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Exploring the human and physical factors associated with telescopic handler overturning

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A combination of machine instability and various human factors elements are important precipitating factors in telescopic handler overturn incidents. Industry guidance makes a number of assumptions about the impact of operator "knowledge gaps", however the link between operator knowledge gaps and overturn risk is, at present, hypothetical and remains empirically untested.

This study was done to identify:

- the full range of human factors issues that might potentially contribute to telescopic handler overturn incidents;
- the human factors issues that appear to be most important in terms of overturn risk and
- key operator knowledge gaps that could increase the probability of an operator overturning a machine.

The research indicates that a machine is more likely to overturn when its boom is raised and /or extended. Overturn incidents are also strongly related to lateral (in contrast to longitudinal) instability. As some operators were not aware of the overturn risk related to lateral instability, this implies the possibility of a knowledge gap among operators. Weaknesses in training and site management/supervision are also likely to increase overturn risk.
The installation of lateral instability warning technology could reduce overturn risks by warning operators of dangerous situations before a critical threshold is reached.

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Exploring the human and physical factors associated with telescopic handler overturning

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KEY MESSAGES

- A telescopic handler overturn is more likely to occur when a machine’s boom is raised and / or extended. Therefore, operating a telescopic handler with an extended/raised boom, regardless of whether loaded or not, is to be regarded as a risk situation, particularly when a machine is used on uneven or unstable ground.

- Incident data shows that overturn incidents related to lateral instability have a higher probability of occurrence than overturns due to longitudinal instability. Telescopic handlers are, therefore, more likely to overturn in a sideways direction (lateral instability) rather than tipping forwards (longitudinal instability) because of a shift in a machine’s centre of mass.

- As some operators were not aware of the overturn risk related to lateral instability, this implies the possibility of a knowledge gap among operators.

- Challenging ground conditions (e.g. soft, sloping and uneven ground) are associated with lateral overturns.

- Weaknesses in training and site management/supervision are likely to increase the risk of an overturn incident.

- The installation of lateral instability warning technology, and improving or supplementing visibility from the cab, could reduce overturn risks by warning operators of dangerous situations before a critical threshold is reached.

EXECUTIVE SUMMARY

Background

Telescopic handler overturn incidents have resulted in a number of fatalities in the UK construction sector. This research was commissioned as a contribution to developing a better understanding of the human factors issues underpinning telescopic handler overturn risk.

Method

The research used a combination of quantitative and qualitative methods. A quantitative approach was used to analyse UK telescopic handler overturn incident data. Semi-structured interviews with subject experts (employed as trainers and manufacturers) and telescopic handler operators generated information relating to overturn likelihood that included factors such as accidental operation of controls, visibility from the vehicle, improving control design, site environment, external/use factors that affect machine stability, maintenance and operator training. The quantitative and qualitative information was analysed and combined to draw conclusions and to identify implications.

Key Conclusions

- Analysis of UK telescopic handler overturn incidents shows that operating a telescopic handler with its boom raised is an important physical risk factor influencing vehicle stability that can increase the risk of an overturn incident; therefore overturning is more likely to occur when a machine's boom is raised.

- Overturn incidents related to lateral instability are more prevalent, and therefore have a higher probability of occurrence; therefore a telescopic handler is more likely to overturn due to lateral instability than longitudinal instability.

- Challenging ground conditions (e.g. soft, sloping and uneven ground) are also associated with lateral overturns.

- Not all operator interviewees saw lateral instability as a problem, suggesting the possibility of a knowledge gap in this population, and

- Important risk factors that could contribute to an overturn incident include:
    - Operating on sloping ground
    - Operating on uneven ground
    - Using a telescopic handler with incorrect tyre pressures

Implications

The findings from this research study may have implications for HSE and industry, including:

- considering the impact of possible lateral instability related knowledge gaps in the operator population that may have a bearing on telescopic handler overturn risk;

- thinking about the potential benefits of encouraging manufacturers to explore the safety advantages of introducing lateral instability warning technology (alongside existing safe load indicator systems) and improving, or supplementing, visibility from the cab and

- assessing the benefits of promoting "best operational practice" around the use of telescopic handlers on construction (and other) sites, with the aim of minimising the risks related to the combination of raised boom situations and unstable/uneven ground conditions.

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1. INTRODUCTION

1.1 RESEARCH AND POLICY CONTEXT

Telescopic handler overturns have been the cause of a number of fatal accidents in the UK Construction Sector. The Strategic Forum for Construction[1] guidance suggests that telescopic handler stability, along with various human factors elements, are important precipitating factors in overturn incidents. The industry guidance makes a number of assumptions about the impact of deficiencies in risk relevant operator knowledge (e.g. the importance of using manufacturer specified tyre ply and pressure, the function and purpose of longitudinal load moment indicators[2] etc.)

The link between operator knowledge gaps and overturn risk is, at present, hypothetical and remains empirically untested. Should human factors play a major role in overturn situations, treating telescopic handler instability as an engineering problem that has only engineering solutions will, at best, yield only a partial understanding of overturn risk. HSE Construction Division believe that a better understanding of the human factors issues in overturn situations, in particular the perceptions and opinions of telescopic handler operators, will place them in a stronger position to influence “key players” (e.g. manufacturers, construction companies, industry associations, training organisations, relevant standards committees etc.) to:

- develop the best possible set of control measures;
- promote best operational practice, and, where appropriate,
- to adopt different, more effective design ideas.

A schematic illustration of a basic telescopic handler and key components that are relevant to this report are shown in Appendix 4.

1.2 STUDY AIMS

As a starting point to help HSE’s Construction Division to develop a better understanding of the human factors issues implicated in telescopic handler overturn incidents, HSE researchers have been commissioned to undertake a research study that aims to identify:

- the full range of human factors issues that might may potentially contribute to telescopic handler overturn incidents;
- the human factors issues that appear to be most important in terms of overturn risk;
- key operator knowledge gaps that could increase the probability of an operator overturning a machine, and
- possible design changes to the machines that may reduce overturn risk.

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[1] Safe Use of Telehandlers In Construction, Strategic Forum for Construction Plant Safety Group (2011)
[2] A warning system fitted in the cab alerting the operator that a load is heavy enough to tip the machine in a forward direction. The system uses sensors on the vehicles rear axle.

2. METHODOLOGY

2.1 RESEARCH DESIGN

A mixed-method research design was employed consisting of four stages:

- **Stage 1**: a review and analysis of telescopic handler overturn incidents occurring in the UK, USA, Australia and New Zealand;
- **Stage 2**: six semi-structured interviews with "subject experts" i.e. operator trainers and engineers employed by a telescopic handler manufacturer;
- **Stage 3**: 14 semi-structured interviews with telescopic handler operators, and;
- **Stage 4**: an analysis of the influencing interactions between risk factors identified in the expert and operator interviews.

A combination of qualitative and quantitative methods was employed in this research. Basic frequency statistics were used to understand the incident analysis data. Qualitative methods, in the form of semi-structured interviews, were used to gather data about the opinions and perceptions of the telescopic handler operators, trainers and manufacturer employees. Employing a qualitative approach offered opportunities for an in-depth consideration of the knowledge base, attitudes and experiences of these groups around a set of specific themes deemed relevant to the research. The analysis of the influencing interactions between risk factors made further use of the qualitative data to better understand how the subject expert and operator interview data were related.

2.2 STAGE 1: INCIDENT ANALYSIS

A review of incident data involving telescopic handler overturns was undertaken, with the objective of gathering objective evidence concerning the nature and extent of the overturning problem.

To obtain an international perspective on overturns, searches of the (US based) Occupational Safety and Health Administration (OSHA) and vertikal.net[3] websites were conducted using a 10-year timeframe. These data were collected primarily as background information and were not subjected to detailed analysis. To obtain information on UK overturn incidents, a search was made of the HSE RIDDOR[4] (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations) and HSE COIN (Corporate Information System) databases to identify incidents occurring between 2004 and 2010, using the following search terms:

- telehandler;
- teleloader;
- telescopic handler;
- teleporter and
- telescopic.

[3] *http://www.vertikal.net/*
[4] *http://www.hse.gov.uk/riddor/*

2.3 STAGE 2: SUBJECT EXPERT INTERVIEWS

2.3.1 Sample selection

A purposive sample[5] of six respondents were selected so as to reflect the views of two distinct groups of subject experts deemed to have in-depth experience of key topics: operator trainers and design engineers (employed by a major telescopic handler manufacturer). Manufacturing design engineers were interviewed to gather an engineering design perspective on overturning risk. By contrast, trainers were interviewed in order to obtain a well-informed, but less technical perspective, on the human factors underpinning overturn incidents.

2.3.2 Recruitment procedure

The six respondents were recruited by making use of contacts provided by HSE Construction Division. Individuals were contacted by telephone by an HSE researcher to explain the purpose of the research and to request their participation. Four subject experts were interviewed by HSE researchers in their place of work, two interviewees offered to travel to HSE's Buxton laboratory.

2.4 STAGE 3: OPERATOR INTERVIEWS

2.4.1 Sample selection

A purposive sample of 14 operators was recruited. A purposive sampling strategy was used to ensure operators had a broad range of experience.

2.4.2 Recruitment procedure

Two HSE based telescopic handler operators were recruited to pilot the interview questionnaire prior to its use for the main batch of site interviews. Following this, twelve construction industry operators were recruited by approaching health, safety and environment professionals from three house building construction companies. Individual interviews were arranged at construction sites with the assistance of site management personnel.

2.4.3 Interview Protocol

Two interviews were conducted at HSE's Buxton Laboratory, the remaining 12 at the interviewee's place of work. All interviews were audio recorded using a digital Dictaphone and then transcribed. To ensure that the data analysis process was reliable and consistent, interviews were conducted by two researchers, and utilised a "cross checking" procedure. The latter involved the assistant researcher checking the coding of the primary researcher to ensure consistency in data interpretation.

2.5 STAGE 4: INFLUENCING INTERACTIONS BETWEEN RISK FACTORS

To understand the complex interactions between risk factors implicated in telescopic handler overturns, a representation of the subject expert's knowledge was formulated into a table based on the structure of the interviews and responses provided. The table is included in Appendix 3. Risk factors were identified and added to the table by reading the extractions of transcripts relevant to each topic area. Headings and links naturally emerged to form what is intended to be a logical framework for representing subject expert knowledge on telescopic handler overturns.

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[5] *A sample selected to represent participants with particular characteristics.*

It is acknowledged that different researchers may illustrate the subject expert knowledge in slightly different ways, although the content should remain the same. The interaction between the risk factors is shown in the tables through links to other topic areas, and by providing examples of specific risk factors within these topic areas where interactions can occur. Because of the nature of the topic, it would be possible to continue re-organising and making links, but this would be a process with ever diminishing returns.

