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Research article

Barriers to achieving satisfactory dropped objects safety performance in the UK construction sector

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ABSTRACT

In 1980 a deadly explosion occurred at a nuclear missile base precipitated by a dropped object. The potential for major catastrophe, an industry call to action and a research gap forms the rationale for this research into dropped objects. The aim of the research was to devise guidance to assist United Kingdom (UK) based construction sector companies to reduce the frequency of dropped object incidents. A mixed research approach that includes literature review, semi-structured interviews and case studies were used to achieve the purpose of this research. The trend data revealed that dropped object incident rates have remained flat in recent years. The quantitative incident reports and qualitative feedback from interviews concluded that design is a contributory factor in a significant number of incidents and possibly in many cases but more research with a larger quantitative research sample is required. The interviews and literature review revealed several useful recommendations to sector bodies, construction sector companies and for further academic research. Recommendations to Individual Construction Sector Companies are grouped into different themes including manage, eliminate and control. The main recommendations to regulators included ensuring that tool tethering and containers are marked and inspected in line with other lifting equipment. Industry bodies could consider liaising with the energy industry to develop a suitable general construction exclusion zone calculator. Initiatives to improve the design of Mast Climbing Work Platforms to provide integral storage and enclosure solutions could be initiated with the vendors of this equipment. Practitioners and companies could consider offsite construction as a strategic means to reduce the number of dropped objects and consider work scopes that could be executed at ground level rather than at height. Consideration could be given to the more commonly deployed off-site fabrication options such as façade panels and bathroom pods. During detailed design, companies could have a high focus on the mechanism of reducing fixings in facades using Building Information Modelling.

There are a number of areas which can be investigated further such as the implications of offsite construction on dropped objects accidents when compared with traditional methods. The research findings hint that Business Information Modelling might be a useful tool to reduce dropped objects on construction sites especially related to facades.

While there were several limitations of the research including a limited amount of quantitative data and availability of the specific interview group, the findings of the research will still be useful for the construction sector in the UK and overseas to improve safety performance in construction.

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1. Introduction and background of research

In the early hours of September 19, 1980, an explosion rocked the Arkansas countryside killing one person and ejecting a nuclear warhead from its silo. The cause of the deadly blast was traced back to a serviceman dropping a tool into a missile silo at a Titan II nuclear missile base [1]. In addition to being one of the main industrial accident types this potentially catastrophic incident illustrates that dropped objects are worthy of study [2]. A similar trend is also evident by the statistics of Occupational Health and Safety Administration (OSHA) which reveals that falling objects cause more than 50000 injuries each year [3]. Apart from injuries, dropped objects can also cause damage to equipment and structural parts which can affect overall structure stability [4].

Initial discussions with a major UK construction company (Company D) have indicated that the risks presented by objects dropped from height are a major concern for them and other large UK construction companies as they were felt to be relatively under researched. This is also supported by evidence in literature that suggests that dropped object risks in construction are sometimes overlooked compared to other construction risks [5–7]. The current HSE statistics indicate that a third of injuries are caused by falling objects [8] Company D raised the general dropped objects elimination by design topic initially and this suggestion was used in conjunction with an intensive literature review to formulate appropriate research objectives. For instance, a survey conducted by the Centre for Construction Research and Training in 2022 established the lack of understanding on how to address hazards associated with dropped objects [9].

Given the above research gap, the potentially catastrophic consequences of incidents and the construction industry call for action, the aim of the research is to devise guidance to assist UK construction companies to reduce the number of dropped object incidents. The research was based around the initial hypothesis that sub-optimal design of some element of the work scope is a contributory factor in the majority of objects dropped from height incidents. Sub-optimal design refers to a design or solution that is not the most efficient, effective, or ideal one in a given context. It falls short of achieving the best possible outcome or performance based on certain criteria or requirements [10]. In various fields such as engineering, architecture, software development, or business, sub-optimal design can arise for various reasons, including limitations in resources, time constraints, lack of expertise, inadequate planning, or the presence of constraints or trade-offs. It often represents a compromise between different factors or objectives [11].

The key research question set for the research was "To what extent are sub-optimal design of task, equipment, and materials a contributory factor to objects dropped from height incidents?"

The objectives of the study were then developed in relation to dropped objects hazards:

- To understand the trends related to hazards caused by sub-optimal design of task, equipment, and materials (this will include traditional on-site fabrication).
- To explore the problems related to traditional onsite fabrication and sub-optimal design of task, equipment, and materials.
- To evaluate optimal solutions related to offsite fabrication and designing out or mitigating hazards related to task, equipment, and materials.
- To provide recommendations for companies to improve safety outcomes linked to offsite fabrication and optimising design of task, equipment, and materials and to identify further research goals

The scope is focussed on greenfield but does include findings and learnings from refurbishment projects. Dropped objects include objects dropped from cranes, below ground and from scaffolding or masonry collapses. Design of task, equipment and materials includes the design of an entire building project where appropriate.

A mixed research approach was selected that includes literature review, semi-structured interviews and case studies to achieve the purpose of this research. The trend data revealed that dropped object incident rates have remained flat in recent years. The quantitative incident reports and qualitative feedback from interviews concluded that design is a contributory factor in a significant number of incidents and possibly in many cases but more research with a larger quantitative research sample is required. The interviews and literature review revealed several useful recommendations to sector bodies, construction sector companies and for further academic research including key findings on reviewing Lifting regulations and mandating training for items such as Mast Climbing Work Platforms (MCWP).

2. Literature review

A critical analysis of recent relevant literature related to optimal accident causation models, Prevention through Design (PtD) and Dropped Object specific research has been performed.

2.1. Accident causation models

Optimal accident causation models are generally high level and theoretical [12] (whereas PtD and Dropped Objects specific research is more empirical, and practice based [13–15]. Accident causation models provide a general theoretical framework of incident examination and prevention and sometimes form the basis of governmental safety policies, safety decision making or incident investigation techniques [16]. The most optimal models for dropped object incident reduction research are explored here [17]. Accident causation theories are still a focus of research investigation [18,19]. And there is currently no universally accepted accident causation model [20]. There are many theories and a multitude of classification systems for these theories and the distinctions can overlap [21,22]. Out of the available classifications the energy transfer and system/systematic models are explored here as they were found to be relevant ones to the research goals [18].

2.1.1. Energy transfer/Release models

Energy transfer models consider incidents to be caused by a transfer of disparate forms of undesired energy between a source to the victim [18]. Haddon [23] noted that the most concerning energy transfer type was related to delivery of mechanical energy including dropped objects. Haddon [23] then later followed up with strategies designed to reduce energy transfer hazards. These strategies included a hierarchy of controls similar to the general hierarchy of control starting from prevention of generation of energy and progressing to controls such as safety barriers [23]. Haddon finally recommended that development of these strategies for specific applications required systematic analysis [23].

In the case of dropped objects the control of mechanical energy transfer can be attained by eradication of the source (e.g., working from ground level) and the path of the energy can be mitigated by installation of barriers [24]. Haddon later produced matrices which can be used as an aid to effective strategy identification in different contexts including reducing mechanical energy exchange injuries [25,26]. These matrices have been used in a variety of recent papers including research on hospital earthquake response [27]. These insights are considered to be a major step forward in injury reduction [28] and these matrices could be applied in further research related to the reduction of dropped object related injuries.

