Developing a prototype decision aid for determining the risk of work systems at height when using temporary access systems

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Developing a prototype decision aid for determining the risk of work systems at height when using temporary access systems

S M Whitaker, R J Graves, M James, P McCann, C Wilson, C Dymiotis, J Wolfram, M Baker
Schools of Management and The Built Environment
Heriot-Watt University
Riccarton
Edinburgh
EH14 4AS

Access to height has associated risks of falls of people and objects that can arise due to structural and procedural inadequacies. Previous research suggests that the basic risks are not sufficiently controlled across industry, and that the injury rate in work requiring access to height is disproportionately high. One method of supporting safe practices when working at height is the provision of prescriptive guidelines in a readily accessible format for workers at all levels involved with the work. Decision aids are one means of presenting information. The research described in this report aimed to develop and test appropriate decision aids for people involved in temporary access to height.

The analysis of a large sample of accidents and incidents occurring during work at height, and which were reported to the HSE over the last ten years, is described. This analysis provided information on the root-causes of the incidents as well as the more distal causes preceding the event, such as safety management deficiencies. Two work systems emerged as particularly well represented in the statistics in terms of absolute numbers of cases; these were temporary access scaffolds and work on roofs.

Two flowchart decision aids, SCAFPASS and ROOFMATE, were constructed for scaffold and roof access systems based on the case analyses and information gathered during consultations with safety advisers in a selection of construction companies. The issues included the relevant basic risk controls, staffing suitability and communication among staff. The decision aids addressed generic aspects of safety management in a way that was accessible to workers at all levels within a company. The design of the decision aid attempted to accommodate the diversity of contracting companies likely to work with scaffolds and roofs. SCAFPASS and ROOFMATE were tested through table-top exercises and field trials. The user trials showed that that SCAFPASS/1 assisted the users in selecting more relevant controls. Appropriate modifications were made based on the results of these trials. Versions of the decision aids were also designed in abbreviated pocket-size formats termed PocketSCAFPASS. The latter underwent pilot field trials. Within the limitations of the low questionnaire response rate, PocketSCAFPASS was well received. For the ROOFMATE trials, on the whole, both versions were well received by participants. Frequency of use, ease of understanding, and perceived effectiveness of ROOFMATE, as well as the willingness to use decision aids emerged favourably for the majority of respondents.

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# Table of Contents

<table>
<thead>
<tr>
<th>Page No</th>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>v</td>
<td>EXECUTIVE SUMMARY</td>
</tr>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>1.1</td>
<td>BACKGROUND</td>
</tr>
<tr>
<td>1.2</td>
<td>PROJECT AIMS</td>
</tr>
<tr>
<td>1.3</td>
<td>PROJECT OVERVIEW</td>
</tr>
<tr>
<td>2</td>
<td>LITERATURE REVIEW</td>
</tr>
<tr>
<td>2.1</td>
<td>OVERVIEW</td>
</tr>
<tr>
<td>2.2</td>
<td>CONCLUSIONS</td>
</tr>
<tr>
<td>3</td>
<td>ACCIDENT AND INCIDENT ANALYSES</td>
</tr>
<tr>
<td>3.1</td>
<td>OVERVIEW</td>
</tr>
<tr>
<td>3.2</td>
<td>SUMMARY OF FINDINGS</td>
</tr>
<tr>
<td>4</td>
<td>CONSULTATIONS WITH SCAFFOLD-RELATED COMPANIES</td>
</tr>
<tr>
<td>5</td>
<td>DECISION AID FOR SCAFFOLD SAFETY: DEVELOPMENT</td>
</tr>
<tr>
<td>5.1</td>
<td>BASIC DESIGN REQUIREMENTS</td>
</tr>
<tr>
<td>5.2</td>
<td>DESIGNING FOR THREE GROUPS</td>
</tr>
<tr>
<td>5.3</td>
<td>DESIGNING FOR PROJECT STAGES</td>
</tr>
<tr>
<td>5.4</td>
<td>PRELIMINARY DESIGN OF A DECISION AID FOR SCAFFOLDS</td>
</tr>
<tr>
<td>6</td>
<td>DECISION AID FOR SCAFFOLD SAFETY: EVALUATION</td>
</tr>
<tr>
<td>6.1</td>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>6.2</td>
<td>METHOD</td>
</tr>
<tr>
<td>6.3</td>
<td>RESULTS</td>
</tr>
<tr>
<td>6.4</td>
<td>DISCUSSION</td>
</tr>
<tr>
<td>6.5</td>
<td>NECESSARY MODIFICATIONS TO SCAFPASS/1</td>
</tr>
<tr>
<td>7</td>
<td>DECISION AID FOR SCAFFOLD SAFETY: DEVELOPMENT AND USER TRIALS OF A POCKET-SIZE VERSION</td>
</tr>
<tr>
<td>7.1</td>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>7.2</td>
<td>PocketSCAFPASS MODIFICATION</td>
</tr>
<tr>
<td>7.3</td>
<td>USER TRIALS OF PocketSCAFPASS</td>
</tr>
<tr>
<td>8</td>
<td>SCAFFOLD RELIABILITY: ASSESSMENT USING EXPERT JUDGEMENT</td>
</tr>
<tr>
<td>8.1</td>
<td>INTRODUCTION AND AIM</td>
</tr>
<tr>
<td>8.2</td>
<td>METHOD</td>
</tr>
<tr>
<td>8.3</td>
<td>RESULTS</td>
</tr>
<tr>
<td>8.4</td>
<td>CONCLUSIONS</td>
</tr>
<tr>
<td>9</td>
<td>SCAFFOLD RELIABILITY: ASSESSMENT USING SOFTWARE</td>
</tr>
<tr>
<td>9.1</td>
<td>INTRODUCTION AND AIM</td>
</tr>
<tr>
<td>9.2</td>
<td>METHOD</td>
</tr>
<tr>
<td>9.3</td>
<td>RESULTS</td>
</tr>
<tr>
<td>9.4</td>
<td>CONCLUSIONS</td>
</tr>
<tr>
<td>10</td>
<td>SCAFFOLD CHECKLIST: DEVELOPMENT</td>
</tr>
<tr>
<td>11</td>
<td>DECISION AID FOR ROOF SAFETY: DEVELOPMENT AND EVALUATION</td>
</tr>
<tr>
<td>11.1</td>
<td>DEVELOPMENT</td>
</tr>
<tr>
<td>11.2</td>
<td>EVALUATION</td>
</tr>
<tr>
<td>12</td>
<td>REVIEW AND SUMMARY</td>
</tr>
<tr>
<td>13</td>
<td>ACKNOWLEDGEMENTS</td>
</tr>
<tr>
<td>14</td>
<td>REFERENCES</td>
</tr>
<tr>
<td></td>
<td>APPENDIX A: LITERATURE REVIEW</td>
</tr>
<tr>
<td></td>
<td>APPENDIX B: ACCIDENT ANALYSES</td>
</tr>
<tr>
<td></td>
<td>APPENDIX C: LIST OF AGENTS DEFINED BY FOCUS</td>
</tr>
<tr>
<td></td>
<td>APPENDIX D: LIST OF DEFICIENCIES DEFINED BY FOCUS</td>
</tr>
<tr>
<td></td>
<td>APPENDIX E: CONSULTATION WITH COMPANIES INVOLVED WITH SCAFFOLDS</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>PAGE</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>F: INCIDENT DESCRIPTIONS USED IN USER TRIALS</td>
<td>81</td>
</tr>
<tr>
<td>G: SCAFPASS VERSION 2</td>
<td>85</td>
</tr>
<tr>
<td>H: INSTRUCTIONS FOR SCAFPASS</td>
<td>91</td>
</tr>
<tr>
<td>I: PocketSCAFPASS</td>
<td>105</td>
</tr>
<tr>
<td>J: MODELLING THE RELIABILITY OF A SIMPLE SCAFFOLD</td>
<td>115</td>
</tr>
<tr>
<td>USING EXPERT JUDGEMENT</td>
<td></td>
</tr>
<tr>
<td>K: QUESTIONNAIRE USED IN EXPERT JUDGEMENT</td>
<td>121</td>
</tr>
<tr>
<td>L: PROBABILITIES TABLE USED IN EXPERT JUDGEMENT</td>
<td>127</td>
</tr>
<tr>
<td>M: MODELLING THE RELIABILITY OF A SIMPLE SCAFFOLD</td>
<td>129</td>
</tr>
<tr>
<td>USING COMPUTER SOFTWARE</td>
<td></td>
</tr>
<tr>
<td>N: DESIGN OF A SCAFFOLD CHECKLIST</td>
<td>143</td>
</tr>
<tr>
<td>P: ROOFMATE VERSION 1</td>
<td>147</td>
</tr>
<tr>
<td>Q: ROOFMATE VERSION 2</td>
<td>149</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

BACKGROUND

It is said that the construction industry has an unenviable safety record. In the UK, the construction industry has one of the highest fatality rates across all sectors. A large proportion of injuries in the construction industry is due to falls from height. In the UK, it is estimated that falls from height accounted for between 44% and 60% of all fatal accidents in the construction industry across the years 1996 to 2001. It is perhaps not surprising, given the ubiquity of scaffold structures in the construction industry, that falls from scaffolds represent a large proportion of all work-related falls. Clearly, the large loss of life and the financial costs of these accidents to the construction sector justify research into safety aspects of working on and around scaffolds.

An internal report by the Health and Safety Executive (HSE) in the UK identified the leading causes of collapse in 76 cases involving various scaffold types (Health and Safety Executive, 2001). These included: deficient ties to the building, overload, faulty components, accidental temporary overloading, deficient bracing, subsidence of foundations, training, and other causes. In the United States, the categorisation of 85 fatal scaffold-related incidents according to their primary cause indicated that faults in guard-rails or lack of guard-rails was the most common cause of injury, followed by faults in the connections between components in the scaffold, aspects of the work environment, for example weather, and ties to the building. These occurrences are examples of root-causes, so-called because they were most central to the occurrence of the event. However, root-causes are themselves often a consequence of failings in the management of safety at a higher level in the organisation.

The construction industry lags behind in competent safety management for a number of reasons. These include the short-term and transitory nature of contracts, lack of a controlled environment, complex arrangements within and between contractors, competitive tendering that mitigates the priority of safety, and a high labour turnover. Safety management of projects involving scaffolds should aim to minimise the risk of workers falling, material falling and structural faults. Competent safety management can be supported by the provision of specific operational advice at the relevant time to the companies involved. Decision support systems (DSS) offer a method of providing a content and structure to this aim. DSS are designed to manage and quantify data and present it in a form that supports the decision-making process of the user. Competent management of safety in projects involving temporary access with scaffolds may be viewed as a sequence of decisions that must be made within the phases of bidding, pre-planning of the work, the erection of the scaffold, its hand-over, and its use and eventual dismantling.

Simple checklists of structural elements of scaffolds are perhaps the only widely known tools relevant to scaffold safety that could, in some sense, be viewed as decision aids. The National Access and Scaffolding Confederation in the UK provides check guides for use with scaffolds. Checklists for scaffolds of varying detail have also appeared in trade journals. However, such checklists often address only root-causes, leaving unchanged the higher managerial issues that can perpetuate these root-causes. Additionally, checklists often fail to integrate with the temporal sequence of the project. A decision aid for safety management of scaffold access must incorporate the proven best practices of construction safety management and meet the requirements of various regulations at each point. It must also be based on a thorough analysis of injuries on and around scaffolds so that the frequency and type of root-causes can guide the inclusion of safety managerial issues. This report describes mainly the development of a prototype decision support aid called SCAFPASS (an abbreviation for Scaffold Planning Aid for System Safety) and the feasibility of developing a Decision Support Aid for those working on Fragile Roofs.
APPRAOCH AND FINDINGS

Decision Aid Development
There were essentially a number of separate but related parts to the project. Decision aid content was determined in part by the results of analyses of incidents involving temporary access systems. This included not only content but also which work activities (roofing, scaffolding etc) the decision aid was to address.

Activities associated with large numbers of fatalities and injury should be prioritised when deciding on the target population for which a decision aid will be designed. Therefore, recorded incidents which have involved temporary access equipment were examined in for the purpose of specifying the application area(s), and the content of the decision aid(s). Further, the types of structures and the types of failures involved in these incidents, and the underlying shortcomings at the operator and management level that supported the failures were examined in detail. This helped identify the range of controls that should be considered in developing a decision aid for avoiding the conditions supporting the common failures.

Consultation with industry provided input on key safety decisions throughout the lifetime of a project, unsafe occurrences and problems with communication and information, scaffold equipment and training of staff. This information proved useful in developing the content and structure of a decision aid because, *inter alia*, it provided an indication of important safety issues for scaffolds at stages within the lifetime of the project, and the problems that safety advisers encountered in achieving and maintaining safety on sites with scaffolds.

As it was recognised that the diversity of access systems in type, complexity of equipment and staffing requirements probably precluded a generic decision aid applicable to all systems, it was decided to focus on two types of access system. Scaffolds were chosen as the first system because of their frequency in the accidents and incidents, and because of the potential complexity of their structure and the socio-technical organisation required on site. The second was access to roofs.

The principles underlying the development of the decision support aid for scaffold access systems were developed. The latter included it’s design to inform users of the more common risks, include the risk assessment and control procedures and the specific controls that will avoid the more common root cause failures. This work led to the first prototype decision aid, SCAFPASS/1.

Decision Aid Evaluation
An evaluation process was undertaken with 40 users. The purpose of the user trials was two-fold; to familiarise participants with SCAFPASS/1 through paper-based exercises, and to collect data to answer specific questions.

The first version of SCAFPASS/1 was tested on participants who regularly work on or around scaffolds. The first question to be answered was whether the use of SCAFPASS/1 would allow a higher number of potential countermeasures or solutions to be suggested by users. Answering this question was important because one of the intended purposes of SCAFPASS/1 is to guide the user through the necessary safety precautions at different points in the project so that resources may be used efficiently to reduce risk. With limited resources it is important that the user is able to prioritise the risk controls relevant to the specific project. When content of suggestions was taken into account, the results suggested that SCAFPASS/1 assisted the user in selecting the more relevant controls.

The second question addressed the comprehensiveness of SCAFPASS/1 by examining the free-listed suggestions for countermeasures to identify any not encompassed within SCAFPASS/1. SCAFPASS/1 emerges as a comprehensive tool that captures the essential
safety management issues of these two incidents – incidents that were selected as typical examples of FOCUS and FCG cases. However, there are some issues not currently included in SCAFPASS/1 which did emerge as legitimate safety management concerns. Foremost among these were: method statements; scheduling; and the hand-over procedures from user to scaffolder after use. One of the difficulties in designing SCAFPASS/1 was striking a balance between comprehensiveness and over-complication. While it was not possible to include all issues relevant to scaffold safety, it was essential to include the issues relevant to the large majority of cases.

The third question examined whether there was convergence of opinion about which Steps were not addressed but relevant. Ideally, SCAFPASS/1 would allow users to reach a general consensus on which safety management issues are lacking. Results suggested that such a consensus was not usually present. One explanation may be that participants naturally differ in which safety management issues they tend to prioritise, perhaps because of previous experiences. A second explanation is that participants interpret the written incident descriptions differently.

Question 4 looked at whether the mean ratings of importance of each Step will differ within each Part of SCAFPASS/1. It would be unlikely for any one incident to have the same ratings of importance across Steps in the same Part of the decision aid. There was limited support for this hypothesis. Participants tend to rate all Steps with high importance without discriminating between them. This is not necessarily a shortcoming on the part of the users because it could mean that respondents are equally vigilant on all aspects of safety management.

Finally, question 5 examined whether SCAFPASS/1 would receive favourable assessment by users. Results from respondents on these issues indicated that:

- 51.4% thought the length was about right
- 64.7% thought the level of detail was about right
- 57.1% experienced some difficulty in using SCAFPASS/1
- 94.3% thought that all or nearly all the important issues were included
- 61.7% stated that they would either definitely or probably use it
- 58.8% stated that the company would either definitely or probably use it
- 70.6% felt that the decision aid would be likely or very likely to improve safety

Although the majority of participants provide favourable ratings on all questions, there is some cause for concern about the length and ease of use of SCAFPASS/1. While it might be expected that, during familiarisation, users will initially have some difficulty in using SCAFPASS/1, the level of difficulty should be a minimum. SCAFPASS/1 consisted of four pages. Each page had a large amount of information that the user must read. One difficulty in designing SCAFPASS/1 was in accounting for the range of potential users, all of whom will have different job roles and capabilities (including ranges in literacy skills). The level of detail required of the decision aid probably depends on the job role of the user.

Overall, it can be concluded that SCAFPASS/1 formed the basis of a useful support aid to assist the user in selecting the more relevant controls. As a result of the user trials, changes were made to SCAFPASS/1 to produce version 2, (SCAFPASS/2). It was clear that there was a need for full instructions so these were developed. SCAFPASS/2 was designed for office use.

From user feedback, there was an indication that there was support for a simplified version that could be carried around, literally in the users pocket. Subsequently, a simplified version termed PocketSCAFPASS was developed.
Within the limitations of the low response rate (23%) of the user trials, the outcome indicated that:

a) A majority of users perceived User PocketSCAFPASS to:
   (i) be usable on a regular basis (66.6%)
   (ii) be easy to use (78%)
   (iii) be of an acceptable length (100%)
   (iv) contain the most important issues (89%)
   (v) have acceptable terminology (100%)

b) the instructions seemed acceptable, although there may be room for some improvement which might be remedied by proper training (78%)

c) PocketSCAFPASS could be used as a memory aid in scaffolding safety (89%)

d) The use of such flow charts could be a useful aid to scaffold safety (78%)

e) A majority of companies would use it (78%)

**Modelling and Scaffold Checklist Development**

Other parts of the project involved using expert judgements of absolute probabilities to model the reliability of a simplified scaffold system and modelling the effects on structural integrity of various faults in a scaffold system of well-defined specifications (the same specifications as with expert judgements). The aim of these activities was to derive an order of priority for the various faults in terms of their implications for safety.

An additional activity was developing a Checklist for inspecting scaffolds. This was based on the accident statistics (particularly the list of the most common primary features that caused the injury) and the results of the modelling (particularly the ratings of risk and the overall probabilities of injury).

**Roof Access**

Roof access was the second area of safety addressed through the design of a decision aid. The development of a prototype version and its evaluation via small scale user trials is described.

In summary, the results show the following:

a) 14 participants (58%) reported that they had used ROOFMATE always, often or sometimes.

b) All participants agreed or strongly agreed that the instructions had been easy to understand

c) participants (71%) agreed or strongly agreed that ROOFMATE had been effective as an aid to roof safety

d) participants (75%) agreed or strongly agreed that ROOFMATE had helped them to remember the essentials of fall prevention and protection

e) 15 participants (63%) agreed or strongly agreed that they would be prepared to use a similar decision aid in the future

On the whole, both versions of ROOFMATE were well received by participants. Frequency of use, ease of understanding, and perceived effectiveness of ROOFMATE, as well as the willingness to use decision aids emerged favourably for the majority of respondents. Further, the instructions listed on the reverse of ROOFMATE were easily understood. Based on the results and the comments during the structured interviews, ROOFMATE was modified.
1 INTRODUCTION

1.1 BACKGROUND

It is said that the construction industry has an unenviable safety record. In the UK, the construction industry has one of the highest fatality rates across all sectors (Health and Safety Executive, 1984; Health and Safety Commission, 2001). High fatality rates are also evident in the United States where the construction industry throughout the 1980s had the second highest fatality rate among industrial sectors (Kisner and Fosbroke, 1994).

A large proportion of injuries in the construction industry is due to falls from height. In the US, just under half of all fatal work-related falls occur in construction (Cattledge, Hendricks, and Stanevich, 1996; Janicak, 1998), and falls from height account for around a third to a half of all work-related fatalities (Keyserling, 1988; Bureau of Labor Statistics, 2001) in this sector. In the UK, it is estimated that falls from height accounted for between 44% and 60% of all fatal accidents in the construction industry across the years 1996 to 2001 (Health and Safety Commission, 2001). The statistics are equally alarming outside the US and UK. Across a five-year period in the Capital and Hawalli districts of Kuwait, for example, it has been estimated that falls from height, including from scaffolds, roofs, and ladders, accounted for 48.5% of all work-related accidents and just over 50% of all fatal work-related accidents (Kartam and Bouz, 1998).