Further analysis of the end user interviews was undertaken to investigate whether critical elements of subject expert knowledge was matched in the perceptions of operators. To indicate the overlap of operator and subject expert knowledge, the following coding system was used and incorporated into the risk factor tables:

- *Knowledge* of a risk factor demonstrated by one or more operators mentioning the issue (green font);
- *No knowledge* of risk factor demonstrated by no operators mentioning the issue (red font) and
- *Potential new risk factor* demonstrated by one or more operators mentioning the issue, but no subject expert mentioning it (blue font).

2.6 DATA MANAGEMENT AND ANALYSIS

2.6.1 Incident analysis data

For the UK data, key risk factors in each incident were identified, categorised and then subjected to a simple frequency analysis. This approach allowed the research team to identify important risk factor trends in the range of identified incidents.

2.6.2 Interview data

The qualitative data in this study were analysed using a variant of Framework[6], an analytical approach devised by researchers at the National Centre for Social Research[7] (NatCen). The variant of Framework used in this study involved the following steps:

- A thorough reading of the transcripts to allow identification of the more relevant information provided by the respondents;
- Extraction of this relevant information into a matrix format with columns containing topic areas and rows containing cases (interviewees);
- The data for each topic area was then summarised into relevant themes, based specifically on the accounts of respondents, and, finally,
- A “cross checking” (inter-rater reliability) procedure was undertaken.

The final matrix provided a summarised “themed” record of interviewee responses to questions around specific topics of interest. These emerging themes provided a basis for the research team to examine and understand interviewee perspectives on overturn related human factors issues.

[6] *Richie, J. and Lewis, J. (2003) Qualitative Research Practice: A Guide for Social Science Students and Researchers, Sage Publications*
[7] *http://www.natcen.ac.uk*

3. RESULTS

3.1 INCIDENT ANALYSIS

The search of the Occupational Safety and Health Administration (OSHA) and vertikal.net websites generated 49 incidents occurring in the USA, UK, Sweden, Australia and Ireland. Excluding the UK incidents, the factors underpinning the overturn events (for a period spanning 2003 to 2013) included:

- no outriggers deployed;
- sloping ground;
- soft ground;
- dynamic loading;
- machine travelling;
- uneven ground;
- accidental operation of controls;
- inadequate training and experience and
- poor maintenance.

The search of the HSE RIDDOR and COIN data produced 107 incidents occurring during the period 2004 to 2010. Given the source of the data (i.e. based on reportable overturn incidents in the UK), it appears reasonable to assume that it represents a representative snapshot of the type and nature of telescopic handler overturn incidents occurring across UK industry.

A frequency analysis of the data was carried out using the following informational categories:

- type of overturn – lateral or longitudinal;
- primary causal factor;
- boom position raised or not;
- industry/sector; and
- year.

3.1.1 RIDDOR reportable overturns by year and industry

Figures 1 and 2 show that the majority of RIDDOR reportable overturn incidents ocurred in the construction industry, with a gradually increasing trend in incident numbers between 2004 and 2010.

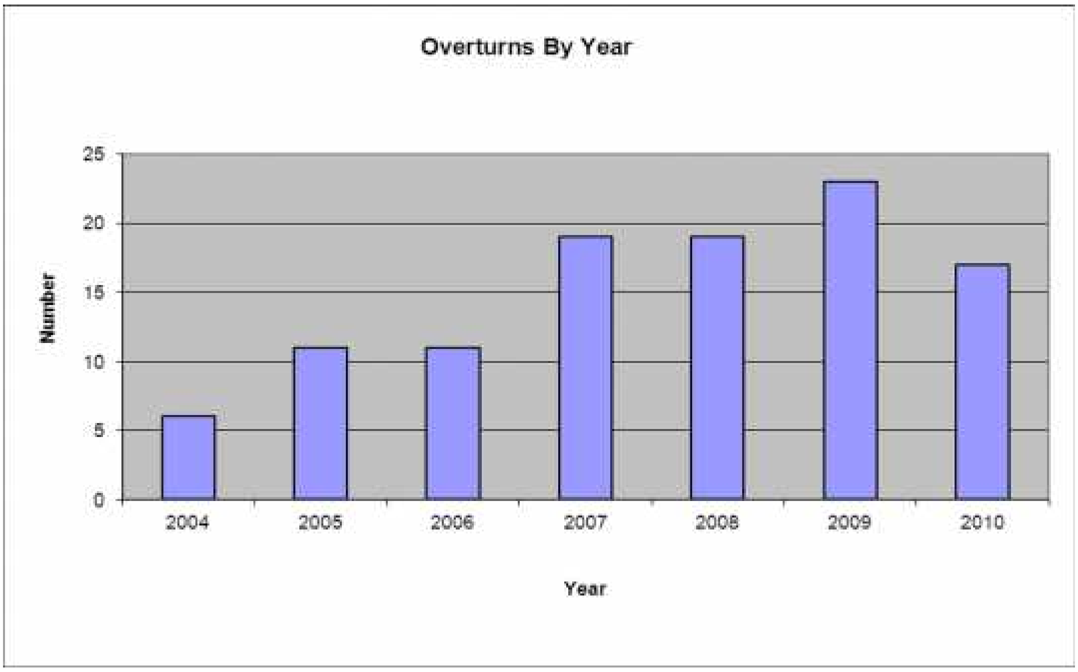

Figure 1 RIDDOR reportable overturn numbers by year

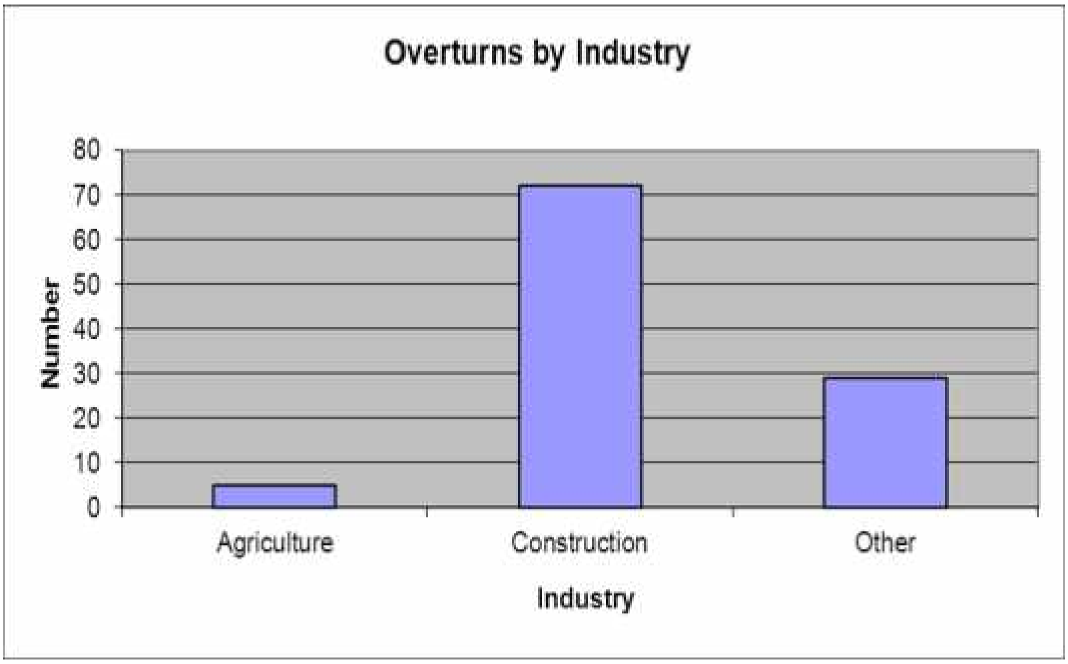

Figure 2 RIDDOR reportable overturn numbers by industry

3.1.2 RIDDOR Reportable Overturns by type and year and boom position

Figure 3 shows that lateral instability RIDDOR reportable overturn incidents are more prevalent than longitudinal overturns, and show an increasing trend between 2004 and 2009. By contrast, longitudinal overturn frequencies are fewer and do not show an increasing trend. Lateral instability, therefore, appears to be associated with higher overturn risk.

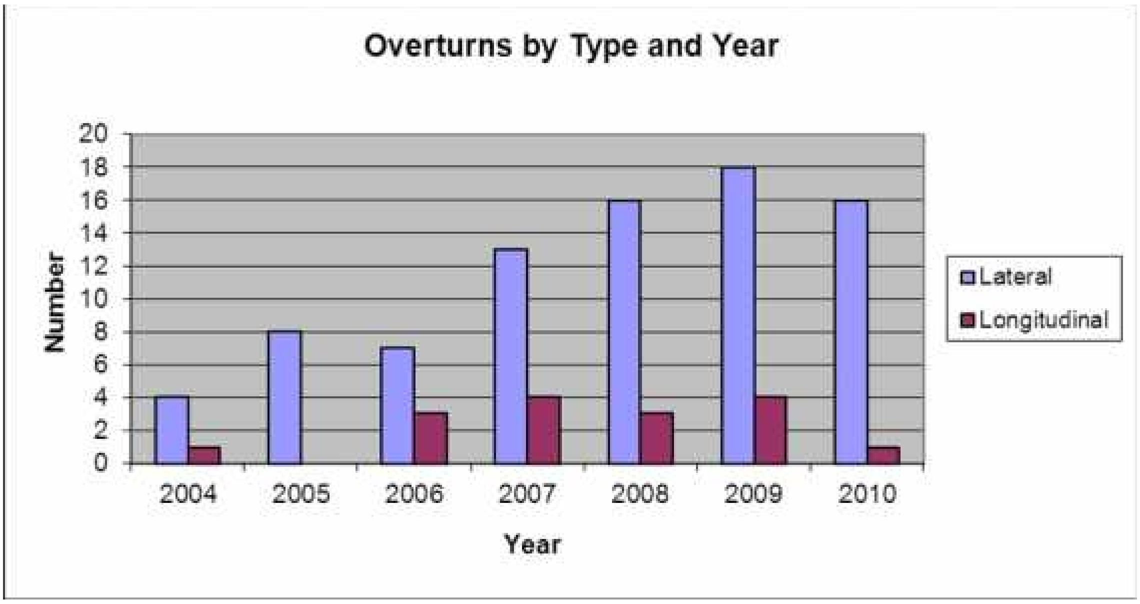

Figure 3 RIDDOR reportable overturn numbers by type and year

Figure 4 shows that most RIDDOR reportable incidents (for which data exists) occurred when the telescopic handler's boom was raised.

