different hazards were based on the results of an exposure survey from 2011. By combining accidents and exposures it was possible to calculate the risk for temporary and non-temporary workers of having a reportable accident per unit of exposure for 62 hazard bow-ties. The data also contain failures of the specific safety barriers and their underlying causes. The results indicate that the risks for temporary workers are much higher with some hazards but in half the cases are less than 1.5 times higher. For example, the risk of a fall from a mobile scaffold is 16 times higher but for fall on the same level the risk rate is only 1.3 times higher. The complete range across the hazards was 0.2 – 272. This ratio is higher the higher the bow-tie risk rate for the temporary worker. The highest risks are for dismantling a scaffold and loss of containment of normally closed containments through adding, removing or opening. The underlying causes across 4 sample bow-ties show management failures relating to not delivering adequate risk awareness, competence, or procedures as well as not providing adequate safeguarding and personal protective equipment to protect people working in the danger zone of hazards. Human errors in these examples consisted of violations in the use of safeguards and protection and mistakes in relation to the dangerous properties of objects. So, both provision of physical protection and training are needed.

Keywords

risk analysis, temporary workers, management

1. INTRODUCTION

According to the European Agency for Safety & health at Work (2002) workers with temporary contracts comprised up to 15% of employees in Europe. Dutch statistics (Souren 2009) suggest that the number of temporary workers has been on the increase, being around 8% of the working population in 2008. For 2013 the picture presented by the Dutch Central Bureau for Statistics (CBS 2014) is that despite declines in permanent contracts since the economic crisis the number of employees with flexible contracts and self-employment has increased.

Temporary work is generally associated with a higher risk of having an accident. For example, in Finland it is reported that temporary workers in industry face a 10-15% higher rate in accidents than permanent workers (European Agency 2002). Accident statistics suggest that temporary workers are 2 to 3 times more likely to have an accident than permanent workers (Benavides et al 2006, Hintikka 2011, Patussi et al 2008, Smith et al 2010). Also, according to Smith et al (2010) the incidence rate ratio (IRR) of temporary agency workers to standard employment workers was around 4 and 5 for "caught in" and "struck by" injuries for the manufacturing and construction sectors respectively, where incidence rates were standardised to units of 10,000 full time equivalent workers (FTEs). Ratios lower than 1, on the other hand, were found for secretarial and clerical work and electrical work (Hintikka 2011). Fabiano et al (2008) calculated differences between the Frequency Index for fixed and temporary workers in Italy using the formula: FI= (Number of total accidents/Number of worked hours) * 10^6. The mean FI for fixed workers was 20.76 ± 1.42 and for temporary workers was 91.63 ± 2.22, which is more than 4 times higher.

This paper concerns an exploration of temporary worker accidents in the Dutch serious reportable occupational accident database in the program Storybuilder™ (Bellamy et al 2014, RIVM 2014). The impetus was the issue of newcomers to the workplace and what special needs they have. Should extra safety measures apply and if so what? A newcomer is a person who comes new to a workplace and therefore lacks experience in that specific environment. A temporary worker does not have a fixed workplace. Newcomers and temporary workers might also be young people who are also considered vulnerable. A report on young workers by the European Agency for Safety and Health at Work (2007) states that most temporary workers in the EU are under 25 and people employed on temporary contracts have less access to training and to participation in long-term competence development than workers with permanent contracts. Temporary workers also have less control over the order of tasks, pace of work and work methods, have lower job demands and are less informed about risks at work. In addition, agency workers are disinclined to complain about hazards or injuries because this can mean losing the job placement (MacEachen et al 2012).

This paper explores the risk issues through examining serious reportable accident risks for the Dutch population of temporary (also called flexworkers) versus non-temporary workers. The focus is on identifying differences in serious accident per hour risk rates between the two groups and in discovering what the major contributors might be for such differences. Fabiano et al (2008) have identified through a survey amongst Italian temporary workers that differences can be traced to lack of experience, insufficient specific knowledge and an inadequate training period. Human factors of distraction, work pressure in particular and lack of specific job training covered the majority of perceived accident causes. Hintikka (2011) discusses previous research on the subject and indicates that the characteristics of the work and working conditions may explain the higher risk of temporary work than the fact of it being temporary suggesting that work-related risks are being transferred to temporary employees. The analysis of the Finnish data identifies higher manual work with higher relative frequencies in production, manufacturing, processing, storing and excavation, construction, repair, demolition, handling objects, and carrying by hand.

2. THE DATABASE AND CALCULATIONS

2.1 Temporary workers

Temporary workers (flexworkers) are persons who have an employment contract of limited duration or no fixed agreed number of hours in service such as from temporary worker agencies (employment bureaus) or working as trainees (interns) as a part of education. This study used the analysis of 3,261 detailed accident scenarios of victims who were temporary workers (of which 92% were categorised as employment bureau and around 8% as interns) and 20,447 who were not identified as being temporary workers, these being the rest of the database. The latter are workers on fixed contracts, the self-employed, students, and a small number of temporary workers (160 victims) for age groups not included in the temporary worker analysis. The data are from 20,030 serious reported investigated occupational accidents over the period 1998-2009. The accidents are reportable under Dutch labour law, are investigated by the Dutch Labour Inspectorate and constitute the 1% most serious

occupational accidents in the Netherlands. These accidents have been analysed in a safety barrier model which has been described elsewhere (e.g. Bellamy 2014, RIVM 2008).

It should be noted that in this paper the use of the terms "temporary workers" or "flexworkers" refers to the Dutch Labour Inspectorate categories of "uitzendkracht" (employment bureau workers) and "stagiairs" (interns). However there are other types of temporary workers with flexible contracts besides these groups but which are not identified by the Dutch Labour Inspectorate in their classification of type of work contract. "Employment bureau" is a term used more broadly by the Labour Inspectorate. Hoeben & Smit (2014) reporting on these Labour Inspectorate data suggest that within their definition of employment bureau workers there is a 7 to 8 times higher risk rate compared to non-employment bureau workers, whereas TNO (Hooftman & van de Meer 2013) report for 2007-2012 an accident population of 9% of employment bureau workers and 7% of non-employment bureau workers, a difference of 2% or a ratio of 1.3. The latter is for a broader category of accidents, being based on a national survey. However, the Hoeben & Smit (2014) results can be explained not by the difference in seriousness of the accidents but by not having the denominator data that match the accident data population and which should include more than only the employment bureau workers hours from the Central Bureau of Statistics (CBS) since the definitions do not match. Data on the workforce from the Dutch Central Bureau of Statistics (CBS Statline 2014) indicates that around 15% of workers have a flexible contract and only 3% of workers are from employment bureaus so 12% of temporary workforce exposure is not being included in the analysis by the Labour Inspectorate, although it is unclear where this should be applied.

