Built Environment Project and Asset Management

Machinery transportation management: case study of “plant-trailer” H&S incidents

Gary D. Holt David J. Edwards

Article information:

To cite this document:
Gary D. Holt David J. Edwards , (2014),"Machinery transportation management: case study of “plant-trailer” H&S incidents", Built Environment Project and Asset Management, Vol. 4 Iss 3 pp. 264 - 280
Permanent link to this document:
http://dx.doi.org/10.1108/BEPAM-01-2014-0001

Machinery transportation management: case study of "plant-trailer" H&S incidents

Gary D. Holt
Birmingham City Business School, Birmingham, UK and University of Central Lancashire, Preston, UK, and
David J. Edwards
Birmingham City Business School, Birmingham, UK

Abstract

Purpose – The purpose of this paper is to investigate causal agents of health and safety (H&S) incidents among "plant-trailers" (as used by construction and utility contractors to transport mechanical machinery); including the relationship(s) of such incidents to routine safety inspections and, plant maintenance functions.

Design/methodology/approach – H&S plant-trailer incident data, from a collaborating UK-based case study utility company are analysed using inductive, interpretative and descriptive statistical methods.

Findings – Principal incident occurrences relate to trailer wheels, wheel bearings, tyres and braking systems. All forms of incidents observed harbour significant risk and especially, if they occur during travel on public highways. Derived recommendations for incident mitigation and control, suggest a requirement for improved human behaviour, machinery inspection regimes and maintenance systems.

Research limitations/implications – The findings will be valuable to academia as a basis for advancing this new research subject, both empirically and internationally. Direction is offered in this respect.

Practical implications – Recommendations will be of practical relevance to machinery management practitioners generally and to plant-trailer stakeholders more specifically. For the latter, the study encourages introspective consideration of plant-trailer H&S systems.

Originality/value – No previous research has targeted these issues relating to plant-trailers.

Keywords Risk, Inspection, Maintenance, Machinery, H&S, Trailers

Paper type Case study

Introduction

Construction relies extensively on mechanical machinery (also known as "plant") to maximise output and productivity (Holt and Edwards, 2013). Typical plant items include concrete mixers, excavators, dump trucks and lifting equipment (Meyer, 2006; Construction Labour Solutions, 2013). These kinds of mechanical work equipment present myriad health and safety (H&S) hazards (Health and Safety Executive, 2012) and the most serious of these include, "Getting hit by, run over, or entangled in machinery [...]" (the European Agency for Safety and Health at Work, 2013). Intuitively, this is because the risks associated with such hazards can lead to severe injury or death. Accordingly, much research has addressed workplace plant H&S risks, from various (e.g. risk removal/mitigation) standpoints. For instance, relating to slips and falls from transport (Holt and Edwards, 2011); H&S management systems (Riaz *et al.*, 2011); safe use of tower cranes (Shapira *et al.*, 2012); mini-excavator instability (Edwards and Holt, 2011);

The authors thank the collaborating company, without whom, the study would not have been possible.

Built Environment Project and Asset Management
Vol. 4 No. 3, 2014
pp. 264-280
© Emerald Group Publishing Limited
2044-124X
DOI 10.1108/BEPAM-01-2014-0001

types of injury relating to mechanical work (Fredericks *et al.*, 2002); and safe use of excavators for object handling (Holt and Edwards, 2012).

A particular plant item commonplace within the construction and utility sectors is the "lightweight" trailer – generally referred to in the workplace as a "plant-trailer" (hence, this description is used hereafter for consistency). There are various types (e.g. single or double axle) and configurations of plant-trailer available and often, these are used to transport smaller plant items such as mini-excavators or pedestrian compaction rollers[1]. A typical plant-trailer loaded with a mini-excavator in its towing configuration, is shown in Plate 1. The popularity of these trailers stems mainly from the fact that (within the UK), they can be towed behind a lorry or commercial vehicle on a "standard" driving licence and therefore, help contractors save costs that would otherwise be incurred using larger, or specialist transportation equipment such as a "low-loader"[2].

Notwithstanding said previous plant research, none of this has studied the H&S risks that plant-trailers can present. Hence, the present study's aims are to: first, address this void in extant knowledge by examining in-house company plant-trailer H&S incident data; second, conceptualise the main aspects of these (and potential) H&S incidents; and accordingly, third, offer outline guidance for plant-trailer H&S management and other stakeholders. The latter includes associated functions such as, worker competence and habits, safety inspection regimes, and maintenance. Given the newness of this research area, the study is by design exploratory and inductive. So albeit results are entirely novel, in terms of generalisability, they should be viewed in this exploratory context. The study concludes with suggestion for taking the research subject forward – both empirically, and internationally.

Source: © Authors, reproduced with permission

Plate 1.
Typical plant-trailer configuration (twin axle)

Background and context

The types of plant H&S hazards introduced earlier, were broad in description and accordingly, comprise numerous "sub-hazards" of their own. "Getting hit by (plant)" for instance, might involve: a travelling self-propelled machine; the moving part of a stationary machine, such as the excavating arm of an excavator[3] (Electronic Library of Construction Occupational Safety and Health, 2013); or from more extreme events, such as a machine overturning (Edwards and Holt, 2010). Hence, the extent and nature of hazards associated with each class or type of plant can also be extensive; as confirmed for instance, by those listed for earth moving machinery in the relevant British Standard (BSI, 2006) (see Table I).

A working hypothesis for this study (underpinned by anecdotal evidence accrued by the researchers through their network of plant professionals), was that plant-trailers present a unique set of hazards which frequently recur in practice. This hypothesis served as a catalyst for the research and accordingly, an inductive study was designed to focus on a collaborating organisation's fleet of (part owned, mainly hired) plant-trailers. The organisation is a large – as defined by number of employees in The Companies Act (2006) – British contractor operating internationally in the construction and utility sectors.