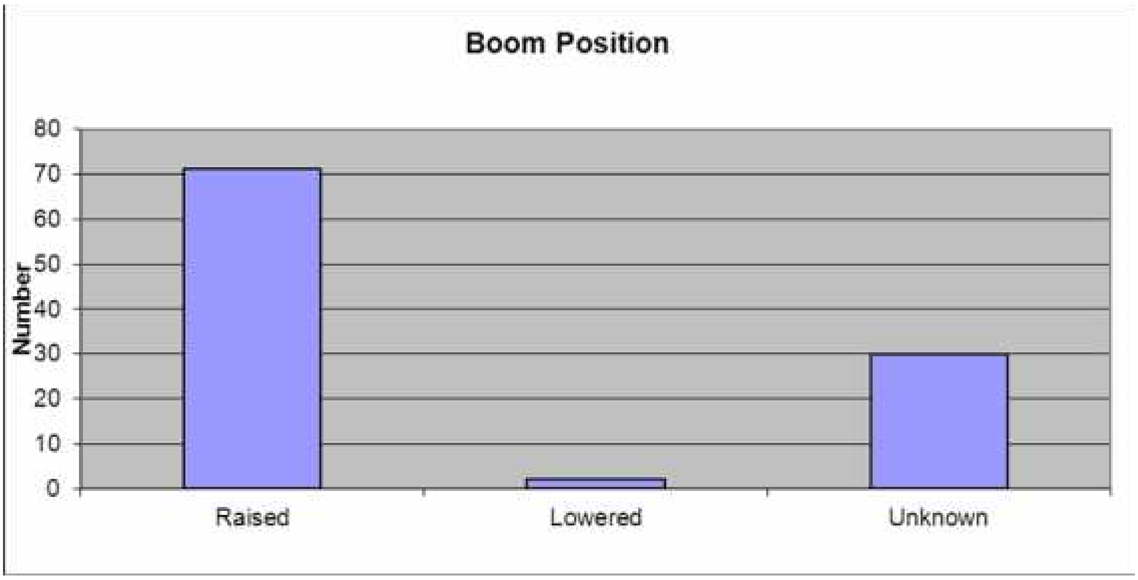

Figure 4 RIDDOR reportable overturn incidents by boom position

3.1.3 Type and cause of overturn

Table 1, produced using the Stata[8] 12 statistics package, shows a cross-tabulation of lateral/longitudinal overturn data with incident cause data.

Table 1 Analysis of overturn incidents by type and cause

Overturn cause	Type of Overturn				
	Fail	Lateral	Longitudinal	Unknown	Total
External	0	7	0	1	8
Drop	0	14	0	0	14
Failure	0	4	0	0	4
Loading	0	2	0	0	2
Overload	1	0	15	1	17
Override	0	0	1	0	1
Slope	0	20	0	1	21
Soft ground	0	21	0	0	21
Stabiliser	0	1	0	0	1
Unknown	0	15	0	3	18
Total	1	84	16	6	107

The numerical groupings in Table 1 clearly highlight the important causal factors in both lateral and longitudinal overturn incidents.

3.1.4 Lateral overturns by cause

Figure 5 shows that ground conditions (i.e. soft, sloping, uneven ground (Drop/kerb on chart) have been a major causal factor in UK lateral overturn incidents.

These HSE RIDDOR reportable incident data provide empirical evidence that identify key risk factors in UK telescopic handler overturning incidents. The key observations are:

- overturn incidents related to lateral instability are more prevalent, and therefore have a higher probability of occurrence;
- challenging ground conditions (e.g. soft, sloping and uneven ground) are associated with lateral overturns; and
- overturning is more likely to occur when a machine’s boom is raised.

8 StataCorp L, 4905 Lakeway Drive, College Station, Texas 77845-451, USA

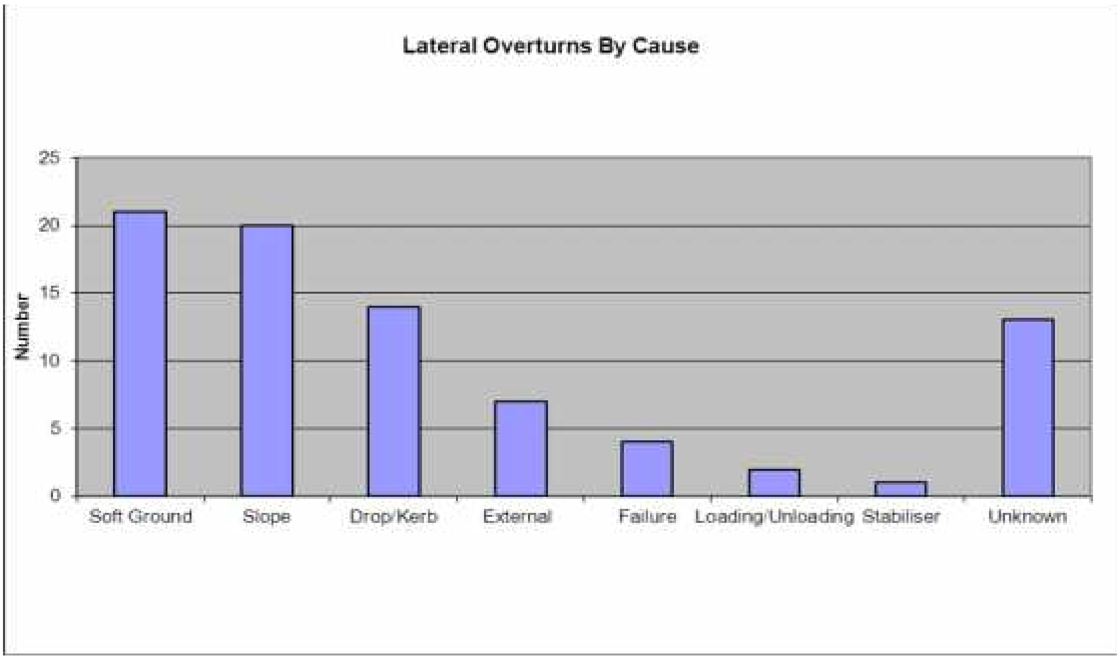

Figure 5 RIDDOR Reportable Lateral overturn incidents by cause

3.2 QUALITATIVE SAMPLE CHARACTERISTICS

3.2.1 Subject experts

Six subject experts were interviewed in the following job roles:

- Trainer/instructor (3);
- Engineer (2);
- Machine assessor (1).

All respondents had direct experience of operating telescopic handlers, including holding various formal operating competence qualifications awarded by bodies such as CITB[9] (CPCS scheme[10]). Trainers and instructors reported experience across a broader range of makes and models of machine than did the engineers or the machine assessor.

3.2.2 Operators

Twelve of the 14 operators were currently operating telescopic handlers on new house build construction sites, typically using their machines to unload material deliveries to site (e.g. bricks, roof tiles etc.) and transporting materials across the site for use by the various trades people. The remaining two respondents reported operating telescopic handlers in an engineering environment. The construction sector operators reported that their operating experience was gained across both large and small sites, with several reporting experience of using the machines on civil engineering as well as on new house build sites.

[9] *Construction Industry Training Board*
[10] *Construction Plant Competence Scheme*

Respondents' experience of operating telescopic handlers ranged from two to 27 years and the average time experience of operation was 13 years. All but one of the construction industry operators held formal "blue card" CPCS credentials (the exception being a less experienced operator holding a "green card"), and reported using their machines on a daily basis while on-site. Four respondents reported experience of operating agricultural type telescopic handlers[11], while six said that they had experience of operating other types of plant/vehicle, including Mobile Elevated Work Platforms (MEWPS), tractors, standard type forklifts and site dumpers.

3.3 EQUIPMENT FACTORS: MACHINE DESIGN, CONTROLS AND VISIBILITY

3.3.1 Control related errors

Subject experts

Moving between makes and models of telescopic handler
Subject experts cited unfamiliarity with control layouts as an important control related risk factor that could contribute to a machine overturn. Possible circumstances mentioned, included:

- operators facing a lack of consistency between control layouts i.e. control system layouts might be different between different machine types/makes; and
- complacency and overfamiliarity with the control layouts of machines made by one manufacturer.

The experts mentioned an operator moving between different brands/models/type of machine, leading to unfamiliarity with control layouts, as a situation that could lead to an overturn through the operator choosing an incorrect control. However, the experts were of the opinion that using a control incorrectly was a rare and unlikely event.

Accidental operation of controls
In terms of accidental operation of controls precipitating an overturn, the experts highlighted a running engine as an important causative risk factor, compounding the impact of other risk factors such as wearing loose clothing, moving around in the cab and reaching over controls to access items or other controls. Hence, the lack of an engine isolation facility was perceived as a contributory risk factor leading to accidental operation of controls precipitating an overturn.

Other circumstances cited by the experts that may lead to an operator accidently knocking or moving the controls were:

- moving between different machine control designs;
- a dirty cab floor;
- using a mobile phone and
- selecting the wrong service on a multi-control control joystick.

[11] *Agricultural type telescopic handlers typically have shorter (one or two section) booms compared to machines manufactured for use in the construction industry*

Improving telescopic handler controls
The experts put forward a number of suggestions for improving the controls in telescopic handlers:

- increasing standardisation between manufacturers;
- ensuring adequate separation of the controls;
- electronically protecting key controls when the boom in vulnerable position (e.g. elevated) and
- providing adequate cab space to enable easier movement around the cab.

Visibility
Subject experts saw visibility related overturn risk arising from two main possibilities:

- the blind spot created by the boom, resulting in an operator being tempted to raise the boom (and hence decreasing stability) to improve visibility and
- operators not seeing pot holes or ruts (e.g. due to dirty windows or the cab glass misting up).

The experts cited a range of factors that may contribute to poor visibility, including:

- dirty windows;
- cracked mirrors or mirrors not adjusted correctly;
- poor operator eyesight;
- position of the boom;
- sunlight glare, and
- fogged up windows.

In terms of measures designed to improve an operator's visibility levels from the cab, the most popular subject expert suggestion was the installation of Closed-Circuit Television (CCTV) systems, proximity sensors, the introduction of low profile booms and better hemispherical mirrors. These additions, if not installed as standard, would provide operators with enhanced information about the environment in the immediate vicinity of the telescopic handler. Of these enhancements, CCTV was regarded as the most practical option.

> *"Yeah, the sensors….It's another add-on but it's something that will audibly bring... and perhaps visually, bring to the attention of the operator that he's closer than he thought to a proximity hazard, particularly when reversing".*

Two respondents pointed out the continued value of operators walking around the operating area prior to commencing work as a way of gaining familiarity with potential hazards.

Operators

Moving between makes and models of telescopic handler

In terms of the overturn risks posed by moving between telescopic handlers made by different manufacturers, respondents were split. Around half of the operator respondents thought that there was some risk; the remainder said that the risk was either minimal or non-existent. A need to become familiar with different control layouts if moving between machine types was mentioned by respondents who perceived a risk:

> "*…because sometimes the controls are different and if you're not used to controls, it takes you a while to get used to them. So then if you're like used to a JCB and stepping into a Manitou*[12] *or something and the controls are different and you press a lever the wrong way it can, if you've got a load on, it can affect the load*".

> "*I've gone from a JCB to a Manitou or something like that, yeah, or any other machine but when I have it's been, hang on a minute, the control is in a different place. So I think, yeah maybe the manufacturers should group together and think let's get everything the same as everybody else just to make everything a bit more easy for the guy operating it*".