2.1.2. System/Systematic models

The system/systematic models include human factors and management factors [18].

In these models' unsafe acts are seen as a consequence rather than the determining cause of incidents. It is inevitable that humans make mistakes and latent conditions such as poor design, supervisory failures or ambiguous procedures are thus the principal causes. Typically, active failures are immediate and committed by front-line staff whereas latent failures are long-term and generally driven by senior management or regulators. Reason's Swiss Cheese model is a key example of this model type where in the ideal world there is a set of layered impenetrable defences but in the real world each layer has weaknesses [29].

The Reason model has had a number of criticisms related mainly to the fact that it is not possible to refute it by standard scientific methods, but that was not the intent of the model which was to form a strong visual heuristic [30]. Researchers believe that the Swiss Cheese model still remains a useful model to conduct incident analysis [31]. Incident investigation techniques have been driven from this model such as TRIPOD Beta which was developed for use in the oil industry [22]. It is not clear from the literature to what extent TRIPOD Beta investigation models are used in building construction investigation if at all and this might be a suitable line of enquiry for future researchers.

2.2. Prevention through design (PtD) research evaluation

Empirical evidence and the theoretical frameworks have been reviewed to demonstrate whether there is support for the hypothesis that sub-optimal design is a contributory factor in the majority of dropped object incidents. There is significant empirical evidence related to the linkage of design to construction accidents and these are described in this section. There is also a reasonable amount of theoretical thinking on the subject. However, some of this earlier research is flawed to some extent and these flaws will be discussed. These results are for general construction design rather than for dropped objects specifically.

As early as 1964 it was recognized by the International Labour Organization (ILO) that architects and designers had a duty to protect the safety of construction workers during the planning stage and a general code of practice was developed which encompassed specific guidance to architects, designers, and engineers. This code was updated in 1992 [32].

The theoretical basis for the involvement of designers is via the Hierarchy of Controls concept where elimination of a risk is the most effective of a descending list of measures.

The Hierarchy of Controls is part of the PtD Strategy which attempts to design out hazards. PtD is also known as Designing for Safety or the Design for Construction Safety Concept [14,32–35]. The first studies of design failures caused in construction were executed in the early 1990s before any regulations related to PtD were implemented [36]. A European Foundation for the Improvement of Living and Working Conditions (Eurofound) study determined that circa 60 % of fatal accidents arose from planning decisions either in design or caused by work organisational failures quoted in Behm [37]. Unfortunately, this widely cited original study which is considered a critical part of the PtD evidence base is not available online and a recent paper describes some potential weaknesses in the basis of the Eurofound report principally that it does not describe how the original data was collected or how the causal attributions were determined [38].

The HSE commissioned a major academic study in the early 2000s which examined causal factors related to construction accidents by expert analysis of a representative sample of accidents volunteered by companies [39,40]. The results were that a substantive number of accidents were linked to sub-optimal design of some element of the work-scope, materials, or equipment (ibid.). Deficiencies with equipment were identified in more than half (56 %) or all incidents and problems with conditions and appropriateness of materials was an issue in more than a quarter of incidents (27 %) [39,40]. An earlier report linked to the same overall study found that up to half of the accidents could have been mitigated by a design change [41].

A study at around the same time in the United States (US) suggested that 42 % of fatalities could have been mitigated or avoided if the PtD concept had been used [37].

The methodology and research sample chosen was different from the earlier HSE study (ibid.). Over 200 incidents were gleaned from the United States National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment Control and Evaluation

(FACE) database and reviewed to determine if poor design was a factor against a methodology mainly focussing on design suggestions determined by an earlier study (ibid). An acknowledged weakness in this study was that the FACE programme does not investigate all fatal work-related incidents and there is a bias towards specific safety campaigns (ibid).

In terms of prevention through design leadership, the importance of Designers having site experience is highlighted in the literature. A well-structured research project identified that skill at identifying hazards is 45 % greater for designers who possess construction experience [42].

Management of change (MoC) has garnered little research in general construction [43]. Interface Management and the related topic of Building Information Modelling (BIM) as a means of delivering PtD by contrast is reasonably well described in the literature. BIM is seen to provide a logical interface in the execution of good Interface Management [44].

2.3. Dropped object specific research

Dropped Objects are not only an occupational risk but also present a danger to the public as well as in some situations resulting in Major Accident Hazards (MAH) as a dropped object could lead to fires, explosion or collapse [45]. Catastrophic events related to dropped objects in construction noted include collapses of temporary works such as scaffolds and formwork and a high potential near miss when a steel frame collapsed just after staff had left the worksite [46,47]. For this reason, energy organisations globally see dropped objects as of major concern and there are many examples of good practice from the energy industry such as the Dropped Objects Protection Scheme [48].

By contrast it is asserted that dropped objects in construction are sometimes overlooked compared to falls from height and certainly a relative lack of specific research related to dropped objects in construction was apparent during the literature review [5,6]. Companies may view drop prevention equipment as overly restrictive or pursue a generic approach for all objects which is not effective (ibid.). There may be an element of psychology and culture that impacts this – fall prevention protects the individual worker, drop prevention protects others [49]. The two relevant regulations for dropped objects are the Work at Height Regulations 2005 (WAHR) and indirectly the Lifting Operations and Lifting Equipment regulations (LOLER) 1998 [50,51]. Unfortunately, there is only one clause in the WAHR regulation related to falling objects, and the related guidance is mainly focused on avoiding falls [51,52]. MCWP are suitable as a substitute for scaffolding for high-rise refurbishment projects such as over-cladding [53]. Passive controls for dropped objects encompass equipment that prevents a dropped object from hurting personnel or members of the public such as toe-boards, containment nets and sheets [54]. Active controls by contrast move with the workers during the job such as tethers or containers [55]. Exclusion zones are studied extensively in the process industries but there appears to be limited literature related to general construction [56]. There is some new technology related to exclusion zone alarms noted in the literature [57].

The impact of deflections of objects against buildings or equipment depends on factors including size of object and type of surface impacted and, in some cases, the exclusion zone would be too large to be practical [58]. Energy Safety Canada (ESC) has produced a draft dropped object exclusion zone tool with the intent of publishing this in a journal [59].

A new voluntary American National Standards institute standard has recently been rolled out with the intent to provide design and performance criteria for active tool tethering, attachment, and containment systems [60]. The standard has been well received in the United States [60].

Overall, the quality of the literature despite noted flaws lends strong support to the idea that design can be a contributory factor in a significant number of all cause construction incidents although the literature is silent in terms of whether that is also the case for dropped objects specifically. In terms of management of PtD the literature stresses the need for site experienced Designers but has little to add about general construction MoC [61]. The process and energy industries offer stronger quality of evidence overall for the implementation of engineering control methods to eliminate or substitute dropped objects hazards than the general construction industry but there is evidence of innovation in the general construction marketplace related to replacements for scaffolding which could improve dropped objects prevention.

3. Research methodology

A mixed research method methodology that includes both quantitative and qualitative approaches has been employed [62,63]. Trend data has been gleaned from HSE sources [64]. Incident data received from Company D has been employed to gather quantitative data linked to dropped object incidents. Then in parallel the main thrust of the research effort was to conduct qualitative exploratory and attitudinal semi-structured interviews within a Case Study of several occupational groups across several companies. Views from the different companies and occupational groups were compared and contrasted. The rationale for this is it allows the researcher to explore both quantitative data and qualitative findings in one study allowing an attempt to resolve both what the causal factors might be and also to determine potential solutions to these issues [65–67].

