

Risk Perception and Risk-Taking Behavior of Construction Site Dumper Drivers

Jonathan Bohm

Health and Safety Executive, UK

Don Harris

Cranfield University, Cranfield, UK

In the UK construction site dumpers cause more serious accidents than any other type of construction plant. Previous research has indicated that driver behavior plays a pivotal role in the vast majority of these accidents. This study used a paired comparison technique to explore dumper drivers' and subject matter experts' (SMEs') risk perception and its relationship to risk-taking behavior. It was found that driver risk perception significantly differed from measures of "objective risk", derived from accident data and also from SMEs' risk perception. Furthermore, drivers still engaged in undertaking perceived high risk behaviors. The results suggest that driver risk perception was linked to the "perceived dread" of an accident, rather than its likelihood and that risk-taking behavior was often driven by situational factors, such as site safety rules or the behavior of other personnel on the site, together with an overarching culture that prioritizes production over safety.

risk perception hazard awareness consruction site dumper construction site safety accidents

1. INTRODUCTION

Construction site dumpers are one of the most common pieces of plant to be found on construction sites; they also have one of the poorest accident records. In the UK they account for a third of construction transport accidents [1] and cause more fatal, major and lost-time accidents than any other type of construction plant [2]. While dumper design has evolved considerably, the basic principle has remained the same. The skip is positioned forward of the driver who does not have the protection of a cab (Figure 1). Dumpers can be articulated or rigid-framed; have two- or four-wheel drive (with either manual, automatic or semiautomatic transmission) and can have front-tipping, side-tipping, swivel or high-lift skips. They can range in size from those with a payload

of under 1 tonne to some which can carry over 10 tonnes.

Driver behavior plays a pivotal role in the vast majority of dumper accidents [3]. The following accidents are typical and illustrate some of the risks: an untrained dumper driver was killed when he was thrown from the dumper after it hit a shallow trench; a dumper driver was killed when a forward-tipping dumper overturned on a slope after reversing; another driver was killed when his dumper ran off the road and overturned in a ditch. It has been suggested that the "misjudgement of risk may cause inappropriate decisions, as well as unsafe behavior and human error" (p. 393); however, it is unclear if such unsafe behaviors are predicated on an ignorance or misunderstanding of the hazards and risks or a willingness to

drive unsafely despite good knowledge and understanding of the risks involved [4].

There is a clear distinction between hazard and risk. Hazard can simply be defined as something with the potential to cause harm. Risk is more problematic. Renn noted that “there is no commonly accepted definition of the term risk, either in science or public understanding” (p. 51) [5]. The International Organization for Standardization (ISO) defines risk as the “combination of the probability of an event and its consequences” (p. 1) [6]. Weyman and Kelly in their wide-ranging review of the literature on risk perception produced a typical definition of risk [7]. They suggest that risk is “founded upon some notion of mathematical probability (likelihood of occurrence), frequently combined with (aspirations towards) some objective measure of severity” (p. 1).

Similarly, there is no commonly accepted definition of risk perception. Several studies have confirmed that likelihood and consequences are dimensions of risk perception, but for most ordinary people severity of outcome is a stronger dimensional factor than probability [8, 9, 10]. Other authors have sounded a note of caution, though [11]. They assert not only is risk perception a poorly specified hypothetical construct but they also suggest that people can be cued into a certain way of thinking and responding about risk in an experimental context. As a result, they can make reasonably accurate risk assessments. However, they contend that such risk judgments have little bearing on the processes of how the same respondents perceive risk (and act) in everyday life.

While sensitive to this issue, an essentially pragmatic position is adopted in this study in that it draws a simple distinction between hazard awareness and risk perception. Hazard awareness simply involves having a knowledge or understanding of hazards; risk perception implies further calculation or consideration of the likelihood and severity of consequences of an accident.

With regard to hazard perception there have been relatively few studies situated in the workplace and many of these have concentrated

exclusively on worker’s knowledge of health hazards. Such studies have explored the knowledge of hazards related to electroplating [10]; perchloroethylene (dry cleaning chemical) and solder flux [12]. All such studies have revealed significant gaps between expert and nonexpert (workers’) understanding. There have also been relatively few studies of risk perception in the workplace. However, these studies have encompassed a wide range of industries, including nuclear [8], offshore oil production [13, 14, 15], farming [16, 17], construction [18], fishing [19, 20], forestry [21] and mining [22].

Risk perception is often compared to “objective risk”. The usual convention for operationalizing objective risk is to use injury or fatality rates derived from accident data [23] although the outputs from quantitative risk assessments have been used where the risks relate to potentially large-scale accidents which occur rarely (e.g., nuclear or offshore oil industries). The greater the degree of congruence between the two, then the more accurate subjective risk perception is held to be. A second common theme is the scaling of worker perceptions of risk on a series of typical workplace hazards.

Many studies observed that workers’ risk perception was significantly different to measures of objective risk. In a study of farmers’ risk perception it was found that they would tend to overestimate some risks (e.g., being injured by animals) but underestimate others (e.g., falling from height) [16]. Similar findings have also been found with regard to the risk of falls from height in the construction industry [18] and in relation to the risks faced by chainsaw operators [23]. By contrast, studies of risk perception in the oil industry have shown that offshore oil workers have a reasonably accurate perception of their occupational risks [14, 15].