Accidental operation of controls

Most operators thought it not possible, or very unlikely, that a telescopic handler could be overturned through making a control related error. For example, most respondents thought it unlikely that accidently knocking or moving a control would result in an increased risk of overturning a machine, and only one recalled a personal experience of accidental control operation. The views of the operators on the issue of accidental operation stand in contrast to the views expressed by the subject experts, the latter being more willing to acknowledge the possibility of, and hence the risks implied by, accidental control operation.

Improving telescopic handler controls

When asked if changing the design of the controls would reduce overturning risk, most operators said no. The two respondents taking an opposite view mentioned the following potential improvements to control design:

- adopting the joystick as a standard method of controlling the boom (in contrast to levers) and
- having the capability to deploy the machine's stabilisers at any time.

Defeating alarms and indicators

Telescopic handlers are typically fitted with an alarm/indicator designed to warn operators if a load is too heavy to lift safely and may hence jeopardise the longitudinal stability of the machine. Operators may sometimes be tempted to defeat alarms/indicators e.g. because they may grow tired of an audible warning if it sounds on a regular basis. Pressure of work was cited as a key reason for operators being motivated to defeat alarms and/or indicators. In terms of how these practices work, covering sensors with coins or tape was mentioned as a possible "modus operandi". Operators either did not know, or would not disclose in detail, how prevalent these practices are.

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[12] *JCB and Manitou are different brands of telescopic handler.*

Visibility

The operators expressed divided opinion when asked if poor cab visibility increases overturn risk. Those who saw a link between poor cab visibility and overturn risk tended to mention the right side of the cab/vehicle as the main area of risk:

> *"the right hand side[13] does, yeah, because you're blind. Some of the new machines, they hire these machines but even then, you know, you can see a bit more, obviously, but if you have an accident it's always on the right".*

> *"your right hand side window, you've always have a blind spot on this back end….doesn't matter what machine you're in, doesn't matter if you've got all the mirrors, you will still have just a small blind spot here".*

However, an important observation was that some respondents did not report understanding a link between reduced visibility from the cab and overturn risk.

3.3.2 Suggested design improvements to reduce overturn risk

Both subject experts and operators mentioned a range of possible design changes that may mitigate the risk of overturn incidents. These suggestions are summarised in Table 2.

Table 2 Design change ideas to mitigate overturn risk

Human Factors/Design Issue	Leading to:	Proposed Design Change Solution
Operator not aware of a lateral instability situation	Potential machine instability	Installation of lateral instability warning technology
Lack of consistency in design of control layouts between makes and models	Accidental operation of controls leading to machine instability	Increase standardisation of control design and layout between makes and models e.g. adopt joystick (replacing levers) as a standard method of boom control
Independence of key control functionality	Accidental operation of controls leading to machine instability	Electronically integrating key controls (e.g. forward and reverse traction controls) to limit functionality when boom is raised and extended
Limited control over stabiliser deployment when boom deployed	Potential machine instability	Offer full control over stabiliser deployment that is independent of other machine systems
Limited cab space	Accidental operation of controls leading to machine instability	Provide larger cab space
Boom obscuring operator visibility to right hand side of	Operator not seeing hazards on right hand side of machine	Adoption of low profile boom design as standard on new

[13] *Telescopic handlers are designed typically with the boom arm on the right side of the machine, its location creating a blind spot on the right side of the vehicle obscuring a section of the operator's field of vision. The position of the blind spot depends on the position of the boom.*

Human Factors/Design Issue	Leading to:	Proposed Design Change Solution
machine		models
Restricted operator view of ground conditions in immediate vicinity of machine	Operator not seeing ground related hazards (e.g. pot holes) and risking machine stability	Installation of CCTV systems
Restricted operator view of above ground obstacles (e.g. people) in immediate vicinity of machine	Machine hitting obstacles leading to machine instability	Installation of proximity sensors

3.4 JOB FACTORS: CONDITIONS OF USE – LOCATION (WEATHER, GROUND CONDITIONS ETC), STABILITY AND MAINTENANCE

3.4.1 Location – tasks, weather and ground conditions

Subject experts
The main tasks/operations associated with overturn risk were cited as:

- the machine being too big for job;
- travelling at speed;
- operating the machine in a confined space;
- working with a suspended load;
- operating with a raised boom, and
- working under time pressure.

The experts thought a range of adverse weather conditions could increase overturn risk. They thought that operating a telescopic handler in windy and rainy weather conditions precipitates the highest risk of overturn. Risk from wind is associated with raised boom situations, and rain with soft and slippery ground conditions. One respondent suggested that using a banksman may help to reduce risk when operating in adverse weather situations.

The experts agreed that operating a telescopic handler on soft, slippery and non-level ground (or combinations of) is associated with overturn risk. All three types of ground condition have the potential to make the machine unstable by shifting its centre of mass. Soft and slippery ground conditions are precipitated by wet weather conditions.

Operators
The operators mentioned a broad range of scenarios that they thought associated with overturn risk (not in order of importance; items in italicised font illustrate overlap with overturn risk related tasks mentioned by the experts):

- operating on inclines;
- *travelling at speed*;
- operating on slippery surfaces;
- poorly secured loads;
- turning at speed;
- performing tight turns with a suspended load;
- operating the machine on uneven ground;

- having incorrect tyre pressures;
- carrying trusses;
- poor visibility on right side of the cab;
- *working under time pressure* ;
- overloading the telescopic handler and
- *operating with the boom raised*.

Operators saw particular weather conditions as increasing overturn risk, including rain, ice, snow and high winds. Rain was associated with soft and slippery ground surfaces, increasing the possibility of the machine sliding around, particularly when laden. Snow was perceived as increasing overturn risk because it covers the ground, obscuring holes, ruts, hollows and (if deep enough) trenches, thus increasing the probability of the telescopic handler becoming unbalanced.

> *"….any wet road and sludge you're sliding about, you could slide and you're soon into somewhere, aren't you?"*

> *"Rain, yeah rain, snow…...because there's obviously stuff you can't see with snow".*

In terms of ground conditions, operators associated uneven, unstable (soft) and sloping ground surface conditions with increased overturn risk. Operating on ground that was anything other than flat and stable was seen as contributing to increased risk of overturn. There was a clear perceived link between poor ground conditions and machine instability:

> *"our ideal ground condition is flat and solid ground, but that's not the real world, but if both your side wheels into a ditch, you've thrown yourself at a great angle. So that's going to increase your chance of tipping over, specially if you've got a load on, filling up....It just throws your centre of gravity straight away".*

Operator respondents also made the obvious links between weather and ground conditions in their responses.

3.4.2 Stability

Subject experts
The main perceived reason for operators not making use of stability outriggers was to save time and/or increase productivity. Operating the telescopic handler in confined spaces was also seen as a reason for not deploying stability outriggers. Only one respondent mentioned operator ignorance for outrigger non-use.

The experts mentioned a range of reasons why operators may not use load charts:

- laziness;
- indifference;
- macho culture;
- poor operator understanding of load charts;
- rushing to save time;
- poor training and
- operators relying on in-cab safety systems (primarily the longitudinal load moment indicator) rather than load charts.

Operators' lack of understanding of load charts was the most mentioned reason for not using load charts. The experts perceived that this situation was amplified by no or poor training, and working under time pressure (rushing). Operator indifference was also seen as relevant to not using load charts.

All the experts viewed correct tyre pressure as ***absolutely key*** to safe operation. Therefore, using a telescopic handler with incorrect tyre pressures, and also tyres not meeting manufacturers' exact tyre specifications, was seen as an important risk factor that would adversely impact on machine stability.

> *"they are a key factor. You know, they are an absolute key factor in the lift".*

> *"Tyres, yes, very crucial. The right pressure certainly has to be right with the… with an approved tyre make and type. That includes the ply, as well, and if they were… if the tyre isn't right then, yes, it does make the machine more vulnerable to tipping over".*

When asked about the significance of lateral versus longitudinal instability, the experts were evenly split; some regarded lateral instability as a more significant factor, while other thought both types of instability as equally significant. All but one expert thought overturn risk increases when a telescopic handler is travelling.

When asked to comment on situations that might increase the probability of overturning, the experts mentioned a wide range of circumstances:

- travelling across slopes;
- travelling with the boom raised;
- turning on a slope;
- the side shift of a load;
- heavy braking whilst turning;
- travelling over unconsolidated ground;
- disabling safety devices;
- operating in darkness - may not see uneven ground;
- sudden steering movements;
- lifting a load beyond the capacity of the machine;
- ground conditions - if it's on a very uneven surface with the boom raised;
- transporting suspended loads;
- speeding;
- turning too tightly and
- the boom being elevated and lightly laden.

Key risk situations appear to relate to excessive speed and turning behaviour, situations involving a raised boom, operating on slopes and exceeding the operating capacity of the machine.

Operators

Operators were evenly split in answer to a question about whether they used load charts. This finding reflects a similar split response pattern to a subsequent question about whether load charts are easy to understand. When asked how often they knew the weight of a load, a majority of respondents said they knew the load weight either some or most of the time. This finding suggests that there may be instances where loads are lifted but the weight is not known.

Most operators reported that they do not always use their stability outriggers when lifting loads. Lifting situations where stability outriggers are not typically used include lifts of smaller, lighter loads with weights of less than one tonne (e.g. joists), and lifting loads at or below first storey height. Accidently raising the stability outriggers during a lift was regarded as an unlikely and/or difficult to engineer situation.

The importance of operating a telescopic handler using the correct tyre pressure was acknowledged by the operators, as was the risk of overturn (due to instability) if operating with “soft” (i.e. underinflated) tyres.

In terms of recognising the relative importance of lateral versus longitudinal stability, operator opinions, like those of the experts, were evenly split. The following operator transcript quotations illustrate the wide range of operator opinions and knowledge around machine stability and overturn vulnerability:

> *“I think it would be sideways, wouldn’t it?.... Cos that’s where I’ve, like I’ve seen, I’ve seen accidents happen from… not seem them, seen them on videos….of people getting crushed in them and they’ve always been going sideways”. (Interviewee 2)*

> *“Well, if you’re lifting a load and the load’s too heavy, then you’re going to tip forwards…If it’s too much it’s going to stick it on its nose…If you’re travelling with a load, weight on, you know prime example is going round a corner too quickly…Then you could go over sidewards...it depends what you’re doing...”. (Interviewee 3)*

> *“I’d say forwards, myself….Because obviously, if you’re doing a high lift, we’re talking about high lifts now, and you’ve got your both jacks down….Obviously you’d be on stable ground, because you wouldn’t be doing a high lift without stable ground...So the only risk in my eyes would be to go forward, because you’re over-reaching”. (Interviewee 10)*

Most operators recognised the increased overturn risks associated with travelling with a suspended load.

3.4.3 Maintenance

Subject experts
In answer to a question about what could happen if a telescopic handler were poorly maintained, most experts mentioned the importance of tyre pressures and their impact upon stability. Adverse impact of poor maintenance on the braking system and not spotting additional minor defects were also mentioned.