Scaffolds are built from a set of standardised components according to the relevant technical guidelines. In the UK, British Standard BS5973: 1993 currently applies to access and working scaffolds, and scaffold structures in steel (British Standards Institute, 1993). While scaffolds vary in complexity, size, and type, they require a number of essential features for structural stability. Foremost among these are proper connections between individual components, stable foundations, internal bracing to prevent lateral movement, correct dimensions between components at key points, and almost invariably, secure attachments laterally to a stable supporting structure. Sub-structural requirements of scaffolds might be regarded as barriers (Haddon, 1973) preventing workers and objects from falling. They include edge protection, guard railing, boarded working platforms, suitable means of access, safety netting, and harness systems for operatives. It is perhaps not surprising, given the ubiquity of scaffold structures in the construction industry, that falls from scaffolds represent a large proportion of all work-related falls. Cattledge, Schneiderman, Stanevich, Hendricks, and Greenwood (1996) found that 21.4% of non-fatal work-related falls were from scaffolds. Cattledge, Hendricks, and Stanevich (1996) examined all fatal occupational falls in the US for the period 1980 to 1989, reporting that 18.6% were from scaffolds. Clearly, the large loss of life and the financial costs of these accidents to the construction sector justify research into safety aspects of working on and around scaffolds.

While falls account for most scaffold-related injuries, falling objects and scaffold collapses account for the majority of the remainder. Scaffold collapses can result not only in falls but also in injury to workers and public below. In the UK, across the period 1989 to 1993, there were 3,738 falls from a scaffold but these were accompanied by 1,304 injuries from falling objects, and 345 scaffold collapses (HSE, 1994). In its most recent report, the National Access and Scaffolding Confederation (NASC) in the UK surveyed the safety performance of 110 companies with a combined total of 10,779 employees, and an estimated coverage of over half the total number of scaffolding operatives in the UK scaffold industry (NASC, 2001). A total of 253 accidents was reported, consisting of falls of persons (22.1%), falls of materials (11.5%), handling of materials (26.1%), and “other site accidents” or “other yard accidents” (40.3%).

An internal report by the HSE in the UK identified the leading causes of collapse in 76 cases involving various scaffold types (Health and Safety Executive, 2001). In order of frequency
these were: deficient ties to the building (28%), overload (25%), faulty components (13%),
accidental temporary overloading (7%) deficient bracing (9%), subsidence of foundations
(6%), training (1%), and other causes (11%). In the United States, Fattal and colleagues
(1980) categorised 85 fatal scaffold-related incidents according to their primary cause. Faults
in guard-rails or lack of guard-rails was the most common cause of injury (21%), followed by
faults in the connections between components in the scaffold (20%), aspects of the work
environment, for example weather (17%), and ties to the building (15%).

Fattal et al. (1980) also makes reference to an unpublished study by the Bureau of Labor
Statistics that describes 801 incidents involving scaffold structures. In 27% of cases the event
was “person fell – nothing happened to scaffold”. Other categories were more informative,
and included “plank slipped” (16%), “plank broke” (8%), “support poles tilted or tipped over”
(7%), “wheels on bottom of the scaffold rolled” (6%), “cross-bracing gave way” (6%) and
“anchoring into structure gave way” (5%). The remaining cases were categorised as “slipped
on work material” (5%), “wood or metal support pole(s) broke” (5%), “scaffold tilted on
unlevel ground” (4%), “scaffold base slipped” (4%), “struck by falling object while on
scaffold” (3%), “support poles sank” (2%), “high winds” (1%), “line broke” (1%), and
“guardrail broke” (<1%).

These occurrences are examples of root-causes, so-called because they were most central to
the occurrence of the event. However, root-causes are themselves often a consequence of
failings in the management of safety at a higher level in the organisation (Reason, 1997;
Rasmussen and Peterson, 1999). While a detailed review of safety management systems is
outside the scope of this paper, the important elements of safety management in the
construction industry include the following broad themes (European Construction Industry,
1995; Levitt and Samelson, 1993; Stanton and Willenbrock, 1990; Jaselskis, Anderson and
Russell, 1996):

a) Procurement sequences that prioritise health and safety criteria and which use health
and safety criteria in contractor selection;
b) Development of risk assessments, risk controls, and work procedures;
c) Clear assignment of responsibility for issues of health and safety and the establishment
of personal accountability for safety performance;
d) Ensuring procedural compliance among the workforce;
e) The dissemination of information among staff and contractors about hazards and how
to minimise risk;
f) Incident reporting procedures and follow-up;
g) Prioritisation of safety in all activities and an observable commitment to safety by
supervisors and management in day to day running of projects;
h) Ensuring competence of staff and adequacy of supervision;
i) Quality control of stock, including a program of stock inspections.

The construction industry lags behind in competent safety management for a number of
reasons. These include the short-term and transitory nature of contracts, lack of a controlled
environment, complex arrangements within and between contractors, competitive tendering
that mitigates the priority of safety, and a high labour turnover (Kartam, Flood and Koushki,
2000). Smaller construction companies are over-represented in the accident statistics in the
sector generally (McVittie, Banikin and Brocklebank, 1997), and specifically within the
scaffold trade (NASC, 2001). This is probably because safety management tends to be less
developed in the smaller scaffold companies (Jannadi and Assaf, 1998).

Safety management of projects involving scaffolds should aim to minimise the risk of
workers falling, material falling and structural faults. Competent safety management can be
supported by the provision of specific operational advice at the relevant time to the companies
involved. Decision support systems (DSS) offer a method of providing a content and structure
to this aim. DSS are designed to manage and quantify data and present it in a form that supports the decision-making process of the user. The term has become broader in recent years. In its strict definition (Davis, 1988), DSS must allow exchanges between the user and the source of information in an interactive, tolerant and informative style, an exploration of the various scenarios of choice, and flexibility for the user to adapt the system to his or her specific problem. The term Decision Aid includes all tools that provide advice during decision-making processes but which may not fulfil in the strictest sense the requirements for a DSS.

Decision aids are prominent in the medical sector as diagnostic tools as well as aids for the decision-making of patients (Estabrooks et al., 2001; Kaplan, 2001; Molenaar et al., 2000). Decision aids have been successfully applied to areas outside medicine, including food safety (Wijtzes, et al., 1998), accidental release of air pollutants (Graber and Gassmann, 2000), genetically modified products (Hallerman, et al., 1999), laser safety (Clarke, et al., 1995) and aircraft maintenance (Rankin, et al., 2000).

Competent management of safety in projects involving temporary access with scaffolds may be viewed as a sequence of decisions that must be made within the phases of bidding, pre-planning of the work, the erection of the scaffold, its hand-over, and its use and eventual dismantling. At a generic level, the structure and types of decisions would remain relatively invariable across different scaffold projects, but the specific details of the decisions would change according to the exact nature of the work undertaken and the physical environment on site. This assumption is implicit, for example, in much of the legislation regarding health and safety at work in the UK, such as the Construction (Design and Management) Regulations 1994, known usually as the CDM Regulations. In this sense, the decision aid would be a thought-structuring system (Davis, 1988), informing and reminding the site manager or supervisor of requirements to manage safety.

Simple checklists of structural elements of scaffolds are perhaps the only widely known tools relevant to scaffold safety that could, in some sense, be viewed as decision aids. The National Access and Scaffolding Confederation in the UK provides check guides for use with scaffolds. Checklists for scaffolds of varying detail have also appeared in trade journals (e.g., Concrete Construction, 1995; Hinson, 1989), texts on safety management (e.g., Bielby, 1992), texts on scaffolding practice (e.g., Doughty, 1986) and academic journal papers (e.g., Peng, et al., 1996). However, such checklists often address only root-causes, leaving unchanged the higher managerial issues that can perpetuate these root-causes. Additionally, checklists often fail to integrate with the temporal sequence of the project.

A decision aid for safety management of scaffold access must incorporate the proven best practices of construction safety management and meet the requirements of various regulations at each point. It must also be based on a thorough analysis of injuries on and around scaffolds so that the frequency and type of root-causes can guide the inclusion of safety managerial issues.

The code of practice for scaffold structures in the UK is mainly through BS5973: 1993 Code of Practice for Access and Working Scaffolds and Special Scaffolds in Steel (British Standards Institute, 1993). This code is currently being revised to accommodate the European Standard EN 12811. It defines the method of constructing access scaffolds, the criteria and calculations necessary for designing special scaffolds, and the precautions necessary to protect the public in the vicinity. The recommendations generally relate to the scaffold hardware, although issues of training, supervision, and inspection of work are mentioned. There are also legislative documents, which must be incorporated into the decision aid. In the UK, these include the Personal Protective Equipment at Work Regulations 1992, the Management of Health and Safety at Work Regulations 1996, the Health and Safety at Work Act 1974, and the Construction (Health, Safety and Welfare Regulations) 1996.
This report describes mainly the development of a prototype decision support aid called SCAFPASS (an abbreviation for Scaffold Planning Aid for System Safety). Its development was guided by these data and by the relevant regulatory and legislative requirements pertaining to scaffolding. The next sub-section provides a short discussion of the thinking behind the design of the project.

1.2 PROJECT AIMS

1.1 Identify those factors that increase risk of falls from height for two high risk work at height systems, established as being temporary access with scaffolds and working on Fragile Roofs.

1.2 Assess the main requirements of a Decision Aid by examining the decisions that need to be made during the management of safety in projects involving temporary access with scaffolds.

1.3 Develop and evaluate a prototype Decision Aid to help in the management of safety in projects involving temporary access with scaffolds

1.4 Investigate the feasibility of developing a Decision Support Aid for those working on Fragile Roofs

1.3 PROJECT OVERVIEW

1.3.1 Project Steering Group

A Project Steering Group was set up with representatives from the HSE, and the disciplines of Safety, Safety Risk Management, Engineering and Ergonomics. The remit of this group was to agree a detailed study plan covering each of the study objectives, to assist in specific steps in the execution of the study, and to review the progress of the study at regular intervals.

1.3.2 Project Overview

There were essentially a number of separate but related parts to the project. Decision aid content will be determined by the results of analyses of incidents involving temporary access systems. In fact the statistics could be expected to determine not only content but also which work activities (roofing, scaffolding etc) the decision aid is to address.

Activities associated with large numbers of fatalities and injury should be prioritised when deciding on the target population for which a decision aid will be designed. Therefore, recorded incidents which have involved temporary access equipment were examined in sections 2 and 3 for the purpose of specifying the application area(s), and the content of the decision aid(s).

Further, in Section 3, the types of structures and the types of failures involved in these incidents, and the underlying shortcomings at the operator and management level that supported the failures were examined in detail. This helped identify the range of controls that should be considered in developing a decision aid for avoiding the conditions supporting the common failures.

Consultation with industry (Section 4) provided input on key safety decisions throughout the lifetime of a project, unsafe occurrences and problems with communication and information, scaffold equipment and training of staff. This information proved useful in developing the content and structure of a decision aid because, inter alia, it provided an indication of important safety issues for scaffolds at stages within the lifetime of the project, and the problems that safety advisers encountered in achieving and maintaining safety on sites with scaffolds.
As it was recognised that the diversity of access systems in type, complexity of equipment and staffing requirements probably precluded a generic decision aid applicable to all systems, it was decided to focus on two types of access system. Scaffolds were chosen as the first system because of their frequency in the accidents and incidents, and because of the potential complexity of their structure and the socio-technical organisation required on site. The second was access to roofs.

Section 5 describes the principles underlying the development of the decision support aid for scaffold access systems. It describes how it was designed to inform users of the more common risks, include the risk assessment and control procedures and the specific controls that will avoid the more common root cause failures. This led to the first prototype decision aid, SCAFPASS/1.

The evaluation process is outlined in Section 6. The purpose of the user trials was two-fold; to familiarise participants with SCAFPASS/1 through paper-based exercises, and to collect data to answer specific questions. These included determining whether SCAFPASS/1 provided users with a broader understanding of the possible safety management shortcomings that can lead to injury with scaffolds. Amongst other issues, the trials were also designed to assess how potential users of SCAFPASS/1 viewed its usability, content, length, structure, and usefulness? As a result of the user trials, changes were made to SCAFPASS/1 to produce version 2, SCAFPASS/2.

It was clear that there was a need for full instructions so these were developed. SCAFPASS/2 was designed for office use. From feedback, there was an indication that there was support for a simplified version that could be carried around, literally in the users pocket. Section 7 describes the development and evaluation of Pocket SCAFPASS, the simplified version.

Other parts of the project involved using expert judgements of absolute probabilities to model the reliability of a simplified scaffold system (Section 8) and in Section 9, modelling the effects on structural integrity of various faults in a scaffold system of well-defined specifications (the same specifications as with expert judgements). The aim of these activities was to derive an order of priority for the various faults in terms of their implications for safety.

An additional activity was developing a Checklist for inspecting scaffolds. This is described in Section 10 and is based on the accident statistics (particularly the list of the most common primary features that caused the injury) and the results of the modelling (particularly the ratings of risk and the overall probabilities of injury).

Roof access was the second system addressed through the design of a decision aid (ROOFMATE). Section 11 describes its development and evaluation via user trials.

**1.3.3 Report Structure**

Each Section summarises the main results of each project activity with further detail as necessary in related Appendices.
2. LITERATURE REVIEW

2.1 OVERVIEW

The details of the literature review is given in Appendix A. In summary, it reviews published and, to a lesser extent, unpublished research concerning the following issues:

a) Prevalence of falls from height in general, and from roofs and scaffolds specifically
b) Prevalence of injury as a result of falling objects and structural collapse during work with roofs and scaffolds
c) Causes of scaffold- and roof-related incidents at a root-cause level and at a higher socio-technical level
d) Aspects of safety management that are of relevance to these incidents
e) Decision aids generally, and their potential usefulness for preventing work-related injury with scaffolds and roofs

The review contributed to the development of the decision aids principally by providing the following information:

a) Relative contributions of different access systems to national accident statistics thereby allowing us to prioritise the access systems that we selected for decision aids
b) Areas of risk for access systems, and the causes of injury at a proximal and distal level (in advance of our own analyses in the next section); this allowed an early indication of the necessary content of decision aids
c) The format and application of decision aids that have been used in the past in related areas

2.2 CONCLUSIONS

A decision aid;

a) must address the higher managerial issues surrounding safe work practices across all stages of a project.

b) incorporate the applicable regulatory standards including codes of construction for scaffold systems in the UK such as BS5973: and BS1139: 1994 series.

c) reflect the responsibilities for safety is distributed between client, designer, planning supervisor and principal contractor, reflected within The Construction (Design and Management) (CDM) Regulations 1994.


e) have content determined by the results of analyses of incidents involving temporary access systems, and,

f) cover work activities (roofing, scaffolding etc) associated with large numbers of fatalities and injury.
3. ACCIDENT AND INCIDENT ANALYSES

3.1 OVERVIEW

The analyses of accidents and incidents involving access systems are given in detail in Appendix B. In summary, the analyses addressed the following issues:

a) Prevalence of accidents and incidents with access systems generally, and with scaffolds and roofs specifically
b) Root-causes of falls of people from these structures (with a focus on scaffolds and roofs).
c) Root-causes of falling objects and structural collapse (with a focus on scaffolds and roofs)
d) Distal causes for these incidents, including management deficiencies and performance shaping factors

The analyses contributed to the development of the decision aids by informing us of:

a) Relative contributions of different access systems to national statistics, thereby offering guidance on which access systems we should select for the design of decision aids
b) Specific preventative measures at the ‘shop-floor’ and management level that need to be considered in the decision aids.

3.2 SUMMARY OF FINDINGS

3.2.1 FCG Cases

Analysis of the FCG cases was essential in understanding the types of failures and their frequencies, and in highlighting the diversity of issues and controls that need to be addressed in any decision support aid.

The type of structure in the majority of cases was a roof or working scaffold. In incidents involving roof structures it was usually the case that the worker fell through fragile material. For working scaffolds the majority of cases involved a collapse when the scaffold was in use.

The five most common features of the access system in which failure was centred were generally associated either with scaffolds or roof structures, and were defective components, lateral attachment, crawling boards, barriers over fragile areas, edge protection and overload.

Examination of the mode of failure for the ten most common failure elements suggested that in many cases the error was one of not fitting / using the element from the outset or of quality of execution. However, the mode of failure for the area of lateral attachment (relevant to 13% of cases -nearly all of them scaffold-related), was removal at an inappropriate time.

These figures illustrate the critical role that was played in the majority of the 186 incidents by human factors rather than purely defective hardware. Relatively few incidents involved defective components where the defect would not have been detected by routine visual inspection on site before the commencement of work.

3.2.2 FOCUS Cases

The analysis of FOCUS provided the following information:
a) Absolute frequencies of cases for various structures associated with temporary access and roof work
b) An indication of the proportions of these cases that were subsequently investigated
c) An indication of the relative frequencies of areas of failure based on keyword searches
d) The frequency of deficiencies thought by investigators to be active in causing the incident.

The large number of moveable ladders in use across many sectors of industry probably explains why these cases account for approximately half the sample. Falls from scaffolds make up the third largest group, although some of these are expected to involve a partial or complete collapse of scaffold.

The proportions of cases that were subsequently investigated varied across agents. Typically falls from scaffolds, collapses of scaffolds, and falls from tower scaffolds had the highest investigated proportions. Scaffold incidents, perhaps more than other temporary access systems, have the potential for injuring more than one person; their high investigation rate may reflect that potential.

A search of 2,876 investigated cases across 14 types of access system examined the accompanying short text description of the incident in order to establish the root cause. A little less than half the cases did not provide sufficient information. Overall, the most common failed features were ladder footings, ladder ties, edge protection, defective component, roof-light protection, harnesses, trespass, ingress/egress, crawl boards and vehicle collision. Scaffold-related cases occurred because of shortcomings in harnesses, defective components, internal bracing, edge protection and structural overload. Falls through or from a roof occurred mainly because of shortcomings with roof-light protection, crawling boards, edge protection, and controls on trespassing.

Finally, the same investigated cases in FOCUS were queried on the frequency of 24 potentially relevant deficiencies from a total of 61 available in the database. The most frequent deficiencies concerned failure to control risk, unsafe systems of work on transient jobs, unsafe procedures, and defects in a fixed or temporary work platform. The same leading deficiencies were apparent when scaffold-related cases were considered. For these cases the third and fourth most common deficiencies were inadequate standard of supervision and inadequate training.
4. CONSULTATIONS WITH SCAFFOLD-RELATED COMPANIES

The report of consultations with scaffold-related companies is given in Appendix C. In summary, our enquiries provided the following information:

   a) Views of safety advisers with respect to key safety decisions that they make throughout the lifetime of a project
   b) Unsafe occurrences they have encountered in the past
   c) Problems they have encountered with communication and information, scaffold equipment and training of staff

This information proved useful in developing the content and structure of a decision aid because:

   a) It allowed us to assess what experienced safety adviser see as the important safety issues for scaffolds at stages within the lifetime of the project
   b) It provided indications of what incidents they had encountered in the past, and this allowed checks with our accident and incident analyses to make sure there was a general match
   c) It allowed us to assess the problems that safety advisers encountered in achieving and maintaining safety on sites with scaffolds.

The following sections of the report build on the findings of the literature review, the accident analyses and the consultations. We were involved from hereon with designing a decision aid for work on scaffolds and a decision aid for work on roofs. We describe first the development, testing and refining of the decision aid for scaffolds.
5. DECISION AID FOR SCAFFOLD SAFETY: DEVELOPMENT

The diversity of access systems in type, complexity of equipment and staffing requirements probably precludes a generic decision aid applicable to all systems. We therefore decided to focus on two types of access system. Scaffolds were chosen as the first system because of their frequency in the accidents and incidents, and because of the potential complexity of their structure and the socio-technical organisation required on site.

The statistics showed that incidents on and around scaffolds accounted for 2,648 (14%) of the 19,348 access-related cases reported in a four-year period (Appendix B). That figure includes falls from scaffolds, collapses of scaffolds and falling objects from scaffolds. While cases involving ladders do exceed the number of scaffold-related cases, scaffolds structures are more complex and they can have many more interacting causes. The potential role of a decision aid in preventing injury with scaffolds is likely to be considerable because there are many considerations necessary to ensuring safety.

5.1 BASIC DESIGN REQUIREMENTS

A decision aid for scaffold work must:

a) - inform users of the more common risks with scaffolds  
b) - emphasise the risk assessment and control procedures that should be used in an effort to reduce the more common causes of injury  
c) - emphasise the specific controls that will avoid the more common root cause failures

Additional desirable attributes for the decision aid include:

a) - an order of stages that is consistent with the sequence of the project  
b) - a design that is not work intensive for the user when used in real-time or as an audit tool  
c) - a content and sequence that accords with current guidance notes and regulations published by the Health and Safety Executive and with British and European standards, as well as with other best practice in the safety management literature  
d) - a level of detail that permits the user an overview of the requirements within each stage of the project as well as a level of finer detail providing criteria on which to assess whether safety requirements are met.

5.2 DESIGNING FOR THREE GROUPS

The interests of three parties must be incorporated in the design:

(i) The person overseeing the planning and work, i.e. the overseer: It is inevitable that the identity and specific role of this person will vary as the project progresses through its stages. The overseer will include the client, planning supervisor, principal contractor, and site agent. In smaller projects there may only be the client.