It can be seen from Figure 1 that accidents to temporary workers are particularly concentrated around the age of 18-19 and then decrease. For the non-temporary group the number of accidents rises from age 15 to around age 40 and then decreases, particularly after 60. The distribution of victims over severity of consequence is shown for each category of work in Table 1. That permanent injury is the largest category for the temporary worker accidents suggests that there is a higher risk for amputations and disabling injuries such as occurs with the use of moving machinery.

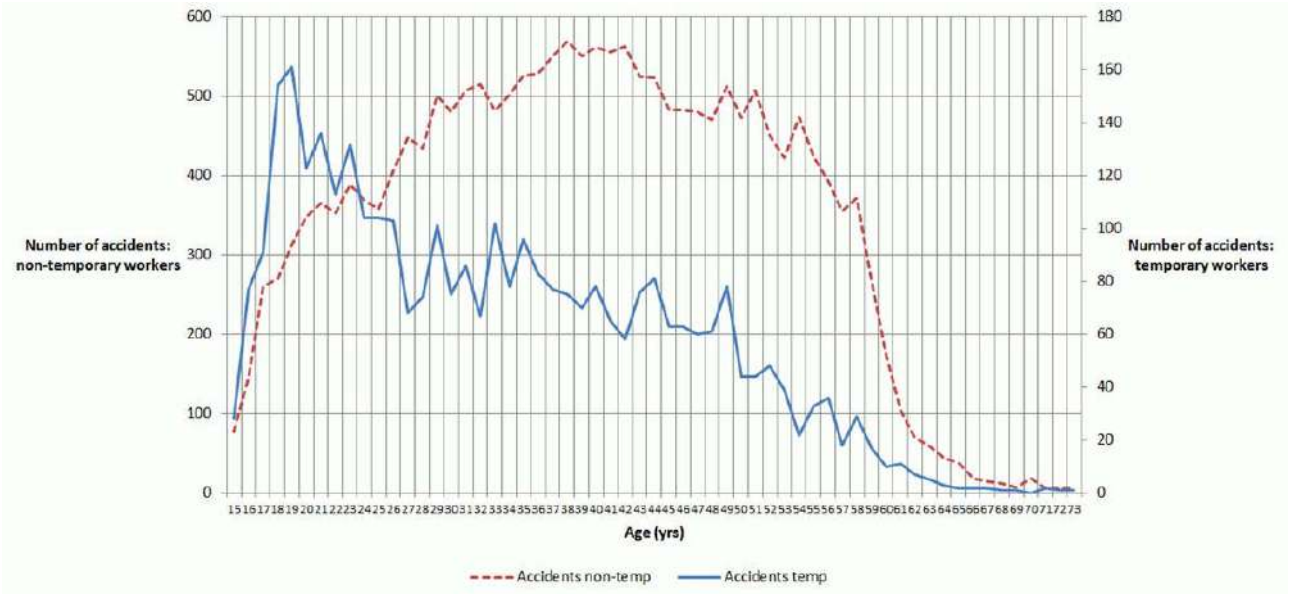

Figure 1 Number of accidents for non- temporary and temporary workers according to age of the victim.

Table 1 Distribution of the accidents across the consequence classes

	Death	Permanent injury	Recoverable injury	Unknown	Total
Temporary	2.9%	38.9%	38.0%	20.2%	100.0%
Non-temporary	4.0%	34.4%	39.4%	22.2%	100.0%

2.2 Risk rates

Hours exposure to hazards for temporary and non-temporary workers were calculated from the results of an internet panel survey in 2011 of 25,000 representatives from the Dutch workforce, 1009 of which were temporary workers. This survey is further described below. These temporary workers data were sparse and in some cases the exposures could only be reliably estimated for certain age groups as shown in column (a) in Table 2 and Table 3. This means that for the age groups not represented the temporary worker accidents had to be included in the non-temporary worker accident population for 7 of the bow-ties; in total this is 160 temporary worker victims. The worst cases are for 01.1.2.*3 Fall from height - (de)installing scaffold* with 16% of the non-temporary victims being temporary workers and for *01.1.2.2 Fall from height fixed scaffold* with 10% of the non-temporary victims being temporary workers. By definition only the exposures of the age groups included in the temporary worker population are used for the temporary population, the rest being in the non-temporary group.

The Dutch serious accident database 1998-2009 is constructed in a software program called Storybuilder™ and has 36 accident hazard bow-ties (Bellamy et al 2006, 2007, 2008, 2010, 2014). These accident data have been split into 64 bow-ties in the development of an occupational risk model (RIVM 2008). Exposure data corresponding to these bow-ties were collected in an exposure survey carried out for the first time in 2006 and again in 2011 (Damen et al 2012). These exposures have been factored up for the Dutch working population using weighting factors for sector, job, type of employment, education level, age and gender. With the exception of education level, these are also classes within which accident data can be grouped. This means, therefore, that both exposure data and accident data can be defined for temporary workers as they can be found in the types of employment category. The whole accident and exposure population can therefore each be divided into 2 groups – temporary workers and non-temporary workers (the rest of the population). In the database there are more than 23,000 accidents with which this can be done.

The number of accidents divided by the calculated exposure for the equivalent period in which the accidents arose gives the the per hour risk rate. This has been done for each of the 64 hazards (RIVM 2008, Aneziris et al 2014). When the accident and exposure data are divided into temporary and non-temporary workers, risk rates for the two groups can be calculated for each of the hazards. In the current study 62 of these 64 bow-ties were used (fall from rope ladder and loss of containment from normally closed containment during closing were excluded due to insufficient data). A special development of Storybuilder™ called “Storybuilder Magus” was made in order to be able to calculate the risk rates for selected classes of accidents using an estimate of the exposure for this group. The analysed 1998-2009 accidents were distributed over the 62 bow-ties in Storybuilder Magus. Then the temporary worker accidents were identified in the model; the inverse of these made up the non-temporary class. A view of the risk calculation module from this database is shown in Figure 2. The screen is showing that there are 266 accidents in the loss of containment bow-tie for adding, removing or opening and that this is over a 12 year period. The selected accidents are the flexworkers, 8.27% of the total accidents. The yearly exposure as provided by Damen (personal communication) is 103,331 hours per year. The risk is always calculated per year, so to get the hourly risk rate means choosing only 1 hour per year exposure in the model. This risk is 1.77E-5 serious reportable occupational accident per hour. It can then be selected which fields to distribute the risk over – here the consequence field (code FO) is chosen for the results for individual risk; the accidents per year are in fact the hourly risk rates because of the 1 hour per year chosen. For the total risk this gives the accidents per year if 100,000 persons were exposed for 1 hour.