The country selected for the analysis is the United Kingdom of Great Britain. This region benefits from good quality construction safety statistics analysis via the regulator the Health and Safety Executive [64] which assists in the analysis of trends. It has also adopted the principles of prevention through design via the Construction and Design Management regulations [68].

3.1. Sampling

For the quantitative research the sample was based on a significantly sized public company with operations across all general construction sectors except housebuilding in the hope that this would be a reasonably representative sample. The trends data was based on verified data across all reported UK construction sector data from the HSE [69].

For the qualitative research sampling was based on selecting a range of different companies involved in the construction sector with operations in the UK [70]. The number of interviewees selected was based on research concluding that thematic saturation was generally achieved between 9 and 17 interviews and thus interviewing was stopped after 15 interviewees across the full range of occupational groups was achieved [71]. The choice of interviewee occupational type reflected key personnel that would typically have responsibility for aspects of safety in a construction or design organisation [72].

3.2. Quantitative research

The approach was to execute quantitative secondary data screening using corporate in-house data and primary HSE data to develop an understanding of key issues and trends and to develop a set of descriptive statistics to describe this. The following steps were taken to investigate Company D incident investigation reports and other in-house data available.

3.2.1. Data collection

The following data was captured, evaluated, and categorized.

- The company view of contributory factors due to incidents.
- Whether there were design issues that contributed to the incident.
- Exclusion zones effectiveness
- If the incident happened on a restricted site or from a high-rise development.

Where insufficient in-house Company data was available then public domain sources of information were consulted to fill in any gaps.

3.2.2. Methodology to determine whether incident was caused by design

The researchers had to define the boundaries of design in this situation. The design of task here includes the entire construction project and Risk Assessment (RA) failures are included as part of Design. The justification is that RA is a fundamental part of PtD [14] and is part of the Construction (Design and Management) Regulations 2015 process which requires Designers and Contractors to manage their risks in their respective phases [68]. Thus, as part of the assessment of whether design was a contributory factor then if a Risk Assessment and Method Statement (RAMS) is identified as either required but not done or the RAMS is inadequate then design is seen as a contributory factor for that incident. The Researchers' view of contributory factors was not always the same as Company view as will be explained in Discussion section.

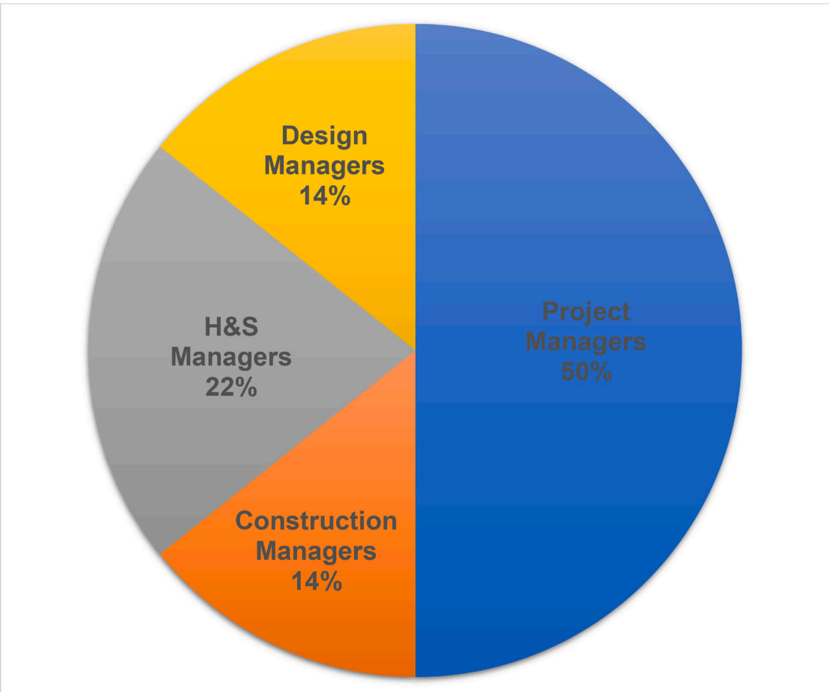

Fig. 1. Occupational group breakdown.

3.3. Qualitative research

For the qualitative research sampling was based on selecting a range of different companies involved in the construction sector with operations in the UK [70]. The response rate to invitations for interview was 83 %.

3.3.1. Sample selection

The qualitative sample was selected by harnessing the authors networks to select a range of suitable companies and interviewees with professional expertise linked to construction safety from companies involved in the UK construction sector. Four companies took part with the occupational groups being Construction managers (CM), Health and Safety Managers (H&S), Design Managers (DMs) and Project Managers (PMs). Initial suitability based on personal knowledge of these companies was confirmed by a check on the company websites to ensure that the companies took safety seriously either by having ISO 45001 Occupational Health and Safety Management Certification or by being regulated by UK professional institutions such as the Royal Institution of Chartered Surveyors (RICS).

A pie-chart showing the breakdown of each occupational group is shown in Fig. 1.

As noted in Fig. 1, the respondents were predominately Project Managers. Most of the participants were experienced with almost all having over ten years of industry experience. The four occupation types were chosen as the common occupations within the construction industry that have a wide and deep understanding of important safety impacts. Project Managers and Construction Managers are generally responsible for safety at the worksite [68]. Design Managers have formal safety responsibilities for the Design where they are Principal Designers under the UK Construction Design and Management regulations [68]. Health and Safety managers are responsible for developing safety policies and monitoring [73].

Respondents were from a range of companies that varied by size and construction sector. Data on Principal Activity and company size information was gleaned from company websites but not referenced to preserve company anonymity (See Table 1 for overview).

3.3.2. Preparation of a semi-structured interview framework

The existing literature review was used to form a list of all possible questions related to the research topic [74]. Once these questions were identified then they were high graded and then a questionnaire was constructed ready for a pilot study (ibid.). These questions were assigned into modules which were based on the relevant research objectives and a funnel approach was used to commence with broad questions and then narrow down to specific points [75]. The interview questions were designed to be open ended and probing questions were used where necessary [75]. The modules are shown as follows in Table 2.

The Pilot Questionnaire was then tested on the first interviewee. Feedback was sought from the interviewee including specific feedback questions. The results of a reflection session post interview were incorporated into the final questionnaire [75]. The main findings from the pilot were that there were too many questions to achieve within the 1 h allotted timeframe and there were insufficient open questions. There were also too many questions related to codes and standards which was not a topic area that leant itself well to this line of questioning.

Verbatim transcriptions were prepared from recorded sessions.

3.3.3. Analysis of results

Transcriptions from the interviews were then analysed using Thematic Analysis [65]. The process of analysis was iterative, codes were developed using ideas from literature and comments from interviewees eventually developing a set of final themes. A thematic analysis table was prepared identifying key insights, data inconsistences and relating the findings to the previous literature review. The thematic analysis table is shown in the Results and Analysis Section. Ultimately the analysed data was used as a framework to prepare a narrative. This narrative is included in the Discussion section and the discussion incorporates and compares findings with the literature review and the quantitative analysis [67].