The anecdotal evidence referred to, suggested that most incidents involved unintentional trailer wheel stud or nut loosening (studs are threaded and secure a wheel through a series of holes in the wheel by tightening into a series of threaded holes in an axle; whereas a nut contains a threaded hole and secures a wheel by tightening onto a series of threaded studs protruding from the axle. The term stud is used hereafter, to represent both of these securing options for brevity). The loosening of a stud(s) can lead to unintentional wheel loosening. In turn, a loose wheel can (for instance) wobble and affect vehicle handling or make contact with adjacent trailer components (e.g. mudguards, brakes, bearings); which may also produce secondary damage (and concomitant additional hazards). In extreme cases, loose studs become detached altogether and lead to wheel loss, with potentially, much greater hazards indeed.

These issues and especially wheel loss, though not widely reported in the literature regarding plant-trailers are well recognised in relation to commercial vehicles (Freight Transport Association, 2009). The problem has been described as a risk so significant, that the road safety organisation Brake (2013) described loose wheels as "bouncing

Generic hazards[a]	Specific examples[a]
Mechanical	Cutting, shearing, trapping, impact, stabbing, friction
Electrical	Direct contact, electrostatic phenomena, thermal radiation
Thermal	Burns, scalds, extreme temperatures, explosion, heat radiation
Noise	Hearing loss, physiological risks, interference with communication[b]
Vibration	Whole body vibration, posture related exacerbation
Substances	Contact with or inhalation of harmful fluids, fire, explosion
Unexpected events	Unexpected start-up, control(s) failure, software errors, human error
Travelling	Unintentional movement, excessive oscillation, lack of control ability
Work position	Risk of falls, exhaust gases/lack of oxygen, emergency evacuation
Power source	Hazards from engine and electrical systems

Notes: [a]Paraphrased from the standard, lists not exhaustive; [b]this can induce a new set of hazards in itself
Source: BSI (2006)

Table I.
Example of significant hazards per class of plant (earth moving machinery)

bombs". Knight *et al.* (2006) in a report produced by the UK Transport Research Laboratory (2013) provided some estimates of the frequency of commercial wheel fixing problems in the UK (with corresponding sources in parentheses) as follows: 7,990 incidences of wheel studs becoming loose or missing (WSLM), leading to 175 wheel detachments (DETR, 1998); 3,888 incidences of WSLM leading to 254 detachments[4]; 8,250 incidences of WSLM leading to 224 detachments (from data on the Vehicle Operator and Services Agency prohibition database for the period 2002-2005) (see Knight *et al.*, 2006, p. 7); and 368 wheel detachments leading to 140 damage-only collisions and 16 injury accidents (DETR, 1998).

Hence, the risk of wheel loss applies equally to plant-trailers and in some ways, may be more commonplace than hypothesised at the outset. This is because: first, plant-trailers are often hired and used by a transient workforce, which could engender a "lack of ownership" and concomitant due care in their use (see later); second, given minimal extant literature regarding said risks, there may exist lack of awareness or competence in this respect among workers that use plant-trailers; and third, it is generally accepted that a degree of apathy exists among the "construction" workforce regarding H&S matters generally. The latter has been attributed (*inter-alia*) to: reluctance to embrace H&S, because it seen as having to do "something extra" for no extra pay (HSE, 2002); apathy or lack of commitment (Musonda and Haupt, 2011); and (financial) disincentives for reporting or otherwise acting on unsafe work practices (Lunt *et al.*, 2008). The latter will become quite apparent in this study.

Methodology

The literature review was followed by qualitative (e.g. narrative) and quantitative (e.g. content) analysis, of data supplied by the collaborating organisation, that comprised internal and external H&S trailer documentation. This (inductive) method is intrinsic to interpretative document analysis tradition; being concerned with perceptions of reality that may be embodied within such data (Drew *et al.*, 2006, p. 67). A unique feature of document analysis is that data were originally recorded without the researcher's intervention (Bowen, 2009) and so intuitively, optimally represent reality. The method has been employed considerably among numerous research fields. See for instance, Bencich *et al.* (2002) (dissertation research); Smyth (2006) (historical studies); and Richardson (2011) (technology).

Those qualitative data analysed here, mainly represented accounts of incidents in the form of "near miss" reports (see Wu *et al.*, 2010); actual H&S incident reports; and in some cases incident follow-up reports. (A near miss in this context is a dangerous occurrence with the potential to cause harm that did not transpire into an H&S incident (HSE, 2012, 2013).) All data related to incidents occurring in the organisation between 2005 and 2011 and the descriptive aspects of these data, were abstracted to form a single narrative for content analysis purposes. In so doing, some words were "standardised" to achieve analytical consistency. These were: "mini digger" and "mini excavator" (transposed to "mini-excavator"); "near side" (transposed to "nearside"); off side (transposed to "offside"); and driver's side (transposed to "offside"). Nearside is the side of a vehicle nearest the kerb line and in the UK this is on the driver's left-hand side of a vehicle (hence, offside is the right-hand side).

Data were analysed both manually (Saldańa (2013) provides a useful treatise on manual methods) and using a word frequency content analysis technique within N-Vivo qualitative data analysis software (QSR, 2013). Prior to presenting these analyses (and discussion of their findings) in the following section, Figure 1 shows key incident

