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ASSESSING OCCUPATIONAL RISK IN THE NETHERLANDS

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ABSTRACT

A methodology and associated tools for supporting decisions relevant to the management of occupational risk have been developed in the ORCA (Occupational Risk Calculator) project, performed on behalf of the Ministry of Social Affairs and Employment of the Netherlands. As part of the ORCA project a list of 63 generic hazards related to various aspects of worker's activities has been identified and the risk to workers in the Dutch population from each of these hazards has been quantified. Quantification of risk requires in general two types of data: a) Number of accidents; b) Exposure of working population to the corresponding hazard. The number of reported accidents during the period 1998-2010 has been assessed from the analysis of the data base of the Dutch Labour Inspectorate (I-SZW), where work related serious accidents are reported under Dutch law. A survey of the Dutch working population performed in 2011, has provided the total time the worker population subject to the reportable system has spent working in activities involving each of the 63 hazards. Assuming that the occurrence of accidents follows a Poisson random process, the risk for each generic hazard has been assessed as a maximum likelihood approximation. Point estimates of the risks have been calculated using the average yearly exposure of the workers to each hazard. Risk has also been assessed for the following sectors: agriculture and forestry, construction, industry and mining, transportation & communication and trade & commerce. A relative ranking of the 63 hazards on the basis of the risk of fatality, recoverable and permanent injury per working hour is provided for the specific sectors and for the overall working population. Risk assessment across sectors permits the estimation of the most risky sectors for each hazard and therefore the introduction of specific safety measures for the needs of each sector.

Key words. Occupational hazard, risk rate, occupational risk rates for sectors, number of accidents per hazard

1. INTRODUCTION

Occupational health and safety is a major concern to many countries since occupational accidents represent a major source of risk. In 2010, accidents at work killed 3691 workers in in EU-28, while 2721629 workers were injured , with absence of work more than three days , as reported by Eurostat.

Traditional occupational safety methods are analysis of accidents and accident statistics, regulations, standards and safety guidelines. The most significant standards used for occupational safety are the British BSI (1996,1999) and the international standard by ILO (2001). In addition various analyses of occupational accidents have been published, examining causes of injuries and fatalities such as those performed for the construction sector by Ale et al (2008), for the electric power industry by Carnero and Pedregal (2010) and for the extractive industry by Silva and Jacinto (2012).

Recently a number of attempts to a more systematic and consistent approach to quantitative occupational risk assessment have appeared in the literature. A model has been developed by Attwood et al (2006) to predict the frequency of occupational accidents in offshore oil and gas industry, based on direct, corporate and external factors. Quantified risk has been performed for various occupational groups by Larsson and Forsblom (2005). Fuzzy methods have been proposed for risk assessment of occupational accidents in a steel company by Mure and Demichela (2009), at construction sites by Gürcanli and Müngen (2009),Pinto (2014) and Liu and Tsai (2012), and at workplaces by Grassi et al (2009). In addition artificial neural networks and a fuzzy inference system have been proposed to assess occupational injury risk indexes and predict number of injuries by Ciarapica and Giacchetta (2009).

The Ministry of Social Affairs and Employment in the Netherlands developed, a large scale project during 2003–2008 to improve the level of safety at workplace, by introducing quantitative occupational risk. This project had four major parts: assembly and analysis of occupational accident concerning all 63 hazards and assessment of exposure data, generalisation of these data into a logical risk models, deriving improvement measures and their costs and developing a tool for supporting the selection of risk reduction strategies, as presented by Papazoglou et al (2008), Ale et al (2008) and Oh and Sol (2008). Results of the Workgroup Occupational Risk Model (WORM) project are presented by Ale (2006) and RIVM (2008) and its main achievements were: (a) the quantitative assessment of risk for 63 hazards presented in Table 1, such as fall from ladders, scaffolds, roofs presented by Papazoglou and Ale (2007), hit by falling objects by Aneziris et al (2008, 2014) etc., and (b) the development of the probabilistic occupational risk model (ORCA), which performs risk calculation of workers performing various tasks and exposed to several hazards, as presented in construction and manufacturing case studies by Aneziris et al (2010, 2012).

The purpose of this paper is to present the quantification of the risk rates for several sectors which are the following: agriculture and forestry, construction, industry and mining, trade, transportation & communication and trade & commerce. This work is based on the following: a) analysis of 23997 accidents, which have occurred in the Netherlands during 1998-2010, and have been extracted from the Occupational Accident Database GISAI (Gemeenschappelijk Informatie Systeem Arbeidsinspectie) and b) data concerning the exposure of the Dutch population to various hazards, according to the exposure survey performed in 2011. A relative ranking of the 63 hazards on the basis of the risk of fatality, recoverable and permanent injury per working hour is provided for the specific sectors and for the overall working population. Risk assessment across sectors permits the estimation of the most risky hazards for each sector.

The paper is organised as follows: section 2 outlines the modelling of the arrival of occupational accidents as a Poisson random process and briefly describes the procedure for identifying the number of accidents and the exposure of the Dutch working population to the occupational hazards during a given period of time. The point estimates of the risk rates for the average worker but also for workers in different sectors are assessed and presented in section 3. Section 4 presents conclusions and identifies the most important hazards for each sector.