(ii) The contractor erecting the access system: Often this group will be scaffolders who are providing an access system for use by other parties. The decision aid should be designed for the supervisors of this group. This is because supervisors are in a position to use a decision aid efficiently and with authority. However the design should also encourage supervisees to use the decision aid in the same proactive manner.
(iii) The contractor using the access system: Users of the access system, and therefore the decision aid, will belong to a wide diversity of trades. While the skills and specialist equipment will vary across trades, the requirements for safe use of the scaffold will not substantially vary. Once again, the decision aid should be designed for use by supervisors and supervisees.

The variation in size, length and staffing of construction projects means that some projects may not include all the parties in (i), (ii) and (iii).

5.3 DESIGNING FOR PROJECT STAGES

The design of the decision aid must reflect the natural stages of a project. These stages are: bidding/procurement; pre-planning; erecting, using and dismantling the scaffold; and hand-over of the erected scaffold. The activities within each stage can be summarised:

**Bidding/procurement:** Contractors intending to use and erect the scaffold are expected to gather information about the site, liaise with the overseer, and establish a work specification before compiling a preliminary risk assessment and list of controls for the risks that they are likely to encounter. The overseer is expected to provide sufficient information about the site, the work to be done and the necessary co-ordination between contractors to allow the user group and scaffold group to compile their preliminary risk assessment and list of controls. The overseer is also expected to select the contractor based partly on the health and safety plan they submit and partly on safety-related information about the bidder.

**Planning:** The contractors intending to erect or use the scaffold are expected to consolidate information gathered about the work and site during the procurement stage, consider the hazards, devise risk controls and ensure that their staff are well briefed in safety issues. The overseer will devise their own risk assessment and control procedures to reduce the risks for all parties working on site under their charge. Their health and safety plan will cover hazards common to all workers on the site.

**Erection:** All parties must ensure that their own risk controls are in place and that discrepancies are rectified swiftly. Each party must also ensure that other contractors’ are not putting their staff at undue risk. At the end of this stage the access system is handed over to the contractor(s) intending to use it.

**Hand-over:** In this stage all parties share the same goal, this being to ensure that the temporary access system is handed over in a safe state with information necessary for safe use of the structure. The hand-over would proceed first from the scaffold contractor to the user, and then later from the user back to the scaffold contractor. A schedule of maintenance and checks must also be arranged.

**Use:** The contractor receiving the scaffold then has the responsibility (and duty) for ensuring work is conducted in a safe manner, and that necessary inspections are carried out. The overseer has an obligation to ensure that work on site progresses safely.

**Dismantling:** The access system is dismantled once all parties agree that access is no longer required and that dismantling can proceed safely. Responsibility for the access system returns to the scaffold contractor.

In reality, the stages may not be as well-defined. For example, dismantling of the scaffold might occur at intervals during its use, e.g. during demolition of a building, so that the
scaffold would in essence be handed over to the user more than once. Nonetheless, division of the decision aid according to these stages provides a realistic structure.

5.4 PRELIMINARY DESIGN OF A DECISION AID FOR SCAFFOLDS

The preliminary design of the decision aid for scaffold safety was based on input from the accident and incident analyses, and the consultations with contractors and safety advisers. This decision aid was called SCAFPASS/1, an abbreviation for Scaffold Planning for Access System Safety, Version 1.

The first page explains the general structure and logic of SCAFPASS/1 to its user. The decision aid itself consists of four Parts, each with varying numbers of Steps. The Steps form the central column in each Part. At each Step there is a question that asks the user whether a particular safety issue has been properly addressed. Notes to the left of the Step provide further explanation in the form of detailed criteria. The user progresses through the Steps in the Part of the decision aid that applies to the current stage of the project.

The decision aid is colour coded: Steps particularly relevant to the overseer appear in green; Steps particularly relevant to the scaffold contractor or contractor intending to use the scaffold appear in blue; Steps where responsibility is more evenly shared appear in black. All parties have a responsibility to ensure that they and other contractors have properly addressed and continue to properly address the issue at each Step. Co-operation and collaboration between contractors in meeting safety requirements is encouraged because all contractors are working from the same decision aid. In this sense, SCAFPASS/1 can be used as a facilitation device for discussion and continual auditing of safety on site.

Part A: Bidding and Procurement

Part A guides the user through a process of bidding or procuring that takes account of safety-related criteria. This is the only Part that has different versions for the overseer and scaffold contractor/contractor intending to use the scaffold. The overseer must at the very outset ask whether access to height is actually required to complete the task and, if so, whether scaffolding is the most suitable means of access (A1). They then go on to screen the potential contractors (A2) before issuing a clear brief on which all proposals are based (A3). Finally, they assess bids on health and safety criteria (A4, A5) before selecting a contractor (A6).

The scaffold contractor/contractor intending to use the scaffold must ensure that the brief is clear, sufficient and that it cannot be simplified (A1, A2). Within the bidding stage they must take into account whether the scaffold must be specially designed (A3), whether the principal risks are identified and controlled (A4, A5), and whether the scaffold will be compatible with intended loads (A6), foundations (including the façade) (A7), and staffing (A8).

Part B: Planning

Part B and all later Parts are identical for all groups. Part B guides the user through a consideration of the planning required for safe work with scaffolds. It begins by asking whether responsibility for health and safety has been established within their company and whether contact points for health and safety issues are known for the other collaborators (B1). This is a necessary first Step because it instils personal accountability, removes role ambiguity with respect to health and safety, and facilitates efficient exchange of health and safety information between contractors. The next Step (B2) asks whether the site has been visited so that any necessary details for planning the structure or the work can be collected. Next, three Steps (B3, B4, B5) enquire about the measures that will be put in place to prevent falling persons or material and to prevent overloading the scaffold. These issues are quite
specific to the scaffold and therefore appear for special attention by the scaffold contractor / contractor intending to use the scaffold. The next two Steps (B6, B7) relate to the issue of interference with the scaffold, either inadvertently or deliberately. Unauthorised alteration of the scaffold, especially on a localised level, can make the scaffold unsafe; B6 asks whether measures are planned to prevent such alterations occurring. The public can represent a danger to the scaffold, so B7 asks whether measures are planned to prevent trespass on or around the scaffold and to prevent vehicular collision with the scaffold. These are issues that are more general to the site as a whole and are therefore marked as having special relevance to the overseer.

The next Step (B8) asks whether plans have been made to provide appropriate safety information to staff and to share safety information among contractors working on site. The next Step (B9) asks whether plans have been made to check equipment and scaffold structure. The final Step in this Part asks whether the number and skills of staff will be sufficient to complete the work safely (B10).

Part C: Erecting, Using and Dismantling the Scaffold

Part C uses the same themes as Part B and nearly identical wording in the Steps. It ensures that the plans made in Part B are realised during the working phase of the project.

Part D: Hand-over of the Scaffold

Part D makes recommendations for the period during which the scaffold is commissioned and given to the contractor intending to use it for access. Part D is to be used after the erection of the scaffold but before use of the scaffold for access. The first Step asks whether arrangements have been made with the scaffold contractors for later routine or urgent modifications. Step D2 requires a check on the scaffold. The next Step (D3) ensures that all users of the scaffold know the limits of the structure. Step D4 checks that the contractor using the scaffold and the overseer are aware that they inherit responsibility for safe use of the scaffold. Finally, the contractor intending to use the scaffold must understand that persons without the necessary training must not alter the structure (D5).
6. DECISION AID FOR SCAFFOLD SAFETY: EVALUATION

6.1 INTRODUCTION

The purpose of the user trials was two-fold: to familiarise participants with SCAFPASS/1 through paper-based exercises, and to collect data to answer the following questions:

a) Does SCAFPASS/1 provide the user a broader understanding of the possible safety management shortcomings that can lead to injury with scaffolds? One goal of SCAFPASS is to broaden the user’s appreciation of possible antecedent failures in safety management before these failures result in injury.

b) For any incident, do users of SCAFPASS/1 generally agree on whether the Step is important in preventing the occurrence of the incident? Ideally, SCAFPASS/1 would result in users converging in their opinions of the importance of each Step.

c) Do participants provide potential countermeasures for particular incidents that are not already included in SCAFPASS/1? Although the content of the decision aid was carefully considered, there may be issues of potential importance that were overlooked when it was constructed.

d) How do potential users of SCAFPASS/1 view its usability, content, length, structure, and usefulness? SCAFPASS/1 must be easy to use, show face validity to the users, be of a manageable length, and be perceived as capable of improving site safety.

e) The user trials involved the application of SCAFPASS/1 to two written descriptions of accidents. The descriptions were based on two cases selected from written accident reports in FOCUS (for an explanation of FOCUS see Appendix C).

Participants used SCAFPASS/1 retrospectively to identify the shortcomings in safety management that led to the incidents. Their performance with SCAFPASS/1 was compared to their performance when the decision aid was not used but when the participants instead adopted a free-listing approach. A set of questions then asked participants about their views on the ease of use, length, content and usefulness of the decision aid, as well as their perceptions of the likelihood that they or their company would adopt it.

The hypotheses that we wished to test can be listed:

Hypothesis 1: Use of SCAFPASS/1 allows the participant to envisage a larger total number of possible countermeasures for each incident than when the participant does not use the decision aid. One of the reasons for introducing a decision aid is to make the user more aware of possible countermeasures to the occurrence of incidents.

Hypothesis 2: The number of relevant countermeasures generated without SCAFPASS/1 and which are not included as Steps in SCAFPASS/1 will be at a minimum. SCAFPASS/1 should include all the important countermeasures to the incidents.

Hypothesis 3: The proportions of participants at each Step of SCAFPASS/1 who believe the Step is not properly addressed but that it is relevant to preventing the incident will be polarised to high or low proportions. SCAFPASS/1 should allow a consensus to emerge on where mistakes are occurring in safety management.
Hypothesis 4: _Mean ratings on the importance of each Step will differ within each part of SCAFPASS/1._ Perceptions of the importance of each Step within a part of SCAFPASS/1 should differ for any particular incident because it is unlikely that all Steps will have the same importance for a specific incident.

Hypothesis 5: _The majority of respondents will provide favourable assessments of SCAFPASS/1 in terms of its length, level of detail, ease of use, content, likelihood of use, and effects on safety._ Ideally, respondents of SCAFPASS/1 will provide favourable ratings on various dimensions of SCAFPASS/1.

6.2 METHOD

Participants

Participants were recruited from the Construction Industry Training Board (CITB) in Glasgow. The CITB is an organisation providing a high standard of training across a broad range of building trades. A total of 40 participants was drawn from classes on site safety and scaffolding. Participants were paid a token sum of £5 for their assistance.

Apparatus

A booklet was compiled for the user trials. In summary, it contained a brief description of two incidents. The incidents were based on actual FOCUS cases. After the description of the first incident, participants were given an opportunity to list the possible preventative measures within different phases of the project that might have avoided the incident’s occurrence. The phases were the same as those in SCAFPASS/1, namely: bidding, planning, erection/use/dismantling, and hand-over. For each preventative measure, the participant was asked to give a rating of importance of the measure for preventing incidents of the kind described.

The participant then read a description of a second incident and applied SCAFPASS/1 to the incident in the following way. At each Step in SCAFPASS/1, the participant completed a series of three questions on an adjacent fold-out flap of paper. The three questions asked whether the Step was properly addressed prior to the occurrence of the incident, whether the Step would have been relevant in preventing the incident, and how they rated the importance of the Step in preventing incidents of the kind described. The incident descriptions are given in Appendix F.

A section entitled _Your Impressions_ then asked participants about aspects of SCAFPASS/1, including its length, level of detail, ease of use, comprehensiveness, likelihood of it being used by them or their company, and how effective it would be in improving safety on sites with scaffolds. A final section then asked for the participant’s age, experience working on or around scaffolds, qualifications in scaffolding, and professional duties.

Procedure

There were two versions of the user trials booklet, differing only in the order of the two incident descriptions. The participants were divided equally into two groups, and each group completed one of these versions (Table 1). Groups were matched on age and experience. The design generated two independent sets of data for the free-listing and SCAFPASS/1 conditions. Participants were permitted to take the booklet away with them and return it the following day. They were asked not to consult with each other while completing the exercise, and not to backfill the booklet once they had left a particular section.
Once all the data were collected, it was necessary to re-code the free-listed countermeasures. Each countermeasure was compared to the Steps in SCAFPASS/1 and, when it matched a Step, the identity of that Step was recorded, e.g. A5, B7, etc. When a countermeasure could not be re-coded as any Step in SCAFPASS/1 and when it was deemed relevant to preventing the incident, it was noted as outside the scope of SCAFPASS/1. One investigator re-coded the data and a second investigator verified the reliability of this coding for a sub-sample of cases.

6.3 RESULTS

The age of participants was known in 34 cases; it ranged from 21 to 55 years, with a mean of 37 years (SD = 8). The number of years of experience working on or around scaffolds was known in 33 cases; it ranged from 1 to 40, with a mean of 15 (SD = 10). Group 1 and 2 were matched groups and therefore they did not differ significantly in age or experience. Thirty-three participants provided information on their scaffold qualifications: nine participants were basic or advanced scaffolders or in training for these qualifications; and 25 had no formal training in scaffolding. Finally, Table 2 shows the job roles for the 36 participants who provided this information.

### Table 2

<table>
<thead>
<tr>
<th>Job roles</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor of a scaffold team on site</td>
<td>5</td>
<td>14.7</td>
</tr>
<tr>
<td>Supervisor of a team using a scaffold for access</td>
<td>9</td>
<td>26.5</td>
</tr>
<tr>
<td>Site agent on sites with scaffolding</td>
<td>15</td>
<td>44.1</td>
</tr>
<tr>
<td>Designer of scaffolds</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Contracts manager for projects involving scaffolds</td>
<td>5</td>
<td>14.7</td>
</tr>
<tr>
<td>Planning supervisor for projects involving scaffolds</td>
<td>2</td>
<td>5.9</td>
</tr>
<tr>
<td>Site foreman on sites involving scaffolds</td>
<td>6</td>
<td>17.6</td>
</tr>
<tr>
<td>None of the above</td>
<td>2</td>
<td>5.9</td>
</tr>
</tbody>
</table>

*Note: One person can appear in more than one category

**Hypothesis 1:** Use of SCAFPASS/1 allows the user to envisage a larger total number of potential countermeasures for each incident than if SCAFPASS/1 were not used.

The mean total number of free-listed countermeasures, irrespective of their content, was compared to the total number of Steps which the respondent believed were not addressed but were relevant to preventing the incident (Table 3). The statistical analysis used Student’s t-test and assumed equal variances. In the case of Incident A, significantly more countermeasures were suggested in the free-listing condition than when SCAFPASS/1 was used. This trend disappeared for Incident B; here the numbers were comparable.
Table 3
Comparison of absolute numbers of countermeasures for free-listing and SCAFPASS/1

<table>
<thead>
<tr>
<th>Phase</th>
<th>Incident A</th>
<th>SCAFPASS</th>
<th>Test</th>
<th>Incident B</th>
<th>SCAFPASS</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidding</td>
<td>3.7 (1.81)</td>
<td>2.05 (1.82)</td>
<td>t=2.88; p&lt;0.01</td>
<td>2.85 (1.42)</td>
<td>2.55 (2.35)</td>
<td>not sig.</td>
</tr>
<tr>
<td>Planning</td>
<td>3.8 (1.70)</td>
<td>2.55 (2.06)</td>
<td>t=2.09; p&lt;0.05</td>
<td>2.50 (1.79)</td>
<td>3.05 (1.85)</td>
<td>not sig.</td>
</tr>
<tr>
<td>Erecting/using/</td>
<td>4.3 (1.98)</td>
<td>2.35 (1.90)</td>
<td>t=3.18; p&lt;0.01</td>
<td>3.80 (1.74)</td>
<td>3.95 (2.74)</td>
<td>not sig.</td>
</tr>
<tr>
<td>dismantling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand-over</td>
<td>1.85 (1.35)</td>
<td>0.85 (1.42)</td>
<td>t=2.28; p&lt;0.05</td>
<td>2.10 (1.21)</td>
<td>2.35 (1.53)</td>
<td>not sig.</td>
</tr>
</tbody>
</table>

Note: Figures in brackets are standard deviations

Using absolute numbers of suggestions for countermeasures, however, does not take account of the content of the free-listed suggestions and whether free-listed suggestions are repeated. The free-listed suggestions were therefore re-coded to Steps within SCAFPASS/1 and the analysis was repeated. This tested how many Steps within SCAFPASS/1 had been presented in the free-list condition without prompting from SCAFPASS/1. The number of suggestions did not differ significantly for Incident A (Table 4). For Incident B, however, the use of SCAFPASS/1 was associated with a significantly higher number of suggestions in the Planning and Erecting/ using/ dismantling phases.

Table 4
Comparison of numbers of countermeasures generated for free-listing and SCAFPASS/1 after re-coding of free-list responses into SCAFPASS/1 Steps

<table>
<thead>
<tr>
<th>Phase</th>
<th>Incident A</th>
<th>SCAFPASS</th>
<th>Test</th>
<th>Incident B</th>
<th>SCAFPASS</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidding</td>
<td>1.80 (0.89)</td>
<td>2.05 (1.82)</td>
<td>not sig.</td>
<td>1.75 (1.06)</td>
<td>2.55 (2.35)</td>
<td>not sig.</td>
</tr>
<tr>
<td>Planning</td>
<td>2.65 (1.73)</td>
<td>2.55 (2.06)</td>
<td>not sig.</td>
<td>0.85 (0.75)</td>
<td>3.05 (1.85)</td>
<td>t= 4.94 (38); p&lt;0.01</td>
</tr>
<tr>
<td>Erecting/using/</td>
<td>2.55 (1.61)</td>
<td>2.35 (1.90)</td>
<td>not sig.</td>
<td>1.85 (1.23)</td>
<td>3.95 (2.74)</td>
<td>t= 3.13 (38); p&lt;0.01</td>
</tr>
<tr>
<td>dismantling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand-over</td>
<td>0.30 (0.47)</td>
<td>0.85 (1.42)</td>
<td>not sig.</td>
<td>1.85 (1.09)</td>
<td>2.35 (1.53)</td>
<td>not sig.</td>
</tr>
</tbody>
</table>

Note: Figures in brackets are standard deviations

Hypothesis 1 was therefore only partially confirmed. In terms of absolute numbers of suggestions for countermeasures to the incidents, the use of SCAFPASS/1 did not enhance performance. When the content of the suggestions was assessed, SCAFPASS/1 produced a comparable or larger number of potential countermeasures.

Hypothesis 2: The number of relevant countermeasures generated without SCAFPASS/1, and which are not included as Steps in SCAFPASS/1, will be at a minimum.

The free-listing of potential countermeasures provided an opportunity to check, at least in relation to two incidents, whether SCAFPASS/1 included the large majority of safety management issues for scaffold projects. Table 5 presents issues that are not addressed by the current version of SCAFPASS/1 but which were mentioned in the free-listing as legitimate safety management issues. The number of issues was limited; in this respect Hypothesis 2 was confirmed. However, three key issues that did emerge were: work schedules that are known to all contractors; protocols for handing the scaffold back to the scaffold contractor after use; and method statements that are available within and between contractors.
Table 5
Safety management issues suggested by participants but not included in SCAFPASS/1

<table>
<thead>
<tr>
<th>Step</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bidding</strong></td>
<td>Design drawings for the scaffold are to be presented</td>
</tr>
<tr>
<td></td>
<td>A pre-tender meeting should be standard</td>
</tr>
<tr>
<td></td>
<td>The site should be visited prior to bidding</td>
</tr>
<tr>
<td></td>
<td>Sufficient funds should be allocated specifically for all risk controls</td>
</tr>
<tr>
<td></td>
<td>The proposed scaffold design should be reviewed by all parties</td>
</tr>
<tr>
<td><strong>Planning</strong></td>
<td>A pre-start meeting should be standard</td>
</tr>
<tr>
<td></td>
<td>There should be an agreed schedule to involve all contractors which is circulated to all parties.</td>
</tr>
<tr>
<td></td>
<td>Method statements for work should be available to staff and other contractors</td>
</tr>
<tr>
<td><strong>Erection/use/dismantling</strong></td>
<td>A permit to work system should be in place</td>
</tr>
<tr>
<td></td>
<td>Written procedures should be available to staff</td>
</tr>
<tr>
<td></td>
<td>Certificates for dismantling should be used</td>
</tr>
<tr>
<td></td>
<td>The schedule of dismantling should not interfere with any work on site, and all work from the scaffold should have ceased.</td>
</tr>
<tr>
<td><strong>Hand-over</strong></td>
<td>There should be procedures for handing the scaffold back to the scaffold contractor for dismantling</td>
</tr>
</tbody>
</table>

**Hypothesis 3:** The proportions of participants at each Step of SCAFPASS/1 who believe the Step is not properly addressed but that it is relevant to preventing the incident will be polarised to high or low proportions.

