Automation and Robotics in Construction XI
D.A. Chamberlain (Editor)
1994 Elsevier Science B.V.

Safety Problems in On-site Construction Work Processes

S. Nishigaki[a] and K. H. Law[b]

[a]Technical Research Institute, Hazama Corporation, 515-1 Nishimukai Karima, Tsukuba, Ibaraki 305, Japan

[a]Department of Civil Engineering, Stanford University, Stanford University, Stanford, CA 94305-4020, USA

Abstract

Although automation/robotization have been and are being implemented in the Japanese construction industry, a combination of human operated and semi- or automated methods are still a common practice and safety in construction sites remains a problem of significant concerns. Of particular concern here is to understand what hazards construction workers are exposed to and how the hazards are inflicted by the workers themselves. A safety survey of workers in a Japanese general constructor was conducted in 1993. This paper reports the partial results derived from the safety survey.

1. Motivation

One of the major goals of automation/robotization in on-site construction works is to avoid, eliminate, or mitigate potential hazards to produce harm or other undesirable events. While automation/robotization have been and are being implemented in the Japanese construction industry, a combination of human operated and semi- or automated methods still exist and safety in construction sites remains a problem of significant concerns. Many work processes (e.g., working on high-rise building, transporting heavy loads) in construction sites are physically dangerous. In 1992, there were 993 fatalities in the Japanese construction industry, a per capita rate 2.38 times greater than that of the Japanese manufacturing industry [1].

Of particular concern here is to understand what hazards construction workers are exposed to and how the hazards are inflicted by the workers themselves. One of the undesired events is hiyari-hat (near-miss) experienced in construction sites. Hiyari-hat is a worker's experience that, luckily, does not result in injury, although under slightly different circumstances, it might have led to a work jury and/or property damage. Workers at construction sites of a Japanese general constructor were surveyed in 1993. The objectives of this questionnaire survey are:

(1) to collect and to analyze the data regarding the incidences of hiyari-hat to identify potential safety problems associated with hardware (e.g., machinery equipment, tools, etc.), software (e.g., standard work procedure, safety regulations, a regime of safety management, etc.) and humanware failures just before the hiyari-hat occur;
(2) to summarize the survey results, present them to the workers and to help them to enhance their ability to
    - anticipate the potential hazards in their workplace;
    - discover the problems that are inflicted by the workers themselves;

(3) to develop a risk diagnosis system to identify potential safety problems in on-site construction work processes and to gauge safety performance on a timely basis before an accident occur [2].

This paper reports the partial results derived from the questionnaire survey conducted in 1993.

2. Survey Results

2.1 Data Collection

One day of July in 1993, a questionnaire was distributed to each of the workers in a Japanese general constructor. They were asked to answer 'yes' or 'no' to questions about unsafe acts and conditions which they experienced on that day and then whether or not they encountered hiyari-hat. 10242 workers responded to the questionnaire. The respondents had an average age of 41 years and an average work experience of 13 years.

2.2 Human Error and Hiyari-Hat

35% of the respondents reported to have experienced hiyari-hats on that day. Table 1 shows the actual reported frequency of hiyari-hat occurrence.

Table 1
The actual reported frequency of hiyari-hat occurrence

Type of Hiyari-Hat	Frequency	Percent
z1 Stumbling or Slipping	1428	14
z2 Backache, sprain or strain	974	10
z3 Person falling	737	7
z4 Struck by falling objects	647	6
z5 Step on sharp objects	629	6
z6 Traffic accidents	548	5
z7 Exposed to electric shock	285	3
z8 Misoperate machinery equipment or tools	377	3
z9 Struck by or against objects	267	3
z10 Caught in or between objects	196	2
z11 Abraded or rubbed	189	2
z12 Collapse (earth fall, etc.)	141	1
z13 Other	317	3

In construction sites of this general constructor, verbal or written instructions of safety work procedures are offered by on-the-spot decision making at crew safety meetings or in planning and allocation daily meetings. One of those instructions is that every worker regardless of their position has to participate to keep the workplace in good housekeeping order. Nonetheless, because insufficient instruction, inadequate plans and workers' negative attitude towards the supervisor, present construction sites are often cluttered with tools, packaging materials and waste materials such as, wood shaving, defective nails and boards. The conditions frequently result in hiyari-hat occurrence associated with stumbling or

slipping and stepping on sharp objects.