With regard to the scaling of risks the simplest option is to ask respondents to rate the level of risk for each hazard on a scale [20]. This approach is intuitive and relatively easy for participants (especially with low numbers of items) but it lacks rigor. A superior alternative is the paired comparison technique (based upon an extended card-sort), which simply requires respondents

to compare each item with every other item until every permutation of paired comparisons has been exhausted. This has well-founded theoretical underpinnings. It is based on Thurstone's law of comparative judgment, which contends that scaled judgments can be made for practically any attribute [24]. The advantages of this technique are that it has intrinsic rigor and it can also provide insights into problems with the scaling of items and/or the judgment of the rater. However, the technique can only be used with relatively small item sets otherwise the number of paired comparisons becomes unmanageable. Both Ostberg in a study of the perceived occupational risks in forestry workers [21] and Weyman and Clarke in a study of miners [22] used this approach. Participants were required to judge a series of paired, carefully selected and industry-specific risk scenarios represented in the form of line drawings plus explanatory text. In both cases a high level of agreement was observed in the risk perception scales derived. Unfortunately, in neither study was the accuracy of the perceived risks compared with an objective measure of the same risks derived from accidents as these data sets were either unsuitable or unreliable.

The relationship between risk perception and risk-taking behavior is not a straightforward one, either. Behaviors known to be risky are still knowingly engaged in by workers. An obvious explanation why workers appear to take risks may simply be that they have poor knowledge of the hazards involved and an inaccurate perception of risk, hence they may not realize that what they are doing is unsafe [4]. However, this offers only a partial explanation since unsafe behavior has often been evidenced even when risk perception has been substantially accurate [25].

Various explanations have been proffered about the disconnect observed between risk perception and risk-taking behavior including value expectancy theory, safety culture research and the behavioral affordance perspective. Value expectancy theory assumes that people estimate the magnitude of the risk involved, weigh up the costs and benefits of various options and then select a course of action that will maximize the expected outcome [26]. This provides an

intuitive and rational explanation for the apparent contradiction in people accurately perceiving risk yet still engaging in risky behavior. It is reasoned that they are behaving on the basis of their estimate of personal risk and not of general risk [9] and that they rate the risk lower for themselves than their peers, a tendency referred to as "comparative optimism" [26]. Expectancy theory has been criticized, though, for overstating the strength of the relationship between attitudes and behavior and for not taking sufficient account of social and cultural factors in the workplace [7]. Safety culture theorists have emphasized the role of factors such as employee motivation; attitudes towards safety, site rules, job satisfaction, priority of production over safety, time pressures, supervisory and managerial control, and board level commitment to health and safety goals [4, 13, 14, 15, 25, 27]. Organizational cultures (and subcultures) can exert a powerful effect on behavior. However, one implication of this finding is that it demotes the role of risk perception and assigns a far stronger role to supraindividual factors likely to influence the expression of unsafe behaviors. Finally, Ayres, Wood, Schmidt and McCarthy [11] and Ayres, Wood, Schmidt, Young, et al. [28] assert that the practical importance of risk perception has been overstated. They distinguish between risk judgments and risk perception and suggest that in experimental studies, people can be cued into providing reasonably accurate risk judgments but "this does not necessarily mean that people perceive risk" (p. 36) [11]. They espouse the view that for commonplace, everyday activities people do not consider the risks per se but rather whether their actions will be successful or "afforded". They are not considering the possibility of harm that is necessarily implied by risk perception.

The aim of this study is to go one step further than the previous studies by Ostberg [21] and Weyman and Clarke [22] and to rank the perceived risk of various scenarios often encountered in the day-to-day operation of dumpers (by both subject matter experts [SMEs] and drivers); investigate how driver risk perception relates to estimates of objective risk (derived from accident data) and to explore the

relationship of self-reported risk-taking behavior with risk perception.

2. METHOD

2.1. Sample

The sample consisted of 40 construction site dumper drivers (39 males and one female), mean age 39 years (*SD* 11.7) with a range of 17–63 years. The drivers' mean experience of driving was 14.6 years (*SD* 10.1) with a range between 2 months and 40 years. All drivers were formally certificated or in the process of being formally certificated as competent to operate a dumper. Twenty percent of the sample had a supervisory level of responsibility.

Seven SMEs also took part. This group comprised an HSE (Health and Safety Executive) specialist inspector and expert on earth moving plant, the managing director and the head of engineering from a small dumper manufacturer, the head of engineering and senior design engineer from the UK's largest manufacturer of dumpers, a senior instructor for construction skills from the National Construction Industry Training Board, the managing director of a regional company providing plant training and an expert witness on dumper accidents. These SMEs were deliberately chosen on the basis that they were all regarded in some capacity as construction site dumper experts who could offer differing perspectives on the operation and hazards and risks associated with the on-site use of dumpers.

2.2. Generation of Dumper Risk Scenarios

Typical risk scenarios associated with the operation of construction site dumpers were generated from a combination of SME interviews, HSE publications [29] and studies of accidents involving dumpers [2, 30]. SMEs were asked to think of typical scenarios covering the full range of risks, from high to low. Initially 16 candidate scenarios were generated; however, to reduce the workload on participants, the number of scenarios was reduced to just seven, thereby requiring 21-paired comparison judgments to be made.