Figures 1 and 2 show the proportions of participants who at each Step believed that the Step was not properly addressed but that it would have been relevant to preventing the incident. These charts do not suggest polarisation of opinion among participants; this is because there are many instances of proportions lying between 0.4 and 0.6. Hypothesis 3 is therefore not supported.

![Figure 1](image-url)

**Figure 1**
Proportions of participants at each Step of SCAFPASS/1 who believed the Step was not properly addressed but that it was relevant to preventing the incident (incident A)
Figure 2
Proportions of participants at each Step of SCAFPASS/1 who believed the Step was not properly addressed but that it was relevant to preventing the incident (incident B)

**Hypothesis 4:** Mean ratings on the importance of each Step will differ within each part of SCAFPASS/1.

Incident should vary in terms of where the failures occurred, and ratings should reflect this variation. Figures 3 and 4 show the Mean ratings on the importance of each Step.
Two-way analysis of variance for incident A showed that the ratings differed significantly only in the Bidding ($F_{[7,196]} = 2.71; p<0.05$) (Figure 3). For Incident B, ratings differed significantly for Planning ($F_{[9,172]} = 3.5; p<0.001$) and Erecting/using/dismantling ($F_{[9,171]} = 3.48; p<0.001$) (Figure 3). There is therefore partial confirmation of Hypothesis 4.

**Hypothesis 5:** The majority of respondents will provide favourable assessments of SCAFPASS/1 in terms of its length, level of detail, ease of use, content, likelihood of use, and effects on safety.

The questions and responses are given below for groups 1 and 2 pooled.

**Question:** How would you rate the length of the decision aid?
Thirty-five responses: Much too long 5.7%; Too long 40.0%; About right 51.4%; Too short 2.9%.
A small majority of respondents (51.4%) thought the length was about right. However, a relatively large proportion believed it was too long.

**Question:** How do you rate the level of detail of the decision aid?
Thirty-four responses: Far too detailed 5.9%; Too detailed 17.6%; About right 64.7%; Not enough detail 8.8%; Far too little detail 2.9%.
The majority of respondents (64.7%) thought the level of detail was about right.

**Question:** How do you rate the ease or difficulty of use of the decision aid?
Thirty-five respondents: Very easy to use 2.9%; Easy to use 22.9%; Some difficulty in use 57.1%; Difficult to use 14.3%; Very difficult to use 2.9%.
The majority of respondents (57.1%) reported that they experienced some difficulty in using SCAFPASS/1.
Question: How do you rate the content of the decision aid?
Thirty-five respondents: All important issues are included 54.3%; Nearly all important issues are included 40.0%; Only some of the important issues are included 5.7%. The majority of respondents (94.3%) thought that all or nearly all the important issues were included in SCAFPASS/1.

Question: Would you use this decision aid if you were in charge of a scaffold project?
Thirty-four respondents: I would definitely use it 23.5%; I would probably use it 38.2%; There’s a 50/50 chance I’d use it 17.6%; I would probably not use it 17.6%; I would definitely not use it 2.9%. The majority of respondents (61.7%) stated that they would either definitely or probably use SCAFPASS/1.

Question: Do you think your company would use this decision aid?
Thirty-four respondents: It would definitely use it 17.6%; It would probably use it 41.2%; There’s a 50/50 chance it would use it 23.5%; It would probably not use it 14.7%; It would definitely not use it 2.9%. The majority of respondents (58.8%) stated that the company would either definitely or probably use SCAFPASS/1.

Question: Do you think widespread use of the decision aid would improve safety on sites with scaffolds?
Thirty-four respondents: Very likely improvement in safety 26.5%; Likely improvement in safety 44.1%; There’s a 50/50 chance of improvement in safety 29.4%. The majority of respondents (70.6%) felt that the decision aid would be likely or very likely to improve safety.

On the basis of these results Hypothesis 5 is confirmed, except as it applies to the ease of use of SCAFPASS/1.

6.4 DISCUSSION

The first version of SCAFPASS/1 has been tested on a group of participants who regularly work on or around scaffolds. Hypothesis 1 stated that the use of SCAFPASS/1 would allow a higher number of potential countermeasures to be suggested by participants. When absolute numbers of suggestions were assessed the hypothesis did not hold, and in fact the reverse trend emerged. The trend disappeared or reversed when content of suggestions was taken into account. One of the intended purposes of SCAFPASS/1 is to guide the user through the necessary safety precautions at different points in the project so that resources may be used efficiently to reduce risk. With limited resources it is important that the user is able to prioritise the risk controls relevant to the specific project. These results suggest that SCAFPASS/1 assists the user in selecting the more relevant controls.

Hypothesis 2 addressed the comprehensiveness of SCAFPASS/1 by examining the free-listed suggestions for countermeasures that were not encompassed within SCAFPASS/1. SCAFPASS/1 emerges as a comprehensive tool that captures the essential safety management issues of these two incidents – incidents that were selected as typical examples of FOCUS and FCG cases. However, there are some issues not currently included in SCAFPASS/1 which did emerge as legitimate safety management concerns. Foremost among these are: method statements; scheduling; and the hand-over procedures from user to scaffolder after use. One of the difficulties in designing SCAFPASS/1 was striking a balance between comprehensiveness and over-complication. While it is not possible to include the totality of issues of relevant to
scaffold safety, it is essential to include the issues relevant to the large majority of cases. Any future modifications of SCAFPASS/1 must take account of Table 5.

Hypothesis 3 looked at the convergence of opinion about which Steps were not addressed but relevant. Ideally, SCAFPASS/1 would allow users to reach a general consensus on which safety management issues are lacking. Results suggest that such a consensus is not usually present. One explanation may be that participants naturally differ in which safety management issues they tend to prioritise, perhaps because of previous experiences. A second explanation is that participants interpret the written incident descriptions differently.

Hypothesis 4 stated that the mean ratings of importance of each Step will differ within each Part of SCAFPASS/1. It would be unlikely for any one incident to have the same ratings of importance across Steps in the same Part of the decision aid. There was limited support for this hypothesis. Participants tend to rate all Steps with high importance without discriminating between them. This is not necessarily a shortcoming on the part of the users because it could mean that respondents are equally vigilant on all aspects of safety management.

Finally, Hypothesis 5 suggested that SCAFPASS/1 would receive favourable assessment by participants. Although the majority of participants provide favourable ratings on all questions, there is some cause for concern about the length and ease of use of SCAFPASS/1. Nearly 46% of respondents rate SCAFPASS/1 as too long or much too long and only 25% of respondents rated SCAFPASS/1 as easy or very easy to use. While it might be expected that, during familiarisation, users will initially have some difficulty in using SCAFPASS/1, the level of difficulty should be at a minimum. SCAFPASS/1 currently consists of four pages; each page has a large amount of information that the user must read. A difficulty in designing SCAFPASS/1 was accounting for the range of potential users, all of whom will have different job roles and capabilities (including ranges in literacy skills). The level of detail required of the decision aid probably depends on the job role of the user.

6.5 NECESSARY MODIFICATIONS TO SCAFPASS/1

As a consequence of the user trials, SCAFPASS/1 was modified to SCAFPASS/2. The modifications were:

a) Reducing the number of parts to the decision aid by combining (with appropriate changes to the wording) the original Parts B and C to form a new Part B.

b) Making the original Part D (which now becomes Part C) applicable to either direction of hand-over, i.e. from scaffolder to user or from user to scaffolder.

c) Incorporating the concept of method statements into the wording of Steps B3 to B7, and introducing an extra Step at A9 to address, at an early stage, the scheduling arrangements between contractors.

d) Alterations to the wording of certain Steps and of the titles to each Part.

SCAFPASS/2 appears in Appendix G.

Some of the participants expressed doubts on the ease of use of SCAFPASS/1. This prompted us to write clear instructions for the use of SCAFPASS/2 that guide the user on the general layout of SCAFPASS/2, its potential areas of application, and literally a step-by-step talk-through of each Part (Appendix H). Ease of use should also be improved by the reduction in the number of Parts to SCAFPASS/2.
It is assumed that SCAFPASS/2 would be used in an office environment. There remains a need for a simpler version of SCAFPASS based on SCAFPASS/2 that would be more appropriate for use on site and may be carried in the pocket. The next sections describe the development and refinement of a pocket version including limited user trials.
7. DECISION AID FOR SCAFFOLD SAFETY: DEVELOPMENT AND USER TRIALS OF A POCKET-SIZE VERSION

7.1 INTRODUCTION

SCAFPASS/2 was principally designed for office-based use. The level of literacy that it requires is relatively high. These factors tend to preclude its use in the field. Based on suggestions by our user group we complemented the full version of SCAFPASS/2 by developing a set of pocket-sized laminated cards featuring the same Steps but omitting the explanations that would otherwise appear to the left. The pocket version was therefore designed to be durable, easily carried, and brief in the information it presented. The wording of the Steps was changed in Part B and Part C. The front card included a description of the structure of SCAFPASS/2 and how to use it.

The pocket version of SCAFPASS/2 used for the trials is presented in Appendix I. We have called the overall version PocketSCAFPASS. Supervisor PocketSCAFPASS is designed to be used by site managers and supervisors, while User PocketSCAFPASS is mainly for supervisors, scaffolders and scaffold users.

7.2 PocketSCAFPASS MODIFICATION

7.2.1 Structure

The size of each individual card comprising either Supervisor or User PocketSCAFPASS is 3.5 inches by 5 inches (8.8 by 11.3 cm), and each overall set of cards is designed for lamination and to be folded to fit into a pocket of the user. The first card has instructions on its first side that explains the arrangement and method of use of each version of PocketSCAFPASS.

Supervisor PocketSCAFPASS consists of instructions, Part Ai, and Part Aii on one side (see Appendix I (a)). The wording for the latter parts is exactly the same as the full version of SCAFPASS/2, mainly because both Parts are intended for use by the more literate user. With this version of PocketSCAFPASS, the other side consists of Parts B and Part C, and a part with space for notes.

User PocketSCAFPASS consists of instructions and Part B on one side. On the other is Part C with a part with space for notes, (see Appendix I (b)). The wording for Parts B and C are the same for both versions of PocketSCAFPASS.

Parts B and C were designed for use in the field by relatively less literate users. In discussion with the Project Steering Group, the wording was simplified from the full version under the assumption that the typical user will have a reading age of around eleven years.

At the bottom of Part C there is space for critical information to be written on the card, and reference is made to this information in certain Steps of Part B and C. The information includes the name of the person responsible for safety on site to whom any safety concerns must be raised, and the name of the person to whom requests for scaffold alterations are to be directed. Additionally, there is a set of check-boxes where the maximum loading of the scaffold may be written.

It was expected that the site agent or supervisors within individual contractors would write this information on the card before handing it to all staff involved in the project. On the same site, this information may vary in some or all of the details from contractor to contractor. The card with Parts B and C was therefore designed as a stand-alone component of the pocket
version for use on site by all workers, including supervisors. *It was expected that the site agent or supervisor within each contracting company would provide Parts B and C at the time of the induction.* He or she would also complete details of contact names and maximum loading at that time.

### 7.2.2 WORDING

While the wording of Parts Ai and Aii remains identical, Parts B and C were altered in the following ways:

1. **Choice of words** was based on an assumption of a readership with an average reading age of eleven years.
2. **Steps** were phrased to be action-oriented and appeal directly to the user through the personal pronoun.
3. **Wording** was kept to a minimum in each Step. Words such as ‘a’ and ‘the’ were sometimes omitted when the meaning of the question could be preserved.
4. **The comments for a no response** consist either of a brief list of remedies or a referral to the supervisor or safety adviser. The wording here was different from the full version because it is designed for use on site by people directly involved in the work.

*In Steps B1, B5, B6, C1 and C3 the user is referred to the critical information that should already have been written in the box below Part C.*

The wording of Parts B and C was designed for both workers and their supervisors on site, as well as planners at a higher level because all may be involved in the hand-over. There were some Steps in Part C that were difficult to word in this respect. Here the Part must actually be designed not just for the different levels of personnel but also for different contractors (user and scaffolder) who may be handing the scaffold over in one of two possible directions: from scaffolder to user, or from user to scaffolder.

Field trials of User *PocketSCAFPASS* were undertaken in order to determine whether *PocketSCAFPASS* was successful in providing support for scaffolders.

### 7.3 USER TRIALS OF *PocketSCAFPASS*

#### 7.3.1 Introduction

The purpose of the field trials was to assess the usability of User *PocketSCAFPASS* on site by scaffolders.

#### 7.3.2 Method

**Participants**

Participants were recruited from the Construction Industry Training Board (CITB) in Glasgow. The CITB is an organisation providing a high standard of training across a broad range of building trades. There were 39 participants who were trainees undertaking the Part 1 and Part 2 scaffolding courses. Participants who returned the questionnaire were paid a token sum of £5 for their assistance.

**Apparatus**

CITB course members for these courses came from all over Scotland. As it was going to be impractical within the timescales and resources of the project to interview all participants on site, it was decided that the information would be obtained by postal survey. A response pack was developed which contained a questionnaire, a stamped addressed envelope, instructions...
for the User version of *PocketSCAFPASS*. As User *PocketSCAFPASS* was to be used by those considered to be less literate, the instructions were simplified and targeted at Parts B and C (see Appendix I(d)).

The questionnaire is shown in Appendix I(e). The majority of questions utilised a five rating scale to obtain participant’s views. Space was provided for comments at the end of most questions.

After instructions on how to use the questionnaire and space for personal information, the questionnaire contained four sections. The first section dealt with “First impressions” and covered the parts of *PocketSCAFPASS* used, initial feeling about its appearance and ease of use of instructions.

The second section covered how each respondent used *PocketSCAFPASS*. Questions covered how often the Aid was used and in what way. The latter included issues such as retention and its use to as a memory aid.

Section 3 covered ease of use, length, content and wording. Questions covered ease or difficulty of use and its length. In addition, the user was asked to rate and comment on both content and terminology.

The final section dealt with the perceived effects of the decision aid. Issues such as whether the flow-chart(s) would improve safety in scaffold work for individuals and the company, and whether that individual would recommend the use of the Aid were explored.

**Procedure**

Individual classes were visited and the response pack distributed at that time. Each part of the response pack was covered and participants were briefed in groups in relation to the User *PocketSCAFPASS*. They were taken through each part of the laminated version being used and the instructions. At the end of the session any questions were taken.

A reminder letter to those who had not responded, with a spare copy of the questionnaire and SAE, was sent out after six to eight weeks from the initial briefing.

### 7.3.3 Results and Discussion

There were nine replies out of 39 trainees (23%) undertaking the Part 1 and Part 2 scaffolding courses. Overall, this was a low response rate and must influence the degree of generality of the results.

The age of participants was known in the 9 cases; it ranged from 20 to 51 years, with a mean of 32 years. Five out of nine were scaffolders, with one unknown, the others being a roofer, fork lift driver, and general operative. The number of years of experience working on or around scaffolds was known in 6 cases; it ranged from 2 to 8, with a mean of 4.1 years.

The responses for the nine respondents are summarised below in relation to each question.

#### 1 Which part(s) of the flow-chart were you using?

Seven (78%) reported using Part B with no indication of which part used from the rest of the replies. As this sample only received Parts B and C it can be assumed that they must have used either of these.
2 When you first saw the flow-chart and before you used it, how simple or complicated did it look?

Six (67%) reported that it was simple, while three (33%) reported that some parts were complicated and some simple. This result could be interpreted as possibly indicating that first impressions would not put off the majority, although a minority might have some feelings that parts were complicated.

3 Did you find the instructions easy or difficult to understand?

Seven (78%) reported that it was simple while two (22%) reported that some parts were complicated and some simple. For the majority the instructions seem acceptable, although there may be room for improvement for some. This outcome might be influenced by the short initial briefing, where there was no time to undertake proper training.

4 How often in a week would you say you looked at the flow-chart during work?

Three (33%) reported Never and then went on to Question 8. Four (44%) reported once or twice a week, one every other day and one every day. It seems that some felt confident without the flow-charts but others used it throughout the week.

5 The flow-chart can be used in different ways. Which of the following best describes how you used it?

Of the 6 respondents for this section, four (67%) used it to jog their memory, one as a checklist after a period of work and one once because he knew the issues. The majority seemed to use it as a memory aid.

6 Could you remember information from the flow-chart without having to look at it

Of the 6 respondents for this section, all said they were able to do this. It would appear that the issues were presented simply enough for the users to remember them independent of the Aid.

7 How often did you apply issues in the flow-chart without having to look at it?

Of the 6 respondents for this section, one applied issues more than once a day. Three said they did this every other day or so, while one did this only once or twice in a week. It would appear that the users were familiar with the issues.

8 How do you rate the ease or difficulty of use of the flow-chart(s)?

Seven (78%) reported they were easy to use, while two (22%) reported some difficulty in use. One of the latter indicated section B.5 as the source but did not amplify the problem. B.5 deals with knowledge of the scaffold’s maximum load. The majority seemed comfortable with the use of these flow charts, although it would be useful to explore those issues associated with the minority’s concerns.

9 How do you rate the length of the flow-chart(s)?

All the respondents indicated that the length was about right. It appears that PocketSCAFPASS was an appropriate length.
10 How do you rate the content of the flow-chart(s)?

Five respondents (56%) indicated that all the important issues were included, while a further three indicate that nearly all were included. One said that only some were included. None of the latter four indicated any issues that were not included. As it stands, PocketSCAFPASS seems to cover the majority of important issues but a sizeable minority seem to feel there are others.

11 Were there any phrases or terms that you think are not appropriate or you didn’t understand?

All the nine respondents indicated that the phrases or terms were appropriate and understood. The terminology appears acceptable in this version of PocketSCAFPASS.

12 Do you think the flow-chart(s) would improve safety in scaffold work for you and your company?

One definitely agreed while seven (78%) said probably yes to this question. One was unsure. It seems that the majority felt that PocketSCAFPASS could improve scaffold safety in their companies.

13 Do you think widespread use of the flow-chart(s) in scaffold companies would improve safety on sites with scaffolds?

Seven (78%) definitely agreed, while two agreed that their use would improve safety. One was unsure. It seems that the majority felt that PocketSCAFPASS could improve scaffold safety generally.

14 Would you recommend the flow-chart(s) to others?

Six (67%) would definitely recommend the flow-charts to others while three were unsure.

15 The HSE is considering publishing a set of flow-charts like the one you used. Scaffold companies would be invited to use them on a voluntary basis. If one was published do you think your company would use it?

Three thought their company would definitely use it, while four thought the company would probably use it. One respondent said probably no and the other definitely no.

**General Discussion and Conclusions**

It is not clear why the response rate was so low. It could be due to the well known problem of getting feedback from the construction industry, or perhaps due to some of the participants not having time to use it, or perceived difficulty in having to fill in a questionnaire, or a combination of these factors. This will limit the generality of findings. The results from those responding, however, seemed to indicate that PocketSCAFPASS was usable and has the potential to be helpful in improving safety in scaffolds.

Within the limitations of the low response rate, in particular it can be concluded that:

1. A majority of users perceived User PocketSCAFPASS to;
   
   (vi) be usable on a regular basis
   (vii) be easy to use
   (viii) be of an acceptable length
(ix) contain the most important issues
(x) have acceptable terminology

g) the instructions seemed acceptable, although there may be room for some improvement which might be remedied by proper training

h) *PocketSCAFPASS* could be used as a memory aid in scaffolding safety

i) The use of such flow charts could be a useful aid to scaffold safety

j) A majority of companies would use it
8. SCAFFOLD RELIABILITY: ASSESSMENT USING EXPERT JUDGEMENT

8.1 INTRODUCTION AND AIM

We used expert judgements of absolute probabilities to model the reliability of a simplified scaffold system. The aim was to derive an order of priority of faults based on experts’ estimates of the likelihood of fault occurrence and risk. The details are given in Appendix J; a summary of the exercise follows.

8.2 METHOD

Ten participants were chosen as experts. The criterion was involvement with scaffolds over a number of years in a health and safety context.

Two ratings were requested: absolute judgement of probability of the fault occurring; and a rating of risk of the fault for the safety of workers and public. Ratings were made with reference to a four-bay, four-lift, independent tied scaffold. From these ratings, we calculated the probability that any one fault or fault combination would result in injury to workers or public.