It has been predicted that many experienced workers will be retiring in the soon future but very few newcomer will join the construction professional because the dirty, unpleasant and dangerous work environment as perceived by the general public. It has been reported that an average age of construction workers has been and is being advanced in the Japanese construction industry. As mentioned before, the respondents of this survey had an average age of 41 years. Physical problems such as back ailment increase with age.

Many field works (e.g., erection, alternation, or dismantle, etc.) are associated with temporary facilities, machinery equipment and structural steel at high elevated place in construction sites. And also there are many group works which vertically or horizontally cross traffic and transportation of heavy loads. Construction workers are always exposed to danger of falling, being struck by or against objects, or being struck by falling objects in those kinds of works.

The Ministry of Labor in Japan reports of the causes of all the fatalities in the Japanese construction industry as shown in Figure 1 [1]. Person falling, traffic accidents and collapse account for 66.6% of the fatal accidents. It can be seen from Figure 1 that hiyari-hat associated with person falling, traffic accidents, and collapse are very dangerous experiences.

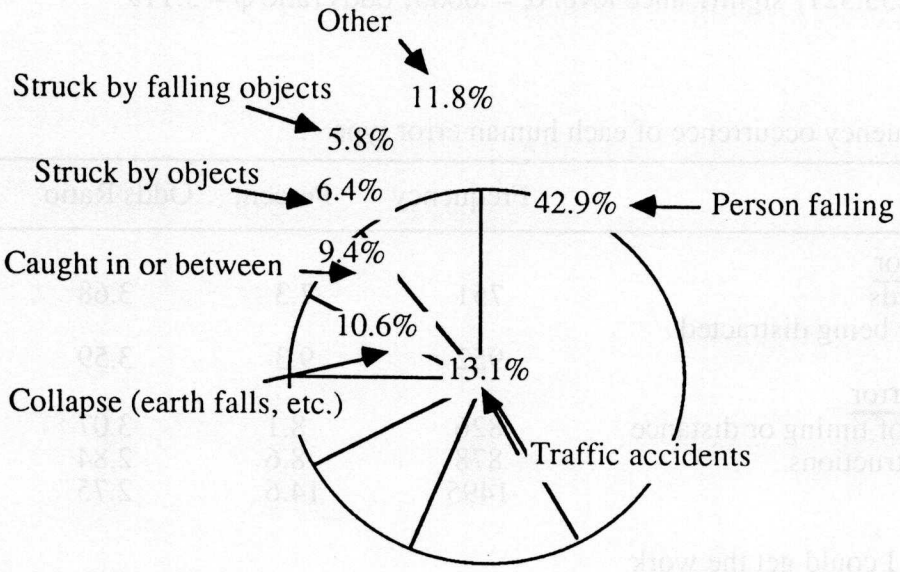

Figure 1. The causes of all the fatalities in 1992 in the Japanese construction industry

Of interest is the relative occurrence of Hiyari-Hat for the two groups, absence and presence of human error shown in Table 2. The odds of hiyari-hat occurrence with the presence of human error is about 3 times greater than that given an absence of human error. Human error is a trigger of hiyari-hat occurrence.

Table 3 shows the actual reported frequency of each type of human errors and each odds ratio of those human errors to hiyari-hat occurrences. Inadequate implementation, jumping to conclusion, and stereotype take-over with misconception frequently occur. The values of the odds ratio in Table 3 tell us that the perception/cognitive errors, say, inattention and distraction, and the action/handling errors related to low achievement motive and willful transgression, which is belonging to categories of humanware failure, are more likely to trigger hiyari-hat.

Table 2
2*2 contingency table of human error and hiyari-hat

Frequecy Percent		Hiyari-Hat		
		not experience	experience	Total
Human Eorr	Absence	6300 66.97	3107 33.03	9407 100
	Presence	329 39.40	506 60.60	835 100
Total		6629 65.06	3613 34.94	10342 100

chi-square statistic χ^2= 255.321; significance level α = .0000; odds ratio φ = 3.119