The experts recognised a number of faults specifically related to overturn probability:

- tyre wear;
- tyre damage;
- damage to stabiliser legs;
- damage to the steering system and
- load motion indicator damage.

Regular daily checks were seen as the most effective way of minimising risk due to faults and damage.

Operators
In response to a question about what could happen if a telescopic handler were poorly maintained, operators recognised the importance of good regular maintenance. Tyre pressures, tyre failure and brake failure were specifically mentioned. However, despite the implicit

recognition of a link, respondents did not clearly describe the relationship between poor maintenance and overturn risk.

3.5 ORGANISATIONAL AND INDIVIDUAL FACTORS: OPERATOR TRAINING AND LONE WORKING

Subject experts

The experts were asked about the types of bad habits operators may develop due to lack of experience or training. Respondents mentioned a wide range of bad habit behaviours (see Table 3) that operators may develop due to lack of experience or training. Some of these behaviours are the same as, or similar too, behaviours previously mentioned by the experts that could increase overturn risk.

Table 3 Bad habit behaviours and lack of operator training

Not reading the handbook
Not knowing the machine's capabilities
Not reading the load charts
Not driving at a speed consistent to the ground conditions
Not using the mirrors
Braking heavily
Driving erratically
Trying to pick a load up when the operator doesn't know what the load weighs
Travelling with the boom raised
Driving at high speeds
Not being aware of hazards
Not being aware of ground conditions
Not keeping loads low to the ground
Driving too fast
Turning too tightly

In terms of how lone working might affect overturn risk, the experts recognised that operators may be inclined to take risks due to a lack of direct supervision. Driving too fast, not using a banks-man (when it may be prudent to do so) and taking short cuts were specifically mentioned.

Operators

All but one of the operators regarded their practical experience, rather than their training, as being more important in terms of understanding overturn risks. This strongly suggests that operators' value their "on the job" experience as a credible means of developing insight into overturn risk.

Most of the operators said stability and centre of mass issues were covered during their training, suggesting the possibility that stability and overturn risk might be addressed during training in a way that is less than useful for some operators (perhaps dealt with too theoretically).

"You've got to get more hands-on and in a proper situation I think rather than this little classroom set-up here. You're better off doing it out there".

However, operators varied in their opinions as to whether overturn risk was adequately covered in training, with both positive, and less positive, views expressed:

"It's certainly covered, yes….[Researcher: Does it cover it well, do you think?] *Yes. What training I've had, yes"*.

"I don't think it does, if you want the honest truth….I don't think it covers it at all because you're taken on what's supposedly rough ground, but it's not. There's a purpose built hill which you'll go over but there's nothing about potholes or… there's only one lift up and down, there's nothing about turning into something with lift on, there's nothing about lifting trusses".

3.6 INFLUENCING INTERACTIONS BETWEEN RISK FACTORS

Findings from this analysis suggest that circumstances leading to an overturn are complex, with one or more risk factors potentially contributing to an incident situation. Key topics naturally emerged and are indicated in the diagram below.

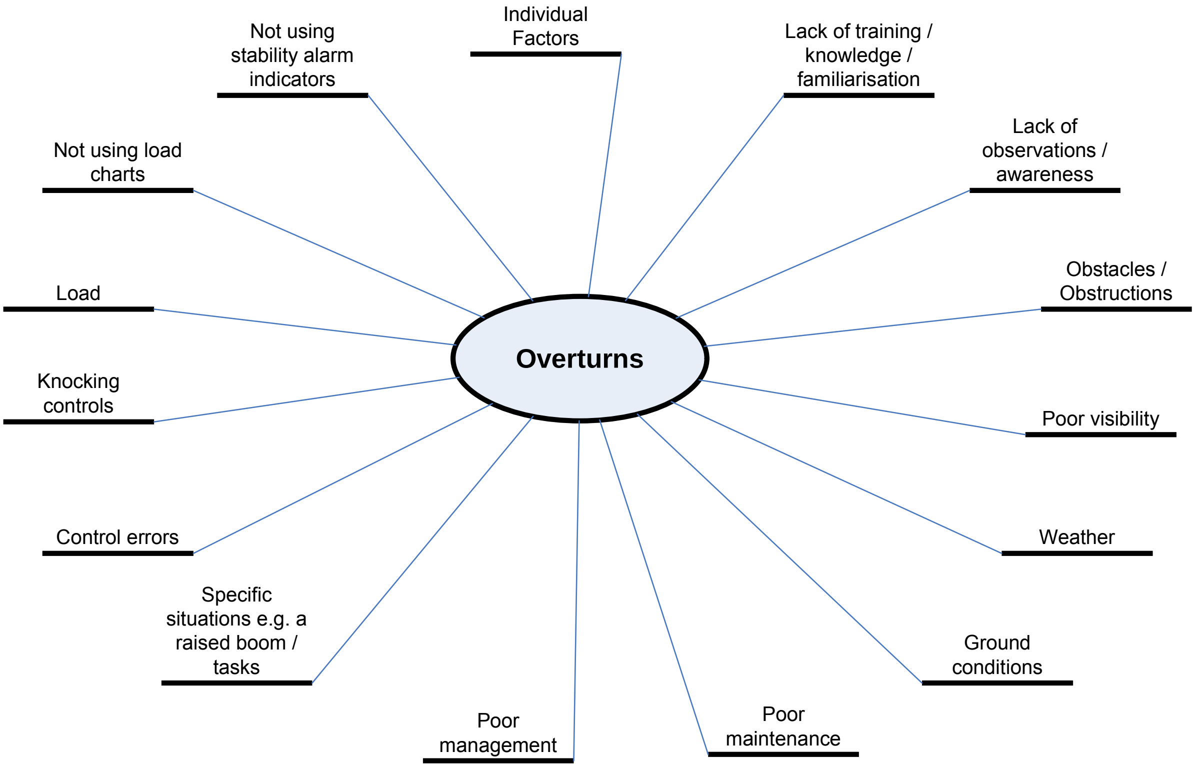


Figure 6 Key topics with the potential to contribute to an overturn

Analysis revealed that some risk factors may be more influential in contributing to an incident than others. The situation is complex due to the large number of identified interactions between topic areas. Appendix 3 presents these interactions in a series of tables, and identifies risk factors where:

- knowledge was demonstrated as shared by subject experts and end users;
- knowledge was not shared; and
- 'new' risk factors were reported by end users but not subject experts.

The topic areas considered most influential, based upon the number of links to other topic areas, are listed below:

- Individual factors interacted with all risk factor topics (apart from weather) e.g. if an operator is under time pressure this may result in rushing, which could then contribute to inadequately assessing the ground conditions, even if they have the knowledge that ground conditions are a key risk factor.
- A lack of training, knowledge and familiarisation was identified as a key risk factor. For example, an operator may increase the potential for an overturn by using a telescopic handler with incorrect tyre pressures if they are unaware of the importance of this.
- A lack of observation, and/or awareness, was linked to many risk factors including obstructions / obstacles; these in turn interacted with many risk factors such as poor visibility.
- Management of the operator, working environment and task were identified as key factors. If there is poor management or a lack of supervision, there is the potential for many overturn influencing factors going undetected.
- Ground conditions, poor maintenance and specific situations (e.g. a raised boom) were factors deemed equally important contributing factors to overturn risk, due to the number of influencing links to other risk factors.

There were knowledge gaps relating to the risk of overturns where all operators failed to demonstrate some of the risk factors identified by the subject experts. However, it is understandable why the end users have not mentioned some of these risk factors, as they are highly specific.

By considering the knowledge gaps identified, and the complex interactions between risk factors, interventions can be targeted accordingly. Training and familiarisation can be seen as influential in all areas of identified risk for overturns, in addition to ensuring there is effective management of these factors. For example, when work is effectively managed, time pressure can be kept to a minimum, which in turn could limit the effect that rushing could have on increasing the risk of overturning a telescopic handler. However, it is worth considering that training is low down in the preferred hierarchy of control measures and it is best targeted after other measures, e.g. such as those relating to design.

Every time an individual operates a telescopic handler, it would be implausible that all risk factors are present, and what may be influential in one situation may not be in another. Consequently, these findings represent the sum of all risk factors and influences as identified by this research.

4. CONCLUSIONS AND IMPLICATIONS

4.1 IDENTIFYING THE KEY PHYSICAL FACTORS ASSOCIATED WITH TELESCOPIC HANDLER OVERTURN INCIDENTS

Analysis of the HSE incident data indicates that the key physical risk factor implicated in overturning incidents is operating the telescopic handler in a raised boom situation. This empirically identified physical risk factor is entirely consistent with the importance of operating the machine within its "stability triangle"[14] in order to minimise any significant centre of mass shift.

Any scenario in which a telescopic handler is operated with its boom extended is, therefore, likely to be a "higher risk" situation, particularly when the machine is also operated on non-level and/or unstable ground conditions. The incident analysis data strongly suggest that overturn incidents resulting from such circumstances will result in lateral rather than longitudinal instability.

4.2 KEY KNOWLEDGE GAPS

Qualitative analysis of the interview data identified proportions of both the operator and expert groups who thought longitudinal instability to be the more important factor. Considering the relatively high proportion of incidents from the incident analysis where lateral instability was identified as key, this could be a potentially important knowledge gap in both respondent groups.

With the exception of tyre pressures, operators were aware that good maintenance of a telescopic handler is important, but were unable to explain clearly how poor maintenance could contribute to an overturn risk.

Other knowledge gaps between the subject expert and operators, where the operator's knowledge levels were less than optimal, were in the areas of:

- accidental operation of controls;
- moving between different makes and models of telescopic handler and
- poor visibility of ground conditions from the cab.

By way of confirmation, overturn related knowledge gaps in both respondent groups was also identified in the analysis of the influencing interactions between risk factors.

4.3 IDENTIFYING THE KEY HUMAN FACTORS SITUATIONS RELATED TO TELESCOPIC HANDLER OVERTURN RISK

Two inclusion criteria were used as a method of identifying the most important overturn related human factors, as perceived by the study participants:

- agreement between subject experts and operators that a particular human factor is an important precursor of overturn risk and/or

- a high consensus amongst operators that a particular human factor is an important precursor of overturn risk.

[14] *The triangular area within which a telescopic handler's centre of mass needs to be maintained in order to minimise the risk of overturn.*

Based on these inclusion criteria, the key risk factors identified are (not in order of importance):

Individual Factors

- lack of knowledge of lateral overturn risks; and
- working under time pressure.

Job Factors

- operating with the boom raised;
- poor visibility of ground conditions from the cab;
- moving between vehicles made by different manufacturers;
- operating in rain (slippery ground); operating in snow (ground hazards obscured);
- operating on sloping ground; and
- operating on uneven ground.

Organisational Factors

- travelling at speed;
- turning too tightly;
- operating with incorrect tyre pressures; and
- non-use of load charts by operators.