The faults that we addressed were:

**Ties**
- a tie is removed when it should not be
- all ties are removed when they should not be
- a tie is not fitted during erection of the scaffold
- no ties are fitted during erection of the scaffold
- there are sufficient number of ties but they are not distributed correctly

- a coupler has not been tightened or is omitted between a ledger and standard

**Bracing**
- a ledger brace is not fitted
- all ledger braces are not fitted
- a façade brace is not fitted
- all façade braces are not fitted

**A defective component is used**
- a scaffold board
- a clip for attachment of staging
- a ledger
- a transom
- a component in lifting apparatus such as a hoist

**Significant resettlement of lower standards occurs**

**The safe working load of any part or all of the scaffold is exceeded by 50%**

**The wall or building supporting the scaffold is locally or generally unstable**

**Edge protection:**
- is not fitted
-is poorly fitted

Netting or sheeting is not fitted when the situation requires

Traffic margins for work and public vehicles are not considered

8.3 RESULTS

The five largest probabilities of occurrence were associated with:
- Defective scaffold board
- Defective attachment of staging
- A ledger brace is not fitted
- The safe working load of any part or all of the scaffold is exceeded by 50%
- Edge protection is poorly fitted

The five largest risks were associated with:
- All ties missing AND significant resettlement of lower standards
- All ties missing AND all ledger braces missing
- All ties are removed when they should not be
- No ties are fitted during erection of the scaffold
- All ties missing AND 1 ledger brace missing

The faults most likely to cause injury were calculated as:
- Defective scaffold board
- The safe working load of any part or all of the scaffold is exceeded by 50%
- Defective attachment of staging
- Traffic margins for work and public vehicles are not considered
- Edge protection is poorly fitted

8.4 CONCLUSIONS

- Ratings of probabilities of occurrence and rating of the risks of faults do not overlap
- Ties do not feature strongly except in the risks category
- These data may be used to guide the choice of content for a scaffold checklist

The reader is referred to Appendix J for further details.
9. SCAFFOLD RELIABILITY: ASSESSMENT USING SOFTWARE

9.1 INTRODUCTION AND AIM

The NAF (Non-linear Analysis of Frames Series)- Non-linear Integrated Design and Analysis (Nida) computer program (Chan et al..) was used to model the effects on structural integrity of various faults in a scaffold system of well-defined specifications (the same specifications as with expert judgements). The aim was again to derive an order of priority for the various faults in terms of their implications for safety. The details are given in Appendix M; a summary of the exercise follows.

9.2 METHOD

The NIDA software package permits the introduction of faults to a scaffold in the input file. The distributed load on the scaffold may then be incrementally increased until failure in one or more of the members. Only downward forces were assessed (forces away from the building were not examined). The input file used a four-bay, four-lift, general purpose, independent tied scaffold.

The faults were:
- Single missing tie (in critical place)
- All ties missing
- Single ledger brace missing (in critical place)
- All ledger braces missing
- Single longitudinal brace missing (in critical place)
- All longitudinal braces missing
- Foundations sink on one standard (in critical place)
- Foundations sink on all front standards

9.3 RESULTS

Table 6 gives the results. The lower the number in the second column, the lower the maximum load that could be sustained before failure.

<table>
<thead>
<tr>
<th>The effects of different faults on maximum load for a simplified scaffold</th>
<th>Critical scaffold load (as a factor from NIDA)</th>
<th>Critical load on scaffold (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaffold system without any fault</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Scaffold system without any faults including the wind load</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Single missing tie (in critical place)</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Foundations sink on all front standards</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>All ties missing</td>
<td>1.52</td>
<td>1.14</td>
</tr>
<tr>
<td>Single ledger brace missing (in critical place)</td>
<td>1.52</td>
<td>1.14</td>
</tr>
<tr>
<td>All ledger braces missing</td>
<td>1.50</td>
<td>1.125</td>
</tr>
<tr>
<td>Single longitudinal brace missing (in critical place)</td>
<td>1.50</td>
<td>1.125</td>
</tr>
<tr>
<td>Foundations sink on one standard (in critical place)</td>
<td>1.49</td>
<td>1.118</td>
</tr>
<tr>
<td>All longitudinal braces missing</td>
<td>1.46</td>
<td>1.095</td>
</tr>
</tbody>
</table>

9.4 CONCLUSIONS

The results showed that the most serious fault has all longitudinal braces missing, then sinking of one standard, and then a single longitudinal brace missing. Ties have very little
effect on the maximum working load of the scaffold. It is likely that, had forces away from
the building been assessed, ties would have had a more significant effect.

The reader is referred to Appendix M for further details.
10. SCAFFOLD CHECKLIST: DEVELOPMENT

Checklists for inspecting scaffolds should ensure that the criteria for structural integrity are met. The checklist that we designed is given in Appendix N. The inclusion of items in the list is based on the accident statistics (particularly the list of the most common primary features that caused the injury) and the results of the modelling (particularly the ratings of risk and the overall probabilities of injury). In all, there are 25 items in the list, arranged in the general order of bottom of scaffold to top of scaffold. We have attempted to provide an order of priority in the checklist by highlighting the most important issues. The method of use of the checklist can be summarised.

1. The inspector at the site progresses through the list ticking *yes* for the presence of the item and *no* if the item is absent or sub-standard. For clarification, the inspector can make notes next to each item.

2. After the inspection, the inspector signs the form and returns it to the site agent / overseer.

3. On the instruction of the site agent / overseer, the faults are corrected by the inspector or another person, and ticked off as such.

4. The checklist is returned to the site agent / overseer for their signature.

In cases where the inspection is made by one company and corrections to the scaffold by another company, the checklist continues to be functional but is simply handed between these parties after the initial inspection.
11. DECISION AID FOR ROOF SAFETY: DEVELOPMENT AND EVALUATION

11.1 DEVELOPMENT

Roof access was the second system that we addressed through the design of a decision aid. The accident statistics show that 1,148 incidents (5.9%) from a total of 19,348 reported incidents involved workers falling from a roof edge or through roof material. Our choice of roof work as the subject of the second decision was justified by these statistics.

11.1.2 BASIC DESIGN REQUIREMENTS

As with scaffolds, a prototype decision aid for roofing work must:

a) inform users of the more common causes for incident and injury when working on roofs
b) emphasise the risk assessment and control procedures that should be used in an effort to reduce the more common root cause failures
c) emphasise the specific controls that will avoid the more common root cause failures

Once again, the order of stages must accord with the order of preparations for work and performing the tasks. The decision aid must not be work intensive to use.

Designing for one group

In contrast to SCAFPASS, the decision aid for roof work was designed for one user group; this was because roofing work commonly occurs in isolation from other contractors and the roofing contractor is often the only contractor involved. The user group was presumed to be roofers and non-specialist workers seeking access to roofs for new-lay, maintenance and repair.

Designing for project stages

While SCAFPASS/2 consisted of three Parts that reflected various stages within a project, the decision aid for roof work comprised a single Part for preparation of and carrying out the work. The bidding stage and the hand-over Parts were therefore not included. Bidding is probably less formalised for roof work than it is for scaffolding, and rarely is any structure handed-over to another contractor in the same way that a scaffold is handed-over.

11.1.3 PRELIMINARY DESIGN OF A DECISION AID FOR SCAFFOLDS

The decision aid, which we have called ROOFMATE/1, is shown in Appendix O. It was designed for presentation on a laminated pocket-sized card. Two versions were constructed - one in a flowchart format and the other as bullet points. In both cases there are seven Steps:

Step 1 asks whether the user has checked the supervisor’s instructions.
Step 2 ensures that a safe means of access is adopted.
Step 3 ensures that fragile material does not present risk.
Step 4 checks that edge protection is assembled around the working area.
Step 5 checks that safety netting is used where appropriate and that any necessary personal protective equipment is available.
Step 6 asks whether materials are suitably distributed on the working area.
Finally, Step 7 asks whether the weather permits work to proceed safely.
The user progresses through the seven Steps. The reverse of the decision aid gives guidance to the user on satisfying each Step. If s/he answers no or s/he is unsure at any Step then ROOFMATE advises the user against commencing work and refers them to the supervisor. The decision aid is therefore concerned with organisation of the work up to the level of the supervisor. However the decision aid may conceivably also be used by supervisors themselves, who would take measures to satisfy each Step or else refer to the next level of supervision should they be unsure.

11.2 EVALUATION

11.2.1 Introduction

The user trials required the use of ROOFMATE by roof workers over a period of days, and then a follow-up structured interview in which they rated ROOFMATE on key characteristics. We were interested in answering the following questions:

a) Was ROOFMATE used regularly throughout the trial period? One criterion for success of ROOFMATE is how often it is used. To a certain degree, this will depend on the experience level of the user.
b) How easy was it to use? The decision aid should require minimal familiarisation so that the user can put it to use quickly.
c) How effective was it? If workers feel the decision aid was effective they are more likely to use it. The face validity of ROOFMATE is an important aspect here.
d) Would users be willing to use a decision aid in the future? We wanted to assess their willingness to use decision aids in their work.

11.2.2 Method

Participants

There were 24 participants selected from a variety of specialist areas; slaters and tilers (n=6); felt roof workers (n=10); and sheet workers / cladders (n=8). The distribution of ages was as follows: two were below twenty years of age, four were between twenty and thirty, ten were between thirty and forty, six were between forty and fifty, and two were over fifty.

Procedure

The participants were divided up into two groups; both groups were broadly matched on their ages and the type of roof work in which they engaged. One group used the bullet point version of ROOFMATE and the other used the flowchart format. The trial period was usually seven working days although it varied between five and eight days. Participants were asked to use the decision aid as part of their day to day work, and as frequently as they wanted.

After this period, the investigator returned for a structured interview with participants that provided an opportunity for them to comment on potential improvements to ROOFMATE. A questionnaire was also administered at this time with the following questions:

1. Would you say ROOFMATE was used regularly during the trial period?
2. Did you find that the instructions in the decision aid were straightforward and easy to follow?
3. Do you agree that ROOFMATE has been effective as an aid to roof safety?
4  Would you say ROOFMATE has helped you remember the essentials of fall prevention/protection?

5  Do you think a pictorial version of the decision aid would have been more suitable to help in roof safety?

6  Would you be prepared to use a pocket-sized decision support aid, similar to the prototype, as part of standard procedure, and as an aid to your safety?

11.2.3 Results

The results are listed below for the six questions.

1/ How often was ROOFMATE used?

<table>
<thead>
<tr>
<th></th>
<th>always</th>
<th>often</th>
<th>sometimes</th>
<th>seldom</th>
<th>never</th>
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<tbody>
<tr>
<td>Bullet version</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
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<tr>
<td>Flowchart</td>
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<td>4</td>
<td>3</td>
<td>4</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

2/ I found that the instructions in the decision aid were straight-forward and easy to understand

<table>
<thead>
<tr>
<th></th>
<th>strongly agree</th>
<th>agree</th>
<th>50/50</th>
<th>disagree</th>
<th>strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet version</td>
<td>2</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flowchart</td>
<td>2</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

3/ ROOFMATE has been effective as an aid to roof safety

<table>
<thead>
<tr>
<th></th>
<th>strongly agree</th>
<th>agree</th>
<th>50/50</th>
<th>disagree</th>
<th>strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet version</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Flowchart</td>
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<td>2</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>2</td>
<td>15</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

4/ ROOFMATE has helped me remember the essentials of fall prevention/protection

<table>
<thead>
<tr>
<th></th>
<th>strongly agree</th>
<th>agree</th>
<th>50/50</th>
<th>disagree</th>
<th>strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet version</td>
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<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Flowchart</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>16</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

5/ A pictorial version of the decision aid would have been more suitable to help in roof safety

<table>
<thead>
<tr>
<th></th>
<th>strongly agree</th>
<th>agree</th>
<th>50/50</th>
<th>disagree</th>
<th>strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet version</td>
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<td>2</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Flowchart</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

6/ I would be prepared to use a pocket size decision aid similar to the prototype as part of standard procedure and as an aid to safety

<table>
<thead>
<tr>
<th></th>
<th>strongly agree</th>
<th>agree</th>
<th>50/50</th>
<th>disagree</th>
<th>strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet version</td>
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<td>6</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Flowchart</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>14</td>
<td>4</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

In summary, the results show the following:

a) 14 participants (58%) reported that they had used ROOFMATE always, often or sometimes.

b) All participants agreed or strongly agreed that the instructions had been easy to understand.
c) participants (71%) agreed or strongly agreed that ROOFMATE had been effective as an aid to roof safety

d) participants (75%) agreed or strongly agreed that ROOFMATE had helped them to remember the essentials of fall prevention and protection

e) 15 participants (63%) agreed or strongly agreed that they would be prepared to use a similar decision aid in the future

11.2.4 Discussion

On the whole, both versions of ROOFMATE were well received by participants. Frequency of use, ease of understanding, and perceived effectiveness of ROOFMATE, as well as the willingness to use decision aids emerged favourably for the majority of respondents.

Ratings of frequency of use may be misleading because the decision aid is sufficiently short to be committed to memory within a few instances of use, so that the user need not have it to hand. The ratings might therefore represent an underestimate of the use of the Steps listed in ROOFMATE as opposed to the ROOFMATE laminate itself. In addition, because ROOFMATE was designed for all levels of user, the more experienced participants in the study are more likely already to be aware of the necessary precautions listed in the Steps, and their reported frequency of use would be less.

The instructions listed on the reverse of ROOFMATE were easily understood. In principle, any uncertainties that the user may have at any Step should be referred to the supervisor. This is a simple rule to adopt and it places the responsibility on the supervisor for many of the structural aspects of roof access.

Based on these results and the comments during the structured interviews, it was decided to modify ROOFMATE in the following ways:

a) In Step 2, the word egress should be replaced (or omitted) because its meaning may not be apparent to some users. The question now refers specifically to access to the roof.

b) Step 3 was broken into two parts. One Step should refer to checks for fragile material and the second Step to precautions necessary to avoid risk arising from any fragile material that is present. Skylights are now mentioned in Step 3.

c) In Step 6, the term adequately distributed was changed to the simpler phrase arranged for ease of use.

d) The N/A boxes were moved to the right of the arrow

e) Steps 4, 5, 6 and 8, when answered no, displayed the message **DO NOT START WORK** before indicating that the user must report to the supervisor

The revised version, ROOFMATE/2, appears in Appendix P.
12. REVIEW AND SUMMARY

The research aimed to develop decision support aids for working at height. We achieved this goal by a number of stages.

The literature review provided information about accident and incident rates for work at height in this country and overseas, with a focus on roof work and scaffold work. It also reviewed research on the causes behind these cases.

The accident and incident analyses provided information about the numbers of cases for various types of access system. We examined the immediate and more distal causes, with an emphasis on roofs and scaffolds. Injury during roof work usually occurred because of non-use roof boards or skylight coverings. These errors were accompanied by a general failure to control risk, unsafe work systems, workplace defects, and poor levels of supervision. Injury in scaffold work was explained in many cases by unauthorised alteration to the structure (especially to ties), but other causes included defective components (the majority of which would have been visible during checks), overload of the structure, and the failure to erect or maintain guard-rails. These errors were accompanied by a failure to control risk, unsafe work systems, workplace defects and poor levels of supervision.

Consultations were then made with safety advisers of companies involved in day-to-day use of scaffolds to examine the concerns they have with communication on site, unauthorised alterations to scaffolds, training issues, equipment, and inspections and checks. We also examined the decisions they made throughout a scaffold project and unsafe incidents they had experienced.

Decision aids were then constructed for work with scaffolds and roofs. Their content was based on the issues emerging in the accident and incident analyses and in the consultations. The decision aids were evaluated in user trials, and necessary modifications were made based on the results. The decision aid for roof work, ROOFMATE, is a single flowchart in eight steps which is set out on laminated card with instructions on the reverse. The decision aid for scaffolds, SCAFPASS, comes in two formats: the first is a detailed design for office use set out on A4 paper; the second is a set of three laminated, pocket-size cards that can be taken on site. There are three different parts to SCAFPASS that link to bidding/procurement, planing/erecting/using/dismantling, and hand-over.

Reliability analysis of scaffolds followed. Software simulations assessed the criticality of particular faults, and highlightedledger bracing and solid foundations as the most important structural properties for the set of faults that were addressed. A second approach, absolute probability judgement assessed the likelihood and risks of a set of faults and fault combinations. The faults rated as most likely to occur were a missing ledger brace, defective staging, defective edge protection, defective scaffold boards and overload. The highest ratings for risk were given to resettlement of foundations, ledger braces missing, and defective ties. A checklist for scaffolds was then developed, and its content in part determined by the results of the modelling exercise. The checklist may be used in combination with SCAFPASS.

We have presented the sequence of development for two decision aids. In these decision aids we attempted to outline the necessary safety information to users in a simple format, thereby promoting safe and responsible work on scaffolds and roofs.
13. ACKNOWLEDGEMENTS

We wish to acknowledge the kind support and assistance provided by the following organisations and individuals throughout the life of the project:

AMEC, Glasgow
Ballast Construction, Glasgow (Douglas Smith)
Health and Safety Executive, Bootle
Health and Safety Executive, Edinburgh
Health and Safety Laboratory, Buxton (Paul McCann; Carl Wilson)
John Mowlem, Glasgow (Paul O’Donnell)
Malcolm James Consultancy, Sowerby Bridge, Yorks. (Malcolm James)
Melville Dundas, Glasgow (Martin Brennan)
MPE Services Ltd., Bellshill (Tony Gildea)
Turner Plus Eight Ltd., Glasgow (Graham Gallagher; Brian Huston)

We are particularly indebted to John Bissett, William Donnelly, and Gerry Ralph and their staff at the Construction Industry Training Board (CITB) in Glasgow.

In addition we would like to acknowledge the assistance of two postgraduate students, Steve Kelsey and Ioanna Mavridou for their help in carrying out specific projects for us.
14. REFERENCES


CHAN, S.L., ZHOU, Z.H., Non-linear Analysis of Frames Series, Non-linear Integrated Design and Analysis, Version V.


APPENDIX A: LITERATURE REVIEW

A.1 PREVALENCE OF FALLS FROM HEIGHT

The construction industry has an unenviable safety record. In the UK, the construction industry has one of the highest fatality rates across all work sectors (Health and Safety Executive, 1984; Health and Safety Commission, 2001). Most recent fatality rates in the construction industry are based on 252 fatalities within the period 1998 to 2001. The high fatality rates are also evident in the US, where the construction industry throughout the 1980’s had the second highest fatality rate among industrial sectors (Kisner and Fosbroke, 1994).

A large proportion of injuries in the construction industry is due to falls from height. In the UK, it has been estimated that falls account for 49% of construction fatalities (Health and Safety Executive, 1984). More recent figures suggest that falls from height accounted for between 44% and 60% of all fatal accidents in the construction industry across the years 1996 to 2001 (Health and Safety Commission, 2001). In the most recent annual figures for the construction sector, 47 (44%) of a total of 106 fatalities were due to falls from height (Health and Safety Commission, 2001). In the US, falls from height account for around a third to a half of all work-related fatalities in construction (Keyserling, 1988; Bureau of Labor Statistics, 2000) and it has been reported that just under a half of all work-related falls occur in construction (Cattledge, Hendricks, and Stanevich, 1996; Janicak, 1998). The statistics are equally alarming outside the US and UK. Across a five-year period in the Capital and Hawalli districts of Kuwait, for example, it has been estimated that falls from height, including from scaffolds, roofs and ladders, accounted for 48.5% of all work-related accidents and 53.7% of all fatal work-related accidents (Kartam and Bouz, 1998).

The majority of work-related falls are from scaffolds, ladders or roofs. For example, Cattledge, Schneiderman, Stanevich, Hendricks and Greenwood (1996) found 33.5% of non-fatal occupational falls in one State of the US were from ladders, 21.4% from scaffolds, and 13.7% from roof trusses, walls, beams or other fixed structures. Cattledge, Hendricks and Stanevich (1996) examined all fatal occupational falls in the US in the period 1980 to 1989 and reported that 40.8% were from a building or structure, 18.6% were from scaffolds and 11% were from ladders. Suruda, Fosbroke, and Braddee (1995) addressed 1,695 work-related fatal falls in a three-year period appearing in the NIOSH data bases and found 17% to be from roofs. The Bureau of Labor Statistics (2000) state that falls from roofs (20.4%) ladders (15.0%) and scaffolds/staging (11.6%) together account for 47% of all fatal work-related falls.

The level of detail within accident reports is often limited and the immediate causes of a fall can be difficult to establish. Janicak (1998) has documented the immediate reasons underlying 566 work-related falls from height. A total sample of 566 falls in the construction industry was categorised among nine possible causes. Lack of fall protection (guard-rails, personal fall arrest systems) accounted for 35.5% of cases; structural or equipment collapse (i.e. collapse of underfoot support) accounted for 22.6%; and a slip or fall off a ladder accounted for 10.1%. Fall protection was not attached in 6.4% of cases and damaged in 3.5% of cases. Stepping on an improper work surface (a surface not intended to bear weight) occurred in 5.8% of cases.