The critical consideration in this process was the need to ensure that the final set of scenarios spanned a broad range of risk. To establish the level of risk in each scenario, the SMEs were asked independently to rate each them on a 1–20 scale (ranging from 1—*lowest risk* to 20—*highest risk*). The experts were told that they should only consider the risk of injury (not damage to plant); it should be assumed that the dumper was used on uneven ground on a busy construction site; the dumper was a typical 6-tonne, forward-tipping frame-steer machine in reasonable working order and equipped with roll-over protection. Finally, scenarios should not relate to a specific manufacturer's make or model.

The selection of the final seven scenarios was an iterative process that took account of the need to ensure a balanced representation of *high*-, *medium*- and *low-risk* situations and that each scenario should be obvious and familiar to all drivers. The scenarios were also required to broadly correspond with existing accident categories used in previous studies of dumper accidents. The final set of risk scenarios was

- driving forward with visibility severely obstructed by load;
- jumping off from the footplate;
- traveling unladen at top speed across uneven ground (seatbelt unsecured);
- driving fully laden in a high gear down a steep gradient (seatbelt secured);
- turning fully laden dumper uphill on a steep gradient (seatbelt unsecured);
- sitting in the seat while being loaded by an excavator;
- after tipping, driving dumper with skip still raised (seatbelt unsecured).

The scenarios were staged and photographed with the help of a national house building company and one of their groundworks subcontractors. An example of the stimulus material is shown in Figure 1.



Figure 1. Example of stimulus material: sitting in the seat while the dumper is being loaded by an excavator.

2.3. Procedure

The data were collected in a series of face-to-face interviews. Participants first undertook a short warm-up exercise to familiarize them with the pairwise comparison process. In this warm-up task they were presented with six pairwise comparisons, comparing four famous footballers. They merely had to state for each comparison (e.g., Pele versus George Best; Paul Gascoigne versus David Beckham) who, in their opinion, who was the better player. This also helped to create a rapport with the interviewee.

The interviewees were then shown the seven dumper risk scenarios and given a few moments to familiarize themselves with the contents of each, before moving onto the paired comparison exercise itself. Each pair of dumper risk scenarios was presented on laminated A4 sheets in landscape format. Order effects were controlled in two ways. Firstly, the sheets were shuffled before each interview to randomize their order. Secondly, the order of appearance of each scenario was alternated such that each scenario would on occasion appear on the left side of the page and at other times on the right.

Participants were directed to identify the higher-risk scenario in each paired comparison. This criterion term was similar to Ostberg's "most risky criterion" [21]. It was judged that the term risk in this study would embrace both lay and professional understandings of the term and would be likely to tacitly and intuitively subsume the dimensions of likelihood/severity and exposure.

This procedure was completed for both construction site dumper drivers and for five SMEs. Near the end of each driver interview all interviewees were shown the seven risk scenarios again and simply asked which of the seven risks (if any) they currently took on construction sites. The interviewees were asked to provide comment on their behavior and factors underlying their risk rankings, as appropriate. These were recorded for later analysis.

Finally, the participants were de-briefed, provided with the contact details of the researcher and formally thanked for their time. Every driver was also provided with a copy of HSE's information sheet on the safe use of site dumpers [1].

2.4. Risk Rankings Derived From Dumper Accident Data

In addition to gathering data on the perceived risk of an accident from both dumper drivers and SMEs, data derived from UK construction site accidents were also used to develop a further measure of what may broadly be termed objective risk in these seven scenarios.

An HSE study of dumper accidents analyzed 136 accidents that took place in 2000–2005 [30]. There were some limitations to this data set as not all incidents are reportable (e.g., overturns which incur no injury) and many incidents go unreported (HSE estimates up to 46%). As a result, there is a likelihood of underestimating some risks. However, as the vast majority of serious accidents are reported the data set was deemed sufficiently reliable and comprehensive to permit an estimate of the rank order of dumper driving risks relating to the seven scenarios studied.

To derive these rankings the percentage of all accidents in the database relating to the seven risk scenarios used in paired comparison exercise was calculated. A simple severity weighting factor based on the known accident history of each scenario was then applied to each scenario (1—*no injury*, 2—*minor injury*, 3—*major injury*, 4—*major injury with disability*, 5—*fatality*). The product of the percentage of all accidents multiplied by the severity weighting was calculated and the relative risk rank order was derived from these data (with higher ranks denoting higher risk).

3. RESULTS

3.1. Treatment of Data

All the participants’ data sets were examined for their within-respondent consistency using Kendall’s coefficient of consistence (*k*). The data sets were also examined for triadic intransitives, which were indicative of inconsistency in the judgments made. Triadic intransitives take the generic form of $A > B > C > A$ [21]. A large number of triadic intransitives may be indicative of a participant failing to exercise

consistent judgment; failing to understand the task requirements or a lack of discriminability between the items being judged (Table 1).