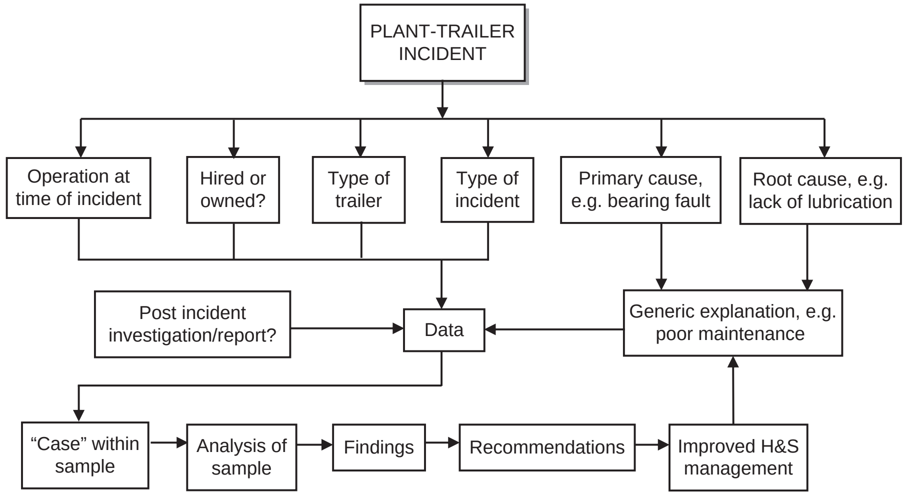


Figure 1.
Relationships among data and methodology

interrelationships and definitions used. That is, each incident was evaluated in terms of: type of trailer (short description); source (hired or owned); type of work being undertaken at time of incident (e.g. towing on public highway); type of incident (e.g. wheel became loose); whether a post-incident report was available (yes/no); and what were considered (explicit within the data) as primary, incident root causes. The figure also highlights the relationship of how analysis fed into development of outline recommendations, to inform plant-trailer H&S management.

Analysis and discussion

Given the varied nature of those data analysed, numerous tabular and graphical summaries were produced *en-route*, so it was decided to discuss these *en-route* also, in order that a conceptualisation of the issues could be iteratively developed as analysis progressed. Accordingly, "analyses and discussion" are presented together in the following, rather than under separate headings.

Initial observations

Initial data overview was undertaken using cloud analysis (Figure 2). This technique (see e.g. Cosh *et al.*, 2008) helps identify initial themes, analyse the most frequently

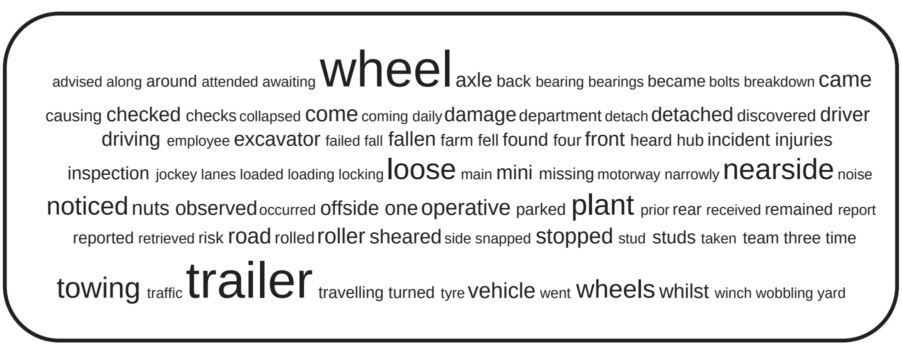


Figure 2.
Initial analysis: tag cloud

occurring words among a narrative, and suggest thematic concepts (QSR, 2013). Figure 2 therefore, indicates that trailer wheels are the focus of the data and, that "towing", "nearside", "plant" and "loose" were the next most frequent words. In turn, these might be interpreted (here to develop specific research questions) as follows:

H1. Towing – did most incidents occur when trailers were being towed?

H2. Nearside – were most incidents associated with the trailer nearside and given that this side of the trailer is nearest the kerb line when being towed in the UK, is a root cause of incidents wheel contact with the kerb?

H3. Loose – do incidents within the data suggest wheel studs becoming loose is a primary issue?

Numerical analysis of narrative data based on word counts and their (individual and cumulative) percentages of the total narrative, confirmed that "trailer + wheel + nearside" cumulatively accounted for almost one-fifth (18.2 per cent) of all words. This reinforced indications of the tag cloud and perhaps suggested that driver-induced problems and/or the relevance of the wheel position or direction to the kerb/road camber may be important. The second numerical indication was a linkage between "towing + plant + noticed + loose + wheels + road" − which combined with the former three words, cumulatively accounted for 30 per cent of the narrative. This suggested that incidents probably involved drivers noticing a loose wheel, while towing a plant-trailer on the public highway.

Incidents in relation to time

The sample data represented a total of 42 incidents, spread with increasing frequency along a timeframe spanning 2005-2012 inclusive and distributed as shown in Table II. The first half of the time frame provided just under one quarter of all data (nine cases); while the three year period 2009-11 inclusive provided the most data (29 cases or 68 per cent). Most incidents recorded in any one year (12 no.) were in 2011. If sample data are "complete" in terms of representing all incidents in the sample period, then the trend suggests a worsening H&S situation over time (2012 data were incomplete). However, this observation may be a "false positive" depending on other circumstances – for instance, if the trailer fleet had grown in number or incident reporting had increased over the same time frame. Alternatively, if data were collected without design criteria

Year	Period	No. cases	Percentage (rounded)	Cumulative (%)
2005	April	1	2	2
2006	May-July	2	5	7
2007	February-September	2	5	12
2008	May-December	4	10	22
2009	January-December	8	19	41
2010	January-October	9	21	62
2011	February-October	12	28	90
2012	March-June	4	10	100
	Totals	42	100	

Table II. Distribution of incidents over the period (2005-2012) (as suspected because formalisation of the problem occurred quite recently in the organisation) then less can be reliably inferred from the observed trend.