A.2 FALLS FROM/ THROUGH ROOFS

Perhaps not surprisingly, the group most at risk of work-related falls would appear to be roofers. The Health and Safety Executive (1984), for example, estimates that roofers account for 11% of all work-related fatal falls. The higher incidence of fatality for roofers is also
apparent in the United States (Toscano 1997; Bureau of Labor Statistics 2000) and Australia (Larsson and Field 2002).

Studies have investigated the immediate causes specific to roof falls. Suruda, Fosbroke, and Braddee (1995) reviewed 288 fatal falls from roofs, finding that 24% were from the roof perimeter, edge or parapet; falls through the roof structure, roof openings, or skylights represented 32% of cases. In 43% of cases the location of the fall could not be established. Falls from roof perimeters can occur from slips and trips near the roof edge on loose material (Parsons, Pizatella and Collins, 1986; Suruda, Fosbroke and Braddee, 1995), from lateral forces due to the work in progress or defective hoist equipment (Suruda, Fosbroke and Braddee, 1995), as well as from environmental effects on a worker’s balance (Hsiao and Simeonov, 2001).

Hsiao and Simeonov (2001) have reviewed the factors that can impair this sense of balance. They include perceptual characteristics of the visual scene (e.g. mere exposure to an edge, moving visual scenes), physical surroundings (e.g. restricted support surfaces, inclined support surfaces, material properties of the surface) and task requirements (e.g. manual handling demands, fatigue, complexity of task). While these factors are at the skill-based level, it is often the case that deficits at the knowledge- or rule-based level are important. For example, falls through roofs can occur due to a lack of knowledge by the roofer about the structural strengths of the roof trusses or sheathing material on roofs and skylights (Suruda, Fosbroke and Braddee, 1995). Consequently, there may be an inaccurate perception of risk by the worker and a lack of awareness that precautionary equipment is required (Hsiao and Simeonov 2001).

A.3 SCAFFOLD-RELATED INCIDENTS

Scaffolds are built from a set of standardised components according to guidelines (currently British Standard BS5973: 1993 in the UK). While scaffolds vary in complexity, size and type, they require a number of essential features for structural stability (Doughty, 1986). Foremost among these are proper connections between individual components, stable foundations, internal bracing to prevent lateral movement, correct dimensions between components at key points, and usually secure lateral attachments to a stable supporting structure. Sub-structural requirements of scaffolds are just as important for worker safety. Sub-structural features might be regarded as barriers (Haddon, 1973) preventing workers and objects falling. They include edge protection, guard railing, boarded working platforms, suitable means of access, safety netting and harness systems for operatives. It is perhaps not surprising, given the ubiquity of scaffold structures in the construction industry, that accidents and incidents with scaffolds, including falls, represent a large proportion of all work-related fatalities in this sector.

Work-related accidents with scaffolds generally fit one of three categories: collapses of scaffolds; falls from scaffolds; and falling objects from scaffolds. In the UK across the period 1989 to 1993 there were 345 scaffold collapses, 3,738 falls from a scaffold, and 1,304 injuries from objects falling from scaffolds (Health and Safety Commission, 1993).

A small number of studies have examined the immediate causes behind scaffold collapses and injury on or around scaffolds. An internal report by the Health and Safety Executive (2001) identifies the following leading causes of collapse across all scaffold types (in order of frequency): deficient ties to the building (28%); overload (25%); faulty components (13%); deficient bracing (9%); deficient foundations (6%). In the same study, tube and fitting scaffolds comprised 52% of all cases; deficient ties were again the leading cause of collapse for these scaffolds.
Other data for the UK come from the National Access and Scaffolding Confederation (NASC) in the form of annual statistics for accidents and incidents experienced by its members. In its most recent report (NASC, 2001), 110 companies were surveyed with an estimated combined total of 10,779 employees, and an estimated coverage of over half the total number of scaffolding operatives in the industry. A total of 253 cases, one fatality amongst them, were reported for a one-year period. Accidents included falls of persons (22%, including one fatality); falls of materials (13%); handling of materials (26%); and “other site accidents” (33%). Of the 56 falls from height, 19 were from the “scaffold structure”, 7 were from a “working platform, gangway, trestles, cradles, boatswains chairs etc”, 9 were from ladders, 3 were “falls in yard” and 18 were “other (from walls, roof, rope, lorry)”. The 33 cases of falling material included 22 “from scaffold” and 11 “other falls of materials”.

In the United States, Fattal, Mullen, Hunt and Lew (1980) categorised 143 work-related scaffold incidents according to what the investigators judged as the primary cause. The records were selected from databases of the Bureau of Labor Statistics and the Occupational Safety and Health Administration (OSHA). Results for 85 fatal and 58 non-fatal cases are summarised in Table XX below. For fatal cases, the failure or lack of guard rails was a frequent cause, followed by problems with connections (i.e. couplers), aspects of the work environment (e.g. weather) and anchors (i.e. ties). For non-fatal cases, anchors and connections emerged as the most common primary faults.

In their report, Fattal et al (1980) reference an unpublished study by the Bureau of Labor Statistics that describes 801 cases involving all types of scaffolds. In 27% of cases the event was “person fell – nothing happened to scaffold”. Other leading causes included “plank slipped” (16%), “plank broke” (8%), “support poles tilted or tipped over” (7%), “wheels on bottom of the scaffold rolled” (6%), “cross-bracing gave way” (6%) and “anchoring into structure gave way” (6%). Data from this study is given in Table A.1 alongside the Fattal et al data.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal (% of 85)</td>
<td>Non-fatal (% of 58)</td>
</tr>
<tr>
<td>Safety devices</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Connections</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Work environment</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Anchors</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Platform</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Human factors</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Support elements</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Foundation</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Access ways</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Scaffold structures appear to have a relatively limited set of faults that affect either the overall structural integrity or the integrity of peripheral, sub-structural elements such as guard rails, boards, safety nets, brick guards, toe boards, and harnesses. The difficulty with the data is that the resolution of analysis is often not fine enough to examine the causal chain in much detail. There is a lack of published studies examining the typical faults in a random selection of scaffolds in the construction sector. When the background rates are unknown it is difficult to estimate the conditional probability of accident or failure given any particular fault.
Computer simulation offers an alternative method of assigning a weight of importance to faults in the overall structural integrity of the scaffold, but here again there is a lack of relevant published studies. Peng, Pan, Rosowsky, Chen, Yen and Chan (1996a, b) provide limited simulations to show the effects of lift height and bamboo bracing on the safe working load for concrete shoring systems. However, these studies are not specific to access scaffolds.

A.4 SAFETY MANAGEMENT IN CONSTRUCTION

Root causes of accidents are the factors that, if changed, could prevent many other incidents and accidents from occurring. One common root cause is a flaw in the safety culture of the organisation. Safety culture is the general attitude and approach to safety reflected by those who participate in an industry or organisation, including management, workers, and government regulators. It is generally accepted that the root-causes behind accidents and incidents are themselves due to failings in the management of safety at a higher level, and that rectifying managerial shortcomings is the more efficient method of improving safety (Reason, 1997; Rasmussen and Peterson, 1999). A detailed review of safety management is outside the scope of this review. However, texts on safety management in the construction industry (e.g. European Construction Industry 1995; Levitt and Samelson, 1993) highlight the key elements of safety management, including:

a) Procurement sequences that prioritise health and safety criteria
b) Dissemination of information among staff and contractors about hazards and how to minimise risk (safety meetings within and between contractor companies, briefings, lines of communication within and between contractor companies)
c) Incident and fault reporting procedures and follow-up
d) Prioritisation of safety in all activities and an observable commitment to safety by supervisors and management in day-to-day running of projects
e) Development and monitoring of a health and safety plan (including risk assessment, risk control and work procedures)
f) Ensuring competence of staff and adequacy of supervision
g) Quality control of stock, including a programme of stock inspections and work inspections
h) Clear assignment of responsibility for issues of health and safety and the establishment of personal accountability for a safe working environment
i) Ensuring procedural and legal compliance by workers and those responsible for health and safety

There are other factors that are associated with competence in safety management. Smaller construction companies are over-represented in the accident statistics generally (McVittie, Banikin and Brocketbank, 1997) and also specifically within the scaffold trade (NASC, 2001), probably because their safety management tends to be less developed (Jannadi and Assaf, 1998). The Health and Safety Executive (1978) isolated three factors, all under management influence, which may be responsible for higher incidence rates among roof workers and scaffolders. First, small gangs are common and the supervisor is directly engaged in the work, therefore often only indirectly supervising. Second, the main contractor regards roofers and scaffolders as specialists and tends not to interfere with their work practices. Finally, the pressure for production is high in these occupations and the associated time pressures can lead to short-cutting safety procedures.

The construction industry as a whole has a number of attributes that can inhibit competent safety management. These include short-term contracts; lack of a controlled environment;
complex arrangements within and between construction contractors; competitive tendering; and a high labour turnover (Kartam, Flood and Koushki, 2000).

**A.5 DECISION AIDS AND ACHIEVING SAFETY**

One method of ensuring competency in safety management within construction is the provision of prescriptive information in the form of a flowchart or structured checklist that supports key safety decisions. In the following section, the literature pertaining to decision aids will be reviewed and its relevance to application in the construction sector will be examined.

Decision support systems are designed to manage and quantify data and present it in a form that supports the decision-making process of the user. The term has become broader in recent years. In its strict definition (Davis, 1988), a decision support system allows the following: exchanges between the user and computer (or other device) in an interactive, tolerant and informative style; exploration of various scenarios of choice; flexibility for the user to adapt the system to their specific task.

Decision aids are prominent in the medical sector as diagnostic tools as well as aids for the decision-making of patients. Estabrooks, Goel, Thiel, Pinfold, Sawka and Williams (2001) reviewed 22 structured decision aids designed to assist patients in choosing among medical treatment or screening options. The decision aids generally did not influence their treatment preferences, their final decision, or the emotional aspects of the decision-making process (e.g. satisfaction with decision-making process, perceived control over decision, perceived benefits). However, knowledge of the decision space did improve, and ratings were favourable for the patients’ general satisfaction with the decision aid, readability of the decision aid, and its ease of use. Other reviews of patient decision aids suggest beneficial effects, although sometimes of a limited nature (Kaplan, 2001; Molenaar, Sprangers et al, 2000).

Decision aids have been successfully applied to areas outside medicine, with varying levels of complexity. These include food safety (Wijtzes, van’t Riet, Huis in’t Veld and Žwietering, 1998), accidental release of air pollutants (Graber and Gassmann, 2000), genetically modified products (Hallerman, King and Kapuscinski, 1999), laser safety (Clarke, Soufi, Vassie and Tyrer, 1995) and aircraft maintenance (Rankin, Hibit, Allen and Sargeant, 2000).

The management of safety in projects involving temporary access may be viewed as a sequence of decisions that should be made within the stages of bidding and pre-planning of the work, erection of the access equipment, hand-over of erected access equipment, and use and dismantling of access equipment. At a generic level the structure and types of decisions would remain relatively invariable across different projects but the specific details of the decisions would change according to the nature of the work undertaken and the specific work environment.

A decision aid to support the sequence of decisions for projects involving temporary access systems might incorporate the proven best practices from safety management with direct application to scaffold and roof work, and make explicit the requirements of the various regulations and the options for satisfying these requirements. In this sense the aid would be a thought structuring system (Davis, 1988), informing and reminding the site manager or supervisor of requirements on site and providing an indication of the priority of each requirement.

Simple checklists of structural elements of the scaffold are perhaps the only widely known decision aids (at least within the scaffold trade) that are relevant to temporary access safety. Checklists presuppose a limited set of root-causes for scaffold accidents and that by removing
these root causes the majority of accidents on and around scaffolds will be avoided. The National Access and Scaffolding Confederation provides check guides for use by site personnel to ensure that scaffolds meet the requirements of BS5973: 1993. Scaffold checklists of varying detail have also appeared in trade journals (Concrete Construction, 1995; Hinson, 1989), texts on safety management (St John Holt, 2001), texts on scaffolding practice (Doughty, 1986) and academic journal papers (Peng, Pan, Rosowsky, Chen, Yen and Chan, 1996b). Checklists for temporary access systems, however, have a number of associated problems. They often address root-causes (no guard railing, lack of ties etc.), but leave unchanged the higher managerial weaknesses that act to perpetuate the same root causes. In addition, checklists may not integrate well with the temporal sequence of the project, and their level of detail can be limited.

A decision aid must therefore address the higher managerial issues surrounding safe work practices across all stages of a project. It must also incorporate the applicable regulatory standards. Effective regulatory control requires that the information within governing standards be known throughout the industry, that standards be presented in a readily understandable format, and that standards be enforced and penalties applied. For example, as mentioned earlier, codes of construction for scaffold systems in the UK are found in BS5973: 1993 *Code of practice for access and working scaffolds and special scaffolds in steel*, and the specifications for components are provided in the BS1139: 1994 series. BS5973: 1993 is in the process of revision (although it still currently applies) to accommodate the European Standard EN12811. It defines the configuration of construction of access scaffolds, the criteria and calculations necessary for designing special scaffolds, and the precautions necessary to demarcate the work area from the public. The recommendations generally relate to the scaffold hardware, although issues of training, supervision and inspection of work are addressed.

The Construction (Design and Management) (CDM) Regulations 1994 aim to provide the basis for a competent health and safety management system and specify the arrangements for managing the health and safety of construction projects. In an effort to combat risks in a co-ordinated way, the CDM Regulations define the roles of key personnel in construction projects and their responsibility for health and safety. The responsibility for safety is distributed between client, designer, planning supervisor and principal contractor, and each have their domains of responsibility at varying points within the project. These responsibilities and their temporal order must be reflected within a decision aid. The Construction (Health, Safety and Welfare) Regulations 1996 also has direct relevance to scaffold and roof work and must be incorporated.

These sources of information will partly determine the content of any decision aid. Decision aid content will also be determined by the results of analyses of incidents involving temporary access systems. In fact the statistics could be expected to determine not only content but also which work activities (roofing, scaffolding etc) the decision aid is to address. Activities associated with large numbers of fatalities and injury should be prioritised when deciding on the target population for which a decision aid will be designed. Therefore, the next section examines the recorded incidents which have involved temporary access equipment for the purpose of specifying firstly the application area(s) of the decision aid(s) and secondly the content of the decision aid(s).
APPENDIX B: ACCIDENT ANALYSES

B.1 BACKGROUND AND AIMS

The analysis of accident and incidents that involved temporary access at height is the initial stage in developing a prototype aid. The general aim is to understand the frequency of accidents involving temporary access to height and the types of failure that occur. More specifically the aims are to:

a) Identify, for a sample of incidents investigated by the Health and Safety Executive, the types of structures and the types of failures involved in these incidents, and the underlying shortcomings at the operator and management level that supported the failures.

b) Determine, at a nation-wide level, the numbers of incidents reported to the Health and Safety Executive across a specified time period that involved temporary access to height.

c) Develop the range of controls that should be considered in developing a decision aid for avoiding the conditions supporting the common failures.

B.2 METHOD

B.2.1 Sample

There were two sources, providing three samples between them.

Field Consultant Group (FCG): The FCG reports comprised a collection of paper-based reports of case investigations conducted by specialist inspectors from the Health and Safety Executive. The FCG reports are held at the Human Safety Laboratories in Buxton, Derbyshire and were made accessible for reference. They represent a sample of incidents occurring primarily within the construction sector and they contain details on the context and type of occurrence of the incident as well as expert opinion on the proximal and distal causes. From a total sample size of over 400 FCG files, there were 186 files that involved at least one of the following: access scaffold; ladder; raised staging; platform at height; fall of person or object from or through a roof, a raised walkway, or a temporary platform. The dates of the inspector’s first site visit listed on these 186 reports ranged from January 1990 to January 1998.

Field Operations Computer System (FOCUS): FOCUS is a database of UK work-related incidents compiled and maintained by the Health and Safety Executive, and it contains incidents from many sectors of industry. These cases are referred to in this report as FOCUS cases. A subset of the FOCUS cases were investigated cases, which means that the basic data provided to the HSE by the injured party have been supplemented with data collected during an investigation by the HSE, usually in the days immediately following the incident. Investigated cases contain a few lines of text written by the investigator at the time.

To summarise, there were three samples providing varying levels of detail: (1) FCG cases, as paper-based files; (2) all FOCUS cases, as basic sets of database variables, a sub-set of which were (3) investigated FOCUS cases with supplementary information in the database gathered during a HSE investigation.
B.2.2 Procedure

**FCG Cases**
A data collection form was designed for reviewing the FCG reports. Items on this form addressed: the severity of injury; height of any fall; type of structure; type of scaffold (where relevant); stage of construction (where relevant); and the type of occurrence. To specify the areas(s) of the access system in which the root-cause was centred, a list of 22 features was developed which were distributed across a number of categories. The categories were:

- **Foundation**: features in this category relate to the permanent support on which the access system rested (usually a building façade or the ground), or the interface between support and access system.

- **Structural features**: these are the features inherent within the structure itself, e.g. lateral attachment of the structure to the building or cross-bracing within a structure.

- **Load**: included here are conditions of overload with people or material in lifting and non-lifting operations.

- **Barriers and PPE**: features in this category prevent objects or people falling, or limiting the damage caused to or by falling objects or people, e.g. netting, harnessing, edge protection.

- **Features directly associated with human behaviour**: included here are aspects which must be regarded as much more closely related to the person involved, such as misuse of equipment, deliberate intrusion by a member of public onto site or equipment, and incorrect manner of ingress/egress.

A further miscellaneous category included defective components, inappropriate components, missing components, features not known, and uncategorised.¹

All cases could be assigned a maximum of four features about which the cause of the incident centred. In the majority of cases only one feature was assigned. The primary feature for each case was defined as the feature of the access system containing the fault most central to the occurrence of the incident. The same person reviewed all the FCG cases. Decisions on which features contained the fault were based on explicit reference within the case notes.

**FOCUS Cases**
FOCUS contains a vast array of variables. Two of the more important for present purposes were, using terminology lifted from FOCUS, the agent and the deficiencies of the case. The agent describes the nature of the event. We were concerned with 14 agents that captured incidents involving various forms of temporary access systems. FOCUS was queried on the frequency of these agents for the four-year period 1997 to 2000.

In the database a deficiency was assigned to a case by an investigator at the time of its investigation. A deficiency is usually a socio-technical failing deemed by an investigator to have influenced the occurrence of an incident. Within FOCUS there are a total of 61 deficiencies from which the investigator may select, but only a maximum of two deficiencies may be assigned to a case. FOCUS was interrogated on the frequency of 24 particular deficiencies chosen *a priori* for their potential relevance to temporary access systems. The accompanying textual descriptions for investigated cases were searched manually to identify the feature of the access system responsible for the incident. Almost identical categories to

¹ Wind loading has not been included as a potential root-cause because it is assumed that the collapse of a scaffold in high wind is attributable to a fault in, or alterations affecting, the scaffold itself resulting in vulnerability to wind loading.
those described above were used for that purpose. One person categorised the cases throughout this process.

B.3 RESULTS

B.3.1 FCG Reports

Severity of the Cases
Within the sample of FCG reports there were known to be 33 fatal cases (18%), 28 serious cases (15%) and 33 minor or no-injury cases (17.7%). Injury severity was not stated or could not be clearly inferred in the remainder of cases.

Type of Structure and Occurrence
The types of structure are listed in Table B.1 in descending order of frequency. The two categories scaffold – working and roof together account for the majority of structures (71%). A distinction was drawn between working scaffolds designed for the purpose of accommodating workers for access tasks, and non-working scaffolds, such as edge guarding and display stands, that were not designed to accommodate workers. Working scaffolds included independent access scaffolds, prefabricated tower scaffolds, suspended scaffolds, and supported staging.

Table B.1

<table>
<thead>
<tr>
<th>Access type</th>
<th>Fall-off</th>
<th>Fall-through</th>
<th>Collapse</th>
<th>Falling object</th>
<th>Break of line</th>
<th>Break of platform</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaffold – working</td>
<td>7.0</td>
<td>-</td>
<td>27.4</td>
<td>2.2</td>
<td>-</td>
<td>5.9</td>
<td>-</td>
<td>42.5</td>
</tr>
<tr>
<td>Roof</td>
<td>1.6</td>
<td>24.2</td>
<td>-</td>
<td>1.1</td>
<td>-</td>
<td>1.1</td>
<td>0.5</td>
<td>28.5</td>
</tr>
<tr>
<td>Ladder</td>
<td>1.1</td>
<td>-</td>
<td>9.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10.8</td>
</tr>
<tr>
<td>Other</td>
<td>2.7</td>
<td>-</td>
<td>1.6</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>4.8</td>
</tr>
<tr>
<td>Suspended cradle</td>
<td>0.5</td>
<td>-</td>
<td>1.6</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
<td>0.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Scaffold – non-working</td>
<td>-</td>
<td>-</td>
<td>2.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.7</td>
</tr>
<tr>
<td>Ceiling</td>
<td>-</td>
<td>2.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.2</td>
</tr>
<tr>
<td>Fixed floor</td>
<td>1.6</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.2</td>
</tr>
<tr>
<td>Ladder used in conjunction</td>
<td>-</td>
<td>-</td>
<td>1.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>with tower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed ladder</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Ladder integral to tower</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>14.5</td>
<td>26.9</td>
<td>45.7</td>
<td>3.2</td>
<td>1.1</td>
<td>7.0</td>
<td>1.6</td>
<td>100</td>
</tr>
</tbody>
</table>

Table B.1 also provides the type of occurrence for each structure. Collapse of a weight-bearing scaffold (27%) and falling through a roof (24%) are the most frequent scenarios. For weight-bearing scaffolds, collapses were the most frequent occurrence, then falls of person and then break of platform.