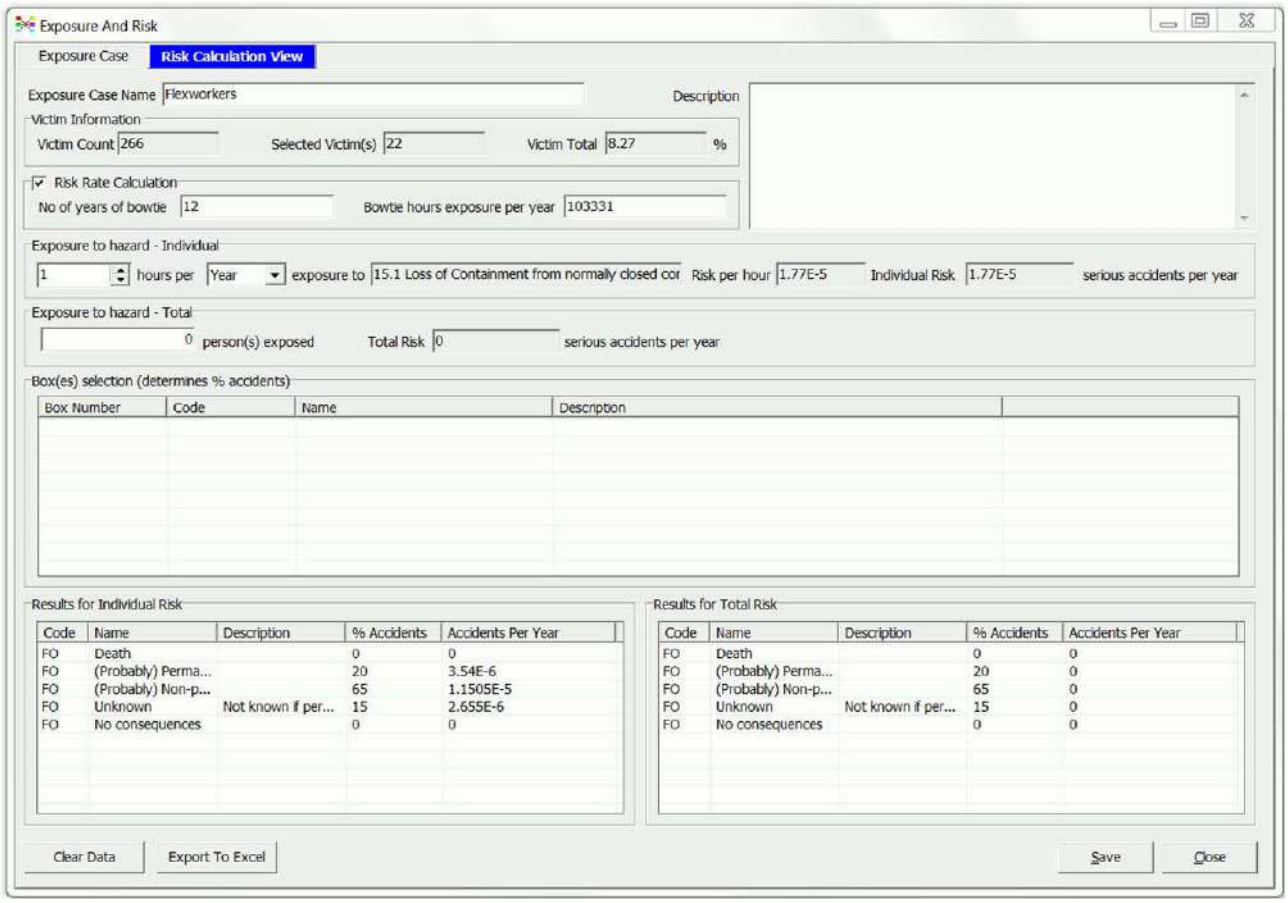

Figure 2 Risk calculation view of Storybuilder Magus for flexworkers for Loss of containment for normally closed containments for adding, removing or opening activities.

2.3 Risk ratios

Risk ratios were calculated as the ratio of the risk rate of temporary workers to that of non-temporary workers. To calculate the 95% confidence interval for the risk ratios the formula for incidence rate ratios (IRR) for a Poisson distribution was used (Sahai & Kurshid 1996).

3. RESULTS FOR TEMPORARY AND NON-TEMPORARY WORKERS

3.1 Risks across all bow-ties

Figure 3 shows some sample risk rate ratios for 10 of the bow-ties for the different consequence classes. Some bow-ties, like falling from a placement ladder, show no increased risk for temporary workers whereas for working on a roof, temporary workers are exposed to 16 times the risk of dying. For clearing a machine the permanent injury risk rate is 8 times higher for temporary workers and for being in or on a moving vehicle it is 4 times higher. Temporary workers undertaking mechanical lifting however do not have an increased risk of being harmed by a dropped object. Different hazards have different risks.

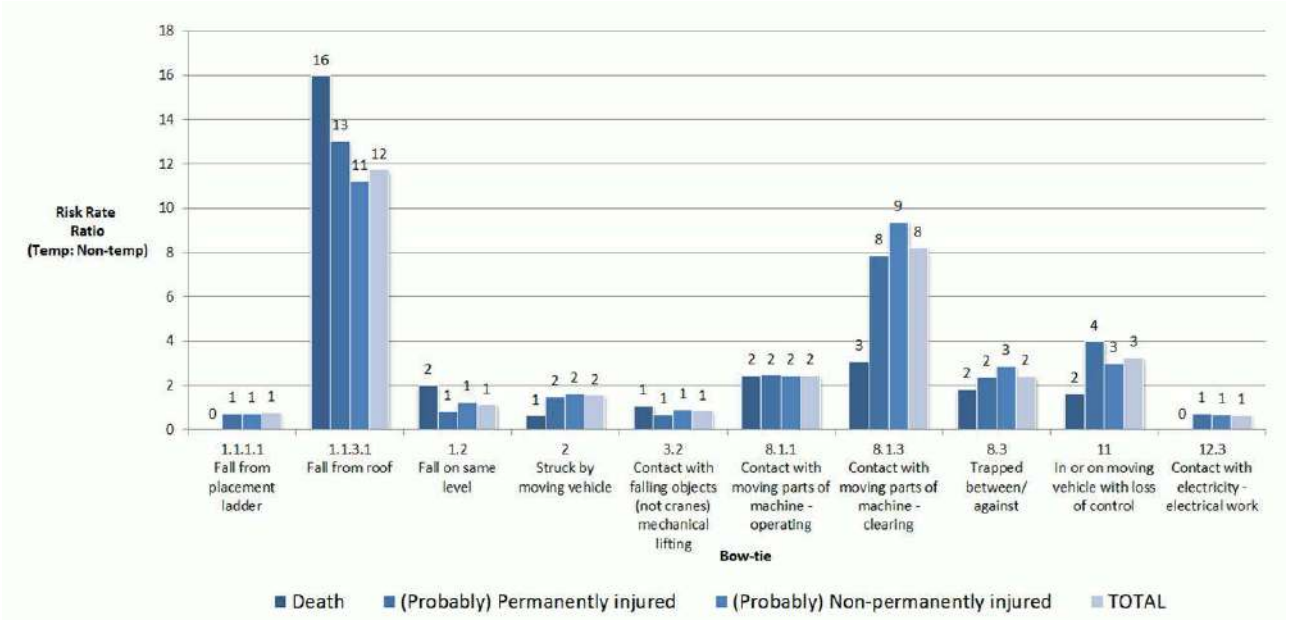

Figure 3 Serious accident risk rate ratios of temporary to non-temporary workers for selected bow-ties and different injury outcomes

The results in Table 2 and Table 3 show for all 62 hazard bow-ties the ratios of the total per hour risk rates in Column (i). Column (a) indicates where there were or were not limitations in the exposure data for reliably calculating risk rates as explained in section 2.2. The bow-ties are sorted in order of highest to lowest ratios. The ratio gives the number of times higher the risk for temporary workers is to non-temporary. For example, fall from height from a roof has a ratio of 11.4. Comparison of columns (e) % of total exposure and (f) % of total victims for temporary workers also provides an indication of where the temporary worker has a higher, lower or equal share of accidents compared with the share of the exposure. For example, for contact with handheld tools the exposure share is 6.5% but the accident share is 20.9%.