2. MODEL AND DATA REQUIREMENTS

Occupational accidents occur randomly in time. As "*time-to-accident" (t)* one can define the time elapsing between the start of a certain job with exposure to a given hazard and the onset of an accident. This analysis assumes that accidents happen randomly as the worker performs the job and that accidents occur according to a *Poisson* random process. This means that the times-to- accidents are exponentially distributed with parameter λ.or that the probability density function (pdf) of the random variable t is given by equation (1).

$$f(t) = \lambda e^{-\lambda t} \tag{1}$$

If a worker is exposed to an accident hazard for τ hours during a calendar period (e.g. a year) then the probability that there will be an accident at any time during this period is equal to the probability that the time of accident occurrence will be less than τ or

$$p = F(t \le \tau) = 1 - e^{-\lambda \tau} \tag{2}$$

2.1 Estimation of accident rates

This sampling method is described in detail by Papazoglou et al (2014) and the main points are presented here. The parameter λ in equations (1) and (2) is estimated from observations of the random process and recording of the times at which accidents occur.

This is usually done by observing a population of N number of workers each for a given period of time t_0. During this period some of the workers will actually suffer an accident with given consequences and some will simply work the whole period t_0 without an accident. Let k be the number of workers suffering an accident at times $(t_1,t_2,\ldots,t_k)$. Then N-k is the number of workers without an accident that is each of them worked for the time period t_0 without an accident.

Assuming that the occurrence of each accident does not depend statistically on the other occurrences or non-occurrences, and that if a worker has an accident at t_i (s)he is no more exposed to the hazard for up to t_0, it is possible to calculate the probability of such an outcome, also called *likelihood.*

It can be shown that the estimation of the accident rate $\hat{\lambda}$ that maximizes the probability of an accidents, also called likelihood L, presented by Papazoglou et al (2014), is given by

$$\hat{\lambda} = \frac{k}{T} \tag{3}$$

where:

k: be the number of workers suffering an accident

T : total exposure time given by $T = \sum_{i=1}^{k} t_i + (N-k)t_0$

Equation (3) is widely used to obtain a point estimation of the accident rate λ. It has been used in the calculation of the point estimates of the various hazard rates given in Table 2.

2.2 Number of Accidents

In this paper the constant accident rate for each of the 63 single hazards has been estimated following the analysis described in the previous section. A total of 23997accidents that occurred in the period 1998-2010 (12 years) have been analysed using the Storybuilder tool, developed by Bellamy et al (2007). These accidents have been reported according to the Dutch labour law and contained in the GISAI (Geïntegreerd InformatieSysteem ArbeidsInspectie) data base. This database contains information on reported accidents and their investigations, reportable according to article 9 of the Dutch Working Conditions Act since they are occupational accidents

resulting in serious physical or mental injury (death within 1 year, permanent injury, in-patient treatment in hospital within 24 hours). These data consist of a short description based on the initial information reported, mostly by telephone, the accident report subsequently made by the inspector, and, in some cases, a prosecution report with more detail, including witness statements and the inspectors conclusions about breaches of the law, as discussed by Hale et al (2007) and Bellamy et al (2008).The Dutch Labour Inspectorate investigates occupational accidents only in cases where the victim was working under the authority of others. This means that accidents involving self- employed, who are not working under the authority of the third party, are not reportable. In addition, the Dutch Labour Inspectorate does not investigate accidents in workplaces where other inspectorates might lead the investigation, such as accidents on an airplanes during take-off, accidents on-board sea- going ships, accidents during drilling that involve the exploration for and extraction of mineral resources. Apart from the exceptions all the reported reportable accidents are investigated and this is therefore a complete dataset of the most serious accidents investigated in the Netherlands, as reported by Bellamy et al (2015).

Storybuilder enables the construction of accident scenarios, incorporating various factors that have contributed to the accident, according to the inspectors. All the 23997 accidents are distributed across 63 Storybuild hazards, these being graphical structures built using the software StoryBuilder, each representing a type of occupational accident. A number of reported accidents had unidentified consequences. These unknown accident consequences have been redistributed to the permanent or recoverable injuries, because it is expected that all deaths are reported. The results are given in Table 1.

Table 1. Occupational hazards that may cause accidents and Number of accidents which have occurred in the Netherlands during 1998-2010

		HAZARDS	Fatalities	Permanent Injuries	Recoverable Injuries
1.	1.1.1.1	Fall from height - placement ladder	24	270	1193
2.	1.1.1.2	Fall from height - fixed ladder	4	23	97
3.	1.1.1.3	Fall from height - steps	8	69	295
4.	1.1.2.1	Fall from height - mobile scaffold	14	83	394
5.	1.1.2.2	Fall from height - fixed scaffold	9	66	290
6.	1.1.2.3	Fall from height - (de-)installing scaffold	8	24	115
7.	1.1.3.1	Fall from height – roof	73	176	538
8.	1.1.3.2	Fall from height – floor	35	146	539
9.	1.1.3.3	Fall from height – platform	17	83	271
10	1.1.4	Fall from height - hole in the ground	5	33	120
11	1.1.5.1	Fall from height - moveable platform	36	128	251
12	1.1.5.2	Fall from non-moving vehicle	17	110	335
13.	1.1.5.3	Fall from height - working on height unprotected	16	125	470
14	1.2	Fall on same level	5	174	650
15	1.3	Fall down stairs or ramp	9	48	231
16	2	Struck by moving vehicle	81	333	629
17	3.1	Contact with falling object - cranes, part of cranes or crane loads	50	265	254
18	3.2	Contact with falling object - mechanical lifting except cranes	30	224	237
19	3.3	Contact with falling object - transportation vehicles	4	60	91
20	3.4	Contact with falling object - manual handling	7	131	196
21	3.5	Contact with falling object – other	113	539	802
22	4.1	Contact flying object - machine or handheld tool	4	232	129
23	4.2	Contact flying object - object under pressure or tension	8	199	204
24	4.3	Contact flying object - Blown by wind	0	2	11
25	5	Hit by rolling/sliding object or person	5	77	95
26	6.1	Contact with object person is carrying or using - handheld tool	1	25	31
27	6.2	Contact with object person is carrying or using - not handheld tool	2	293	178
28	7	Contact with hand held tools operated by self	1	250	280
29	8.1.1	Contact with moving parts of a machine – operating	25	2619	546