The type of occurrence has been recorded among the seven categories shown in Table B.1. Collapse includes all structural failures, including overturning of scaffold systems. Fall off refers to all instances where a person fell without significant structural failure, e.g. from a
roof edge. *Fall-through* refers to all incidents in which a person fell through a roof or skylight during access. *Break of line* refers to the severance of the cable of a suspended cradle.

*Collapse* and *fall-through* incidents account for the majority (72.6%) of cases. For *fall-through* cases, the structure involved included: roof light, 23 cases (46%); asbestos sheeting, 15 cases (30%); plasterboard, 2 cases (4%); and other material, 10 cases (20%).

These statistics set the context but provide little detail about the specifics of each case. In some ways, it is more informative to know the feature of the access system in which some form of failure was centred.

*The features of the access system in which the failure was centred*

Table B.2 provides the frequencies across the categories for the primary, i.e. the most critical, feature. In addition, it provides frequencies when any second, third and fourth features are added to the primary element of failure (column labelled *All*).

When only the primary feature is considered, the most frequent were: lateral attachment (13% of all cases); barriers over fragile areas (13%); crawling boards (12%); edge protection (7%); overload (5%); connector (4%); and manner of use (4%).

In reviewing the files, each feature was assigned an associated mode of failure, such as ‘none’, ‘quality’, ‘too few’, or ‘placement’, or a referent object in the case of features within the categories of foundation, load, issues directly associated with human behaviour, and defective or inappropriate component. For example, if lateral attachment was the element in which failure was centred, ‘none’ might be used to specify that a tie was missing. Similarly, when mode of use was identified as the primary feature, the equipment of misuse was listed as referent.

The ten most frequent primary features, comprising 69% of incidents, are listed below with their failure modes or referent.

a) **Lateral attachment** (n=24): removed 10; none 5; too few 5; wrong type 2; quality 1; wrong placement 1.
b) **Crawling board** (n=23): none 18; wrong type 4; too few 1.
c) **Barrier over fragile area** (n=24): none 24.
d) **Edge protection** (n=13): none 8; quality 5.
e) **Overload** (n=10) with: people 6; with blocks/stone 3; with scaffold pieces 1.
f) **Connector** (n=8): all quality. These cases involved the coupling of: ledger/standard 3; transom/ledger 1; standard/standard 1; roof sheet/purloin 1; leg of kick-stool 1; ladder/cage 1.
g) **Mode of use** (n=8) misuse of: ladder 5; mobile ladder 1; staging 1; prefabricated tower scaffold 1.
h) **Support structure interface** (n=6) with respect to: ladder feet on the ground 4; ladder top on a ship’s hull 1; top of wooden steps on the ground 1.
i) **Internal lateral support** (n=6): none 5; too few 1.
j) **Harnesses** (n=6): none 5; quality 1.

Defective components are not included in the list above. There were 25 (13%) incidents involving a defective component as the primary feature. These were: ladder, 7; staging, 5; scaffold board, 7; leg-lock on a scaffold tower, 1; luffing screw on a suspended cradle, 1; wire fixing and brake on a suspended cradle, 1; holding pin on birdcage decking, 1; transom, 1; bent ledger, 1. In just under half of these cases (12, 48%), the fault would potentially have been visible during any routine inspection.
<table>
<thead>
<tr>
<th>Categories and their features</th>
<th>No for primary feature only</th>
<th>% (of 186)</th>
<th>N for all features</th>
<th>% (of 295) for all features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FOUNDATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-support / structure interface</td>
<td>6</td>
<td>3.2</td>
<td>6</td>
<td>2.0</td>
</tr>
<tr>
<td>-support horizontal</td>
<td>3</td>
<td>1.6</td>
<td>3</td>
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</table>
Table B.3 displays frequencies of the primary features across the types of structure; highlighted figures represent 5% or more of the total sample. The distribution of features across the structure types is not an even distribution. Defective components and faults with lateral attachment are largely associated with working scaffolds. Failure of barriers over fragile areas and crawling boards are generally associated with roofs. The majority of edge protection and overload failures are associated with working scaffolds.

The primary features distributed across eleven types of structure (N=186)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Ladder</th>
<th>Fixed ladder</th>
<th>Ladder: integral to tower</th>
<th>Ladder: not integral to tower</th>
<th>Scaffold: working</th>
<th>Scaffold: non-working</th>
<th>Suspended scaffold</th>
<th>Roof</th>
<th>Ceiling</th>
<th>Fixed floor</th>
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<tr>
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<td>3</td>
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<td>63</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>186</td>
<td></td>
</tr>
</tbody>
</table>

The following list contains the most common primary features, with their modes of failure, for working scaffolds only.

---

2 Here the ladder is an integral part of the tower scaffold.
3 Here the ladder does not integrate into the structure but existed separately.
1. Lateral attachment (n=22): removed 9; too few 5; none fitted 5; wrong type 2; wrong placement 1
2. Defective component (n=8): scaffold board 4; pin for staging 1; warped ledger 1; transom 1; connector for lifting 1
3. Overload (n=5): all overload with building material
4. Guard rails (n=4): low quality 3; none fitted 1
5. Connector (n=4): ledger to standard 2; standard to standard 1; transom to ledger 1
6. Support horizontal (n=3): collapse of a wall 2; collapse of a steel structure 1
7. Netting (n=3): all had none fitted
8. Internal lateral support (n=3): none 2; too few 1
9. Struck by vehicle (n=2): works vehicle 1; public vehicle 1

In the same way, the following list contains the most common primary features, with their modes of failure, for roof incidents only:

1. Barriers protecting roof-light or fragile area (n=23): none 23
2. Crawl boards (n=20): none 15, too few 1, wrong type 4
3. Connection (lifting) (n=1): dog in wall pulled out.
4. Counterweight (n=1): too little
5. Edge protection (n=1): none
6. Object netting (n=1): none
7. Mode of use (n=1): staging
8. Harnesses (n=1): none
9. Trespass (n=1): children
10. Overload (n=1): people
11. Connector (n=1): roof sheet to purlin
12. Not known (n=1)

B.3.2 FOCUS Cases

Numbers of incidents reported to the HSE that involved temporary access systems

One reason for interrogating the FOCUS database was to gauge the relative frequencies of incidents involving temporary access systems. Table B.4 below shows the absolute numbers of incidents reported to the Health and Safety Executive for 14 agents associated with temporary access. Appendix C provides an explanation of each agent. These include investigated and uninvestigated cases and all levels of injury severity. The agents are grouped into:

a) Scaffold collapses (prefixed CM in the terms used by FOCUS);
b) Falls from a temporary access structure (prefixed FA);
c) Falls off or through a roof (prefixed FS);
d) Falls of objects from scaffolds, staging or other such workplace (prefixed SF).
### Table B.4
Absolute numbers of cases reported and the proportions investigated

<table>
<thead>
<tr>
<th>Structure(^\dagger)</th>
<th>Reported cases</th>
<th>Percent investigated</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSCAFFOLD</td>
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<td>27</td>
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<td>FALADDERM</td>
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<td>2,278</td>
<td>2,140</td>
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<td>FSWORKPLAT</td>
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<td>551</td>
<td>549</td>
</tr>
<tr>
<td>FASCAFFOLD</td>
<td>440</td>
<td>479</td>
<td>459</td>
</tr>
<tr>
<td>FAACCESS</td>
<td>422</td>
<td>376</td>
<td>426</td>
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<td>FALADDERO</td>
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<td>280</td>
<td>296</td>
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<tr>
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<td>250</td>
<td>232</td>
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<td>71</td>
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<td>18</td>
<td>27</td>
</tr>
<tr>
<td>FASUSPEND</td>
<td>10</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4,243</td>
<td>4,403</td>
<td>4,298</td>
</tr>
</tbody>
</table>

| FSROOFEDGES           | 149  | 167  | 163  | 153  | 632  | 46.3 | 35.9 | 42.3 | 42.6 | 42.6   |
| FSFRAGILE             | 116  | 127  | 135  | 138  | 516  | 47.4 | 61.4 | 55.6 | 58.5 | 58.5   |
| TOTAL                 | 265  | 294  | 298  | 291  | 1,148| 46.8 | 46.9 | 48.3 | 49.7 | 49.7   |

| SFSTAGING             | 168  | 216  | 203  | 165  | 752  | 8.9  | 10.6 | 14.8 | 18.2 | 13.0   |
| TOTAL                 | 4,713| 4,953| 4,826| 4,826| 19,348| 11.2 | 13.5 | 14.0 | 21.4 | 15.0   |

\(^\dagger\) See Appendix C for terms

Falls from moveable ladders, work platforms and scaffolds represent the largest categories. Collapses of a scaffold account for 136 cases across four years. That figure is probably an underestimate because many incidents of collapsed scaffolds are likely to have been classified, when a fall was involved, under FASCAFFOLD. The agents that are most relevant to scaffold incidents include CMSCAFFOLD, FASCAFFOLD and SFSTAGING. The last of these agents is defined as ‘free-falling objects or material from scaffolds, staging or other such workplace’. Together the three agents accounted for 2,748 incidents in the four-year period. Falls from or through roofs accounted for over 1,148 cases in the four-year period.

The last five columns in Table B.4 show the percentage of all reported cases that were subsequently investigated. Percentages vary according to the structure involved. Typically, collapses of scaffolds, falls from towers, falls from scaffolds and falls from or through a roof were investigated most frequently. Overall, 15% of cases reported to the HSE were investigated. There was no consistent increase in investigated proportions across the four-year period for any of the 14 agents. Proportions of investigated cases involving falls from scaffolds and falls from access towers varied substantially between years. For example, falls from towers were investigated in 22% of cases in 1998 and 39% of cases in 2000.
Estimating the proportion of investigated cases represented by the FCG files

The FCG files represent only a small proportion of all reported cases. The time period for the FOCUS data shown in Table XX and the time period for the reviewed FCG files does not coincide. However, it is possible to offer an estimate of the proportion of investigated cases that the FCG sample represents. There were 186 FCG cases, and these were distributed unevenly across 11 years. Only 2 cases occurred before 1990 and only 6 after 1996. The numbers of FCG cases for the years 1990 to 1996 were 10, 40, 33, 50, 20, 10, and 15.

The numbers of investigated incidents from FOCUS for the four-year period 1997 to 2000 were 528, 671, 674, and 1,037: a mean of 728. Assuming the figure 728 approximates the years 1990 to 1996 as well, we can assume that the FCG files account for approximately 3.5% of all investigated incidents that involved the 14 agents related to temporary access systems.

Proximal causes for investigated cases

The FCG files have already provided detail on the proximal causes of a set of 186 incidents (this was done by identifying the features in which failure centred). A similar but limited interrogation of the proximal causes was possible with the set of investigated cases in the FOCUS database. This is because a short section of text usually supplements the set of variables for any investigated case in the FOCUS database.

In the period 1997 to 2000, a total of 2,876 investigated cases provided textual descriptions of the incident. The length of text varied from a single sentence to an extended paragraph. Based on a reading of the available text, cases could be classified according to the features in which failure occurred. The categories are the same as those used for the FCG files, as well as a small number of additional ones. Occasionally more than one subsystem was assigned to a case. One and the same investigator reviewed all cases and it was a condition that all decisions by that person were to rely on explicit reference within the text. Table B.5 shows the results. The percentages refer to the particular group; for example, 11.9% of all falls off or through a roof involved a fault with the edge protection. The final column gives the overall percentage.

Generally there was a low percentage of cases to which any of the 24 features could be assigned (54% overall). This was largely due to the brevity of the text and its lack of explicit reference to a cause. The exercise still provides an order of priority for the 24 features. Again, there is not an even distribution of cases among the 24 features: the five most common features on which the failure centred are highlighted for each of the five groups in Table B.5 to demonstrate this point. Overall, the large number of cases that involved ladders explain the high percentages of ladder ties and ladder footing features (10.2% and 8.8% cases overall). Edge protection and defective components were involved in 7.5% and 5.2% of cases overall.

More specifically, falls through roofs were largely due to shortcomings in edge protection, roof-light protection, controls on trespass, harnesses, and crawling boards. The 45 cases of injury in scaffold collapses were most often related to shortcomings with harnesses, controls on trespass, edge protection, internal bracing, defective components and structural overload. It is likely that harnesses feature in so many of these incidents because the collapse was partial or localised and the harness attachment point would have remained sound.

The second column in Table B.5 attempts to target scaffold-related cases by combining three agents, namely: fall of persons from a scaffold, fall of objects from a scaffold, and collapse of scaffold. The more common failures in this case occurred with edge protection, harnesses, ingress/ egress, defective components, and controls for trespass.
The deficiencies in the management of safety

Failings in the features listed in Table B.5 are usually symptoms of more ‘upstream’ failings in the management of health and safety within the construction project. Table B.6 below presents a subset of 24 deficiencies that are the potentially more relevant factors for temporary access

Table B.5
Failed features, according to short descriptions of investigated cases in FOCUS (% of cases)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Scaffold collapse (of 45)</th>
<th>Fall of person or object from scaffold or scaffold collapse (of 605)</th>
<th>Fall from temporary access structure (of 2,174)</th>
<th>Fall off or through roof (of 562)</th>
<th>Falling object from scaffold, staging etc. (of 95)</th>
<th>Overall collapse (of 2,876)</th>
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<td>0.0</td>
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<tr>
<td>Internal bracing</td>
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<td>0.6</td>
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<td>0.0</td>
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<td>Counterweight</td>
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</table>

4 A deficiency is defined as a “socio-technical failing deemed by an investigator to have influenced the occurrence of an incident” (see Method section)
5 Group includes CMSCAFFOLD
6 Group includes SFSTAGING, CMSCAFFOLD and FASCAFFOLD.
7 Group includes FAACCESS, FACRADLE, FASCAFFOLD, FSWORKPLAT, FASUSPEND, FATOWER, FATRESTLE, FALADDERF, FALADDERM and FALADDERO
8 Group includes FSROOFEDGE and FSFRAGILE
9 Group includes SFSTAGING
systems. The percentage of cases in each group to which each deficiency applies is listed in the Table. FOCUS abbreviations are expanded in Appendix C.

All groups have failure to identify, assess or control risk; inadequate planning as the most common deficiency, typically applying to one third of cases. Unsafe system of work – transient job is next for all groups except scaffold collapse, typically applying to 20% of cases. Scaffold collapses have instead unsafe operating procedure as the second most frequent deficiency (17%).

For all groups except scaffold collapse there is a marked drop in percentage from the second to the third most common deficiency. For scaffold collapses this third deficiency is unsafe system of work – transient job (13%); for falls from a temporary access structure, and falls off or through a roof the deficiency is fixed or temporary working place or platform defects including confined space (both 9%); and for cases with falling objects it is inadequate standard of supervision (10%).

Overall, the main deficiencies that emerge are failure to identify, assess or control risk; inadequate planning; and unsafe system of work – transient job. These deficiencies are followed by the deficiencies: fixed or temporary working place or platform defects including confined space, unsafe operating procedures, inadequate supervision, and access-egress fault, including inadequate clearance between persons and machinery.

Table B.6
Deficiencies recorded by FOCUS across a four-year period (% of cases)

<table>
<thead>
<tr>
<th>Deficiency</th>
<th>Scaffold collapse (% of 2,910)</th>
<th>Fall from temp. access structure (% of 2,193)</th>
<th>Fall off or through roof (%)</th>
<th>Falling object from scaffold, staging etc (% of 571)</th>
<th>Overall (% of 2,910)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAIL CTRL RISK</td>
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<td>27.1</td>
<td>27.1</td>
<td>27.1</td>
<td>27.1</td>
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<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
</tr>
<tr>
<td>WK PLACE</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>UNSAFE PROC</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
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<tr>
<td>INAD SUPERVIS</td>
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<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>ACCESS/EGRESS</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>UNSAFE MAINTEN</td>
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<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>INAD TRAINING</td>
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<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>UNSAFE ROUTINE</td>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
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<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
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<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
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<tr>
<td>INAD DESIGN</td>
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<td>4.6</td>
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<tr>
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<td>4.6</td>
<td>4.6</td>
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<tr>
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<td>4.6</td>
<td>4.6</td>
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<tr>
<td>FIXED STRUCTURE</td>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
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</tr>
<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
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<td>4.6</td>
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<tr>
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<td>4.6</td>
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</table>

Deficiencies in scaffold-specific cases across four years
Table B.7 is specific to scaffold-related cases, i.e. a combination of collapse of scaffold (CMSCAFFOLD), fall from scaffold (FASCAFFOLD), and falling object from staging
Across all years the most frequent deficiencies for these cases were ‘failure to identify, assess or control risk; inadequate planning’ (26%), ‘unsafe system of work – transient job’ (20%), ‘fixed or temporary working place or platform defects including confined space’ (13%) and ‘inadequate standard of supervision’ (9%).

The five most frequent deficiencies are highlighted within each year to aid comparison. On the whole, the percentages are consistent from one year to the next. However, in isolated instances certain deficiencies show large variations from year to year. For example, ‘failure to identify, assess or control risk; inadequate planning’ has a low in 1997 of 14%, but rises to 31% in 1999. Similarly, ‘unsafe system of work – transient job’ has a high of 33% in 1997 and a low of 12% in 2000, and ‘inadequate standard of design or construction of articles’ reaches 11% in 1997 but remains at one or two percent in later years. It is an open question whether these variations reflect true differences in the quality of the work system across time or testify instead to the changing criteria used by investigators.

Table B.7
Deficiencies recorded in the FOCUS database specific to cases of scaffold collapse, falls from a scaffold and falling objects from staging (% of cases)

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<th></th>
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<th></th>
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<td>12.5</td>
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</table>
B.4 DISCUSSION AND SUMMARY

B.4.1 FCG Cases

Analysis of the FCG cases was essential in understanding the types of failures and their frequencies, and in highlighting the diversity of issues and controls that need to be addressed in any decision support aid.

The type of structure in the majority of cases was a roof or working scaffold. In incidents involving roof structures it was usually the case that the worker fell through fragile material. For working scaffolds the majority of cases involved a collapse when the scaffold was in use.

The five most common features of the access system in which failure was centred were generally associated either with scaffolds or roof structures, and were defective components, lateral attachment, crawling boards, barriers over fragile areas, edge protection and overload.

Examination of the mode of failure for the ten most common failure elements suggested that in many cases the error was one of not fitting / using the element from the outset or of quality of execution. However, the mode of failure for the area of lateral attachment (relevant to 13% of cases -nearly all of them scaffold-related), was removal at an inappropriate time.

These figures illustrate the critical role that was played in the majority of the 186 incidents by human factors rather than purely defective hardware. Relatively few incidents involved defective components where the defect would not have been detected by routine visual inspection on site before the commencement of work.

B.4.2 FOCUS Cases

The analysis of FOCUS provided the following information:

a) Absolute frequencies of cases for various structures associated with temporary access and roof work
b) An indication of the proportions of these cases that were subsequently investigated
c) An indication of the relative frequencies of areas of failure based on keyword searches
d) The frequency of deficiencies thought by investigators to be active in causing the incident.

The large number of moveable ladders in use across many sectors of industry probably explains why these cases account for approximately half the sample. Falls from scaffolds make up the third largest group, although some of these are expected to involve a partial or complete collapse of scaffold.

The proportions of cases that were subsequently investigated varied across agents. Typically falls from scaffolds, collapses of scaffolds, and falls from tower scaffolds had the highest investigated proportions. Scaffold incidents, perhaps more than other temporary access systems, have the potential for injuring more than one person; their high investigation rate may reflect that potential.

A search of 2,876 investigated cases across 14 types of access system examined the accompanying short text description of the incident in order to establish the root cause. A little less than half the cases did not provide sufficient information. Overall, the most common failed features were ladder footings, ladder ties, edge protection, defective component, roof-light protection, harnesses, trespass, ingress/egress, crawl boards and vehicle collision. Scaffold-related cases occurred because of shortcomings in harnesses, defective components, internal bracing, edge protection and structural overload. Falls through or from a roof occurred mainly
because of shortcomings with roof-light protection, crawling boards, edge protection, and controls on trespassing.