This list can be further refined (to draw out the **key** factors) through a comparison with the physical risk factors identified from the incident analysis data, the latter highlighting the combined importance of a raised boom and uneven ground conditions in overturn incidents. The refined list of key factors thus becomes:

> operating the telescopic handler with the boom raised in combination with one or more of the following situations:
>
> - operating on sloping ground;
> - operating on uneven ground;
> - operating under certain weather conditions i.e. rain (slippery ground) or snow (ground hazards such as trenches and pot holes become obscured) and;
> - operating with incorrect tyre pressure.

These key identified risk factors link strongly to the operational environment in which a telescopic handler is used. In practice, in the construction sector, this relates directly to minimum acceptable operational standards (e.g. the adequacy or otherwise of site ground conditions). Furthermore, the analysis of the influencing interactions between risk factors identified the importance of human factors such as training and the potential adverse impact of site management/supervision as additional mediating factors in determining overturn risk.

4.4 EXPLORING THE POTENTIAL OF MINIMISING OVERTURN RISK THROUGH DESIGN CHANGES

When considered in conjunction with the key physical and human factors outlined in Sections 4.1 and 4.3, design changes involving the installation of lateral instability warning technology and CCTV (or other ground detection) systems are considered to have "high impact" value in terms of significantly reducing overturn risk. This conclusion is drawn due to the value of an operator being warned in advance of a potential lateral instability situation **before** a machine's centre of gravity shifts beyond the stability triangle.

This is not to say, however, that the other suggestions provided by both experts and operators do not have value – they do. These other suggestions are, however, considered to play a less valuable early warning role, and are possibly less easy to "retro fit" on to older machines.

4.5 IMPLICATIONS

The findings from this research study may have a number of implications for:

4.5.1 Operator training

Lateral instability knowledge gaps in the operator population could have a bearing on overturn risks; revising the content of operator training courses to address possible knowledge gaps should help to mitigate overturn risk in the longer term.

4.5.2 Telescopic handler design

The fitting of lateral instability warning technology (and possibly CCTV systems) by manufacturers, alongside existing safe load indicator systems, would be a welcome step aimed at reducing overturn risk.

4.5.3 Site management and conditions

Overturn risk could also be addressed by site operators promoting and engaging in "best operational practice" around the use of telescopic handlers. The focus should be on minimising risky practices, particularly the combination of operating a telescopic handler with a raised boom on unstable/uneven ground.

5. APPENDIX 1: SUBJECT EXPERT INTERVIEW GUIDE

INTRODUCTION

- Thank you for agreeing to participate in this research interview.
- **The aim of this research** is to look at the human factors involved in accidents where telescopic handlers have overturned and identify possible solutions. We aim to interview both subject matter experts and operators to help us better understand the problem. Your opinions as an expert in this field are important to us.
- The findings of this research will help to inform HSE sector guidance and may lead to improvements in training and relevant standards.
- **Anonymity – confidentiality:** All the information that you will provide will be anonymous and confidential. The findings will be summarised across all interviews and will not be traceable to any individual or any organisation.
- **Voluntary:** This interview is voluntary and you can withdraw at any time without giving any justification. If there are questions that you do not wish to answer, it is fine, please let me know.
- Do you have any questions about this research before we start?
- **Permission to record the interview:** I would like to ask you if I could record the interview to make sure the interview analysis will be carried out using accurate information. Are you happy for me to record our conversation? At any point, feel free to ask me to stop recording if you wish to.

BACKGROUND INFORMATION

What is your job title and what does your job entail?

(e.g. training, maintenance)

What training have you had in the operation of telescopic handlers?

(e.g. certification (name of awarding body), types of machine covered, which attachments were covered by the training)

What types or models of telescopic handlers have you experience operating?

(e.g. years, frequency of use)

INTRODUCING THE TOPIC

In what circumstances do you think, it might be possible for a telehandler to overturn?

Can you describe any hazardous situations or circumstances that may result in a telehandler overturning?

1. LOCATION (outdoors/indoors/weather/ground)

1.1 What are the main tasks / operations that might lead to an overturn when operating a telehandler **outdoors**?

- Poor lighting levels to identify hazards and controls
- Narrow / enclosed spaces
- Vehicle speed
- Turning circle
- Elevated and extended boom while travelling

How could the probability of overturn be reduced?

1.2 What are the **weather** conditions that could increase the probability of an overturn?

- Rain
- Wind
- Protect suspended load movements from wind / strong draughts

Could these risks be reduced – if so, how do you measure?

1.3 Can you think of any **ground** conditions that may potentially increase the probability of overturning?

Can these risks be reduced?

- Slippery / soft from heavy rain
- Sloping / uneven
- Holes / trenches/ uncompacted ground

1.4 Can you think of any situations that might lead to an overturn when operating the telehandler **indoors**?

- Poor lighting levels to identify hazards and controls
- Narrow / enclosed spaces
- vehicle speed
- turning circle
- elevated and extended boom while travelling

Can these risks be reduced?

2. CONTROL ERRORS

2.1 What sort of errors might an operator make whilst using the controls that might lead to instability/ overturning?

(Opener – allow all answers; note what needs to be talked about in more depth later)

2.2 Can you think of any issues or situations where an operator might accidentally **knock** or move the controls that might lead to instability / overturning?

- Spacing between controls
- No guarding – between/over controls
- No tool storage area
- Loose clothing
- Distracted

How might these risks be reduced?

2.3 Can you think of any issues or circumstances that would result in an operator choosing the **incorrect control** that might lead to instability/ overturning?

Unable to identify? - why?

- Dirty/contaminated/paint over symbols/controls
- Controls not labelled
- Poor lighting levels

Unfamiliar with control panel – why?

- Variation in position of symbol (above/below/to side of control) between makes / models of telehandler
- Variation in control identifying names/symbols between makes/models of telehandler

Location / position of control panel

How might these risks be reduced?

2.4 Can you think of any issues or circumstances that would result in an operator **using a control incorrectly** e.g. moving the telehandler forwards rather than backwards/ raising rather than lowering the boom that might lead to instability/ overturning?

How might these risks be reduced?

- Labels / symbols not visible when actuating control
- Movement of control does not follow direction on label
- Ambiguity regarding position selected
- Poor lighting levels

2.5 In your opinion, what could be done, if anything, to improve telehandler controls?

- Design
- Layout

3. OTHER ERRORS (rushing/distractions/deliberate)

3.1 Can you think of any circumstances where an **operator might make an error** that is not related to the design of the controls e.g. the operator is rushing?

- Lack of care / rushing
- Stress
- Fatigue
- Workload
- Time pressure due to management expectations
- Poor route planning
- Routes not adequately prepared and checked

How do operators assess their routes (visual inspection of ground)?

Are expectations of operators realistic?

How might the risks be reduced?

3.2 Can you think of any situations where or why an operator might intentionally use the machine in an incorrect away that might lead to instability/overturning?

- Poor morale
- Lack of knowledge of consequences of error
- Time pressure
- Workload

3.3 What do you think would be the main reasons for operating the telehandler in an incorrect way?

3.4 Are there any particular situations in which people are more likely to **cut corners** that might lead to instability/ overturning?

3.5 Are there any controls or safeguarding measures in place on the machine to avoid this?

3.6 Can you think of instances when an operator's attention may be distracted that might lead to instability/ overturning?

How might these risks be reduced?

- Distractions (e.g. phone / personal problems)
- Focus on task
- Lack of attention to surroundings (e.g. looking at controls / pedestrians / vehicles in path of telehandler which diverts attention from overhead objects)
- Familiarity with route

4. VISIBILITY

4.1 How do you think poor operator visibility might lead to instability/ overturning?

4.2 What factors might contribute to poor visibility while operating a telehandler?

- Vehicle design
- Mast position

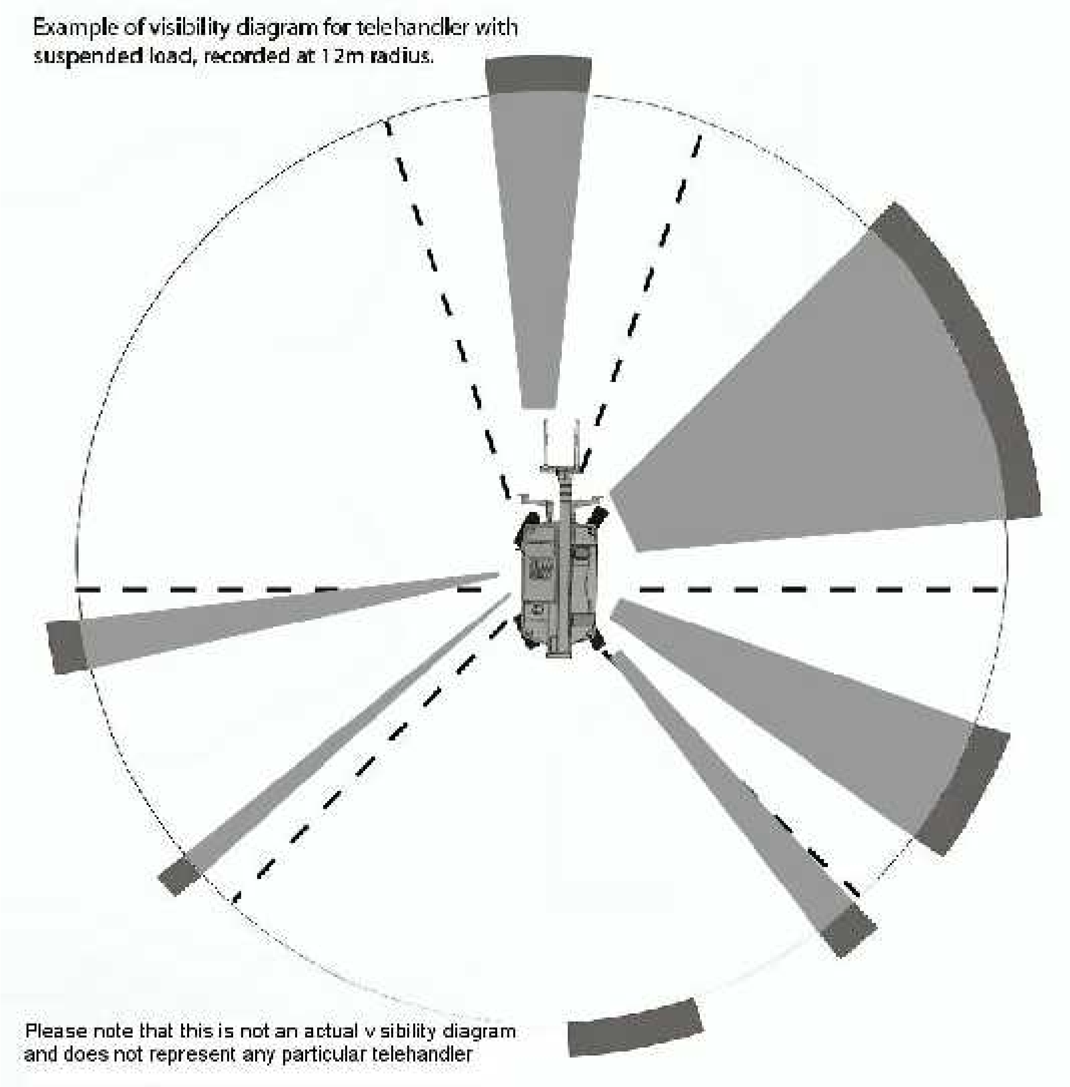
- Cab structure
- Cleanliness of windows
- Operator eyesight
- Lighting conditions (environmental and vehicle)
- Sunlight and other sources of glare

4.3 Are you familiar with the requirements in BS EN15830:2012 *(Visibility: Test methods and verification)* for telehandlers?