Incidents in relation to trailer types

Types of trailers involved in the incidents are listed in Table III. Most incidents were "unspecified" so it is impossible to interpret this observation further. Roller trailers were involved in approximately one-quarter of all incidents, followed by compact excavator trailers at just under one-fifth. This distribution would need to be contrasted against the company's entire trailer fleet to be more meaningfully interpreted, taking into account significant impacts such as fleet changes (e.g. size, portfolio) over time. Unfortunately, data were not available to facilitate this. Hence, incidents are analysed further in Figure 3 which shows the distributions of incident types during the first and

Table III. Distribution of trailer types: all incidents

Type reported	No. cases	Percentage (rounded)
Unspecified	12	29
Roller trailer	11	26
Compact excavator trailer	7	17
Pipe trailer	3	7
Muck trailer	2	5
Traffic light trailer	2	5
Winch trailer	2	5
Coil trailer	1	2
Twin axle unspecified	1	2
3 Tonne unspecified	1	2
Totals	42	100

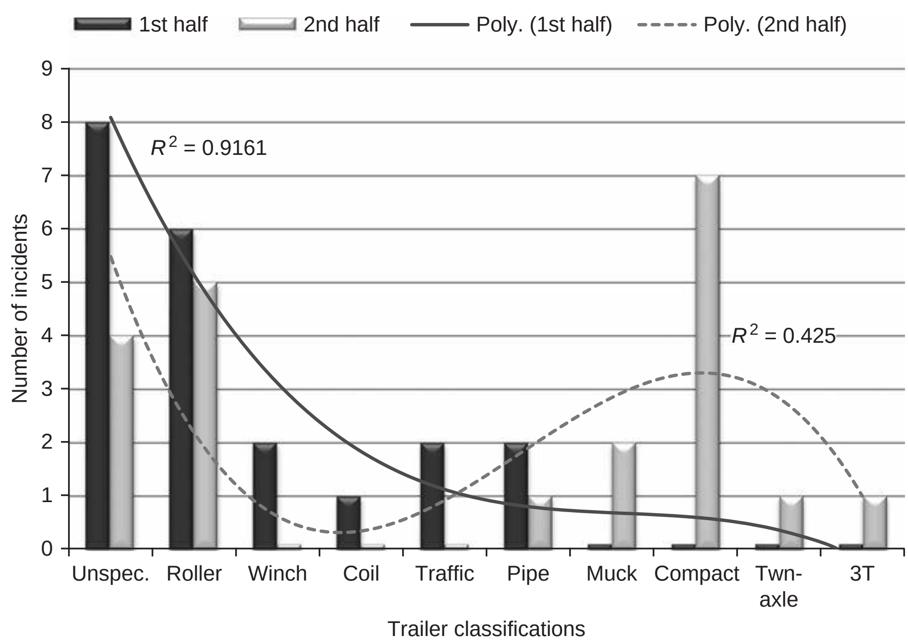


Figure 3. Incidents per halves of chronological data set

second "time halves" of the data set. Time halves were defined by listing all 42 incidents chronologically and dividing this into two equal sub-samples ($n=21$). This method of sub-sample composition was employed because of time-skewness among data (refer Table II). That is, if data were delineated by equal first- and second-half time periods, the 2009-2012 sub-sample ($n=33$) was biased, because there were many fewer incidents ($n=9$) reported during 2005-2008.

Greater frequency of incidents in the second-half period (Figure 3) suggests either a declining H&S situation (but this needs to be reconciled with any growth in fleet size to assess a worsening or improving situation); and/or more rigid incident reporting. Possibly linked to the last proposition, it is noted that the unspecified group declined in number; which too could mirror more accurate reporting procedures (of late). Incidents among classifications increased in the latter period for: muck trailer, compact excavator trailer, twin axle trailer and 3T trailer; simply because no incidents for these machinery types were reported in the first period. The most marked increase was for compact excavator trailers, perhaps being synonymous with increased usage of compact excavators (especially on utility works) since mid-1990 (Holt and Edwards, 2012). Order three polynomial trend lines[5] show a first period downward trend; and a spike from said excavator trailer incidents (causing the low R^2 value $= 0.42$) in the second period.

Incidents in relation to trailer sources

Plant-trailers were sourced from three hirers, an internal fleet and a proportion (eight no., 19 per cent) did not have their source specified. Hire source "A" was involved in 16 incidents, which represented 38 per cent of all sample incidents and 67 per cent of those incidents involving only hired trailers. The latter statistic was converted to a ratio so as to compare each hirer's incident involvement and in this case the ratio was 0.56. Respective statistics for hirer "B" were seven incidents, 17 per cent and 0.58; and for hirer "C", one incident, 2 per cent and 0.5. This suggested no significant influence on incident potential among any of the hire sources. The internal "fleet" witnessed ten incidents (24 per cent of total incidents, ratio 0.23); indicating better H&S performance compared to hired trailers. If the "unspecified" group were "assumed" to be fleet trailers too, the worst case scenario for the organisation's fleet would be 18 incidents, 43 per cent of total, ratio 0.42. However, this would still signify that fleet trailers were less prone to incident than were hired trailers.

Trailer operation at the time of incident

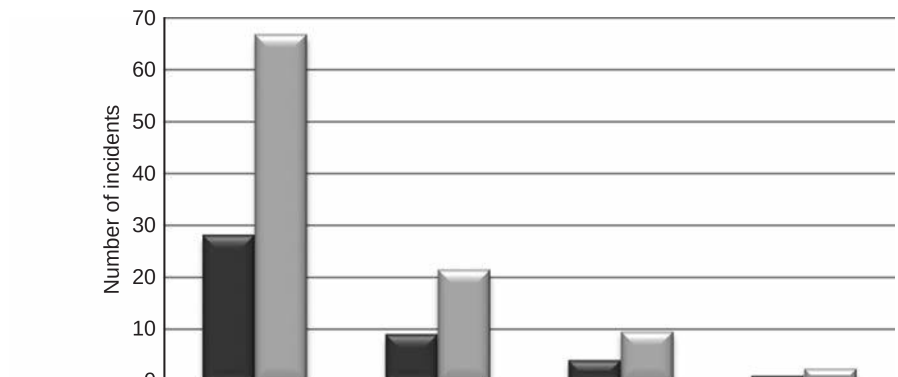
Classifications of trailer operation at the time of reported incidents were as follows. The majority (34 cases, ~ 82 per cent) occurred while the trailer was being towed. Operation was unspecified in five cases (~ 12 per cent), while "reversing", "loading" and (during) "inspection" witnessed one case (~ 2 per cent) each. If the being towed and reversing classifications are combined, it can be stated that ~ 84 per cent of all incidents occurred while the trailer was moving. A corollary of this being, that in the majority of cases problems preceding an incident such as a loose or missing wheel stud, were either unidentifiable or (more probably?) not identified prior to travel commencing. In turn, the need for increased awareness on the part of and/or more thorough pre-journey trailer inspections by drivers, seems a logical conclusion, strengthened further in that only one incident was identified during the act of trailer maintenance inspection. Given that trailer operation was unspecified in five cases (10 per cent), the number of incidents that occurred during travel must lie between a minimum of $(35-5=)$ 30, and a maximum of $(34+5+1=)$ 40 cases (71–95 per cent).