		HAZARDS	Fatalities	Permanent Injuries	Recoverable Injuries
30	8.1.2	Contact with moving parts of a machine – maintaining	18	380	93
31	8.1.3	Contact with moving parts of a machine – clearing	16	648	152
32	8.1.4	Contact with moving parts of a machine – cleaning	13	473	114
33	8.2	Contact with hanging/ swinging objects	19	175	209
34	8.3	Trapped between/against	41	638	293
35	9	Moving into an object	0	148	102
36	10	Buried by bulk mass	2	11	31
37	11	In or on moving vehicle with loss of control	50	233	563
38	12.1	Contact with electricity – wires	6	6	16
39	12.2	Contact with electricity – tools	3	3	34
40	12.3	Contact with electricity - electrical work	16	99	205
41	13	Contact with extreme hot or cold surfaces or open flame	0	14	20
42	14.1	Release of hazardous substance out of open containment	2	71	172
43	14.2	Exposure to hazardous substance without Loss of Containment	3	51	171
44	15.1	Release of a hazardous substance out of closed containment - Adding/removing a substance	2	74	178
45	15.2	Release of a hazardous substance out of a closed containment - Transport of closed containment	0	7	34
46	15.3	Release of a hazardous substance out of a closed containment- Closing a containment	0	10	10
47	15.4	Release of a hazardous substance out of a closed containment	4	46	115
48	17.1	Fire - hot work	3	24	94
49	17.2	Fire - working with or being near flammables/ combustibles	4	28	66
50	17.3	Fire - fire fighting	4	9	47
51	20.1	Victim of human aggression	3	85	54
52	20.2	Victim of animal behaviour	5	19	34
53	22.1	Exposure to hazardous atmosphere in confined space	17	8	65
54	22.2	Exposure to hazardous atmosphere through breathing apparatus	2	0	9
55	23.1	Impact by immersion in liquid - working in, on or under	4	3	5
56	23.2	Impact by immersion in liquid - working nearby	33	0	9
57	25.1	Extreme muscular exertion - handling objects	0	17	29
58	25.2	Extreme muscular exertion - moving around	0	9	37
59	27.1	Physical explosion	7	30	36
60	27.2.1	Chemical explosion - vapour gas	14	69	104
61	27.2.2	Chemical Explosions – dust	1	12	8
62	27.2.3	Chemical Explosions – solids	0	8	0
63	27.2.4	Chemical Explosions – reactions	2	10	22

Table 2 presents the number of accidents across various sectors, which have occurred during 12 years (1998-2010). Most accidents appear in the industry and mining sector, followed by the construction sector, transportation & communication and trade & commerce. The construction sector has the most fatalities followed by industry and mining, transportation and trade and commerce. The same four sectors have the most recoverable and permanent injuries. First in permanent injuries comes industry and mining, while first in recoverable injuries comes the construction sector. Figure 1 presents the percentage of accidents in each sector regarding recoverable, permanent injuries and fatalities. In all sectors fatalities represent a percentage of 0-8% of sector accidents, 0% in case of education and 8% in case of agriculture. Permanent injuries represent 32-53%, 32% for construction sector and 52% for industry and mining. Finally for recoverable injuries the percentage varies between 47-64%, 47% for trade and commerce and 64% for construction.

Table 2. Distribution of accidents in various sectors

	Recoverable Injury	Permanent Injury	Fatality	Total
Construction	3671	1812	252	5735
Industry and mining	3637	4310	201	8148
Agriculture	335	260	52	647
Transport Storage and Telecoms	1120	707	107	1934
Health	246	175	15	436
Financial	193	132	15	340
Hotels	105	108	7	220
Education	169	187	1	357
Trade and commerce	1269	1334	105	2708
Public Administration	390	247	30	667
Other	1430	938	120	2488

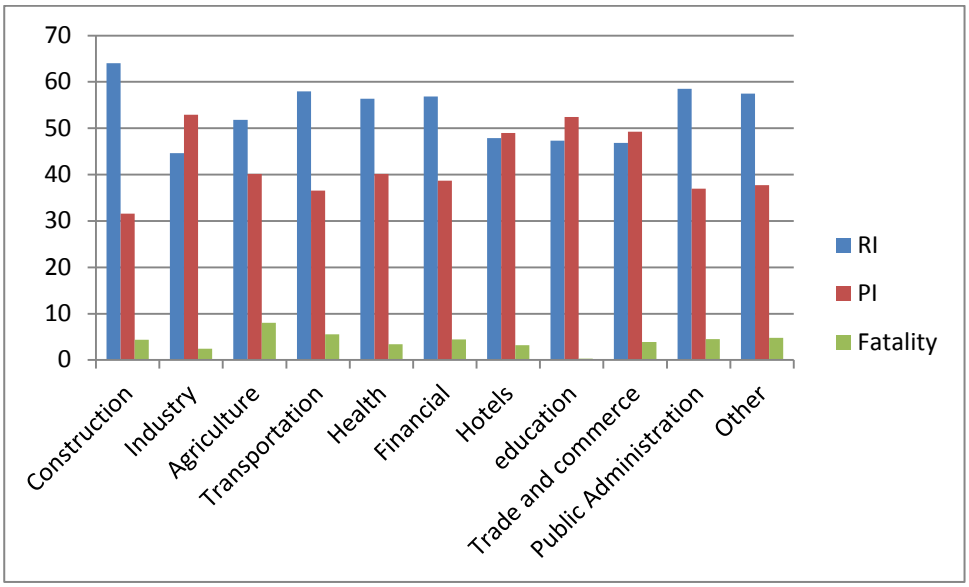

Figure 1. Percentage of accidents resulting in recoverable injury, permanent injury and Fatalities for various sectors