- If yes, what do you think of the adequacy of the standard in identifying areas of poor visibility and relevance to overturns?

- BS EN15830:2012 does not address issues such as visibility of the ground, of obstacles and of the mast end, all of which are important. What are the implications of this?

4.4 Looking at FLASHCARD 1, have you ever seen a visibility diagram for a telehandler?



4.5 If yes, how is this information used?

4.6 How is this information conveyed to telehandler operators?

4.7 What measures are you aware of to improve visibility and the operator's awareness of people / obstacles in the vicinity of the telehandler?

- *Mirrors, CCTV, window cleaning,*

4.8 How practical are these controls to use in real jobs?

- *Are they easy to use?*
- *What feedback have you received from users?*

4.9 Are you involved in the selection of secondary visual aids, such as mirrors, cameras or radar devices?

- *If not who is?*

4.10 Are you aware of any other methods to improve visibility and the operator's awareness of people / obstacles in the vicinity of the telehandler? (For example radar or ultrasonic sensors - to your knowledge have these been fitted successfully to telehandlers?)

4.11 In your opinion, what other control measures / technology could potentially be used to reduce the residual risk associated with poor visibility from a telehandler?

4.12 What impact does travelling with a raised load / boom have on operator visibility?

5. STABILITY

5.1 Why might operators not use outriggers?

- What are the consequences of not using outriggers?
- What design safeguards eg: interlocks/ alarms/ envelope control exist to reduce the likelihood of telehandlers being operated without outriggers being deployed?
- How easy is it to defeat such safeguards (please provide examples)?
- How common is it for operators to defeat safeguards in your opinion/ experience and why would they be motivated to do it

5.2 Why might operators not use load charts?

- What are the consequences of not using load charts
- Do you think load charts are easy to understand and do you think operators understand them?

5.5 What effect do different attachments have on telehandler stability?

- Fly jib
- Integrated access platforms

5.6 What are the effects of tyre pressures/ tyre rating/ tyre make/ tyre ply on the probability of instability/ overturning?

5.7 Which is the more significant issue for telehandlers: lateral or longitudinal (in)stability - please give reasons.

5.8 In your opinion, are operators more at risk of overturns when travelling or when stationary?

5.9 Can you think of any situations that might increase the probability of overturning?

- How could they be addressed?
- Driving with the boom raised
- Lifting a load beyond the capacity of the machine
- Transporting a suspended load
- Proximity to other objects / plant
- Ground surface

6. DESIGN

6.1 Can you think of any examples of how poor design may contribute to the probability of a telehandler overturning?

6.2 Are there design differences between makes and models of telehandler that may impact on the probability of a telehandler overturning?

6.3 Are telehandler controls standardised across different makes and models of machines (e.g. like excavators)?

- If controls are not standardised, what might be the risks for overturning/ instability when operators operate different machines?

6.4 What are your views on the stability indicator / limiters fitted to many telehandlers? (both positive and negative)

- Longitudinal stability indicator
- Longitudinal Load Moment Control

How well do you think operators understand the function, purpose and operation of these devices?
How well do you think operators understand that such devices relate to longitudinal stability and not lateral stability?

6.5 What other control measures are you aware of to prevent or reduce the probability of a telehandler overturning?

6.6 How practical are current control measures?

6.7 In your opinion, what other control measures / technology could potentially be used to prevent a telehandler overturning?

6.8 Is it possible to override any of the controls and can you think of situations where an operator would want to override a control?

7. TRAINING*/EXPERIENCE/FAMILIARISATION

***** *Pick up on this throughout***

(training courses/wrong type/sequence/height/emergency procedure/plan/unfamiliar)

7.1 Can you think of any “bad habits” an operator may develop due to lack of experience or training?

- Lack of awareness of hazards
- Complicated / inappropriate sequence of boom movements
- Using wrong type / size of telehandler for task in hand
- When should you use certain types / sizes of attachments?
- Driving at high speed - what should be done?
- Unfamiliar controls and layout of control panel – different makes / models, how do you combat that?

7.2 Are there a number of training courses that operators can go on? (Construction Plant Competence Scheme)

If so, is there a set of competencies that they must cover?

8. LONE WORKING

8.1 If an operator was working by themselves, how might that increase the probability of an overturning incident occurring?

9. CONDITION OF TELEHANDLER

9.1 What can happen if a telehandler is poorly maintained?

9.2 What faults or condition of telehandler could potentially increase the probability of overturning?

- Age
- Mechanical fault / failure – poorly maintained

9.3 How might these failings be addressed?

10. NEAR MISSES / INCIDENTS

10.1 Have you witnessed any overturning near misses or incidents or been involved in investigating such incidents?

If **yes**, what happened?

10.2 What actions did the operator take that led to this (if known)?

10.3 What do you think would have been the correct actions to avoid the increased probability of a telehandler overturning?

11. AND FINALLY…. PREDICTION OF END USER KNOWLEDGE GAPS

11.1 Do you have any predictions of where end users may have gaps in their knowledge regarding any of the risks that you have identified?

ENDING

Thank you

That’s everything I wanted to talk to you about today, is there anything else that you would like to say?

Reassurance - Your views and contributions are anonymous but if you would like to be formally acknowledged for your contribution to the research please let me know.

6. APPENDIX 2: OPERATOR QUESTION GUIDE

Introduction

Thank you for agreeing to participate in this research interview.

- The aim of this research is to look at the human factors involved in accidents where telescopic handlers have overturned in order to help identify possible solutions. We aim to interview both subject matter experts and operators to help us better understand the problem. Your opinions as a telescopic handler operator are important to us.
- The findings of this research will help to inform HSE guidance and may lead to improvements in training and relevant standards.
- **Anonymity – confidentiality**: All the information that you will provide will be anonymous and confidential. The findings will be summarised across all interviews and will not be traceable to any individual or any organisation.
- **Voluntary:** This interview is voluntary and you can withdraw at any time. If there are questions that you do not wish to answer, it is fine, please let me know.
- Do you have any questions about this research before we start?
- **Permission to record the interview:** I would like to ask you if I could record the interview to make sure the interview analysis will be carried out using accurate information. Are you happy for me to record our conversation? At any point, feel free to ask me to stop recording if you wish to.

About you

- What does your job involve?
- How long have you been operating telehandlers?
- How frequently do you operate a telehandler?
- What type of license/"ticket" do you have and who awarded it? e.g. CPCS, blue or red card
- What sort of sites have you operated telehandlers on?
- Have you operated both a construction telehandler and an agricultural telehandler (telescopic loader - a loader with a telescopic boom which can be fitted with forks, buckets etc.) ?
- What other types of construction plant do you operate?

Using the Telehandler on Site

1. What sort of tasks/situations present the greatest risks of a machine overturn when operating a telehandler?
    - Most likely overturn situations? Which is most dangerous (please rank if possible)
    - Do you wear a seatbelt and what is the risk of not wearing a seat belt?
    - Rushing or cutting corners?
    - Operator being distracted?
2. Do weather conditions increase the risk of overturning?
    - Explanations, reasons and examples please
3. Do ground conditions affect the risk of overturning?
    - Explanations, reasons and examples please

Control Related Overturning Risks

4. In using the telehandler controls, is it possible to make mistakes that could increase the risk of the machine overturning?
5. Do you think that moving between machines made by different manufacturers increases the risk of overturning a machine?
6. Can you think of any situations where you have accidently knocked/moved a control which could have increased the risk of overturning?
7. Can you think of any situations where you have accidently chosen the incorrect control which could have increased the risk of overturning?
8. Would changing the design of the controls in any way reduce overturning risks?

Visibility and Overturning

9. Does poor visibility from the cab increase the risk of overturning?
    - Please give examples

Training and overturning

13. How well does training cover the risks of overturning in a telehandler?
14. Does the training cover stability, centre of gravity etc.?
15. Has training or your experience been more important in terms of learning about the risks of overturning a telehandler?

Stability and Overturning

18. Do you use the load chart when operating a telehandler? (Show example load chart)
19. How easy are load charts to understand - do you think all operators understand them?
20. How often do you know the weights of the things you are lifting?
21. Does the overload alarm(s) in any way affect the way you work with the machine?
    - Is it common practice to disable the alarms?
22. Do you always use the stabilisers when lifting loads?
    - If not, why not?
23. When using stabilisers to lift a load, how easy is it to raise the stabilisers by accidently moving a control?
24. How important are tyre pressures in affecting the stability of a telehandler?
    - Please explain your answer:
25. When the boom is raised and/or when carrying a load, a telehandler can tip sideways or lengthways. In your opinion, which of these situations is most likely to result in an overturn?
26. In your opinion, what is the overturn risk when a telehandler is carrying a suspended load?
    - How can the risk of an overturn be reduced when carrying a suspended load?
27. Are you aware of any manufacturer restrictions on carrying suspended loads on a site?

Design

28. Are you aware of any design differences (such as different control layouts) between different makes and models of telehandler that could affect the risk of overturning?
29. Are there indicator systems fitted to telehandlers designed to warn of an overturn?

- If yes, what are their limitations?
- Do you use them to monitor the lateral stability of the truck? In your opinion could this system be improved in any way?

Defeating alarms / indicators/ moment control interlocks

30. What factors might cause/motivate someone to defeat alarms/ indicators/ moment control interlocks
31. How might these devices be defeated? Provide examples (what are the tricks of the trade/ what are the tell tales signs that something has been defeated)
32. How widespread do you think the defeating of alarms/ indicators/ moment control interlocks is on sites

Planning of Lifting operations

33. Have any of your lifting operations using a telehandler been formally planned - e.g. involving an Appointed Person and/or the production of a formal method statement/ lifting plan?

Condition of Telehandler

34. How could poor maintenance increase the risks of overturn?

Near Misses

35. Have you had any “near misses” that could have resulted in your telehandler overturning OR witnessed or been involved in a telehandler overturning incident?