Table 3
The actual reported frequency occurrence of each human error type

Type of Human Error	Frequency	Percent	Odds Ratio
Perception/cognitive error			
s1 retarded to find hazards	751	7.3	3.68
s2 unware of hazards by being distracted to an foreseen event	952	9.3	3.59
Misjudgment/memory error			
t1 incorrect assessment of timing or distance	826	8.1	3.07
t2 forget the matters/instructions	878	8.6	2.84
t3 jump to conclusion	1495	14.6	2.75
Action/handling error			
t4 dare to work because I could get the work done before	1163	11.4	2.80
u1 omit the current step, being tired of complying with the work procedure	1080	10.5	2.90
u2 lack or improper use of personal protect equipment	771	7.5	2.43
u3 not warn my peers, judging that they knew about the current conditions	1045	10.2	2.89
u4 not inspect it	1107	10.8	2.68
u6 start next step, judging that the current step was finished	1346	13.1	2.44
u7 appropriate action, but inadequate implemented	1549	15.1	3.29
u8 bypass or removal of safety devices	549	5.4	3.41
u9 walking in off limited area	977	9.5	3.02
u10 use of tools for other than their intended purpose	835	8.1	3.12

2.3 Relationships between Hardware and Software Failures and Human Error

Table 4 shows the conditional probabilities of human error occurrence given hardware and software failures.

Table 4
The conditional probabilities of human error occurrence given hardware and software failures.

Human Error	s1	s2	u8	u7	u10	t1	u9	u1	u3	t2	t4	t3	u4	u6	u2
Hardware Failure															
r12 operation at excessive speed	.46	.45	.38	.48	.38	.44	.36	.40	.42	.41	.42	.46	.41	.43	.37
r11 unexpected moved	.45	.45	.38	.49	.38	.44	.36	.40	.41	.41	.43	.47	.41	.42	.38
r10 design lay-out of switch, pushbutton etc. is not good.	.39	.40	.34	.46	.34	.39	.34	.37	.38	.37	.39	.43	.38	.40	.34
Software Failure															
o2 inadequate warning signs regading startup/ shutdown	.33	.36	.28	.41	.30	.33	.30	.33	.34	.33	.35	.40	.33	.37	.29
p1 unlabeled or inadequate labeled material	.33	.34	.27	.41	.29	.32	.30	.32	.32	.32	.34	.39	.33	.36	.28
o5 possible pathway, site work zone, etc. are not clear.	.32	.34	.28	.40	.30	.32	.31	.32	.32	.32	.33	.38	.34	.35	.28
o4 signal words or signs such as caution, warning, and danger are not clear or not posted.	.32	.33	.25	.40	.29	.31	.30	.33	.32	.30	.34	.38	.32	.35	.28

Being difficult in operation of machinery equipment, operation at excessive speed and unexpected movement contrary to the established stereotypes and poor information handling are more likely to provoke the perception/cognitive errors, say, inattention and distraction, and action/handling errors driven from laziness, willful transgression, etc.. Shortcomings in design or plan may cause these failures. To eliminate or to hold human error occurrences to a minimum, fool-proof and fail safe systems should be built in. It is therefore important at the design stage to study misuse of machinery equipment by operator and its unexpected movement while other workers are fastening or loosening loads with their hands, or walking around or through the machinery equipment. The keypoints here are:

- machinery layout, particularly proper working space;
- interlocks protecting workers from the unexpected movement of machinery equipment;
- ease of manipulation in terms of force, precision, and speed;
- not against control movement stereotypes;
- transmission of information from machinery equipment to the operator and other workers.

3. Remarks

It is widely recognized that automation/robotization could improve working conditions, increase productivity, save labor force and reduce occupational accidents in construction sites. Even though it may be true, it may be almost impossible to remove workers from construction work processes because of the expertise, the dexterity and the uniqueness of the job required. As can been seen from the examples in this paper, in somewhat less individual controllable matters, many hardware and software failures, human errors and hiyari-hats are occurring in a mix of human-operated and semi- or automated production systems in construction sites.

The writers have been and are surveying proximate or underlying causes of hiayri-hats. From a questionnaire survey (conducted in 1988) in a Japanese general constructor, we found that the underlying causes of hiyari-hat often include humanware failure and frequently end with human error of individual workers [2-3]. Humanware is defined a function composed of leadership, followership and the reciprocal interaction between the two. Survey results with respect to the relationships between humanware and human error derived from this study will be discussed in a future paper.

Note in particular that most of the effort to date has been focused on the technical aspects of automation/robotization rather than on the human aspects that may be more critical in construction work processes. It is said that productivity is a means to an end, not an end in itself. Safety problems are not distant from oneself, but it is one's own problem.

4. Acknowledgment

This research was partially conducted at the Center for Integrated Facility Engineering, Stanford University while the first author was a visiting research fellow at the center.

5. References

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