Types of incident

Types of incident are summarised in Figure 4. Wheel detachment ("while traveling" given the previous analysis) is the main incident type (28 cases, 67 per cent). These statistics may vary slightly because "studs sheared off" and "other" did not specify whether this led to wheel detachment or wheel loosening. These incident types are analysed in more detail later.

Reporting of incidents

Table IV analyses the frequency and timing of follow-up reports. A follow-up report is a post-incident analysis to investigate cause(s); help better understand them; and subsequently inform H&S management (design, decisions) in striving to avoid or reduce repeat incidents (Ferret, 2012). It may also be a requisite component of relevant legislation (*cf.* HSE, 2012). Sub-sample statistics for "first" and "second" time-halves of the data set within Table IV were determined as (and for the same rationale) explained earlier. It is shown that approximately two-thirds of all incidents did not have a follow-up report. Contrasting of the data halves, identifies that this applies most to incidents in the earlier period (90 per cent) but less so in the later period, for which two-thirds of cases did have post-incident reporting. Assuming data supplied by the client were complete, this indicates: first, that not all incidents attract a post-incident analysis; and second, post-incident reporting has increased over time.



	Trailer wheel detached	Wheel becomes loose	Studs sheared off	Other
Number	28	9	4	1
Percentage	66.7	21.4	9.5	2.4

Figure 4.
Types of incident among all data

Table IV.
Analysis of post-incident reporting frequency

Post-incident report?	All incidents No.	All incidents %	First half No.	First half %	Second half No.	Second half %
No	26	62	19	90	7	33
Yes	16	38	2	10	14	67
Totals	42	100	21	100	21	100

Primary causes of incidents

The analysis confirmed that (explicit and implied) causes of incidents are varied in nature, but may be summarised under five generic, primary causal headings as follows: unspecified (14 cases, 33 per cent); wheel bearing faults (13 cases, 31 per cent); loose wheel studs (11 cases, 26 per cent); sheared wheel studs (three cases, 7 per cent) and a brake problem (one case, 2 per cent). Interpretation of these data is hampered in that one-third of incidents were unspecified. However, almost an additional third were related to wheel bearing failure of one kind or another (see later); while the remaining approximate third involved loose, lost or sheared wheel studs (notable also, there were almost four times as many instances of wheel studs becoming loose as there were of studs shearing off). One distinct case involved a problem with the trailer braking system.

Table V further analyses these primary failure types along with examples of known root causes and, some comments abstracted from the narrative data. This suggests that: wheel bearing problems seem to relate to failings in trailer maintenance (e.g. lack of lubrication) and/or driver behaviour (accidental abuse); the loosening (or loss as a result) of wheel studs appears related to poor maintenance (internal and/or external via hirers, or third parties such as puncture repairers); sheared studs appear related to poor maintenance (over torqueing); and a prevailing theme is the need for more robust (adequate and frequent) inspections, especially by drivers, pre-journey.

Inferences and outline recommendations

Inferences and outline recommendations were derived from results of the former analyses combined. However, there are limitations associated with an exploratory study of this kind that relate primarily to sample size, so the following must be viewed as characteristic only of this particular sample and as such, a degree of caution must be exercised when generalising to a population. Outline recommendations of the study are based on the following inferences:

- Most incidents occurred post-2009 thereby suggesting either a worsening situation regarding trailer wheel H&S incidents over time; a growing number of trailers being used; improved incident reporting procedures; or any combination of these.

Primary cause	Root cause and/or comments
Unspecified	"Wheel nuts were intact; Incident occurred on first use of the trailer since its delivery; Cause linked to lack of pre-journey checks; Post-incident report cites a lack of daily (trailer) inspections [. . .]
Bearing(s) fault	"Wheel studs intact but bearings disintegrated; Attributed to a lack of lubrication grease; Driver hit the kerb line with the trailer wheel prior to incident; Cause attributed to poor hirer maintenance; Lack of inspections and driver behaviour as possible root causes; Lack of inspections and servicing as possible root causes [. . .]
Loose stud(s)	"Poor inspection at internal PDI; Recommended to check stud torque weekly; Possible under-torque [two cases]; Both wheels to one side of trailer all studs were loose; Attempted [interrupted?] theft/sabotage?; Studs were loose; Lack of pre-journey checking; Lack of checks cited in report; Lack of daily checks; Lack of lubrication to studs causing under-torque [. . .]
Sheared stud(s)	"Possible over-torque [two cases]
Brakes	"Attributed to poor maintenance"

Table V. Further analysis of primary failures: root causes/other comments

- Aside from 29 per cent of unclassified cases, most incidents involved roller or mini-excavator trailers, implying that these two trailer types are more prone to incidents and/or, are the most popular types. [The literature confirms that use of mini-excavators has increased significantly over recent years (Holt and Edwards, 2013)].
- Notwithstanding 19 per cent of unspecified cases, most incidents involved hired trailers. This suggests that hired trailers are more prone to this phenomenon and/or, hired trailers form the larger proportion of the sample trailer fleet. Ratio analysis of failures confirmed that in this organisation, their own trailer fleet was less prone to incident than hired trailers; a corollary of which suggests that organisations should carefully consider the trailer maintenance function of any hirers they do business with.
- The majority of incidents occurred while a trailer was being towed (*vis-à-vis* other conditions such as when being manoeuvred or loaded). Approximately two-thirds of incidents involved wheel detachment. Approximately one-fifth of incidents involved wheel(s) coming loose but being discovered before detachment occurred. Aside from one-third of incidents being unspecified, the most common primary causes of incident in declining frequency of occurrence were: bearing faults; loose studs; and sheared studs.
- Primary causes of failure were: for wheel bearing problems – poor trailer maintenance and/or driver accidental abuse; for studs loosening – poor maintenance and/or infrequent inspection; for studs shearing – poor maintenance (suspected over-torqueing); and in general terms – inadequate and/or infrequent inspections especially, pre-journey.