2.3 Exposure to Hazards

Exposure is the time that a worker is at risk of having an accident. The exposure for each of the 63 hazards has been determined by defining the activities/situations – known as *missions* – that can lead to these accidents and then conducting a nationwide survey in the Netherlands to establish the exposure to each mission (expressed as duration in hours). For example for Hazard #11: In or on moving vehicle" the mission is defined as:

"Number of hours workers are in or on moving vehicles such as cars, trucks, buses, military vehicles, forklift trucks, pump trucks, bicycles, lifts, cranes, agricultural and earthmoving machines, vehicles \ on rails (monorails, trains), etc. These are activities that take place on company premises, warehouses, on loading and unloading or for special activities relating to the performance of work on public roads, such as police pursuit cars, and garbage collector behind the garbage truck, etc. are normal road use, e.g. as a driver or passenger riding on public roads is not part of this"

In 2011 at mission survey was carried out by RIGO (2013) among a random sample of 30,000, which is a representative sample of the Dutch working population. For each mission the respondents filled out how many hours they were exposed in the week preceding the survey. Aspects of the population distribution that were considered in this weighting procedure were: industry sector, job type, type of employment, education level, age and gender. Table 3 presents the average working hours to which workers are exposed to each hazard, for some industrial sectors but also totally.

Table 3. Average exposure to each hazard per sector and totally for all sectors ($x10^6$ hours)

	Agriculture &Forestry	Industry& Mining	Construction	Trade&Commerce	Transport Storage &telecomms	TOTAL From all sectors
1.1.1.1	1.26	18.01	43.78	8.27	2.87	95.30
1.1.1.2	0.09	7.87	6.59	1.41	1.50	23.58
1.1.1.3	0.75	18.67	50.06	19.87	1.33	124.08
1.1.2.1	0.00	2.43	11.03	0.49	0.14	16.63
1.1.2.2	1.92	6.16	36.48	0.20	0.00	49.24
1.1.2.3	0.02	2.13	14.89	0.51	0.00	21.47
1.1.3.1	4.94	4.17	16.21	0.49	0.51	30.23
1.1.3.2	0.49	18.15	40.78	9.02	1.77	92.93
1.1.3.3	0.26	29.35	18.37	9.87	6.86	84.74
1.1.4	17.08	44.77	74.31	17.47	7.79	215.39
1.1.5.1	9.06	13.99	15.39	5.31	8.76	62.42
1.1.5.2	2.33	31.80	12.88	29.00	46.66	158.80
1.1.5.3	0.83	15.29	12.89	2.90	5.04	46.03
1.2	101.49	586.31	328.86	741.24	173.70	3,880.71
1.3	3.80	48.58	41.00	33.61	16.27	317.97
2	16.37	121.31	55.87	87.29	75.80	475.03
3.1	6.35	49.83	43.33	3.70	8.86	128.57
3.2	3.68	76.65	31.35	63.88	30.80	243.43
3.3	5.60	45.32	17.03	64.46	19.09	182.46
3.4	11.01	68.98	38.49	100.17	31.62	300.24
3.5	1.05	22.88	24.78	14.74	6.33	87.76
4.1	22.52	224.32	173.36	76.83	11.53	603.05
4.2	8.66	167.74	68.65	49.84	18.28	364.42
4.3	3.32	16.17	53.37	14.95	16.44	146.17
5	4.08	66.58	45.64	63.13	20.98	249.54
6.1	33.96	236.27	207.48	143.44	13.43	846.87
6.2	12.39	91.07	82.72	71.20	24.89	362.57
7	36.56	216.57	209.81	116.73	9.60	776.93
8.1.1	31.33	343.50	137.27	100.47	23.75	791.47
8.1.2	2.51	83.01	16.59	25.23	3.10	155.84
8.1.3	2.91	28.02	7.82	7.55	0.70	55.45
8.1.4	4.33	45.57	13.43	17.03	1.66	114.18
8.2	11.20	11.92	27.53	2.68	7.05	75.43
8.3	6.39	72.60	39.29	33.03	11.87	197.03
9	36.44	277.50	163.32	303.17	84.20	1,567.11
10	14.70	44.01	15.63	3.95	4.39	89.81
11	30.44	76.01	49.54	73.75	135.88	468.31
12.1	0.95	4.36	12.72	0.40	3.12	28.47
12.2	28.42	469.36	214.49	390.32	141.01	3,135.33