4. Results and analysis

4.1. Results and analysis of trends data

Company D supplied incident data was only available for the last 2 years so trends from corporate data could not be analysed. Instead, tabular data available from the HSE RIDDOR database linked to dropped objects over the last 7 years was extracted and then plotted by the researcher. The relevant HSE data comprises moving objects which includes falling or flying objects but excludes strikes

Table 1
Overview of companies analysed.

Organisation	Size of Enterprise [69]	Principal Activity	Construction Sectors	Numbers of Interviewees
Company A	Medium	Principal contractor	Residential, retail, and commercial.	6
Company B	Large	Engineering, Procurement and Construction Management	Oil/Gas, Petrochemicals	2
Company C	Small	Principal Designer	Health, Education, and Ecclesiastical	3
Company D	Large	Principal Contractor	Environment, Defence, Health Infrastructure, Commercial.	3

Table 2
Overview of questionnaire modules.

Module	Module Description	Example Question from Module
A	General Questions related to background and company	Could you tell me briefly about your current role, career experience and approximate years of experience?
B	General Questions Related to Prevention Through Design	What are the barriers to achieving good safety in design for designers?
C	General Questions related to Prevention in Design of Dropped Objects	Do you think that design of task, equipment, and materials can be a significant contributory factor in hazardous situations or incidents linked to dropped objects?
D	Questions related to Elimination of Risk during the Design or Construction Phases	What specific work-scopes might be better done off-site to reduce dropped object incidents?
E	Engineering Controls – Passive Preventative Solutions	Do you think dropped object exclusion zones are a realistic solution on most construction sites for dropped objects given the potential for significant deflection of dropped objects?
F	Engineering Controls – Active Preventative Solutions	Can you explain what your company's policy is on active controls of dropped objects e.g., tethering?
G	Concluding Questions	Would you say that the opinions you have voiced in answer to these questions are commonly held by other people in your occupational group?

by moving vehicle and strikes against something fixed or stationery. The HSE data for fatalities includes both employed and self-employed workers. HSE notes the coronavirus pandemic impact on numbers for 2020/21 and to a lesser extent 2021/22 and also that data collection for 2019/20 was also impacted by the pandemic. For non-fatal injuries data has been revised from previous years to reflect changes in processing methods and exclude railways or offshore incidents. Figures for 2021/22 are provisional [64]. This data is shown in Fig. 2.

From Fig. 2 it can be seen that since 2014 and including the provisional data the number of dropped objects fatalities has fluctuated around a mean of 5. Consideration should be given to the impact of the pandemic on years 2019 through to 2022. Data for the total number of reported non-fatality injuries to employees is also available and this data comprises the sum of all specified injuries and the number of over-7-days injuries [64]. This is plotted below in Fig. 3.

A slightly reducing trend is seen for non-fatality injuries including the provisional data for 2021/22. The mean is 452. Consideration should be given to the impact of the pandemic on years 2019 through to 2022. These trends are similar to general construction industry incident trends where fatality rates have been fairly flat in recent years and for non-fatal self-reported injuries there was a downward trend [69].

4.2. Results and analysis of corporate data

Company D provided extensive recent incident data and reports related to dropped objects which were analysed. Details of the projects on which the incidents occurred are shown in Table 3. No further details of specific incidents will be shared here to preserve company confidentiality.

4.2.1. Statement of hypothesis testing

The hypothesis is tentatively supported by the secondary data screening analysis. Fig. 4 suggests that for the sample data design of task, equipment and materials is a contributory factor for a majority of dropped object incidents in the building construction sector. The sample size is small (15 incidents).

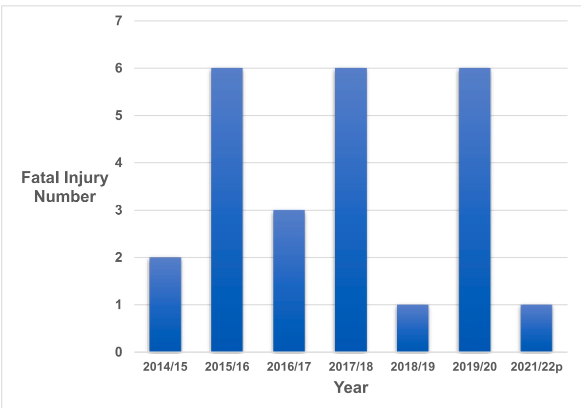

Fig. 2. Dropped objects trend data (2014–2021) (Adapted from Ref. [64]).

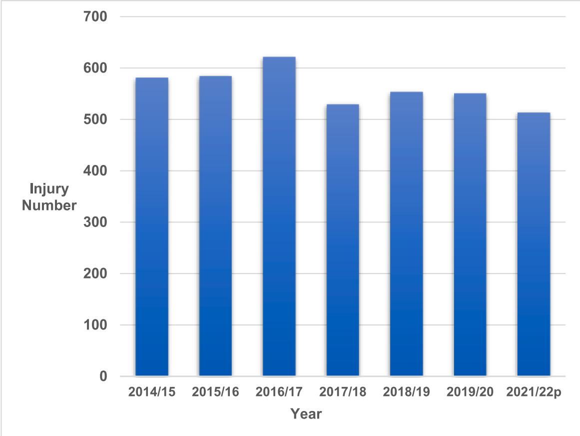

Fig. 3. Total reported non-fatality injury by dropped objects (2014–2021) (Adapted from Ref. [64]).

Table 3
Project details.

Project No.	Contract Value (to nearest £10 MM)	Project Type	Maximum Storeys	Significant Use of Offsite Fabrication	Restricted Site	Project Details
1	90	Mixed-use	18	Not known	Yes	Residential/commercial complex
2	50	Commercial	13	Not known	Yes	Office internal refurbishment
3	10	Educational	3	Yes	Yes	Extension to existing school
4	60	Commercial	4	Yes	No	Business centre
5	10	Educational	2	Yes	Yes	School
6	110	Mixed use	21	Yes	Yes	Brownfield site development
7	60	Mixed use	10	Yes	Yes	Redevelopment of city centre location
8	20	Mixed use	5	Yes	Yes	New theatre
9	50	Educational	4	Yes	Yes	School

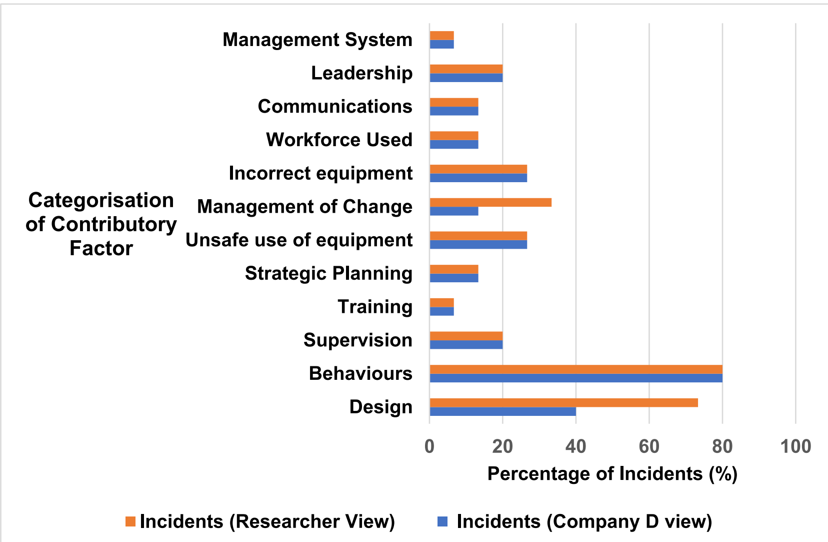

Fig. 4. Company D dropped object incidents contributory factors.