A higher risk rate ratio is statistically significant if the 95% confidence interval does not include the value of 1.0. The risks for temporary workers are much higher with some hazards (Table 2) but in half the cases are less than 1.5 times higher (Table 3). For example, the risk of contact with moving parts of a machine during clearing, releasing or unblocking is 8 times higher for temporary workers and for fall from a mobile scaffold is 16 times higher. However for fall on the same level the risk rate is only 1.3 times higher but is not significant and similarly for contact with falling objects during mechanical lifting (not cranes) the risk rates are the same. The highest ratios are for certain falls from height, loss of containment when adding to, removing from or opening a containment and working with machines or moving vehicle. Also, some risk ratios are less than 1, such as falling from height from a moving platform where the risk ratio is 0.6. (CI 95% 0.4-0.8), so not all falls hazards have a higher risk with temporary workers.

The highest risk rate ratios are associated with the highest temporary worker risks; the risk ratio (i) and the risk per hour (g) almost perfectly correlated over the 62 bow-ties $r = 0.97$ $p<0.0001$ $df=60$. The correlation with the non-temporary worker risk rates is only $r= 0.19$ which is not significant. This suggests that the increase in risk is not just a blanket factoring up for temporary workers, but that the type of hazard itself is an interacting factor. So, the higher the risk ratio, the more important the hazard is for risk reduction. The higher risks appear to only have a small % exposure of the temporary worker group, like fall from roof for example (1.2% pf the exposure compared with 11.8% of the accidents) and in fact there is a small significant negative correlation between temporary worker % of the exposure and the risk rate ratio ($r=-0.3$, $p<0.05$, $df=60$).

Table 2 Accident and exposure data, risk rates and risk rate ratios for temporary and non-temporary workers with ratios 1.5 and higher

Bow-tie	(a) Temporary worker age groups used	(b) All workers 1,000,000 hrs exposure per year (2011 survey)	(c) Temporary worker victims 1998-2009	(d) Non-temporary worker victims 1998-2009	(e) Temporary workers % total exposure	(f) Temporary workers % victims	(g) Temporary worker serious accident risk per hr	(h) Non-Temporary worker serious accident risk per hr	(i) RATIO (g)/(h)	(j) RATIO 95% CI
01.1.2.3 Fall from height - (de)installing scaffold	50+	21.47	5	142	0.0%	3.4%	1.50E-04	5.51E-07	272.2	87.8 - 654.8
15.1 LoC normally closed - adding, removing, opening	All	71.92	22	232	0.1%	8.7%	1.77E-05	2.69E-07	65.9	40.2 - 102.4
01.1.2.1 Fall from height - mobile scaffold	15-29	16.63	20	471	0.3%	4.1%	3.80E-05	2.37E-06	16.1	9.7 - 25.1
01.1.3.1 Fall from height - roof	15-50	30.23	93	694	1.2%	11.8%	2.21E-05	1.94E-06	11.4	9.1 - 14.2
01.1.1.2 Fall from height - fixed ladders	All	23.58	15	109	1.6%	12.1%	3.40E-06	3.91E-07	8.7	4.7 - 15
08.1.3 Moving parts of machine - clearing	15-50	55.45	123	693	2.1%	15.1%	8.80E-06	1.06E-06	8.3	6.8 - 10
15.2 LoC normally closed - transport	15-29 + 50+	31.13	1	40	0.3%	2.4%	8.04E-07	1.07E-07	7.5	0 - 48.3
08.1.2 Moving parts of machine - maintaining	All	155.84	49	442	1.7%	10.0%	1.52E-06	2.41E-07	6.3	4.6 - 8.5
01.1.3.2 Fall from height - floor	All	92.93	85	635	2.1%	11.8%	3.60E-06	5.82E-07	6.2	4.9 - 7.8
07 Contact with handheld tool operated by victim	All	776.93	111	420	6.5%	20.9%	1.83E-07	4.82E-08	3.8	3.1 - 4.7
08.1.4 Moving parts of machine - cleaning	All	114.18	109	491	5.6%	18.2%	1.42E-06	3.80E-07	3.7	3 - 4.6
23.1 Immersion in liquid -working in or under	All	9.08	1	11	2.5%	8.3%	3.72E-07	1.04E-07	3.6	0 - 26.6
11 In or on moving vehicle with loss of control	All	468.31	193	653	7.7%	22.8%	4.44E-07	1.26E-07	3.5	3 - 4.2
06.1 Contact with object used/ carried – handheldtool not operated by victim	All	846.87	11	46	7.9%	19.3%	1.37E-08	4.91E-09	2.8	1.3 - 5.5
08.3 Trapped between/ against	All	197.03	162	810	7.0%	16.7%	9.77E-07	3.68E-07	2.7	2.2 - 3.1
08.1.1 Moving parts of machine - operating	All	791.47	636	2554	9.2%	19.9%	7.31E-07	2.96E-07	2.5	2.3 - 2.7
15.4 LoC from normally closed - working nearby	All	145.02	16	149	4.6%	9.7%	2.02E-07	8.97E-08	2.2	1.2 - 3.8
20.2 Victim of animal behaviour	All	62.58	10	48	8.5%	17.2%	1.56E-07	6.99E-08	2.2	1 - 4.5
27.1 Physical Explosion	All	306.14	6	67	3.9%	8.2%	4.16E-08	1.90E-08	2.2	0.8 - 5
05 Hit by rolling/sliding object	All	249.54	24	153	7.2%	13.6%	1.11E-07	5.51E-08	2.0	1.3 - 3.1
27.2.1 Chemical Explosion -vapour or gas	All	329.59	19	168	6.4%	10.2%	7.50E-08	4.54E-08	1.7	1 - 2.7
01.1.2.2 Fall from height fixed scaffold	15-29	49.24	19	346	3.2%	5.2%	9.95E-07	6.05E-07	1.6	1 - 2.6
02 Struck by moving vehicle	All	475.03	179	864	11.2%	17.2%	2.80E-07	1.71E-07	1.6	1.4 - 1.9
03.5 Contact with falling objects other	All	87.76	205	1249	9.3%	14.1%	2.09E-06	1.31E-06	1.6	1.4 - 1.9
17.2 Fire- working nearflammable/combustibles	All	286.59	8	90	5.4%	8.2%	4.29E-08	2.77E-08	1.6	0.7 - 3.2
03.4 Contact with falling objects manual handling	All	300.24	55	279	11.9%	16.5%	1.28E-07	8.79E-08	1.5	1.1 - 2