Outline recommendations

While legislative requirements such as PUWER (1998), LOLER (1998) and SMSR (2008) take precedence, appropriate operational inspection regimes should be designed and implemented for plant-trailers. These must take into account inspection prior to a trailer being put into use; following service, maintenance or repair; and following any incident that is liable to have rendered a trailer unsafe. Additionally, given workers' lethargy towards inspection and repairing of defects observed in this study, drivers who tow plant-trailers should be educated and encouraged to implement a pre-journey check each time a trailer is used following a period of inactivity. The importance of pre-delivery inspection and certification by hirers (and other external suppliers such as repair and maintenance functions) is also important. These data have confirmed that even new plant-trailers have at times been supplied with H&S failings.

Based on the distribution of faults observed, in addition to the more general aspects of trailer integrity and safety, inspection should particularly focus on wheel bearings (especially lubrication); correct torque and other tightening aspects of all wheel studs (such as need for lubrication to threads to achieve specified torque and the use of safety indicators); braking systems; and signs of any other trailer abuse or accidental damage. Plate 2 shows several aspects of inspection including the use of wheel stud indicators (here, non-aligned suggesting loose studs); and tyre, wheel and bearing damage.

The "human" aspect has a critical role in plant-trailer safety. Only workers competent in trailer use – and especially those that tow them – should work with trailers. Leading on

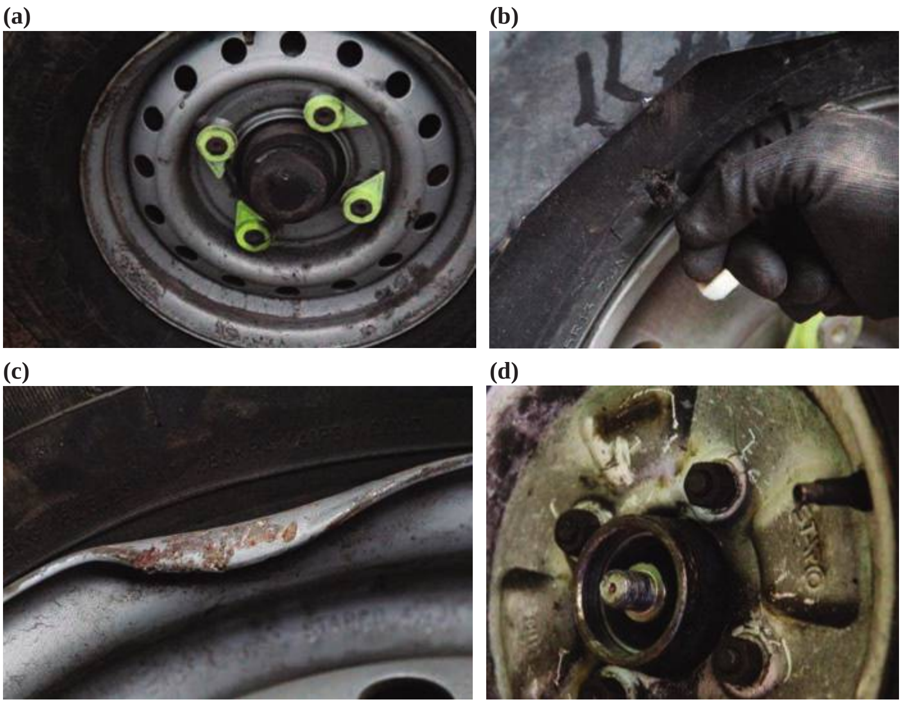


Plate 2. Aspects of plant-trailer inspection

Notes: (a) Wheel stud indicators misaligned (loose studs). Note also valve cap missing (poor inspection/maintenance); (b) tyre wall damage (could be driver abuse from kerbing); (c) wheel rim damage (could be driver abuse from kerbing); (d) bearing damage, hub cap missing, valve cap missing
Source: © Authors, reproduced with permission

from the above "inspection" recommendations, drivers should also be encouraged to report any accidental abuse or damage instantly without (any perceived whether real or not) fear of reprisal. This is particularly important so that hazardous trailers can be quickly taken out of service until defects are repaired. The thoroughness of inspection, maintenance and repair should be emphasised throughout organisations using plant-trailers; not only to underpin safe working but to actively and constantly reinforce the dangers to fellow workers and the company, where procedures are not followed. Many of the plant-trailer incidents observed in this study, could have been avoided if workers had acted appropriately.

The above recommendations are somewhat related to "common sense" but unfortunately, for those incidents studied, seems lacking in practice. Hence, where any of these recommendations are already implemented in the workplace, efficacy of their enforcement by management might benefit from review. Linked to the management function, all (incident and post-incident) reporting should be as comprehensive as economically practicable. Incident data should be safely stored for subsequent analysis. Analysis is beneficial in assessing existing safety, inspection and maintenance regimes; but perhaps more importantly, the effects of any newly implemented procedures at some point in the future.

Conclusions

Hazards and concomitant risks associated with wheels becoming loose or detached are recognised among extant literature with respect to road-going commercial vehicles. However, the same problems apply to plant-trailers, but little has been researched or published for the latter. This study addressed that void and based on analysis of an organisation's plant-trailer H&S incidents, provides greater understanding in this context. Overriding observations of the study indicate that problems associated with plant-trainer wheels represent a worsening situation; which may be a function of increasing plant-trailer usage (reasonably inferred, given significant increase in mini-excavator sales over the last ten years); along with other physical, mechanical, human, inspection and maintenance issues.