4.2.2. Main question: was design of task, equipment and/or materials a contributing factor?

Fig. 4 shows the Categories of Contributory Factors versus the percentage of incidents that this contributory factor occurs. This shows both the Researcher's view and the Company D view.

Fig. 4 shows that Design is a contributory factor in 73 % of all incidents (NB Company D only find Design contributory in 40 % of all incidents). The contributory factor categorisation used is the Company D categorisation. Root causes and contributory factors used by Company D are bundled together into one category here.

The supplementary questions that were tested were as follows:

1. Was an exclusion zone in place?
2. Did the dropped object breach the exclusion zone?

These supplementary questions are linked loosely to the themes developed in the qualitative analysis. Table 4 shows straightforward failures per theme against percentage of incidents.

4.2.3. Was an exclusion zone in place?

The exclusion zone is categorized as either in place, not in place or insufficient. If not explicitly mentioned in report, then the assumption was that they were in place. The analysis shows in Fig. 5 that exclusion zones were not in place in almost 50 % of dropped object incidents. In a further 13 % of cases, they were in place but insufficient. See Fig. 5 for an overview of Exclusion zone failures.

4.2.4. Did the dropped object breach the exclusion zone?

Breach means that either the object entered the public domain or a part of the site that it shouldn't have reached. A breach can occur even if no exclusion zone was formally set up. Fig. 6 shows that in 20 % of all incidents there was a breach to the public domain and in 47 % incidents there was a breach into a non-protected work area. The dropped object deflected in 27 % of incidents. See Fig. 6 for an overview of dropped object breaches.

Please note that Company D found less incidents where design was a root cause or a contributory factor (40 %). Company D mainly implicitly follow the same reasoning as the researcher and this difference may be due to inconsistencies in terms of incident investigation where many different investigators can be involved or because correct categorisation was not the incident investigators priority, or their definition of design was different. There is usually a level of subjectivity in terms of classifications [76]. There were some additional findings.

- 80 % of sites had significant offsite construction.
- In 20 % of sites the extent of offsite construction is unknown.
- The incident occurred on a High-Rise Development in 53 % of the cases.
- 87 % of the incidents occurred on restricted sites.

4.3. Results and analysis of qualitative data

Once the interviews were completed, transcribed and the analysis completed the final coding scheme was developed and is shown in Table 5. The themes are grouped into various main and sub-themes.

Using the codes above a thematic analysis table was then prepared identifying key insights, data inconsistences and relating the findings to the previous literature review. The thematic analysis table is shown in Table 6.

The analysed data from Table 6 was used as a framework to prepare a narrative. This narrative is included in the Discussion section and the discussion incorporates and compares findings with the literature review and the quantitative analysis [62].

5. Discussion

The discussion is divided into five main themes as outlined below.

- Manage
- Lead

Table 4
Failures per theme.

Theme	Failure	Percentage of Incidents
Manage	Management of Change	33 %
	Risk Assessment	67 %
	Interface Management	67 %
	Lifting Equipment	13 %
Control	Passive Control (not exclusion zone)	33 %
	Active Control	7 %

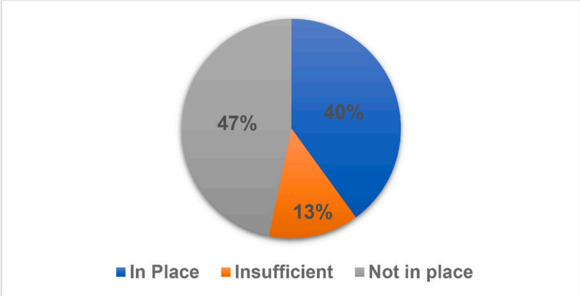

Fig. 5. Exclusion zone failures.

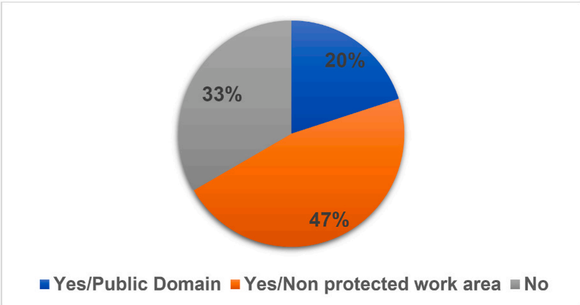

Fig. 6. Dropped object breach.

Table 5
Final coding scheme.

Main Code	Short Description	Sub Code	Short Description
1	Manage	A	General Management
		B	Interface/Management of Change
		C	Train/Competence
		D	Risk Management
2	Lead	A	Accountability
		B	Competing priorities
		C	Behaviours
3	Eliminate & Substitute	A	General
		B	Equipment
		C	Onsite fabrication
4	Control and protect	A	General
		B	Passive
		C	Active
		E	Materials
5	Improve	A	General
		B	Passive
		C	Active

- Eliminate or Substitute
- Control or Protect
- Improve

5.1. Manage

This theme focusses on the broad thrust of the Research question as to whether design of task, equipment and materials is a contributory factor in dropped object incidents. In 73 % of incidents design is found to be a root cause or a contributory factor, and this supports the positive hypothesis. The quantitative data does not prove the positive hypothesis is correct as it is a small sample of only 15 incidents. However, it does suggest that sub-optimal design of some element of the work-scope is a contributory factor in a significant number and perhaps a majority of dropped object incidents given that Company D is a significant construction company in the

Table 6
Thematic analysis table (summary).