TABLE 1. Kendall’s Coefficient of Consistence (*k*) and Frequency Distribution of Triadic Intransitives for Dumper Drivers

Kendall’s <i>k</i>	No. of Triadic Intransitives	Frequency (<i>n</i> = 40)
1	0	19
.93	1	10
.86	2	1
.71	4	5
.64	5	1
.57	6	2
.50	7	1
.28	10	1

Fewer than half the drivers had perfectly scaled responses with no triadic intransitives. Adopting the same principle used in previous studies [21] interviewees with an unacceptable proportion of intransitive triadic relationships were excluded from the analysis. This required a careful balance between excluding those participants who might significantly distort the data set while at the same time allowing a degree of inconsistency reflecting the true variation in the sample. Four interviewees, who had six or more triadic intransitives, were excluded from further analysis.

The within-respondent consistency of the SMEs was much higher. Four out of the five SMEs had perfectly scaled data. The remaining SME had just one triadic intransitive.

3.2. Results of Risk Rankings Derived From Dumper Accident Data

Table 2 presents these results, which provide accident-derived risk rankings for comparison with perceived risk rankings derived from the drivers and SMEs.

3.3. Scenario Risk Ranking

Figure 2 shows the mean rank order and standard deviation of rank order (a measure of agreement) for the seven risk scenarios rated by the drivers and SMEs.

TABLE 2. Rank Ordering of Risk Scenarios as Derived From Accident Data

Scenario	Overall Accident Percentage (%)	Severity Weighting	Product	Rank
After tipping, driving dumper with skip still raised	0	—	0	1
Jumping off from the footplate	0.7	3	2.1	2
Sitting in the seat while dumper is loaded by an excavator	4.5	5	22.5	3
Driving fully laden in a high gear down a steep gradient with the skip forward; seatbelt secured	8.5	4	34.0	4
Traveling unladen at top speed across uneven ground; seatbelt unsecured	14.0	3	42.0	5=
Driving forward with visibility severely obstructed by load	14.0	3	42.0	5=
Turning fully laden dumper uphill on a steep gradient; seatbelt unsecured	14.7	4	58.8	7

Notes. — a tied rank.

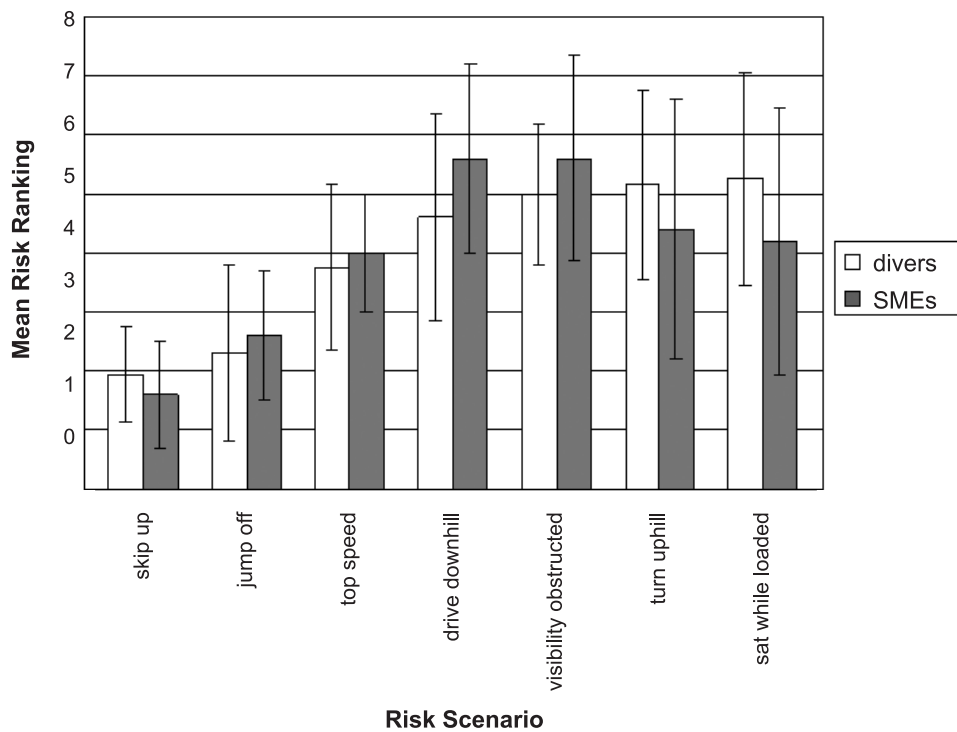


Figure 2. Dumper drivers' ($n = 36$) and subject matter experts' (SMEs) ($n = 5$) mean risk rankings for each scenario. The corresponding standard deviation is shown by the error bar at the top of each column.

Kendall's coefficient of concordance (W) indicated that there was a significant level of agreement over the ordering of the risk scenarios by the drivers ($W = .44$, $p < .001$). A Friedman's nonparametric analysis of variance confirmed there were significant differences in the perceived risk ranking between scenarios ($\chi^2 = 95.99$, $df = 6$, $p < .001$). A series of post hoc Wilcoxon's tests were performed to decompose the result further. To keep the overall type I error rate across the whole analysis to $p < .05$, a Bonferroni adjustment

was used [31], hence the α level for each analysis was set to $p < .002$. Thirteen comparisons between scenarios were significantly different (Table 3).