12.3	1.72	59.90	38.46	10.86	3.77	154.17
13	1.62	87.80	11.12	39.07	3.28	250.24
14.1	3.21	85.51	7.56	27.10	10.93	277.66
14.2	3.05	117.52	22.61	72.39	17.02	405.15
15.1	0.18	42.94	1.12	4.02	2.28	71.92
15.2	0.17	10.90	0.34	3.25	8.18	31.13
15.3	0.07	7.26	0.26	0.44	0.71	13.22
15.4	1.54	59.59	2.65	15.39	14.88	145.02
17.1	0.28	81.14	19.77	18.78	1.61	217.18
17.2	0.96	106.79	18.51	47.27	16.56	286.59
17.3	0.05	2.41	0.13	1.36	0.03	8.94
20.1	4.80	44.23	21.38	312.31	65.33	1,414.39
20.2	14.53	0.71	1.95	5.56	7.34	62.58
22.1	2.20	35.18	10.87	22.02	10.29	158.79
22.2	0.08	11.21	0.14	4.78	1.00	33.80
23.1	0.09	0.26	0.17	0.00	0.03	9.08
23.2	1.39	6.81	3.34	0.47	0.59	31.78
25.1	17.82	68.10	72.41	73.83	30.27	450.19
25.2	16.86	49.01	52.04	42.63	21.06	328.62
27.1	4.89	117.02	27.00	48.53	17.13	306.14
27.2.1	3.50	112.15	29.85	73.29	13.51	329.59
27.2.2	1.34	51.50	10.35	10.45	11.21	107.59
27.2.3	0.00	6.79	5.27	0.44	1.05	20.57
27.2.4	0.08	45.10	6.02	1.29	1.84	70.21

3. RISK ASSESSMENT FOR VARIOUS SECTORS

Occupational risk rates constitute a quantitative measure for prioritising individual occupational risk. In this section risk results are presented for the average worker, but also for several sectors. Figure 2 presents the average risk over the Dutch population by taking into account the number of injuries and fatalities of the 23997 reported accidents which have occurred in the 12 year period of analysis, presented in Table 1, and the exposure data of the 2011 Survey, presented in Table 3. The riskiest hazards per unit of time regarding recoverable injuries are “working on the roof of a building” and “working on a mobile scaffold” . Regarding permanent injuries the most important hazards are “contact with moving parts of machines while cleaning” and “falling objects in spaces where loads stacked in piles or on shelves are present”. Finally regarding fatalities the most important hazards are “fall from a roof of a building” since a worker may fall from protected or unprotected edges or through existing holes on the roof and “falling objects in spaces where loads stacked in piles or on shelves are present”.

In general working on heights are among the riskier occupational hazards for causing all injuries while handling (lifting) objects, falls on the same level, moving into sharp objects, and human aggression are the least risky.

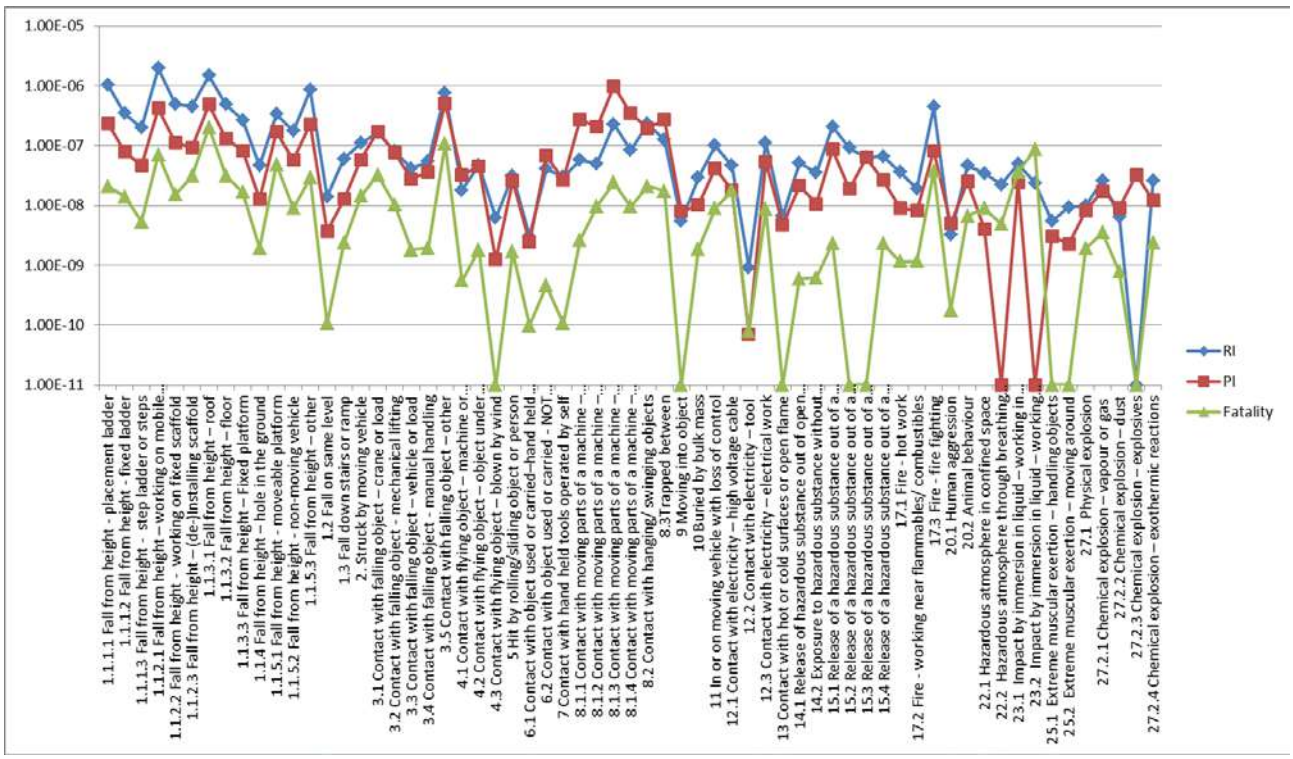

Figure 2. Average risk rates for recoverable, permanent injury and fatality, per hour of exposure

Figure 3 presents recoverable injury risk over the Dutch population for the following sectors: construction, agriculture, industry, transportation & communication and trade & commerce. By comparing risk of specific sectors to average risk it is depicted that for many hazards sector recoverable risk is close to the average. However for some hazards this is not valid, and recoverable risk may be even one order of magnitude greater, as for example for fall from fixed ladders or scaffolds during (de)installation in the agricultural sector. In the transport & communication sector working on a fixed scaffold and fire- fighting has higher risk than average and finally fire- fighting and hazardous atmosphere through breathing apparatus has higher recoverable risk than average, if working in the construction sector. In the trade and commerce sector two hazards have higher recoverable risks than average, which are the following: fall from height while working on roofs and contact with flying object – blown by wind. The highest recoverable risk from all sectors is fall from fixed scaffold while working in the transport, storage and communication sector.