Code	Literature Review	Observations, Implications, or interpretations	Data Consistencies	Data Inconsistencies
1A Manage/General	[68]	A large number of accidents are linked to the unsuccessful management of Human Factors and complacency. A large amount of management attention is required to ensure that workers behave safely One incident raised clearly linked to behaviour. Housekeeping plays a role in preventing dropped objects.	Most of the respondents thought design could be a significant factor in dropped object incidents.	Some argue that behaviours are driven by Management factors. One p.m. from company A thought design of equipment was good nowadays.
1B Manage/ Interface	[44]	There are often clashes in the field in terms of equipment that does not fit. Correct information with specific detail and not generic is desired. Interpretation of CDM can be a challenge. BIM could be useful in terms of reducing numbers of small items like fixings. Quality and experience of Temporary Works Co-ordinator is key. CDM consultants are used by Company B organisation for larger jobs	Safety during MoC was felt to be important but secondary to cost and programme. Construction leads the safety process during change management and Designers follow. Change control processes will be defined in the contract so they will generally be followed. Temporary Works Coordinators can be overstretched with more than role.	Mixed views on usefulness of BIM for PtD. About half thought it could be useful the rest either knew too little about it to comment or did not think there would be much scope. PM from Principal Designer (Company B) thought MoC was fit for purpose.
1C Manage/Train& Competence	[42]	Not all Designer personnel are aware of the potential for major accident hazards causing multiple fatalities due to dropped objects. Significant near misses are not always shared or reported externally. Focus by designers is more on structural stability, long term maintenance. Behavioural factors and training can help. Better training required for safe use of mast climbers.	A key barrier to Safety in Design is site experience for Designer personnel.	One H&S manager (Company A) observed that it was a really common hazard so would be disappointed if designers were not aware of the potential for major accidents cause by dropped objects. Design Manager CDM1 had not encountered much information related to dropped objects suggesting a lack of awareness on the topic. However, Company A and B personnel indicated a focus on this topic within their organisations.
1D Manage/Risk	[37]	Facilitated Safety in Design Workshops are required by CDM and are seen by the interviewees as beneficial. Ensure that there is an independent review of designs of temporary works. Design Manager in Company D had a Hazard Awareness matrix in play with a quarterly update on this. Principal Designer company (Company B) uses PCIs and Early involvement of contractor considered important. The Companies interviewed all provide good evidence of well managed procurement systems with safety at the heart of these. The two Design and Build contractors have Temporary Works Co-ordinators.	The interviewees agreed that barriers to workshops were generally time and gathering the right stakeholders. All interviewees saw workshops as beneficial. The interviewees had a reasonably consistent understanding of PtD	There were some subtleties in emphasis between elimination of risk and mitigation or control of risks.
2A Lead/ Accountability	[68]	Client, construction contractor and Designers have accountability for safety.	All interviewees gave the sense that they and their companies took safety seriously.	There was a feeling by some interviewees that clients saw safety as fully delegated to their contractors. They could buy their way out the accountability.
2B Lead/Competing Priorities	[N/A]	The interviewees consistently felt that Budget and programme came first and then safety as secondary in importance especially for clients. This can drive a focus on ensuring legal minimum requirements are met rather than a 'gold standard approach' to safety.	Both Company A and Company D are very focussed on dropped objects safety. Company A has a Working Group including partner organisations to combat this and Company D has expended resources this summer on shared incident information with the researcher. The	Some Project Managers didn't think that safety was top priority for Designers and that they felt that it was more of a construction activity. Concern that variation processes could not be followed properly due to fast pace of projects (Company C, PM2).

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Table 6 (*continued*)

Code	Literature Review	Observations, Implications, or interpretations	Data Consistencies	Data Inconsistencies
		Some interviewees noted that aesthetics requirements driven by planners (and in some cases clients) also implicitly sometimes have higher priority than inherent safety. These aesthetics requirements are often set in stone so all construction firm can do is mitigate risk rather than eliminate it. In addition, sustainability aspirations and standard estate wide requirements may also drive challenges specifically for dropped objects e.g., need for Roof PV. If projects are tendered then the best technology to ensure safety will not be adopted.	reason for the focus is that new buildings are getting higher and are in restricted sites, so the chance of incident is becoming higher. H&S manager, company D noted that conservatism/traditional solutions can also be a blocker to optimising safety.	
2C Lead/Behaviours	[47]	Developing deep relationships with clients and sub-contractors is key. Working with partner organisations to gather lessons learned and implement on next projects. Embracing change is important – construction can be conservative. Construction companies should be transparent and share lessons learned. Learnings from oil and gas on sharing lessons learned may be useful here. Contractor's early involvement in the design is crucial to influence PtD. These key issues need to be captured at the feasibility and conceptual phases of the project otherwise the design becomes more or less frozen and the ability to eliminate risk or strongly mitigate risks reduces. Contractor is seen by other parties as having the main responsibility for safety and is the backstop to safety – philosophy of controlling and mitigating risks rather than eliminating it.	Both Company A and D personnel stress the importance of working with long term partners to gather lessons learned and implement. Company C PM1 stressed the need as PD to communicate the residual risks from the Design and ensure optimal management. Company C PM1 stressed the need for Designers to recognize the expertise of the construction contractor and to work collaboratively.	Some interviewees suggested that contractors are not always sharing their near miss data. Some Project Managers felt Designers felt construction safety was not their priority.
3A Eliminate or Substitute/ General	[N/A]	Interviewees thought Elimination was a key part of PtD. It was important to try to eliminate risks early in the process. Removing the need for working at height and related to this the possibility of dropped objects was key. Reducing numbers of fixings on facades was thought of as important to reduce dropped objects incidents. Although early involvement of construction in conceptual design can eliminate many risks, high attention can be given by Designers in Detailed design to reduce the number of fixings to low as possible. Example Hop up to Paintbrush on stick.	Some interviewees say there is a move to work at ground rather than at height.	One Design Manager says that working at ground level is considered but is low priority as seen as 'not efficient or sensible' for the type of restricted, high rise sites they are often developing.
3B Eliminate or Substitute/ Equipment	N/A	Drones could be used to substitute for working at height. Company A and Company C personnel had direct experience of using drones. Company C had just completed a survey of a local Public School with a fragile roof.	Most of the interviewees thought it could be a good substitution strategy for working at height reducing the need for abseilers or working on roofs for surveys or visual inspections however given that the drone introduces its own dropped object risk	Two respondents were more sceptical or thought the applications were limited.

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Table 6 (*continued*)

Code	Literature Review	Observations, Implications, or interpretations	Data Consistencies	Data Inconsistencies
		It was postulated that they could also be used for internal inspections of warehouses or even in future for deliveries of certain materials. Generally, the interviewees advised eliminating the use of scaffolding altogether and moving to alternatives such as mast climbers or MEWPs. Move to modular systems, left in systems.	this is a substitution of risk rather than elimination. (Company A, PM3). Company B PM1 considered the impact of drones colliding with something as low Nobody had experience with robots yet.	
3C Eliminate or Substitute/ Onsite Fabrication	[39,56]	The key focus for dropped objects should be façade components as it is much less common for the dropped objects to fall from the internal trades. Factories are controlled areas so are likely to be safer and there would generally be more working at grade. Pre-cast was seen as an appealing alternative to in situ but also has problems and challenges. It can be done at ground level. The materials that are most likely to drop are the fixings so facades should be a significant focus of attention. Consideration could be given to brick panels or structural insulated panels. Again, trade-off versus many small objects with higher frequency of drops versus fewer large objects but with potentially higher risk per incident is mentioned. For internals pods can be considered. Interviewees have some good feedback on specific materials that can be substituted.	The interviewees in general thought the substitution of onsite construction with offsite construction world reduce risk overall. This was generally because of facades and the large number of small fixings which are the items that tend to get dropped. None of the interviewees could say for sure that changing to offsite manufacture reduces risk but the perception is strong that it does. Precast has had safety issues as well. Precast is seen as a good candidate as well as façade panels. Some interviewees say that MMC is not deployed due to cost and programme reasons	One Construction Manager did not agree that offsite construction reduced risks. He felt that onsite fabrication could be just as safe as offsite as long as suitable procedures were followed.
4A Control and Protect/General	[39]	There is a consistent understanding of how risk might be controlled. Housekeeping was stressed as important to control dropped objects. Management of site in general is important. Not discussed much but interviewees did have an understanding that PPE is of very limited use for dropped objects.	All companies described sensible procedures for dealing with dynamic forces, snow, ice, and mud in relation to dropped objects although the focus of these procedures was general site safety.	Not all interviewees were familiar with the difference between active and passive controls.
4B Control and Protect/Passive	[57–59]	It was understood that exclusion zones although required are very much a last resort. Can't control the public domain. Exclusion zone can't go beyond the boundary. Deflections are hard to manage even with scaffold fans. Footprint of site and high rise buildings are particularly challenging. Low rise is easier. Self-climbing cladding screens are recommended to provide complete protection to floors under construction. Oil and gas have higher focus on this. Dynamic objects are touched upon. Exclusion zone was an issue for Construction phase. Designers did not seem to get involved in this. There did not seem to be a scientific method related to calculation of exclusion zone.	An incident was highlighted related to objects dropping beyond exclusion zone into public domain. All interviewees agreed that exclusion zones are of limited use in high rise restricted sites. Interviewees are unclear on design of exclusion zones.	