Figure 2 also shows the mean rank order and standard deviation of rank order for the same risk scenarios as rated by the SMEs. The level of agreement shown by the SMEs was also significant ($W = .472$, $p < .05$). The SMEs exhibited significant differences in their ranking of perceived risk between scenarios ($\chi^2 = 14.17$, $df = 6$, $p < .05$); however, the small sample size

TABLE 3. Post Hoc, Pairwise Analysis of Dumper Drivers' Perceived Risk (Bonferroni corrected α level, $p < .002$)

Scenario	Driving with skip raised after tipping	Jumping off from the footplate	Driving with visibility obstructed by load	Driving fully laden, downhill in a high gear	Traveling at speed across uneven ground	Sitting while dumper is loaded by an excavator
Jumping off from the footplate	ns					
Driving forward with visibility severely obstructed by load	sig.	sig.				
Driving fully laden in a high gear down a steep gradient with the skip forward; seatbelt secured	sig.	sig.	ns			
Traveling unladen at top speed across uneven ground; seatbelt unsecured	sig.	sig.	sig.	ns		
Sitting in the seat while dumper is loaded by an excavator	sig.	sig.	ns	ns	sig.	
Turning fully laden dumper uphill on a steep gradient; seatbelt is unsecured	sig.	sig.	ns	ns	sig.	ns

Notes. sig.— significant.

TABLE 4. Perceived Risk Rankings (From Drivers and SMEs) and Accident-Derived Risk Rankings (7—Highest Risk), and Frequency (and Rank Order) of Corresponding Reported Risk Taking Behavior

Scenario	"Objective" Risk RO	Perceived Risk RO		Reported Risk Taking	
		Drivers	SMEs	Frequency	RO
After tipping, driving dumper with skip still raised	1	1	1	19	1
Jumping off from the footplate	2	2	2	11	3
Sitting in the seat while dumper is loaded by an excavator	3	7	4	12	2
Driving fully laden in a high gear down a steep gradient with the skip forward; seatbelt secured	4	4	6=	0	7
Traveling unladen at top speed across uneven ground; seatbelt unsecured	5=	3	3	6	4
Driving forward with visibility severely obstructed by load	5=	5	6=	5	5
Turning fully laden dumper uphill on a steep gradient; seatbelt unsecured	7	6	5	3	6

Notes. SMEs—subject matter experts, RO—rank order, =— a tied rank.

precluded observing any statistically significant comparisons using further post hoc analyses.

Table 4 contains the rank order data of perceived risk for the seven scenarios for the drivers and SMEs and for the accident-derived estimate of risk. There was no significant correlation between the drivers' and experts' risk perception in terms of their respective rank ordering of the seven risk scenarios (Spearman's $\rho = .667, p > .05$). There was also no significant correlation between either driver risk perception and accident-derived risk rankings ($\rho = .577,$

$p > .05$); or SME risk perception and accident derived risk rankings ($\rho = .664, p > .05$).

The right hand columns in Table 4 also contain the descriptive statistics concerning the number of drivers that reported taking the risks described in the scenarios during their everyday work on construction sites. Again, there was no significant correlation between a driver's risk ranking and the frequency of reported risk-taking behavior ($\rho = .357, p > .05$).

4. DISCUSSION

The pairwise comparison technique was an easy method to elicit perceived risk rankings from both construction site dumper drivers and SMEs. The SMEs were almost perfectly consistent in their judgments. By contrast, just over a quarter of the driver sample exhibited two or more triadic intransitives apiece. This rate was a little higher than that observed by both Ostberg [21] and Weyman and Clarke [22]. This was likely to be attributable to differences in the discriminability of the risk items used, rather than fundamental differences in the way dumper drivers would process risk, compared to miners and forestry workers. Removing those respondents with high rates of triadic intransitives produced a reliable data set upon which to undertake further analyses.

In contrast to intra-rater consistency, only moderate levels of between-respondent consistency were observed for both SMEs and drivers. The levels of between-respondent consistency observed for the drivers were also markedly lower than those observed in previous studies [21, 22]. The results for the SMEs were predictable since they were a heterogeneous group deliberately selected to represent a diversity of knowledge relating to the training, design and operation of construction site dumpers. The drivers' results are understandable when it is considered that in contrast to mining and forestry, the construction industry is far more fragmented, being made up of many small contractors, who are highly mobile and who work on numerous, transient projects. As a result, dumper drivers' exposure to risk information was likely to be haphazard, intermittent and highly variable. In contrast, the mining and forestry industries tend to exhibit greater levels of social cohesion and possess formal, centralized channels of communication which serve to promote greater consistency in the perception of workplace risks.

Table 2 and Figure 2 show that the drivers were able to produce some scale of perceived risk. There was a significant agreement in the drivers' rankings. From the nonparametric ANOVA results (and post hoc tests in Table 3) it can be

seen that this was not a perfect scale; however, the scenarios could be placed into categories of high, medium and low perceived risk. "Sat while loading", "turning uphill" and "visibility obstructed" belonged to the high risk category. "Skip raised" and "jumping off" belonged in the low risk category. The remaining scenarios of "drive downhill" and "travel at top speed" were medium perceived risk. Owing to the small sample size of SMEs it was not possible to produce a parallel risk scale to that of the drivers.