7. APPENDIX 3: INFLUENCING INTERACTIONS BETWEEN RISK FACTORS

Key to tables:

- Knowledge of risk factor demonstrated by one or more end users mentioning the issue
- No knowledge of risk factor demonstrated by no end users mentioning the issue
- Potential new risk factor demonstrated by one or more end users mentioning the issue but no SMEs mentioning it

1. Ground conditions (has influencing interactions between the following topic tables: 2, 3, 4, 5, 6, 7, 8, 9)

uneven / rough	roots	loose / grit / gravel	pot holes / trenches / ditch /gully	sharp objects
Wet kerbs	muddy hidden conditions	slippery changing conditions	soft lack of pre-assessment (ground checks)	sloping insufficient briefing about site issues
poor visibility	lack of observation / awareness			

2. Weather (has influencing interactions between the following topic tables: 1, 3, 4, 7)

Ice bright sunlight	fog clouds disorientating	snow poor visibility	wind poor lighting / darkness	rain

3. Poor visibility (has influencing interactions between the following topic tables: 1, 2, 4, 5, 6, 7, 9)

weather	ground conditions	condensation of windows	poor cab design	position of boom
blind spot	dirty windows	cracked mirrors	wipers not working	obstructions/obstacles
confined / narrow / tight space	lack of observations / awareness	lack of / not using banks man	not using mirrors	telehandler visibility diagram not conveyed to operator
poor eyesight				

4. Poor maintenance (has influencing interactions between the following topic tables: 2, 3, 5, 6, 7, 8, 9, 15)				
wipers	brakes	cracked mirrors	hydraulic failure	tyre pressure incorrect / soft
damaged / punctured tyres	incorrect make/model/size of tyre	equipment not tested to LOLER	load indicators not recalibrated	Steering
stabilisers	latching mechanism for attachments	age of TH / legacy machines	dirty windows	insufficient checks
lack of observations / awareness	unreliable / inaccurate stability alarm indicators			

5. Obstructions / obstacles (has influencing interactions between the following topic tables: 1, 3, 4, 6, 7, 8, 9, 10, 11)				
pedestrians	site traffic	proximity	behind	overhead
cracked mirrors	dirty windows	blind spot	position of boom	poor cab design
condensation of windows	indoors	confined / narrow / tight space	lack of route planning	insufficient briefing about site issues
lack of pre-assessment (ground checks)	poor visibility	lack of observation / awareness	not using mirrors	lack of / not using banks man
telehandler visibility diagram not conveyed to operator	poor eyesight	distractions -other operators -phone -radio -noise	elevated boom	extended boom

6. Individual Factors (has influencing interactions between the following topic tables: 1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15)				
poor morale	work pressure	fatigue	stress	laziness
time pressure	indifference / blasØ	macho culture	confusion	deliberate
productivity/ bonus targets	inadequate communication between operator and banks men	incorrect user expectations of machine capability	lack of attention / concentration	overriding safety features
peer pressure	complacency	rushing	cutting corners	lack of skills recognition
risk taking	Lack of care	misjudging	annoyance	

		distances		

7. Lack of training / knowledge / familiarisation (has influencing interactions between all the topic tables)				
lack of / not using banks man	not using mirrors	inappropriate task for telehandler	incorrect selection of telehandler	limited machine type experience
unaware of vehicle speed	not following manufacturer's instructions	moving from a small to a large machine	lack of competence	lack of understanding of stability triangle
not familiar with BS15830:2012	not using user handbook	no safe system of work	telehandler visibility diagram not conveyed to operator	insufficient briefing about site issues
lack of pre-assessment (ground checks)	lack of daily checks	push telehandler to extreme limits	telehandler for unintended purpose	poor maintenance
ground conditions	not using user handbook	lateral instability	longitudinal instability	fly jibs / attachments increase vulnerability
weather conditions	lack of observations / awareness	obstructions / obstacles	lack of route planning	

8. Lack of observations / awareness (has influencing interactions between the following topic tables: 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13)				
lack of training / knowledge / familiarisation	hidden conditions	poor eyesight	distractions -other operators -phone -radio -noise	poor visibility
ground conditions	poor maintenance	lack of pre-assessment (ground checks)	insufficient briefing about site issues	weather
obstructions / obstacles	poor management	control errors	unknown load	

9. Poor management (has influencing interactions between the following topic tables: 1, 3, 4, 5, 6, 7, 8, 10, 11, 14)				
untrained management	insufficient briefing about site issues	lack of route planning	lack of method statement	lack of supervision
no banks man	lone working	no safe system of work	no facility to blow up tyres	load

			(remote site)
actions / tasks	poor maintenance	inappropriate task for TH	

10. Load (has influencing interactions between the following topic tables: 5, 6, 7, 8, 9, 11, 14)				
elevated load	over loading / heavy	unknown load	lightly laden	un laden
moving with load	not moving with load	load not suitably restrained	lack of checks on load	using 1 fork to lift a load
unstable load	sway of load	not using load charts	poor management	poor visibility

11. Specific situations / Tasks (has influencing interactions between the following topic tables: 5, 6, 7, 8, 9, 10, 14, 15)				
slopes at speed	turning at speed	turning too tightly	going down a slope forwards	braking heavily
driving erratically	elevated boom	extended boom	using 1 fork to lift a load	not applying parking brake
speeding	not using load charts	not using stabilisers	not using stability alarm indicators	

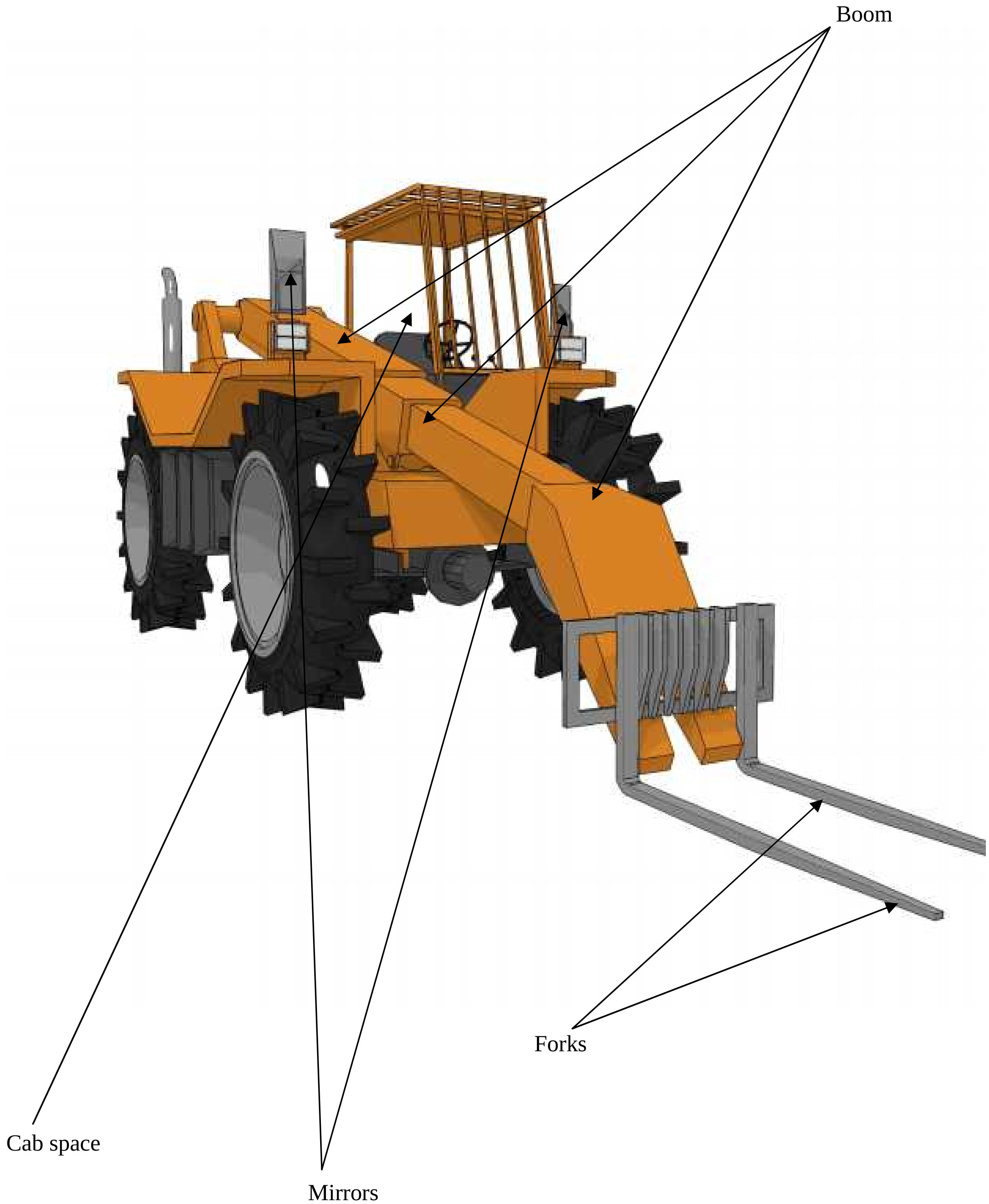
12. Knocking controls (has influencing interactions between the following topic tables: 6, 7, 13)				
loose clothing	items in cab / dirty cab floor	moving inside cab	large operator	inadequate cab space
inadequate control separation	reaching across controls	lack of machine isolation	unfamiliar with controls	

13. Control errors (has influencing interactions between the following topic tables: 6, 7, 12)				
controls not smooth to operate	choose incorrect control	inconsistency between manufacturers/models/machine types	overfamiliarity	knocking controls

14. Not using load charts (has influencing interactions between the following topic tables: 6, 7, 9, 10, 11)		
difficult to understand / complicated	unclear / poor legibility / contaminated	not quick to use

15. Not using stability alarm indicators (has influencing interactions between the following topic tables: 4, 6, 7)				
operator becomes too reliant	unreliable / inaccurate	lack of maintenance	not believing indicator alarms	to prevent annoyance for residents
does not relate to lateral stability				

8. APPENDIX 4: TELESCOPIC HANDLER SCHEMATIC ILLUSTRATION



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Exploring the human and physical factors associated with telescopic handler overturning

A combination of machine instability and various human factors elements are important precipitating factors in telescopic handler overturn incidents. Industry guidance makes a number of assumptions about the impact of operator "knowledge gaps", however the link between operator knowledge gaps and overturn risk is, at present, hypothetical and remains empirically untested.

This study was done to identify:

- the full range of human factors issues that might potentially contribute to telescopic handler overturn incidents;
- the human factors issues that appear to be most important in terms of overturn risk and
- key operator knowledge gaps that could increase the probability of an operator overturning a machine.

The research indicates that a machine is more likely to overturn when its boom is raised and /or extended. Overturn incidents are also strongly related to lateral (in contrast to longitudinal) instability. As some operators were not aware of the overturn risk related to lateral instability, this implies the possibility of a knowledge gap among operators. Weaknesses in training and site management/supervision are also likely to increase overturn risk.
The installation of lateral instability warning technology could reduce overturn risks by warning operators of dangerous situations before a critical threshold is reached.

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