Table 3 Serious accident and exposure data, risk rates and risk rate ratios for temporary and non-temporary workers with ratios 1.4 and lower

Bow-tie	(a) Temporary worker age groups used	(b) All workers 1,000,000 hrs exposure per year (2011 survey)	(c) Temporary worker victims 1998-2009	(d) Non-temporary worker victims 1998-2009	(e) Temporary workers % total exposure	(f) Temporary workers % victims	(g) Temporary worker serious accident risk per hr	(h) Non-Temporary worker serious accident risk per hr	(i) RATIO (g)/(h)	(j) RATIO 95% CI
08.2 Contact with swinging/hanging objects	All	75.43	80	323	14.6%	19.9%	6.05E-07	4.18E-07	1.4	1.1 - 1.9
14.2 Contact with hazardous substance without LOC	All	405.15	31	194	9.9%	13.8%	6.42E-08	4.43E-08	1.4	1.1 - 1.8
01.1.3.3 Fall from height - platform	All	84.74	55	316	10.8%	14.8%	4.99E-07	3.49E-07	1.4	1.1 - 1.9
06.2 Contact object used/carried NOT handheld tool	All	362.57	67	406	10.4%	14.2%	1.48E-07	1.04E-07	1.4	1 - 2.1
22.1 Contact hazardous atmosphere in confined space	All	158.79	9	81	7.4%	10.0%	6.42E-08	4.59E-08	1.4	0.6 - 2.8
09 Moving into an object	All	1567.11	34	216	10.5%	13.6%	1.73E-08	1.28E-08	1.3	1 - 1.6
04.3 Contact flying object - blown by wind	All	146.17	2	11	11.9%	15.4%	9.56E-09	7.12E-09	1.3	1 - 1.6
04.2 Contact flying object - under pressure or tension	All	364.42	40	371	7.5%	9.7%	1.21E-07	9.17E-08	1.3	0.9 - 1.9
04.1 Contact flying object - machine or handheld tool	All	603.05	34	330	7.3%	9.3%	6.46E-08	4.92E-08	1.3	0.9 - 1.8
01.2 Fall on same level	All	3880.71	96	733	9.4%	11.6%	2.18E-08	1.74E-08	1.3	0.1 - 6.2
03.1 Contact falling objects from cranes/ hoists	All	128.57	66	503	9.5%	11.6%	4.51E-07	3.60E-07	1.3	0.9 - 1.9
01.1.1.3 Fall from height -step ladders or steps	All	124.08	51	321	11.4%	13.7%	3.00E-07	2.43E-07	1.2	0.9 - 1.7
14.1 LoC Open containment	All	277.66	33	212	12.2%	13.5%	8.11E-08	7.25E-08	1.1	0.7 - 1.7
03.3 Contact with falling objects vehicle or load	All	182.46	24	131	14.5%	15.5%	7.58E-08	6.99E-08	1.1	0.1 - 4.2
12.2 Contact with electricity - tool	All	3135.33	2	38	4.7%	5.0%	1.13E-09	1.06E-09	1.1	0.8 - 1.6
03.2 Contact with falling objects mechanical lifting	All	243.43	74	417	15.2%	15.1%	1.66E-07	1.68E-07	1.0	0.6 - 1.5
01.1.4 Fall from height - hole in the ground	All	215.39	25	133	16.0%	15.8%	6.04E-08	6.13E-08	1.0	0.8 - 1.3
13 Contact extreme hot /cold surfaces/open flame	All	250.24	3	31	9.2%	8.8%	1.08E-08	1.14E-08	1.0	0.2 - 3.1
27.2.2 Chemical Explosion - dust	All	107.59	2	19	10.6%	9.5%	1.47E-08	1.65E-08	0.9	0.7 - 1
10 Buried by bulk mass	All	89.81	9	35	22.4%	20.5%	3.72E-08	4.19E-08	0.9	0.4 - 1.9
01.1.1.1 Fall from height - placement ladder	All	95.30	137	1350	10.7%	9.2%	1.12E-06	1.32E-06	0.8	0.1 - 3.8
25.1 Extreme muscular exertion - handling objects	All	450.19	4	42	10.6%	8.7%	7.02E-09	8.69E-09	0.8	0.5 - 1.1
20.1 Victim of Human Aggression	All	1414.39	9	133	8.1%	6.3%	6.53E-09	8.53E-09	0.8	0.3 - 1.5
12.3 Contact with electricity - electrical work	All	154.17	31	289	12.5%	9.7%	1.34E-07	1.78E-07	0.8	0.2 - 2.3
27.2.4 Chemical Explosion - exothermic reactions	All	70.21	3	31	11.5%	8.8%	3.09E-08	4.16E-08	0.7	0.5 - 1
01.1.5.2 Fall from height - non-moving vehicle	All	158.80	39	423	11.1%	8.4%	1.84E-07	2.50E-07	0.7	0.1 - 2.4
01.1.5.1 Fall from height - moveable platform	15-50	62.42	46	369	16.8%	11.1%	3.66E-07	5.92E-07	0.6	0.4 - 0.8
01.3 Fall down stairs or ramp	All	317.97	27	257	14.9%	9.5%	4.76E-08	7.91E-08	0.6	0.4 - 0.9

22.2 Hazardous atmosphere - breathing apparatus	All	33.80	1	10	14.7%	9.1%	1.68E-08	2.89E-08	0.6	0 - 4.5
17.1 Fire - hot work	All	217.18	11	110	16.1%	9.1%	2.62E-08	5.03E-08	0.5	0.3 - 1
27.2.3 Chemical Explosion - explosives	All	20.57	1	7	31.5%	12.5%	1.29E-08	4.14E-08	0.3	0.1 - 0.8
17.3 Fire - fire fighting	All	8.94	3	57	17.2%	5.0%	1.62E-07	6.42E-07	0.3	0 - 2.7
01.1.5.3 Fall from height- working on height unprotected	15-29 + 50+	46.03	32	579	18.2%	5.2%	3.18E-07	1.28E-06	0.2	0.2 - 0.4
23.2 Impact by immersion in liquid - working nearby	All	31.78	1	41	10.0%	2.4%	2.62E-08	1.19E-07	0.2	0 - 1.4
12.1 Contact with electricity high voltage cable	15-50	28.47	1	27	14.7%	3.6%	1.99E-08	9.27E-08	0.2	0 - 1.4
25.2 Extreme muscular exertion - moving around	All	328.62	1	45	9.7%	2.2%	2.62E-09	1.26E-08	0.2	0 - 1.3

3.2 Factors contributing to temporary worker risks

The basic building blocks of the Storybuilder model are shown in Figure 4 and their application in one of the bow-ties of the database in Figure 5. The key component is the safety barrier to which barrier tasks and resource management are attached. Failure of the barrier can result in a loss of control event which can cause harm. The safety barriers can be broadly considered to be safeguarding, operational control within the safe envelope, distance from the danger zone of the hazardous object and emergency response to reduce the effects. The barriers are affected by the tasks which provide, use, maintain and monitor each barrier. These tasks are resourced by the management system, with eight key delivery systems identified. Errors may be identified in the carrying out of the tasks in the incident reports and these are recorded according to the system of Rasmussen (1983) and Reason (1990) as violations, mistakes, slips and lapses. A glossary of these elements is provided in Annex I. This model enables the prevalence of underlying causes of accidents to be analysed.