There was no significant correlation between the drivers' and the SMEs' risk perception in terms of their rank ordering of the dumper risk scenarios. An examination of each scenario gives an indication of the reasons underlying this discrepancy.

Driving with the skip raised was rated as the lowest risk by both the SMEs and the drivers. Practically all the drivers assumed that the driver would be bringing the skip down as he reversed, which reflected normal driving practice. Jumping off was the second lowest perceived risk for both groups because it was judged that the worst outcome was likely to be only a broken ankle. This would suggest that, while severity of consequences and likelihood of occurrence constitute two of the main dimensions of risk perception, in common with most people, dumper drivers tended to assign greater weight to the former rather than the latter [6, 7, 8, 9].

Of the medium perceived risk scenarios, traveling unladen at top speed across uneven ground (with their seatbelt off) was regarded by both drivers and SMEs as the third lowest risk. This was rated as a higher risk scenario as it posed a risk both to the driver and to others on the site, in the form of a speeding, possibly driverless, dumper. Driving downhill in a high gear and fully laden (seatbelt on) was ranked the fourth highest risk for drivers but was the top ranked risk for SMEs. Drivers identified two main outcomes of this risk scenario: the dumper could overturn longitudinally (i.e., end over end) in which case the driver would be at risk, or it could run down the slope out of control, posing a risk to others on the site. One explanation for why this scenario was not rated more highly by drivers

could be that they were influenced by the fact that the driver was wearing his seatbelt. However, there was little consensus of opinion from drivers concerning this scenario. Figure 2 shows that this circumstance exhibited the highest standard deviation of mean rank. There was, though, a high level of agreement amongst the SMEs about this scenario being the highest risk. The SMEs' ratings were possibly influenced by a number of factors, including an awareness that drivers have less time to react in a longitudinal overturn than in a lateral overturn; they also had greater knowledge of the possible injuries sustained even when wearing a seatbelt and finally most SMEs knew of instances where the roll-over protection system had failed, killing the driver.

Of the scenarios with high perceived risk, driving forward with visibility obstructed by their load was rated the third highest risk by drivers and the second highest by SMEs. There was general recognition that this scenario presented the greatest risk to other workers on the construction site. There was also some awareness that the drivers could be injured by driving into obstacles or holes that they were unable to see. Turning uphill, fully laden (seatbelt off) was rated as the second highest risk by drivers and the third highest risk by SMEs. Practically all drivers were aware that turning uphill carried the risk of a lateral overturn. SMEs ranked this risk lower than the driving downhill scenario. They may have reasoned that only the driver was likely to be killed or injured in the turn uphill scenario, whereas when driving downhill, there was also an additional risk of other workers being killed by an out-of-control dumper. The scenario with the dumper driver sitting in the seat while the dumper is being loaded by an excavator provoked the greatest disparity between drivers' and SMEs' risk ratings. The drivers rated it as the highest risk but the SMEs just fourth highest. There are several factors which could have contributed to this discrepancy. Drivers had a rational appreciation that, while there was a good chance of survival after an accident in some of the scenarios, if struck by an excavator, their chances of survival would be slight. Secondly, the immediacy-of-effect bias from behavioral

decision theory reflects the tendency to rate the risks of hazards likely to cause immediate harm much more highly than those whose effects are likely to be delayed [32]. This risk scenario also has high "perceived dread" potential [33].

Conversely, the reason why the SMEs rated this risk far lower could be explained by the observation that unlike many of the other scenarios, this posed a risk to just one person (the driver). It is also likely that the SMEs were influenced by knowledge that the frequency for this scenario was very low (i.e., they placed far less emphasis on the perceived dread element when making their ratings).

In common with other studies which have compared perceived risk with "objective" measures of risk derived from accident data [16, 18, 23] this study also found no significant correlation. The risk perception of drivers in this study seems to be aligned with perceived dread rather than risk per se. This is probably as a result of dumper drivers having little conception of the objective frequency of the various types of accident described in the scenarios. Only at the lower end of the risk scale was there any correspondence between the drivers' risk rankings and that derived from the objective, accident-derived rankings. This again would seem to suggest that drivers' risk perceptions were aligned to the fear of injury.

It would be expected that SMEs' risk perception should be more accurate than drivers' for two principal reasons. SMEs' assessments should be more objective and less influenced by the perceived dread of a situation. Furthermore, SMEs are also likely to have a greater factual knowledge of accident frequencies and outcomes. However, the SMEs also exhibited no significant correlation between the perceived risk and the accident-derived objective risk ranking (Table 4). There were some striking inaccuracies evident in the SMEs' assessments. They overstated the risk associated with the "driving down a steep gradient with the skip forward" scenario and understated the risks associated with "traveling at top speed". Why this might be so is open to conjecture. There was no evidence to suggest that SMEs were evaluating the risks subjectively:

most evidence suggests they were primarily basing their evaluations on a rational calculation of how many people might be harmed. The most likely explanation is probably that in the UK there are no openly published statistics of dumper accidents. Therefore, it would be difficult for them to gauge precisely the likelihood of a particular type of accident.