The study observed that most incidents involved pedestrian roller and mini excavator trailers; and the prevalence of incidents was greater among hired *vis-a`-vis* the organisation's fleet trailers. Incidents tended to occur when trailers were being towed and involved, in decreasing order of frequency: wheel bearing problems, wheels becoming loose and studs shearing. Respective root causes are proffered to be poor maintenance, accidental abuse, over tightening of studs and infrequent or inappropriate inspections.

Outline recommendations based on this study are suggested as follows:

- Thorough and appropriate inspection regimes should be designed and implemented that take into account inspection prior to a trailer being put into use; following service, maintenance or repair; and following any incident liable to have rendered a trailer unsafe.
- Workers' apathy regarding inspection and reporting of defects should be countered using training and awareness regimes. Drivers who tow plant-trailers should be particularly targeted here because most incidents occur during trailer travel – a pre-journey check is required each time a trailer is used following a period of inactivity.
- Pre-delivery inspection and certification by hirers (and other external suppliers) is equally important because the evidence shows that even new plant-trailers may be supplied with H&S failings.
- Routine and maintenance inspections should particularly focus on wheel bearings (especially lubrication); correct torque to wheel studs; the use of stud safety indicators; braking system check; and signs of any other trailer abuse or accidental damage.
- The "human" aspect has a critical role in plant-trailer safety, competence is paramount. Workers must be constantly aware of the risks and training or other passive (e.g. signage systems, trailer decals) may help here. Drivers in particular have a crucial role to play in reporting damage or accidental abuse (as part of the former pre-towing inspection regime).
- To encourage the latter, no real or perceived threat of reprisal should exist for reporting. Indeed, a "reward" system might encourage such and hence prove cost effective, in reducing incidents and their associated financial burdens.

Given this was an exploratory study of a new research field, recommendations for taking the research forward are as follows:

- Future research should observe a larger and more broadly stratified sample of incident data. For instance in terms of organisation type, hired *vis-à-vis* fleet trailers, additional trailer sizes and configurations, loads carried and types of work encountered.

- This could be further enriched if in addition to desk-based study, the methods of inquiry embraced an element of physical and invasive investigations at the workface, to better understand the physical and mechanical aspects in more detail.
- Comparisons of the "problem" with other international geographical locations could be made. These might explore the rate of incidents, the influence of geographical legislation and (e.g. national) enforcement regimes – in addition to workers' disposition to the subject given the "human angle" emphasised.

Notes

1. See manufacturers' web sites for additional examples of these trailers. Specific examples have not been given here to avoid such being taken as endorsement or disapproval.
2. A large heavy goods vehicle with a low chassis/trailer, designed to allow self-propelled plant to be driven on and off it for transportation purposes.
3. Excavation work is particularly risky, the fatality rate among excavation works is 112 per cent greater than that for other construction work (Oregon Occupational Safety and Health, 2013).
4. Based on data from the Transport Research Laboratory – see Table IV in Knight *et al.* (2006, p. 6).
5. Order 3 as determined by fluctuations in the data. See Microsoft (2013).

References

Bencich, C., Graber, E., Staben, J. and Sohn, K. (2002), "Navigating in unknown waters: proposing, collecting data and writing a qualitative dissertation", *College Composition and Communication*, Vol. 54 No. 2, pp. 289-306.

Bowen, G.A. (2009), "Document analysis as a qualitative research method", *Qualitative Research Journal*, Vol. 9 No. 2, pp. 27-40.

Brake (2013), "Wheel loss – the fatal bouncing bomb", available at: www.brake.org.uk/facts/wheel-loss-the-fatal-bouncing-bomb.htm (accessed June 2013).

BSI (2006), *Earth-Moving Machinery. Safety. General Requirements*, BS EN 474-1:2006 + A3:2013, British Standards Institution, London.

Construction Labour Solutions (2013), "Types of plant", available at: www.clsuklimited.com/faqs/types-of-plant/ (accessed May 2013).

Cosh, K.J., Burns, R. and Daniel, T. (2008), "Content clouds: classifying content in Web 2.0", *Library Review*, Vol. 57 No. 9, pp. 722-729.

DETR (1998), *The Incidence of Wheel Detachment from Commercial Vehicles*, The Department of Environment, Transport & The Regions, London.

Drew, P., Raymond, G. and Weinberg, D. (2006), *Talk and Interaction in Social Research Methods*, Sage Publications, London.

Edwards, D.J. and Holt, G.D. (2010), "Case study analysis of construction excavator H&S overturn incidents", *Engineering, Construction and Architectural Management*, Vol. 17 No. 5, pp. 493-511.

Edwards, D.J. and Holt, G.D. (2011), "Mini-excavator safety: towards innovative stability testing, procurement and manufacture", *Journal of Construction Engineering and Management*, Vol. 137 No. 12, pp. 1125-1133.

Electronic Library of Construction Occupational Safety and Health (2013), "Preventing injuries when working with hydraulic excavators and backhoe loaders", available at: http://elcosh.org/document/1732/d000602/preventing-injuries-when-working-with-hydraulic-excavators-and-backhoe-loaders.html (accessed June 2013).

European Agency for Safety and Health at Work (2013), "What are the most important safety risks from agriculture machinery, work equipment and other work means?", available at: https://osha.europa.eu/en/faq/some-risks-in-agriculture (accessed June 2013).

Ferret, E. (2012), *Health and Safety at Work Revision Guide for the NEBOSH National General Certificate*, Routledge, Oxon.

Fredericks, T., Abudayyeh, O., Palmquist, M. and Torres, H. (2002), "Mechanical contracting safety issues", *Journal of Construction Engineering and Management*, Vol. 128 No. 2, pp. 186-193.

Freight Transport Association (2009), *Wheel Security. FTA Best Practice Guide to Wheel Security*, Freight Transport Association, Kent.

Health and Safety Executive (2012), *Using Work Equipment Safely*, Document ref: INDG229, revision 2, The Health and Safety Executive, London.