The contributory factors to the temporary to non-temporary risk rate ratios have been examined at a bow-tie specific level. A small sample of bow-ties has been selected for exploration where there are high ratios and one bow-tie where there is a risk ratio less than 1. Risk rates for the underlying events can be calculated just as at the bow-tie level. It can be hypothesised that the contribution to the risk differences between the temporary and on-temporary workers is derived from underlying causes and that the management resource deliveries and barrier tasks will have a higher risk rate ratio in the bow-ties with bigger ratios and vice versa in the bow-ties with a ratio less than 1.

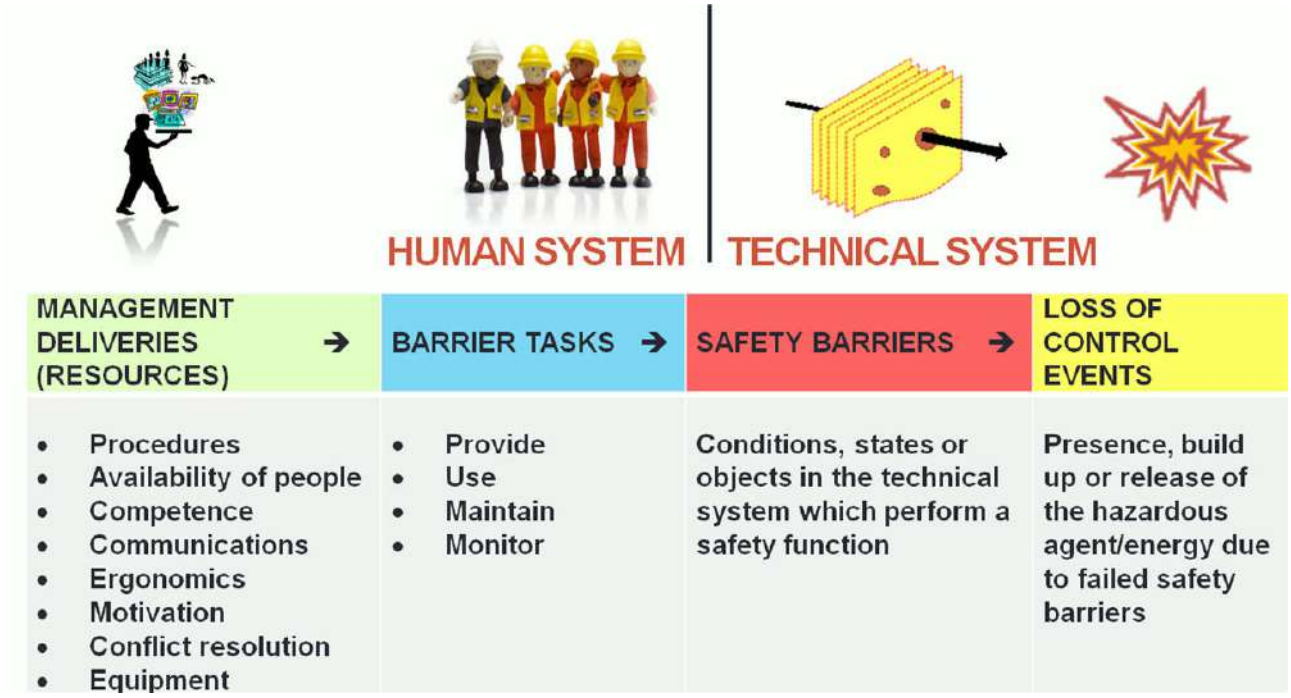

Figure 4 Basic building blocks of the barrier model in Storybuilder

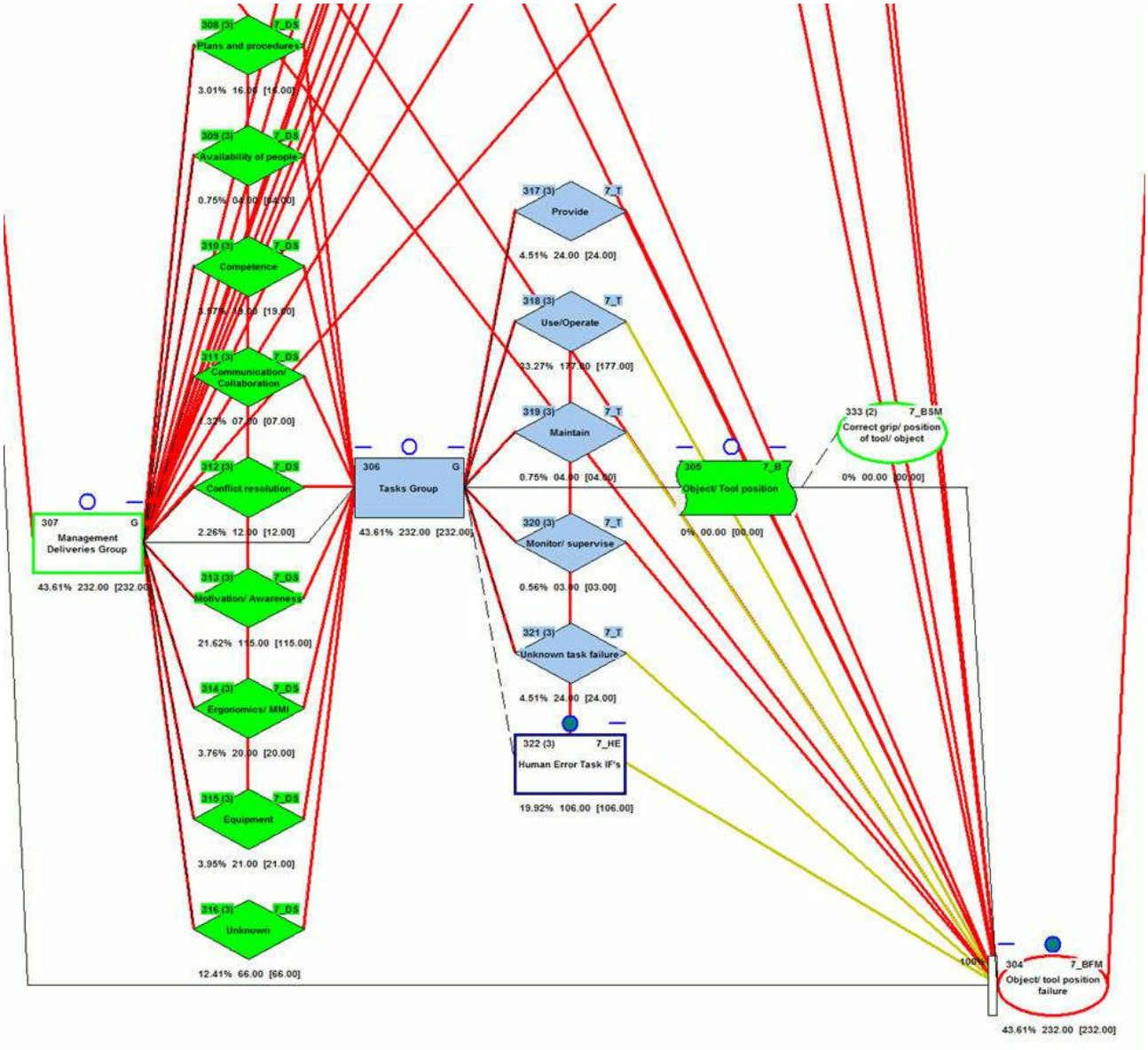

Figure 5 Building blocks of the barrier model shown in bow-tie Contact handheld tool for barrier failure Object/tool position failure showing data for temporary workers below the events: accident %, number of accidents and [number of victims]

Table 4 shows a small sample of results. For four selected bow-ties the risk rate ratios for the two barrier failure modes with the highest % contribution to accidents for that bow-tie were identified. Similarly the highest accident % underlying cause was identified for barrier task, human error and management delivery system. As expected, it was found that the underlying causes were reflecting the risk ratio for the overall bow-tie.

For the fall from roof bow-tie the barrier failure mode of the roof not supporting the weight contributed the most to the accidents (57%). Temporary workers were exposed to 18 times the failure risk of this barrier compared to non-temporary workers, 23 times the risk of not acting correctly with respect to the weight that the roof can support and 51 times higher risk of making a knowledge-based mistake with respect to this barrier. The management system failure to ensure safety motivation and risk awareness of the weight that the roof can support was 16 times higher.

In the examples, risk of violations in relation to using safeguards (fall arrest, personal protective equipment (PPE), physical guarding) were 15-18 times higher for temporary workers. The risk of failure to provide these safeguards in the first place ranged from 10 times higher for physical guarding failure to 137 times higher for failing to provide (adequate) PPE to protect against the effects of a loss of containment of a hazardous substance. 50% of all the loss of containments accidents for adding, removing and opening result in thermal burns and 30%

chemical burns. For loss of containment accidents, the risk of inadequate detection of a process deviation in the containment of hazardous substances due to a competence failure was 215 times higher for temporary workers. By comparison, falling from a moveable platform had a risk rate ratio of less than 1 for the two top barrier failures and their underlying causes. Using the wrong method of operating was actually half the risk rate of non-temporary workers who additionally have a higher risk of violations of the appropriate method. The same can be said of attentional failure and loss of balance.