Finally, there was also no significant correlation between the frequency of reported risk taking behavior and drivers' perception of risk. Some perceived low-risk behaviors were frequently reported, e.g., driving with the skip raised was ranked the lowest risk by drivers and had the highest level of reported risk-taking behavior associated with it (Table 4). Two high perceived risk scenarios ("turning uphill" and "driving with visibility obstructed") were associated with a low frequency of risk taking behavior. However, there were some significant disparities. The "sitting while being loaded" scenario was ranked as the highest risk by drivers; however, it also recorded the second highest frequency of risk taking behavior. This implies that risk perception alone is insufficient to explain risk taking behavior.

Sjöberg distinguished between personal and general risk [9]. In the paired comparison exercise, drivers were asked to compare the general level of risk for each scenario, not the level of risk they personally experienced. There was some evidence in the "sat while being loaded" scenario drivers rated the general level of risk as high but their personal risk as low, because of the skill level of the excavator driver. One driver commented:

With *my* excavator driver I sit there. Rightly or wrongly I'm one hundred percent confident in his abilities. We've been working together for years and I trust him totally, you have to. But some drivers, I wouldn't even be stood near it.

However, other reasons for remaining in the dumper were also proffered. Some drivers admitted that following best practice involved too much hassle and they were simply too lazy to get off the dumper each time it was loaded. Others invoked a balance-of-risk justification,

arguing that they were more likely to get injured by repeatedly getting on and off a large dumper. There were also strong situational factors evident. Some drivers reported that they had to sit in the dumper to apply the footbrake because the handbrake was not working properly. Others blamed the excavator drivers: some "load so fast that it is dangerous to try and get out of the seat sometimes".

The reasons for not wearing a seatbelt largely related to issues in practicality and comfort, which overrode considerations related to risk. Under 40% of the driver sample claimed that they would wear the seatbelt volitionally and then, only for certain conditions (e.g., negotiating gradients). Some drivers believed it was more dangerous, overall, to wear the seatbelt (they felt that they stood a better chance jumping off a dumper that was about to overturn than by remaining in it). Most drivers found the seatbelts uncomfortable and of poor design. Usually the only suspension provided to the dumper is the seat itself. Therefore, when going across rough ground, the driver and seat bounce up and down, forcing the driver's stomach against the seatbelt. Furthermore, in some dumper designs the seatbelt is secured directly to the body of the dumper. This is very painful and could "cut your stomach to smithereens". One driver asserted that a seatbelt was superfluous because he did not "drive round like an idiot to warrant wearing it". Other drivers expressed similar sentiments. They also claimed that the seatbelt was too restrictive and hindered them when turning around to reverse. Some drivers kept their seatbelt off so that they could get off more quickly when the dumper was being loaded. Finally, many drivers mentioned that they often could not wear one even if they wanted to because the seatbelts were often broken. It would appear that the safety culture within both the construction companies and across the wider industry (as exemplified in the training of personnel and the maintenance of plant) has a profound influence on these aspects of driver behavior [27].

5. CONCLUSIONS

Two principal findings emerged from the exploration of driver risk perception. Firstly, it was shown that, with some exceptions, drivers' perception of some key risks was relatively inaccurate compared to measures of objective risk derived from accident data. Secondly, the study revealed that dumper drivers and SMEs evaluated risks rather differently. It is suggested that there were fundamental, qualitative differences in the way the two groups processed risk information: drivers assigned primacy to the potential harm that could be done to the driver, whereas SMEs attended to the potential for multiple casualties or fatalities. Driver risk perception was also more emotive than SME risk perception and exhibited a pronounced dread dimension. While this explains why there was disparity between objective risk and drivers' perception of that risk it did not explain the limited correspondence between risk perception and risk-taking behavior. Detailed scrutiny of drivers' comments though revealed that there were strong situational influences on behavior. Of prime importance was the role of the excavator driver who was complicit in either directly or indirectly creating a number of dumper-driver risks. However, it is likely that both dumper and excavator drivers are victims of an overarching culture that appears to implicitly prioritize production over safety.

The results would imply that educational and instructional materials need to be developed to provide construction site dumper drivers with a better informed appreciation of the risks encountered on a construction site. This information can be promulgated via revised information leaflets to dumper operators, such as those produced by the UK Health and Safety Executive [1] or it can be incorporated into industry training courses and training standards. An appreciation of the perspective of construction site dumper drivers by excavator drivers may also be beneficial. Finally, other measures associated with the design of the construction site dumper itself, such as the design of the seatbelt and handbrake may serve to encourage wider compliance with best safety practice.