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Table 6 (*continued*)

Code	Literature Review	Observations, Implications, or interpretations	Data Consistencies	Data Inconsistencies
4C Control and Protect/Active	[55]	Project Managers, H&S managers and Construction managers were clear what active control mechanisms were. In this sample Design managers were not so aware which is logical as they will not be very close to these systems. Company A H&S manager stated that small items like mobile phones are not meant to be brought up to height. Most interviewees stressed the difficulty related to materials such as bricks which generally can't be tethered during use. Only contained when in storage or transit.	Company D H&S manager wants to see universal tool tethering.as their system is currently risk based. Company A has universal tethering. Company A, B and C described systems for supply chain management related to equipment selection.	No interviewees had encountered the Dropped Objects standards
5A Improve/General	[53]	Mast Climbers Mast climbers are useful and have improved recently Could be improved by having a base specification/guidance which includes inbuilt storage for equipment and fixings (nuts and bolts). Scaffolding: If it can't be eliminated then try to limit scaffold to a standard design. Formwork: Consider Skydeck types. PERI systems. Move from component drive with lots of fixings to modular designs. Left in formwork.		Design Manager 1 Company C mentioned standardisation related to procurement route. Also related to conservatism of construction industry. Disagrees with a Company A PM who thought that industry was very innovative. Company A in discussion with vendors to improve mast climber specifications.
5A Improve/Passive	[57]	Consider modular design K guard edge protection systems can be considered. consideration Systems to prevent dropping fixings. Secondary cladding screens/climbing screens are recommended - all loose objects cannot fall. Edge protection at any height even 0.5m. Exclusion Zones/Alarms, geofencing/geolocating/proximity detectors.	Most interviewees support the idea of installing toe boards at any height rather than the 2m advised by British Standard.	H&S Manager Company D does not like scaffold at all and would prefer to substitute with MEWPs.
5A Improve/Active	N/A	Consider improvements to tool tethers labelling – age, capacity. For scaffold clips – consider using specialized clips that can be have an eyelet added to allow lanyards to be attached.	Many interviewees thought tool tethering was good in general.	Company A Construction Manager 1 highlighted that there is no capacity marked or the age of the tether – could adapt to make similar to requirements for body harnesses.

UK and has operations in most segments of the construction industry. Almost all interviewees agreed with this (H&S Manager, Company A et al.). The question was not posed in a way to ask them to confirm if this would be for a majority of incidents as it was designed to be an open-ended question more related to examining specific problems and solutions. This does not prove the hypothesis, but it is supportive of it.

Management of Change (MoC) was found to be a contributing factor by the Researcher in a third of the incidents. A safety culture should allow for rejecting a change based on HSE concerns (H&S Manager 1, Company B). This is aligned with the finding arriving from some current research [77].

In terms of effective interface management most of the interviewees' concerns related to the appropriate role of Temporary Works (TW) Coordinators. This role can be overstretched as it is generally executed by the PM or Site Manager with multiple functions to manage. The advice was that they should be involved in safety design reviews (H&S Manager 1, Company D).

There were mixed views on the usefulness of BIM related to dropped objects but the consensus of those that that felt it might have some impact was that it could be focussed on reducing the numbers of small fixings in the façade (DM1, Company D et al.*)*. Similar findings were reported by Yang et al. [78] in their study "Automatic detection of falling hazard from surveillance videos based on computer vision and building information modelling".

An issue of almost universal concern for all occupational groups was the competence and training of Designers related to PtD (DM1, Company C et al.). Near misses are not shared or reported externally so thus it was hard for Designers to learn about key safety issues (PM 2, Company C). Site experience for designers would be key to improving this gap (PM 1, Company A/B/C).

The respondents all had a reasonably consistent understanding of PtD although there were subtleties in emphasis between the balance of elimination of risk and mitigation or control of the risk (H&S Manager, Company A et al.).

5.2. Lead

Both Company A and D are currently very focussed on dropped objects safety leadership. Company A has a Working Group including partner organisations to combat this hazard after experiencing some near misses in recent years (PM 2, Company A). In contrast some interviewees consistently felt that budget and programme came first and then safety as secondary in importance for clients (PM2, Company A). Aesthetics requirements driven by planners also implicitly sometimes have higher priority than safety (PM 1, Company C; CM 1, Company A). A key concern raised by Principal Designer was that some contractors that they liaised with were not sharing all their incidents even when required to do so as part of a tendering package (PM 2, Company C).

There are opportunities for policy makers to adopt safety leadership practices to mandate the sharing of anonymized accident and incident data.

5.3. Eliminate or substitute

Examples of genuine elimination where no or very little new risk is introduced could be as simple as installing the safety barriers on scaffold on the ground before a scaffold is lifted into position (PM 1, Company D). Some interviewees thought drones could be a good substitution strategy for WAHR reducing the need for abseilers or roof works for surveys however given that the drone introduces its own dropped object risk this is a substitution of risk rather than elimination (PM 3, Company A et al.).

Another interesting concept was the substitution of scaffolding by other options. There was some explicit advice to eliminate scaffolding completely on High Rises and to select alternatives such as MCWP (H&S Manager, Company D/A). An option for low rise is PECO manual access platforms which are easier to control and safer than podium steps (H&S Manager, Company D). The interviewees in general had the perception that the substitution of traditional onsite construction with offsite construction world reduce risk overall as factories are controlled areas and there would generally be more working at ground level so thus are likely to be safer (H&S Manager, Company A et al.).

Many interviewees were aligned that the key focus for reducing dropped objects should be façade components as it is much less common for the dropped objects to fall from the internal trades. Facades typically have a large number of small fixings which are the items that tend to get dropped (PM 2, Company A et al.). One interviewee felt it would be good to move from a large number of small objects which are each a potentially fatal hazard to a small number of large objects where although the individual risk of each item may be higher this smaller number of hazards can be carefully managed (PM 1, Company B).

Pre-cast was seen by most interviewees as an appealing substitution to in situ as it offers the benefit of larger components compared to in situ forms that have many small, bolted connections. Some of the researchers also appreciate the benefits of using precast to reduce injuries [79]. However, as precast slabs require infills these can't eliminate the dropped objects risk completely (H&S Manager, Company A et al.). Precast lift cars and shafts and preformed manholes could also be considered (DM1, Company D). For facades an option was to prefabricate large scale cassettes and bathrooms can be installed as pods (H&S Manager 1, Company A/D).