There are also sectors which present considerable lower recoverable risk than the average for specific hazards. For example in the agricultural sector fall from fixed scaffold and fall from hole in the ground have an order of magnitude lower risk than average.

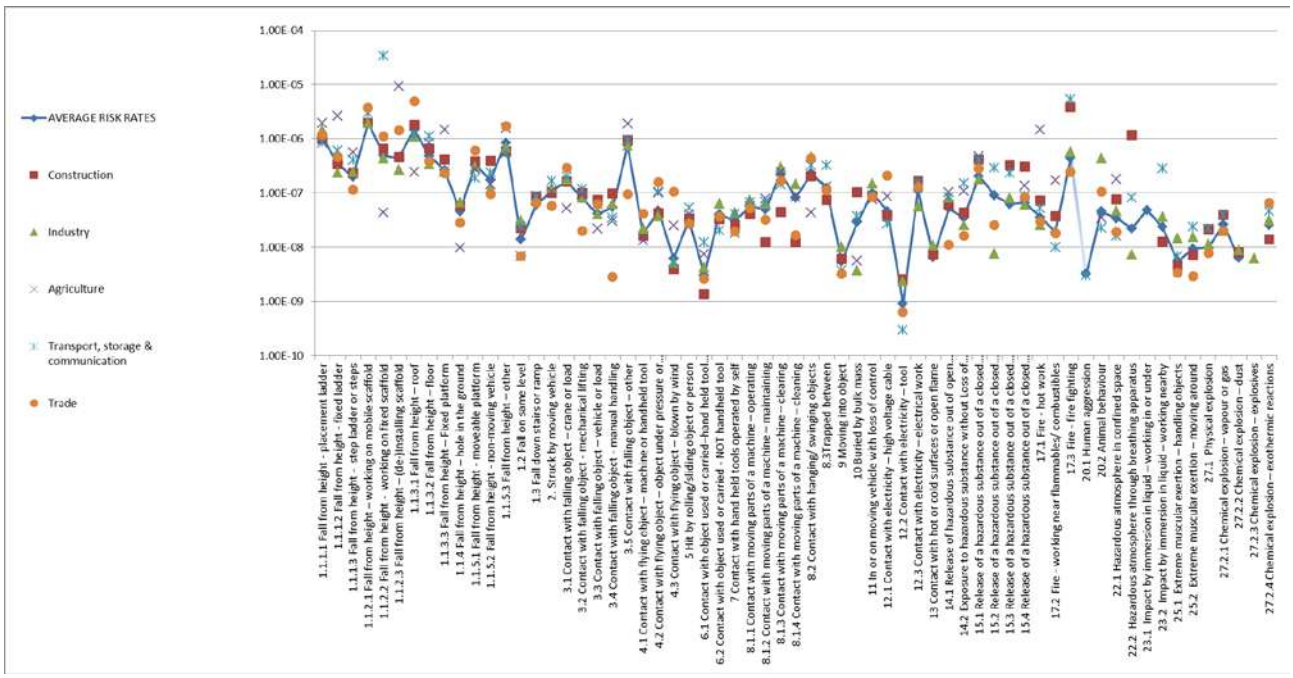

Figure 3. Recoverable injury risk rates for per hour of exposure, for various sectors

Another way to present the same results is to depict recoverable risk of specific hazards across the sectors. Figure 4 presents the variability of recoverable risk for the hazard "fall from height while working on fixed scaffold" for all 5 sectors. Agriculture has the lowest and transport has the highest recoverable risk and the difference is almost three orders of magnitude between workers in these two sectors.

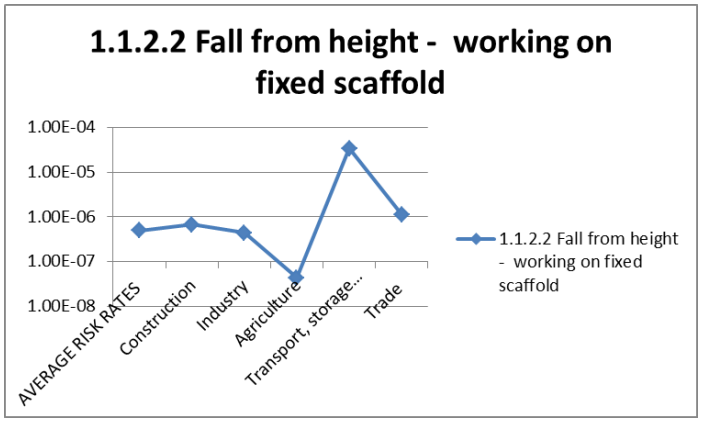

Figure 4. Recoverable injury risk rate (per hour of exposure) for fall from height-working on fixed scaffold

Figure 5 presents permanent injury risk over the Dutch population for the following sectors: construction, agriculture, industry, transport & communication and trade & commerce. It is depicted that for most hazards, such as fall from ladder, fixed platform, moveable platform, struck by vehicle etc., permanent injury risk is close to average permanent injury risk of the Dutch population. However for some hazards this is not valid, as for example for the fall from roof hazard in the trade section. In this case permanent injury risk is one order of magnitude greater than the average.