Holt, G.D. and Edwards, D.J. (2011), *Slips, Trips, Falls and Other Risks when Accessing, Egressing or Working Upon Workplace Transport*, The Off-Highway Plant and Equipment Research Centre in collaboration with Birmingham City Business School, On Track Multi Media, Dudley.

Holt, G.D. and Edwards, D.J. (2012), *Guidance on Using Excavators for Object Handling (Using Excavators as "Cranes")*, Association with the Off-highway Plant and Equipment Research Centre, On Track Multi Media, Dudley.

Holt, G.D. and Edwards, D.J. (2013), "Analysis of UK off-highway construction machinery market and its consumers, using new-plant sales data", *Journal of Construction Engineering and Management*, Vol. 139 No. 5, pp. 529-537.

HSE (2002), *Summary of Responses to Revitalising Health and Safety in Construction*, The Health and Safety Executive, Merseyside, available at: www.hse.gov.uk/consult/2002.htm (accessed July 2013).

HSE (2012), *A Guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995*, The Health and Safety Executive, Merseyside, available at: www.hse.gov.uk/pubns/books/l73.htm (accessed July 2013).

HSE (2013), *Reporting Accidents and Incidents at Work. A brief guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR)*, The Health and Safety Executive, Merseyside, available at: www.hse.gov.uk/pubns/indg453.pdf (accessed January 2014).

Knight, I., Dodd,, M., Grover, C., Bartlett, R.S. and Brightman, T. (2006), "Heavy vehicle wheel detachment: frequency of occurrence, current best practice and potential solutions", Published Project Report No. PPR086, Prepared for Transport Technology and Standards (TTS) 6, Department for Transport (DfT), TFL Ltd, Wokingham, Berks.

LOLER (1998), "The Lifting Operations and Lifting Equipment Regulations 1998 (as amended). Statutory Instruments 1998 No. 2307", available at: www.legislation.gov.uk/uksi/1998/2307/made (accessed July 2013).

Lunt, J., Bates, S., Bennett, V. and Hopkinson, J. (2008), "Behaviour change and worker engagement practices within the construction sector", report prepared by the Health and Safety Laboratory for the Health and Safety Executive, HSE Books, London.

Meyer, M.D. (2006), *Construction Equipment Management for Engineers, Estimators and Owners*, Taylor and Francis, London.

Microsoft (2013), "Choosing the best trendline for your data", available at: http://office.microsoft.com/en-gb/help/choosing-the-best-trendline-for-your-data-HP005262321.aspx (accessed July 2013).

Musonda, I. and Haupt, T. (2011), "Identifying Factors of Health and Safety (H&S) Culture for the Construction Industry", *Proceedings of the 6th Built Environment Conference, Association of Schools of Construction, Lambton, Johannesburg, 31 July-2 August*.

Oregon Occupational Safety and Health (2013), "Excavation safety", available at: www.cbs.state.or.us/osha/educate/materials/Excavation-Safety-320/1-320i.pdf (accessed June 2013).

PUWER (1998), "The Provision and Use of Work Equipment Regulations 1998 (as amended). Statutory Instruments 1998 No. 2306", available at: www.legislation.gov.uk/uksi/1998/2306/made (accessed July 2013).

QSR (2013), "Understand word frequency queries", available at: http://help-nv9-en.qsrinternational.com/nv9_help.htm#procedures/run_a_word_frequency_query.htm (accessed June 2013).

Riaz, Z., Edwards, D.J., Holt, G.D. and Thorpe, T. (2011), "Data flow analysis of plant and equipment health and safety management", *The Journal of Engineering, Design, and Technology*, Vol. 9 No. 2, pp. 178-203.

Richardson, J.W. (2011), "Challenges of adopting the use of technology in developing countries", *Comparative Education Review*, Vol. 55 No. 1, pp. 8-29.

Saldańa, J. (2013), *The Coding Manual for Qualitative Researchers*, Sage Publications Ltd, London.

Shapira, A., Simcha, M. and Goldenberg, M. (2012), "Integrative model for quantitative evaluation of safety on construction sites with tower cranes", *Journal of Construction Engineering and Management*, Vol. 138 No. 11, pp. 1281-1293.

SMSR (2008), "The supply of machinery (safety) regulations 2008 (as amended)", Statutory Instruments No. 1597, SMSR, available at: www.legislation.gov.uk/uksi/2008/1597/made (accessed July 2013).

Smyth, E. (2006), "Notes for further research: through an irish lens viewing the history of Canadian women religious (sic)", *The Canadian Journal of Irish Studies*, Vol. 32 No. 1, pp. 64-67.

The Companies Act (2006), "The Companies Act 2006", Chapter 46, available at: www.legislation.gov.uk/ukpga/2006/46/contents (accessed July 2013).

Transport Research Laboratory (2013), "TRL creating the future of transport", available at: www.trl.co.uk/ (accessed June 2013).

Wu, W., Yang, H., Chew, D.A.S., Yang, S., Gibb, A. and LI, Q. (2010), "Towards an autonomous real-time tracking system of near-miss accidents on construction sites", *Automation in Construction*, Vol. 19 No. 2, pp. 134-141.

About the authors

Gary D. Holt is a Professor of Machinery Management at the Birmingham City Business School, UK and Professor of Construction Management and Economics at the University of Central Lancashire, UK. His research has been broadly published via academic papers, textbooks and industry guidance. He serves on international conference technical advisory panels, is an editorial advisory board member of several journals, a reviewer for many more, and Editor of the *Journal of Financial Management of Property and Construction* (Emerald). Professor Gary D. Holt is the corresponding author and can be contacted at: gdh@blueyonder.co.uk

Professor David J. Edwards is a Director of the Centre for Business Innovation and Enterprise and Director of the Faculty Research at the Birmingham City Business School. His research investigations focus mainly upon plant and machinery management. His work has been funded through engineering councils, government bodies and industrial collaborations. He has published over 100 scientific research papers in leading international journals as well as numerous conference contributions and textbooks. In 2000 he founded the Off-Highway Plant and Equipment Research Centre, which today is the largest international trade body for research in this field with over 6,000 members.