REFERENCES

1. Health and Safety Executive. Construction site transport safety: safe use of site dumpers (Construction information sheet No. 52, Revision 1). Sudbury, Suffolk, UK: HSE Books; 2006. Retrieved July 27, 2007, from: <http://www.hse.gov.uk/pubns/cis52.pdf>
2. Male GE, Corbridge JS. Safety of construction transport. A survey of standards and accidents associated with construction machinery (Specialist inspector report No. 58). London, UK: Health and Safety Executive; 2001.
3. Bomel Ltd. The development of an evidence base to reduce the risk of workplace transport accidents (Contract research report). London, UK: Health and Safety Executive; 2004.
4. Rundmo T. Employee images of risk. *J Risk Res.* 2001;4:393–404.
5. Renn O. The role of risk perception for risk management. *Reliab Eng Syst Safety.* 1998;59:49–62.
6. International Organization for Standardization (ISO). Risk management—vocabulary—guidelines for use in standards (ISO/IEC Guide No. 73:2002). Geneva, Switzerland: ISO; 2002.
7. Weyman AK, Kelly CJ. Risk perception and risk communication: a review of the literature (Contract research report No. 248/1999). Buxton, UK: Health and Safety Laboratory; 1999. Retrieved November 3, 2009, from: http://www.hse.gov.uk/research/crr_pdf/1999/crr99248.pdf
8. Sjöberg L, Drottz-Sjöberg B-M. Knowledge and risk perception among nuclear power plant employees. *Risk Anal.* 1991;11: 607–18.
9. Sjöberg L. Factors in risk perception. *Risk Anal.* 2000;20:1–11.
10. Petts JP, McAlpine S, Homan J, Sadhra S, Pattison H, MacRae S. Development of a methodology to design and evaluate effective risk messages (Contract research report No. 400). London, UK: Health and Safety Executive; 2002.
11. Ayres TJ, Wood CT, Schmidt RA, McCarthy RL. Risk perception and

- behavioral choice. *Int J Cog Erg.* 1998; 2:35–52.
12. Cox P, Niewohner J, Pidgeon N, Gerrard S, Fischhoff B, Riley D. The use of mental models in chemical risk protection: developing a generic workplace methodology. *Risk Anal.* 2003;23:311–24.
 13. Rundmo T. Perceived risk, safety status, and job stress among injured and noninjured employees on offshore petroleum installations. *J Safety Res.* 1995;26:87–97.
 14. Flin R, Mearns K, Gordon R, Fleming M. Risk perception by offshore workers on UK oil and gas platforms. *Saf Sci.* 1996; 22:131–45.
 15. Mearns K, Flin R. Risk perception and attitudes to safety by personnel in the offshore oil and gas industry: A review. *J Loss Prev Process Indust.* 1995;8:299–305.
 16. Knowles DJ. Risk perception leading to risk taking behaviour amongst farmers in England and Wales (Contract research report 404/2002). London, UK: Health and Safety Executive; 2002. Retrieved November 3, 2009, from: http://www.hse.gov.uk/research/crr_pdf/2002/crr02404.pdf
 17. Stave C, Pousette A, Torner M. A model of the relations between risk perception and self-reported safety activity. *Occup Ergon.* 2006;6:35–45
 18. Zimolong B. Hazard perception and risk estimation in accident causation. In: Eberts RE, Eberts CG, editors. *Trends in ergonomics/human factors II*. Amsterdam, The Netherlands: Elsevier Science; 1985. p. 463–470.
 19. Torner M, Eklof M. Risk perception among fishermen and control of risks through participatory analysis of accidents and incidents. In: Lincoln JM, Hudson DS, Conway GA, Pescatore R, editors. *Proceedings of the International Fishing Industry Safety and Health Conference*. Cincinnati, OH, USA: National Institute for Occupational Safety and Health; 2002. p. 237–41.
 20. Pollnac RB, Poggie JJ, Cabral SL. Thresholds of danger: perceived risk in a New England fishery. *Hum Organ.* 1998; 57:53–9.
 21. Ostberg O. Risk perceptions and work behavior in forestry: implications for accident prevention policy. *Acc Anal Prev.* 1980;12:189–200.
 22. Weyman AK, Clarke DD. Investigating the influence of organisational role on perceptions of risk in deep coal mines. *J Appl Psychol.* 2003;88:404–12.
 23. Dunn JG.. Subjective and objective risk distribution. *Occ Psychol.* 1972;46:183–7.
 24. Thurstone LL. A law of comparative judgment. *Psychol Rev.* 1927;34:273–86.
 25. Flin R, Mearns K, O'Connor P, Bryden R. Measuring safety climate: identifying the common features. *Saf Sci.* 2000;34:177–92.
 26. Weinstein ND. The precaution adoption process. *Health Psychol.* 1998;7:355–86.
 27. Macdonald G. Risk perception. *Civil Engineering.* 2006; 159:51–6.
 28. Ayres T, Wood C, Schmidt R, Young D, Murray J. Affordance perception and safety intervention. In: *Proceedings of the IEA 2000/HFES 2000 Congress*, San Diego, California, USA. Santa Monica, CA, USA: Human Factors and Ergonomic Society; 2000. vol. 6, p. 51–4.
 29. Health and Safety Executive. The safe use of vehicles on construction sites: a guide for clients, designers, contractors, managers and workers involved with construction transport. sites (Health and Safety Guidance No. 144). Sudbury, Suffolk, UK: HSE Books; 2009.
 30. Moutrie J. Safety of construction vehicles: a survey of accidents involving site dumpers. Issue 2 (internal report for Health and Safety Executive) [unpublished document]; 2005.
 31. Sankoh AJ, Huque, MF, Dubey SD. Some comments on frequently used multiple endpoint adjustments methods in clinical trials. *Stat Med.* 1997;16:2529–42.
 32. Tversky A, Kahneman D. Judgment under uncertainty: heuristics and biases. *Science.* 1974;185:1127–31.
 33. Slovic P. The risk game. *J Hazard Mater.* 2001;86:17–24.