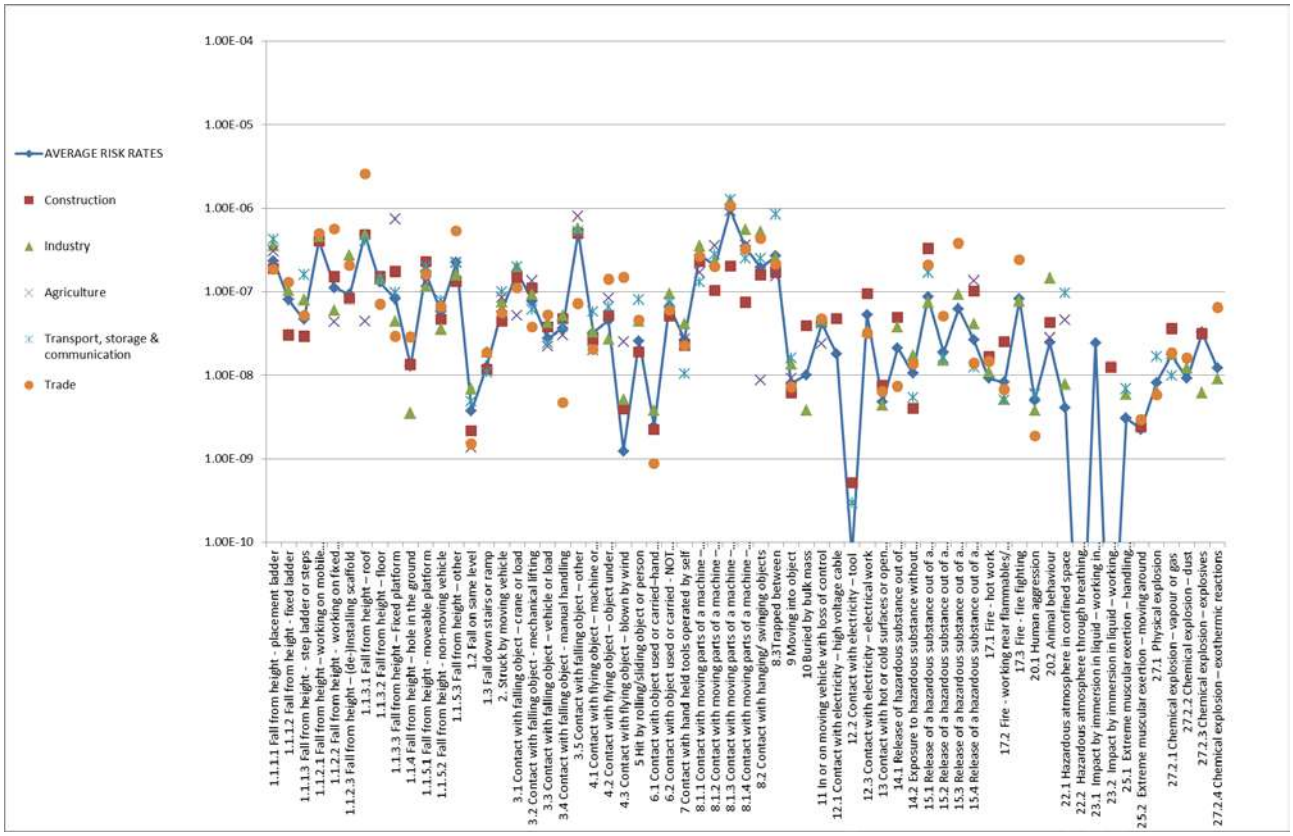

Figure 5. Permanent injury risk rates for per hour of exposure, for various sectors

Figure 6 presents fatality risk over the Dutch population for the sectors analysed. The highest risk appears for the hazards “impact by immersion in water” for the transport & communication sector and for “fall from roof” for the construction sector. Industry and construction have most of their hazard risks near the average values, while agriculture, trade and transport have several risks above average. Agriculture has higher than average risk for falls from ladders, all other falls, contact by falling objects, moving parts of machines, electrical accidents, release of hazardous substance out of open containment, hazardous atmosphere in confined space and Impact by immersion in liquid – working nearby. Trade & commerce has higher than average risk for falls from scaffolds and roofs, contact with flying object – object under pressure or tension and impact by immersion in liquid – working nearby. Transport & communication has higher than average risk for contact with moving parts of a machine – maintaining, contact with hanging/ swinging objects, trapped between, Impact by immersion in liquid – working nearby, physical and chemical explosion of vapour or gas. Considerable fatality risk variability across sectors appears for hazards “fall from roofs”, “contact with falling objects” and “impact by immersion in liquid”.