This exercise demonstrates different types of relative risk contributors for the different hazards. While this has only scratched the surface, it does indicate that a deeper analysis of the risks faced in the workplace is possible. However it is not easy to explain why some hazards are so much riskier than others for the temporary compared to non-temporary workers. The low % contribution of exposure may play a small role.

Table 4 Analysis of the risk rate ratios of selected underlying events of four bow-ties using the top % accident events. Each bow-tie has the two top barrier failure modes and the top underlying events for those barrier failures.

Bow-tie	Barrier failure component	Failure event	% of temporary workers victims per bow-tie	Event risk rate ratio temp :non-temp
01.1.3.1 FALL FROM HEIGHT – ROOF (Risk ratio = 11.4)				
	Barrier failure mode:	**Roof, not intended to support exerted weight**	**57**	**18**
	Barrier task:	Use/Operate	34	23
	Human error:	Knowledge based mistake	10	51
	Management delivery system:	Motivation/ Awareness	17	16
	Barrier failure mode	**Fall arrest failure**	**71**	**18**
	Barrier task:	Provide	41	20
	Human error:	Violation	5	11
	Management delivery system:	Motivation/ Awareness	16	15
15.1 LOSS OF CONTAINMENT FROM NORMALLY CLOSED CONTAINMENT - ADDING, REMOVING, OPENING (Risk ratio = 65.9)				
	Barrier failure mode:	**Process deviation (pressure temperature,flow, substance) indication/ detection failure**	**60**	**96**
	Barrier task:	Use/Operate	30	149
	Human error:	Mistake	10	322
	Management delivery system:	Competence	20	215
	Barrier failure mode:	**Personal Protective Equipment Failure**	80	67
	Barrier task:	Provide	35	137
	Human error:	Situational violation (in using)	10	161
	Management delivery system:	Plans and procedures	40	117
8.1.3. CONTACT WITH MOVING PARTS OF MACHINE – CLEARING (Risk ratio = 8.3)				
	Barrier failure mode:	**Physical Guarding Failure**	94	8
	Barrier task:	Provide	55	10
	Human error:	Violation	8	15
	Management delivery system:	Equipment	45	9
	Barrier failure mode:	**Unaware of danger zone or loss**	**46**	**10**

	of body control		
Barrier task:	Use/Operate	33	9
Human error:	Knowledge based mistake	11	17
Management delivery system:	Motivation/ Awareness	27	10
01.1.5.1 FALL FROM HEIGHT - MOVEABLE PLATFORM (Risk ratio = 0.6)			
Barrier failure mode:	**Wrong method/ equipment for job at hand is chosen**	**36**	**0.4**
Barrier task:	Use/Operate	28	0.5
Human error:	Violation	9	0.4
Management delivery system:	Plans and procedures	13	0.6
Barrier failure mode:	**Loss of control of body/balance**	**23**	**0.5**
Barrier task:	Maintain	9	0.5
Human error:	Attentional slip	4	0.4
Management delivery system:	Motivation/ Awareness	9	0.4

4. CONCLUSIONS

Studies in both Europe and the US find that temporary workers tend to have a higher risk of having an accident than non-temporary workers. This is also the case for the Dutch data on serious investigated reportable occupational accidents but depends on the type of hazard. The serious accident risk per hour of having such an accident differs between hazards. The more risky the work for a temporary worker the increasingly riskier it is than non-temporary work. The pattern of underlying contributors differ between hazards, a few examples illustrating how management failure has been a contributor to the increased risk for temporary workers in terms of not delivering adequate risk awareness, competence, procedures as well as not providing adequate safeguarding to protect people working in the danger zone of hazards like harmful substances or machines.