5.4. Control and protect

The interviewees agreed that exclusion zones were a last resort and that deflections are hard to manage especially in restricted or high-rise sites (CM 1, Company A et al.). The quantitative data strongly agrees with this. Exclusion zones were found in a majority of the incidents to be either insufficient or not in place at all. In 27 % of incidents in the dataset the dropped object was deflected. All of the breach into the public domain incidents occurred on restricted area sites and 2 of the 3 incidents were related to High Rise buildings. The data reveals that in 3 cases (20 %) of the incidents there was a breach with objects falling into the public realm. In 7 cases (almost 50 %) of cases there was a breach into a non-protected work area. However, in around 50 % of cases the exclusion zone provided the last line of defence as per intention. Some interviewees mentioned that the design of exclusion zones was a task for construction professionals rather than designers (DM 1, Company D, PM 1, Company B). However, the interviewees were not able to describe how the exclusion zones were calculated.

Most respondents had a good understanding of active controls and generally thought they were effective (CM 1, Company A et al.). Company A has universal tethering (PM 3, Company A). Company D by contrast has a risk-based approach to tethering but the interviewee's view was that a universal approach should be considered as their current policy was deemed insufficiently robust (H&S Manager, Company D). Interviewees stressed the difficulty related to materials such as bricks which can't be tethered during use (CM1 et al. Company A).

5.5. Improve

MCWPs could be improved by having a base specification which includes inbuilt storage for equipment and fixings plus improved edge protection and an enclosure rather than adapting them using temporary works procedures. Training options are currently inadequate (PM 3, Company A et al.). This is area that Policy makers could champion. Companies should consider modular formwork which reduces the number of small components that are required to execute the work at height and makes it easier to handle without tools (H&S Manager 1, Company A; PM 1, Company D). This can potentially bring environmental and economic benefits as noted in Ref. [80]. Self-climbing cladding screens can be used to provide complete dropped objects protection to floors under construction (PM 3, Company A). Geolocators could be used as incursion alarms into exclusion zones (H&S Manager 1, Company B). A labelling concern was raised related to lack of markings related to the age of the equipment and the weight capacity (CM1, Company 1). This is an area where policy makers could improve or expand existing LOLER regulations.

6. Conclusions

The conclusion to the main research question was that the results lend support to the argument that the design of task, materials and equipment is a contributory factor in a significant number of dropped object incidents and possibly a majority of dropped object incidents however more research using a larger and more representative dropped object incident database is required before this statement could be definitive. In terms of the analysis of industry trends the data confirms that fatality rates related to dropped objects in construction have been fairly flat in the UK for the last 7 years with a slight reduction for total number of reported non-fatal injuries over the same period with the caveat of pandemic related uncertainty.

Early Contractor Involvement in the Design Phase is crucial to eliminating or significantly mitigating risks linked to dropped objects. The PtD concept is reasonably well understood in the construction sector community but there are subtleties in terms of the emphasis that different professionals put on risk elimination versus mitigation. The competing priorities of cost, programme, sustainability, and aesthetics often take priority over PtD. Site experience for Designers is considered crucial to improve safety performance. The use of drones for inspection is no longer novel and thus their use should be evaluated for appropriate tasks. Offsite construction especially related to scopes such as concrete, and façade panels could be an effective substitute of risks. Transitioning from many small objects with multiple possibilities of dropping to smaller numbers of larger objects (then subject to controlled lifts) could be an effective risk substitution. BIM could be used to reduce the smaller object numbers.

7. Recommendations

Recommendations are provided to the HSE and the new Building Safety Regulator (BSR), to general industry bodies such as the Construction Leadership Council [81] and also to individual Construction Sector companies. These recommendations include ensuring appropriate MCWP training is developed and mandated and to confirm whether tethering, attachments and containers fall under LOLER regulations; to ensure that equipment capacities are marked and rules for inspection are developed in a similar fashion to other lifting equipment. In addition, consideration could be given to developing proposals to expand the role of the BSR's Mandatory Occurrence reporting to include all dropped object incidents for high rise buildings.

Turning to organisations outside the regulatory realm it would be helpful if general construction bodies could liaise with the energy industry focussed DROPS organisation to develop a suitable general construction exclusion zone and deflection calculator. Initiatives to improve the design of MWCP to provide integral storage and enclosure solutions could be initiated with the vendors of this equipment.

Recommendations to Individual Construction Sector Companies include involving TW Co-ordinators and Design companies in appropriate Design Safety Reviews for more complex projects and including Safety professionals explicitly in MoC processes ensuring empowerment of employees to stop a proposed change if safety concerns cannot be addressed adequately. Companies could consider integrating site experience for Designers into training requirements. This could be leveraged using existing partnerships with construction companies to ensure enhanced experience. Consideration could be given to adding the Dropped Objects calculator to in-house guidance as a ready reckoner for Risk Assessments linked to dropped objects. Safety could be enhanced by partnering with a specialist vendor to provide the optimal tethering and containment equipment and then let these out to the subcontractor rather than allowing the subcontractor to provide their own equipment. During conceptual design companies in tandem with clients could consider offsite construction as a strategic means to reduce the number of dropped objects and consider scopes that could be executed at ground level rather than at height. Consideration could be given to the more commonly deployed off-site fabrication options such as roof trusses, façade panels, bathroom pods and precast frames. During detailed design once the main design is fixed, companies could have a high focus on the mechanism of reducing fixings in facades using BIM or expert review and consider modular or leave in place formwork where appropriate. Companies could also consider using drones for certain design surveys as a substitute to prevent working from height and thus also dropped object risks. For residual risk once substitution is exhausted then control and protect options could be deployed such as eliminating scaffolding by use of self-climbing cladding screens to provide complete passive protection to the construction of high-rise buildings. Companies could implement universal tool tethering policies on facades with deviations allowed in situations where this is impracticable. Consideration could be given to installing incursion alarms within exclusion zones.

There are a number of areas which can be investigated further such as the implications of offsite construction on dropped objects accidents when compared with traditional methods. The research findings hint that BIM might be a useful tool to reduce dropped objects on construction sites especially related to facades, and this could be further investigated.

8. Limitations

The research suffers from a number of limitations which were beyond the control of researchers including the COVID pandemic impact on recent trends in safety related data maintained by HSE, the lack of availability of incident data from offsite manufacturing facilities, the quantitative incident data small sample size, and the balance of occupation groups used in the interviews. Despite these limitations, the finding of this research is expected to be useful for industry practitioners to improve safety performance in the construction industry.

Ethics statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper or could influence or have the perception of influencing the content of the article.

The paper is based on a Master's thesis. A request for ethical review for the thesis was raised and a decision was made that the study was sufficiently low risk that ethics committee approval was not required. Within the ethical review request the data management procedure was laid out. All participants provided written informed consent to participate in the study and for their anonymized data to be published. All identifiable data was stored in a secure university repository and destroyed within three months of the thesis being submitted.

Data availability statement

Question Response.

Has data associated with your study been deposited into a publicly available repository? No.

Please select why any researcher wishing to access the data can send a request to Jane Peatie at janepeatie@yahoo.co.uk. Please note that all personal data has been destroyed to comply with GDPR and no confidential details of companies can be shared.

CRediT authorship contribution statement

Jane Susan Peatie: Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Hasan Haroglu:** Writing – review & editing, Supervision, Conceptualization. **Tariq Umar:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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