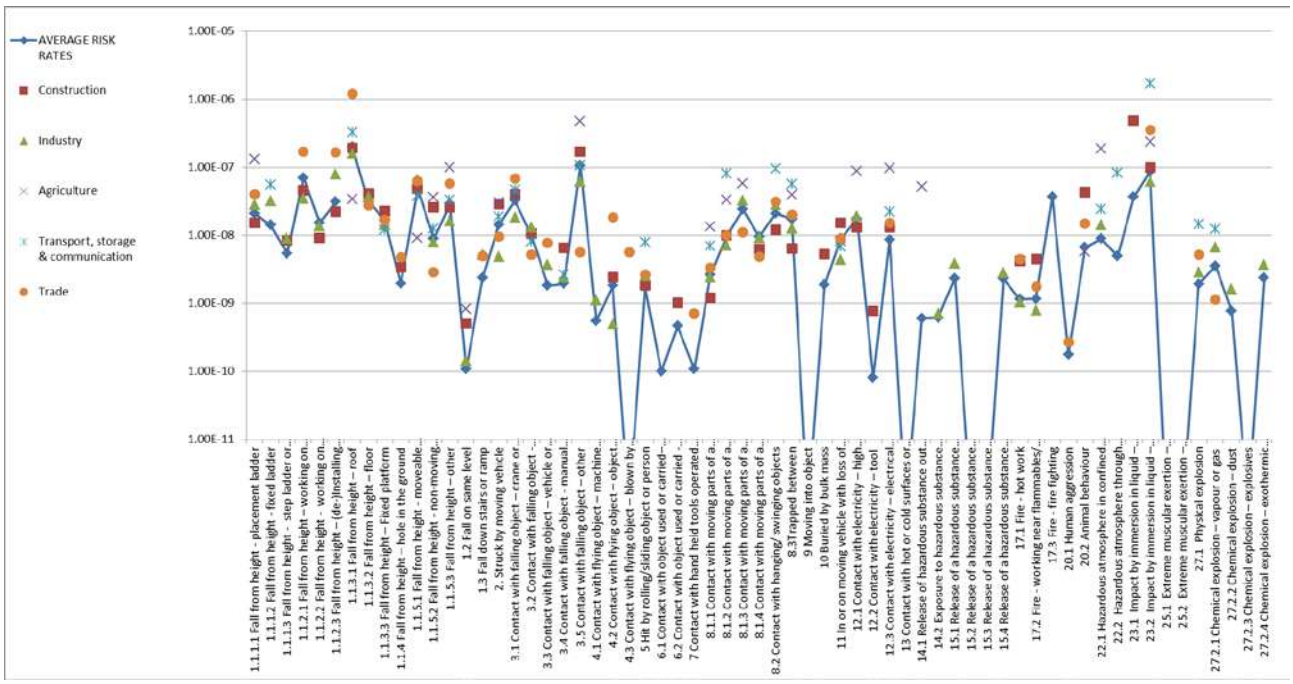

Figure 6. Fatality risk rates for per hour of exposure, for various sectors

4. CONCLUSIONS AND DISCUSSION

In this paper occupational risk quantification has been performed for the average worker, but also for workers in specific sectors such as agriculture and forestry, construction, industry and mining, transportation & communication and trade & commerce. Recoverable, permanent injury and fatality risk have been assessed for all sectors and this estimation permits to classify the most important hazards for each sector.

For *construction* the most important hazards for recoverable injury risk are the following: fire during fire-fighting followed by falls from height (while working on mobile scaffold roof, placement ladder) and contact with all kinds of falling objects. The most important hazards for permanent injury risk, for this sector, are contact with all kinds of falling objects, followed by falls from roofs and scaffolds and release of a hazardous substance out of closed containments. Finally the most important hazards for fatality risk are impact by immersion in liquid, followed by falls from roofs and contact with various falling objects.

For i*ndustry and mining* the most important hazards for recoverable injury risk are the following: falls (from scaffolds, placement ladders, roofs and all other situations), contact with various falling objects and fire during fire- fighting. The most important hazards for permanent injury risk, for this sector, are the following: contact with moving parts of a machine during operating, clearing and cleaning and contact with falling and hanging/ swinging objects and falls (roof, mobile scaffold, placement ladder). Finally the most important hazards for fatality risk are falls from roof, followed by fall from scaffold and moveable platform and contact with various falling objects, and impact by immersion in liquid while working nearby.

For *agriculture* the most important hazards for recoverable injury risk are falls (installing scaffold, fixed ladder, placement ladder) followed by contact with various falling objects and fire during hot work. The most important hazards for permanent injury risk, for this sector are the following: contact with moving parts of a machine during clearing, followed by contact with falling objects and falls from fixed platform. Finally the most important hazards for fatality risk are the following: contact with various falling objects, impact by immersion in liquid, hazardous atmosphere in confined space, falls (placement ladder, other falls).

For *transport &communication* has the most important hazards for recoverable injury risk are the following: falls (working on fixed or mobile scaffold, roof, floor) but also fire during fire -fighting. The most important hazards for permanent injury risk are trapped between objects, contact by various falling objects and falls from placement ladders and roofs. Finally the most important hazards for fatality risk are the following: Impact by immersion in liquid –working nearby, fall from roof, contact with various falling and hanging/swinging objects.

For *trade* & *commerce* the most important hazards for recoverable injury risk are the following: falls from roofs, mobile and fixed scaffolds, (de-)Installing scaffolds and placement ladders. The most important hazards for permanent injury risk are the following: falls (roofs, other, scaffolds) and contact with moving parts of a machine during clearing. Finally, the most important hazard for fatality risk are fall from roofs and impact by immersion in liquid while working nearby.

Even though in all sectors the most risky hazards are falls and falling objects for recoverable injury, falling objects, moving parts of machines and falls for permanent injury and immersion in liquid, falls from roofs and falling objects for fatality risk the priority of hazards is different for each sector and specific important hazards exist for some sectors. For example fire - fighting is a serious hazard for the industry, agriculture and transport, storage and telecoms regarding recoverable injury. Therefore specific measures may be introduced so as to reduce risk in each sector. For example in order to reduce fall from roofs, which is an important hazard for all types of consequences in construction, industry and transport, storage and telecom sections, specific measures which may be introduced are the following: PPEs such as harness belts, guardrails and safety nets, safeguarding of holes and openings, clean and tidy working space, periodic health check-ups, safety training, daily work meetings between all parties to coordinate planned maintenance and toolbox meeting,.

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