Why the risk of being a victim of some hazards appears to be greater in some cases and no greater in others for temporary workers compared to non-temporary is not clear. It is clear however that there are management failures contributing to the inflation of the risk by not ensuring barriers are in place and adequate. Management need to give special attention to factors like those mentioned above to ensure adequate safeguarding and personal protection, awareness and understanding, procedures and keeping to procedures and that are all specific to the control of that type of hazard. These are not the only factors, just those identified in the sample. Priorities should be given to the risks with the higher risk rate ratios, like working on scaffolds or with fixed machinery with moving parts, in combination with consideration of the amount to which a temporary worker is exposed. Low % exposures may mean less anticipation of needs. Other considerations include age. The victim distribution according to age is skewed towards 18-19 years whereas for non-temporary workers it is more symmetrical and peaks at around 40. Reduction should be targeted at this young age group.

There are some limitations in the data analysed. These are only the 1% most serious accidents which are reported to the Inspectorate and when distributed over the different hazards the numbers are quite small. This is also the case regarding the population sample on which the exposure data for calculating risk rates was based. Additionally this exposure data is weighted for a limited period –the year 2010 - and not the whole range from 1998-2009. Apart from the small number of known cases of temporary workers included in the non-temporary worker population, there is still uncertainty as to whether all the temporary workers have been included. Underreporting may also have an influence as it is known that this already occurs in certain sectors but while the risk may be underestimated this does not affect the ranking of the hazards (Bellamy et al 2015). Finally, extrapolating the results to newcomers in a company would assume that temporary workers are also newcomers whereas the data regarding length of experience in the company are not known from the accident data. These are areas where improvement in the recorded properties of the data is needed.

With these limitations in mind, the results for the relative risks between temporary and non-temporary workers still suggest that there would be value in further analysis of the issues. This is especially for seeking

patterns in the underlying causes and to examine other factors like the distribution of temporary worker accidents over the sectors. In these ways targeted solutions can be achieved, also by combining the results with findings of other studies identifying solutions (e.g. Fabiano et al 2008), like the need to handle work pressures on temporary workers through better job design and training.

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ANNEX I: GLOSSARY

Management Delivery Systems

Procedures
Procedures delivery system delivers performance criteria which specify in detail, usually in written form, a formalised 'normative' behaviour or method for carrying out tasks, such as: checklist, task list, action steps, plan, instruction manuals, fault-finding heuristic, rules, permits, programs and risk assessments. This delivery system includes planning of activities in time: how frequently tasks should be done, when and by whom.

Availability
Availability delivery system allocates the necessary time and numbers of competent and suitable (including anthropometrics and biomechanics) people to the barrier tasks to be carried out. It emphasises time-criticality, i.e. competent people available in the required time frame.

Competence
Competence delivery system delivers the knowledge, skills and abilities of the people selected for the execution of the barrier tasks. It also covers the selection and training function of a company to deliver sufficient competence for overall manpower planning. This delivery system also refers to 'right person for the job', i.e. with sufficient barrier task knowledge and skills

Communication
Communication delivery system is relevant when the activity is carried out by more than one person (or group), who have to coordinate or plan joint activities e.g. different shifts. It refers to internal communication and coordination. Internal communications are those which occur implicitly or explicitly within any primary business activity in order to ensure that the tasks are coordinated and carried out according to relevant criteria. This delivery also refers to task instructions and communication channels and means (such as meetings, logs, phones, radio).

Motivation
Motivation delivery system delivers goals and incentives for people to carry out their tasks and activities with suitable care and alertness and keeping to criteria and rules specified for the safety of the activities within the organisation. This delivery system includes alertness, care and attention, concern for safety of self and others, concern for risk control and willingness to learn to improve it.

Conflict Resolution
Conflict resolution delivery system resolves conflicts between safety and other goals within the performance of tasks. It deals with the mechanisms (such as supervision, monitoring, procedures, learning, group discussion) by which potential and actual conflicts between safety and other criteria in the allocation and use of personnel, hardware and other resources, are recognised, avoided or resolved.

Ergonomics
Ergonomics and man-machine system deals with the fit between the man and the task. The ergonomics delivery system optimises system performance through equipment, tools and software appropriate to the person and task, robust/ appropriate/ good interface and labelling, good operability and maintainability, good task design. Ergonomics and man-machine system also covers design and layout of control rooms and manually operated equipment, design of inspection and test facilities, maintenance-friendliness of equipment, design of manning and shift systems, ergonomics of tools.

Equipment
Equipment refers to the hardware needed for provision, maintenance and monitoring of barriers (tools, spares, parts). This delivery system covers both the correctness of the equipment for their use (compatibility, suitability, quality), and the availability of equipment where and when needed to carry out the activities. It includes: spares and parts, including those needed for maintenance, and adequate and correct stocks.

Barrier Task failures

Provide failure
The barrier does not exist, has not been well designed, or it is not provided and / or sufficiently/easily available when you want to use it. For example: the correct tools were not provided to carry out the operations safely.

Use/Operate failure
The correct barrier is provided, but the way in which the provided barrier is used is incorrect, it is only partially used, or it is not used at all. A 'use' failure is also the case when somebody chooses not to use the correct barrier but something else. For example: the correct tools were available but not used.

Maintain failure
The barrier is not kept available according to its designed function and in an adequate state and includes maintain, inspect and test failures. This covers not only the maintenance aspect but also the management of change aspect of a barrier, i.e. a barrier is modified without ensuring that it maintains its barrier function. For example if tools were provided and used but failed because of bad maintenance or because they had been changed.

Monitor/supervise failure
Human performance affecting barrier condition is not checked/ measured/observed/inspected. This task failure relates primarily to the supervision of the barrier condition affected by the performance of barrier tasks.

Human errors

Violation
Deliberate deviation from the rules, procedures, instructions and regulations (which may be deemed necessary for the safe or efficient operation and maintenance of plant or equipment).

Situational violation
Non-routine infringement dictated by local circumstances.

Exceptional violation
Non-routine infringement dictated by extreme local circumstances. Violations that are rare and happen only in particular circumstances, often when something goes wrong.

Routine violation
Habitual deviation from regular practices.

Mistake
Inadvertent errors that occur when the elements of a task are being considered by the operator. They are decisions that are subsequently found to be wrong, although at the time the operator would have believed them to be correct.

Knowledge based mistake
Decisions that are subsequently found to be wrong. No ready-made solution, new situation tackled by thinking out answer from scratch. Knowledge based errors occur in novel situations when the person is beyond their skills, beyond the provision of the rule.

Rule based mistake
Misapplication of good rule/procedure or application of a bad rule/procedure. Rule based mistakes occur when the operation in hand is governed by a series of rules. The error occurs when an inappropriate action is tied to a particular event.

Slip or lapse
Plan of action satisfactory but action deviated from intention in some unintentional way.

Slips and Lapses generally occur in routine tasks with operators who know the process well and are experienced in their work: They are action errors.

Attentional slip
Error resulting from inattention

Memory lapse
Loss of activation slips occur when the person loses track of what they are doing or trying to do (the activation of the process). Essentially a temporary memory loss, often due to interruption or multi-tasking.