Finally, the same investigated cases in FOCUS were queried on the frequency of 24 potentially relevant deficiencies from a total of 61 available in the database. The most frequent deficiencies concerned failure to control risk, unsafe systems of work on transient jobs, unsafe procedures, and defects in a fixed or temporary work platform. The same leading deficiencies were apparent when scaffold-related cases were considered. For these cases the third and fourth most common deficiencies were inadequate standard of supervision and inadequate training.
## APPENDIX C: LIST OF AGENTS DEFINED BY FOCUS

<table>
<thead>
<tr>
<th>Agent</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSCAFFOLD</td>
<td>Scaffolding collapse</td>
</tr>
<tr>
<td>FAACCESS</td>
<td>Falls from or down gangway, catwalk or other means of access not elsewhere classified.</td>
</tr>
<tr>
<td>FASCAFFOLD</td>
<td>Fall from, through or while using a general access scaffold.</td>
</tr>
<tr>
<td>FASUSPEND</td>
<td>Falls from, through, or while using a suspended scaffold</td>
</tr>
<tr>
<td>FATOWER</td>
<td>Falls from, through, or while using a tower scaffold</td>
</tr>
<tr>
<td>FACRADLE</td>
<td>Falls from, through, or while using a bosun chair or cradle</td>
</tr>
<tr>
<td>FATRESTLE</td>
<td>Falls from, through, or while using a trestle scaffold</td>
</tr>
<tr>
<td>FSWORKPLAT</td>
<td>Falls from a platform above ground level</td>
</tr>
<tr>
<td>FALADDERF</td>
<td>Falls from a fixed ladder</td>
</tr>
<tr>
<td>FALADDERM</td>
<td>Falls from a moveable ladder, including a step ladder</td>
</tr>
<tr>
<td>FALADDERO</td>
<td>Falls from other types of ladder</td>
</tr>
<tr>
<td>FSROOFEDGE</td>
<td>Falls from a roof edge</td>
</tr>
<tr>
<td>FSFRAGILE</td>
<td>Falls from or through a fragile roof</td>
</tr>
<tr>
<td>SFSTAGING</td>
<td>Free-falling objects or material from scaffolds, staging or other such workplace</td>
</tr>
</tbody>
</table>
## APPENDIX D: LIST OF DEFICIENCIES DEFINED BY FOCUS

<table>
<thead>
<tr>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO POLICY</td>
<td>Health and safety policy not provided</td>
</tr>
<tr>
<td>INEFFECT POLICY</td>
<td>Health and safety policy provided but no commitment or accountability. Low employee involvement.</td>
</tr>
<tr>
<td>FAIL CTRL RISK</td>
<td>Failure to identify, assess or control risk; inadequate planning</td>
</tr>
<tr>
<td>INAD COMMUNIC</td>
<td>Inadequate arrangements for communicating top-down and bottom-up</td>
</tr>
<tr>
<td>INAD TRAINING</td>
<td>Inadequate standard of training or instruction for competence</td>
</tr>
<tr>
<td>INAD SUPERVIS</td>
<td>Inadequate standard of supervision</td>
</tr>
<tr>
<td>NO MONITOR</td>
<td>No provision for monitoring health and Safety arrangements</td>
</tr>
<tr>
<td>INEFFECT MONITOR</td>
<td>Monitoring systems in place but ineffective, including inadequate reviewing / auditing; poor standards of accident investigation</td>
</tr>
<tr>
<td>UNSAFE PROC</td>
<td>Unsafe operating procedures – includes non-provision</td>
</tr>
<tr>
<td>UNSAFE ROUTINE</td>
<td>Unsafe system of work – routine production job</td>
</tr>
<tr>
<td>UNSAFE MAINTEN</td>
<td>Unsafe system of work – maintenance job</td>
</tr>
<tr>
<td>UNSAFE TRANS WK</td>
<td>Unsafe system of work- transient job</td>
</tr>
<tr>
<td>NO GUARD</td>
<td>Guarding or safety devices not provided, not used, removed</td>
</tr>
<tr>
<td>GUARD FAIL</td>
<td>Guarding or safety devices failed or inadequate</td>
</tr>
<tr>
<td>INAD DESIGN</td>
<td>Inadequate standard of design or construction of articles</td>
</tr>
<tr>
<td>INAD INSTALL</td>
<td>Inadequate standard of installation of articles</td>
</tr>
<tr>
<td>TRANSPORT FAIL</td>
<td>Inadequate traffic control system incl. separation of vehicles and persons</td>
</tr>
<tr>
<td>FIXED STRUCTURE</td>
<td>All defects in physical structure of premises- includes fragile roofs</td>
</tr>
<tr>
<td>WK PLACE</td>
<td>Fixed or temporary working platform defects including confined space</td>
</tr>
<tr>
<td>ACCESS/EGRESS</td>
<td>Any access – egress fault including inadequate clearance between pensions and machinery</td>
</tr>
<tr>
<td>NO PPE</td>
<td>Personal protective equipment not provided</td>
</tr>
<tr>
<td>NOT FOLLOW INSTR</td>
<td>Failure to comply with instructions including safe systems of work, permit to work systems. Also include misinterpretation of instructions</td>
</tr>
<tr>
<td>PPE NOT USED</td>
<td>Failure to use personal protective equipment</td>
</tr>
<tr>
<td>IMPROPER USE</td>
<td>Improper use of or interference with plant, equipment and appliances, including safety devices. Not including incidents that are able to be classed under DEFEAT DEVICE or FAIL USE DEVICE</td>
</tr>
</tbody>
</table>
APPENDIX E: CONSULTATION WITH COMPANIES INVOLVED WITH SCAFFOLDS

E.1 INTRODUCTION AND AIM

The aim of these consultations was to identify potentially problematic issues for safety advisers in ensuring scaffold safety at different points in a project. Participants were safety advisers of three construction companies routinely using scaffolds. The companies were: Amec (Glasgow); MPE Services Ltd (Bellshill); John Mowlem, (Glasgow); and Ballast Construction (Glasgow). In addition to these companies, two other organisations provided their views; these were Turner Plus Eight Ltd, a scaffold manufacturer and erector (Glasgow) and the Construction Industry Training Board (Glasgow).

E.2 DECISIONS AT STAGES THROUGHOUT A PROJECT

**Question:** With respect to scaffolding, what would you say are the three most important decisions that you need to make at the planning and design stage to ensure that work continues smoothly and safely?

*Amec:* The loadings that will be placed on the scaffold; the strength of any structure selected; the strength of the foundations.

*Mowlem:* Compatibility of the scaffold with the structure and its shape/material according to design drawings; space requirements on site; whether alternative methods of access can be used to reduce cost while maintaining or improving safety.

*MPE:* Scheduling of tasks; meeting the requirements of the Construction (Design and Management) Regulations 1994; ensuring risk assessments are completed.

**Question:** With respect to scaffolding, what would you say are the three most important decisions that you need to make at the erection of the scaffold stage to ensure that work continues smoothly and safely?

*Amec:* Meeting the SG4:00 [NASC] safety criteria for working at height; ensuring method statements and risk assessments are followed; ensuring suitable fall protection is used, including the installation of edge protection.

*Mowlem:* The scaffold must be right for the job as work progresses; opportunities should exist to meet with estimators and other contractors working on site; ensuring that space permits safe vehicle operation and storing of material on site.

*MPE:* Ensuring the design of scaffold is followed; ensuring site inspections are completed, including scaffold inspection; ensuring foundations remain secure.

**Question:** With respect to scaffolding, what would you say are the three most important decisions that you need to make at scaffold hand-over stage to ensure that work continues smoothly and safely?

*Amec:* Checking that hand over certificates are in order; ensuring that checks will be made on the scaffold every seven days; ensuring that safe working loads on the scaffold are known.

*Mowlem:* Ensuring that safe working loads on the scaffold are known; ensuring that scaffold design accords with finished structure; ensuring method statement for work on the scaffold has been checked over.

*MPE:* Ensuring that the scaffolders know the scheduling of any alterations; ensuring the scaffold has been checked before use; ensuring materials to be used will not exceed the safe working load of the scaffold.
**Question:** With respect to scaffolding, what would you say are the three most important decisions that you need to make at the maintenance and use stage to ensure that work continues smoothly and safely?

**Amec:** Establishing a method for notification and correction of any defective boards and ties; ensuring the use of competent inspectors to make the necessary checks; preventing overload of the scaffold.

**Mowlem:** Ensuring stability in winds and checking that use of the scaffold accords with its designation; preventing overloads and ensuring that loading bays are present when necessary; ensuring guard rails are in place.

**MPE:** Preventing and checking for removal of ties; ensuring suitable arrangements for alterations to the scaffold; developing an “open door” policy on site for safety issues.

**Question:** With respect to scaffolding, what would you say are the three most important decisions that you need to make at the stage of scaffold dismantling to ensure that work continues smoothly and safely?

**Amec:** Ensuring the method statement is obeyed; ensuring the controlled lowering of material from the scaffold; ensuring incomplete scaffolds are not left in an unsafe state.

**Mowlem:** Ensuring that SG4:00 [NASC] is followed; ensuring appropriate harness use; ensuring incomplete scaffolds are not left in an unsafe state.

**MPE:** Ensuring sufficient tie placements; minimising work near unexposed edges; ensuring appropriate harness use.

**E.3 UNSAFE OCCURRENCES IN THE PAST**

**Question:** Please describe three different mistakes or problems in the planning and design stage of scaffold work in the past that resulted in an unsafe situation either at the time or at a later stage during the work.

**Amec:** (i) The selection of scaffold rating was not fit for the task of grit blasting: the accumulation of grit led to localised overload and the slipping of a standard. (ii) A scaffold was erected with interchanged parts from different scaffold systems. Work was stopped before an unsafe situation arose. (iii) No third incident.

**Mowlem:** (i) An edition of a design drawing did not have sufficient number of ties. (ii) No second incident. (iii) No third incident.

**MPE:** (i) A building was erected near to the M8 but due to oversight at the design stage it was almost impossible to clean the building windows. (ii) No second incident. (iii) No third incident.

**Turner Plus Eight:** Visits to site can provide critical information necessary for putting together a risk assessment and method statement. There should be a requirement that all companies provide a written risk assessment and method statement at the time of bidding. Smaller companies often cut corners in this regard. All jobs should be accompanied by scaffold drawings which the principal contractor may assess during procurement and throughout subsequent stages. Regulation within the scaffolding industry should be directed towards these goals.

**Question:** Please describe three different mistakes or problems in the erection of scaffolding in the past that resulted in an unsafe situation either at the time or at a later stage during the work.

**Amec:** (i) Sandbags were used to build the foundation for a scaffold. These were unstable and work was halted. (ii) A scaffold was declared safe for work but a visit to site revealed faults “all over the place”. (iii) No third incident.

**Mowlem:** (i) On a number of occasions ties have been incorrectly fitted. (ii) No second incident. (iii) No third incident.

**MPE:** No incidents given.
**Question:** Please describe three different mistakes or problems in the maintenance or use of scaffolding in the past that resulted in an unsafe situation either at the time or at a later stage during the work.

**Amec:** (i) A loading bay was installed without edge protection. Harnesses were not being used at the time. (ii) *No second incident.* (iii) *No third incident.*

**Mowlem:** (i) A number of incidents occurred involving the removal of ties, especially reveal ties, by sub-contractors. (ii) *No second incident.* (iii) *No third incident.*

**MPE:** (i) A worker stepped out of a window and fell between the building and the scaffold. The scaffold had been poorly designed without edge protection on the inside. (ii) *No second incident.* (iii) *No third incident.*

**Turner Plus Eight:** The recurring causes of scaffold collapse concern the removal of ties, overload of the structure and undermining of foundations. The recurring causes of falls in this stage are due to the interference with working platforms and guard rails. Often companies using the scaffold are unaware that they have responsibility for the scaffold once it is handed over.

**Question:** Please describe three different mistakes or problems in the removal of scaffolding in the past that resulted in an unsafe situation either at the time or at a later stage during the work.

**Amec:** (i) The throwing of material to the ground. (ii) Non-use of harnesses. (iii) Incidents in which only single boards have been used as working platforms so that work may progress faster.

**Mowlem:** (i) Not working to SG4:00. (ii) The absence of a method statement. (iii) *No third incident.*

**MPE:** *No incidents given.*

### E.4 COMMUNICATION AND INFORMATION

**Question:** During scaffold-related work, how would you rate the communication of safety information between contractors?

**Amec:** Satisfactory. *No other comments.*

**Mowlem:** Satisfactory. But it depends on the contract. As a safety adviser it is beneficial to stop communications that do not involve Mowlem and which would leave Mowlem out of the loop.

**MPE:** Poor. *No other comments.*

**CITB:** A lack of information about small changes to schedules can disrupt planning on scaffold projects. An example is the undermining of scaffold foundations by service engineers; situations which could have been avoided if scaffold contractors were forewarned of the requirements and timings for installing services.

**Question:** In instances where you lack information to do your job safely, what is the information that you lack?

**Amec:** Method statements from scaffold contractors and contractors using the scaffold.

**Mowlem:** Information on the scheduling of visits to site by the scaffold contractors; information concerning costs.

**MPE:** Information about who to contact for changes to the scaffold; the safe working load on the scaffold – usually because this is not expressed in practical terms, e.g. number of blocks; the location of access ways on the scaffold – signs should be provided.

**Turner Plus Eight:** Although information on the safe working load is provided during hand over, this information may not reach the user. It is important to ensure that this information is widely known to those using the scaffold.
E.5 UNAUTHORISED ALTERATION OF SCAFFOLDS

Question: Scaffold structures can be altered without the consent of the scaffold contractors. How frequently or infrequently does this occur on your sites?

Amec: Very infrequently.
Mowlem: Frequently
MPE: Frequently
Turner Plus Eight and CITB: Unauthorised alteration of ties is a leading cause of scaffold collapse.

Question: Are any measures taken to avoid this problem and if so what are they?

Amec: Rules are issued to subcontractors; during hand over the scaffold users sign that all ties are in place; responsibility is assigned for checking that ties are not removed or altered.
Mowlem: Rules are explained during induction to the site.
MPE: No specific measures against it.
Turner Plus Eight: The provision of safety awareness courses for the users of scaffolds may offer a means of combating the problem.
CITB: Locking systems for ties may provide some protection against unauthorised alterations.

E.6 TRAINING ISSUES

Question: During previous scaffolding were there any times when the work done by the scaffolding team was too difficult for their level of training? If so, what factors do you think brought this about?

Amec: No. On occasions that problems arise these problems are usually due to lack of discipline rather than deficient training.
Mowlem: Yes. Usually this occurs because the type of scaffold is not standard and not as familiar to the scaffolders. The problem is compounded by the training schemes currently in use: it is too easy to get a scaffolder certificate. There is also a tendency to take short-cuts when “chasing money”.
MPE: No. No other comments.
Turner Plus Eight: The lack of any requirement to be trained in scaffolding before practising in the trade contributes to unsafe practices. A scheme similar to CORGI [for gas engineers] could be applied successfully within the scaffold trade.
CITB: Scaffolders returning to tube and fitting systems after spending time on proprietary systems require a transition period to relearn some the requisite skills. Scaffolders can be under pressure to complete work with tube and fitting when they are unfamiliar with it. One potential method of resolving the problem is the introduction of a two tier training system: all scaffolders complete a basic scaffold course, gain limited experience in industry, and then take electives either in tube and fitting systems or proprietary systems. Refresher courses may offer a safe means of returning to tube and fitting systems.

Question: How was this issue resolved?

Amec: No comment.
Mowlem: Qualifications were checked before work. But this is made difficult by continual changes in the group of scaffolders involved in the work.
MPE: No comment.
Turner Plus Eight: The HSE are not as effective as they could be in enforcing regulations and correct practice on site. Their task may be made easier by publication of a code of practice for the scaffold industry that covers aspects of the management of safety on scaffold projects.
E.7 HARDWARE

**Question**: During your work are there any aspects of the design of scaffold components that annoy you or make you feel unsafe?

*Amec*: Boards can sometimes be defective.

*Mowlem*: Incompatible components from different systems can become mixed up.

*MPE*: The ease with which hop-up boards can be moved; the ease with which ties can be removed or altered; battens on tube and fitting scaffolds can easily become trip hazards.

*CITB*: 21-foot scaffold tubes can represent a manual-handling hazard for scaffolders; dropped scaffold tubes can exceed safe noise levels.

E.8 INSPECTIONS AND CHECKS

**Question**: Do you use a method of inspection of the scaffold, and if so what method is used, by whom and how frequently?

*Amec*: A scaffold tag system is used to ensure checks are made every seven days. Visual checks are made every day. A competent person makes the checks using an in-house checklist.

*Mowlem*: The site manager uses an in-house checklist on a weekly basis (or as necessary).

*MPE*: The foreman uses a standard form to record any faults. Thorough checks are made on a weekly basis, with daily visual checks. A checklist is not used.

*Turner Plus Eight*: Companies using scaffold contractors should be encouraged to employ the same contractors on a weekly basis to make the necessary checks.
APPENDIX F: INCIDENT DESCRIPTIONS USED IN USER TRIALS

F.1 INCIDENT A

The scaffold structure
The scaffold involved was a three-lift independent tied scaffold erected for maintenance to a building façade in High Street, D***. At the time of the accident, the second and third lifts were in use. These lifts were four boards wide with a two-board hop-up. The scaffold height was 12m and the length 20m. Two points of access existed: one at each end of the structure.

The accident
On Monday 15th October at 1:30pm a 10ft length of scaffold tube fell 5m and struck a passer-by who was passing between the scaffold structure and a truck off-loading scaffold equipment. Two scaffolders were removing a fan that ran the length of the second lift at the time of the incident. The equipment was being handed down to the driver who was standing on the truck below. One section of the partly dismantled fan was being used to store quantities of this scaffold equipment before it was passed to the ground. One of the builders had descended from the third lift to the second lift using the fan as a jumping down point. As he did this a coupler within the partly dismantled fan had slipped allowing the fan to deform and a scaffold tube to slide free from its storage point on the fan and hit the member of public. Major injuries were sustained in this incident.

The background
The work on the building involved repair to the façade of a shop. The company Motown Scaffolds had been contracted to erect, maintain and dismantle the scaffold. Alpha Building had been contracted to make reparations to the building façade while working from the scaffold.

The tight scheduling between these two companies meant that Motown Scaffolds began to dismantle accessory parts of the scaffold as Alpha Building continued work. Work to the façade was close to completion and Motown Scaffolds had decided to remove the fans as a start to dismantling the structure. At the time of the incident Motown’s scaffolders were working close to one of the access points to the third lift and ceased work as and when necessary to permit Alpha Building workers to pass.

There had been some confusion among Motown’s scaffolders on whether the fan was still required. On the basis of observation of Alpha Building’s activities, the scaffold supervisor had assumed that Alpha Building was finishing up that day and that the fan was no longer required as a protection against falling pieces of mortar. On that basis, the supervisor of Motown Scaffolds had given permission to remove the fan at the toolbox talk the same morning. Because it was uncertain when the truck would arrive, the supervisor had suggested making a start to dismantling the fan. For safety reasons, he had cautioned against stacking equipment too high on the second level to allow workers from Alpha Building to move around relatively easily on the second level and between the second and third level.

That day the toolbox talk had not mentioned arrangements to redirect the public while the hoarding was partially removed and the truck was loading. It was resolved later in the morning when one of the scaffolders had raised this issue to the supervisor. The supervisor was in discussion with the site agent at this time but briefly suggested that he redirect any passers-by for the duration of loading. During this task the scaffolder had been forced on one occasion briefly to help his colleague who was loading a 21-foot section. It was at that moment that the

1 All names and descriptions are fictious, the incidents being based upon an amalgam of real events
member of the public inadvertently walked between the truck and the scaffold and received the injuries.

Safety on site for Motown Scaffolds was managed by the scaffold supervisor, who was himself an advanced scaffolder. Because Motown Scaffolds was a relatively small outfit he had been involved with the project since the bidding stage. The supervisor was present at the site nearly all the time and was potentially in a good position to make well-informed decisions about technical and safety issues.

The main contractor had described the job to such high detail that a visit to site was made at the beginning of the planning stage after Motown Scaffolds had their bid accepted. It was a relatively simple work specification and a standard independent tied scaffold was chosen to fulfil it. The basic-qualified scaffold team had erected hundreds of such scaffolds before.

The public location of the scaffold meant that Motown Scaffolds paid attention to preventing falling objects in the bidding and planning stages including movement of material, toeboards, use of fans, and access restrictions around the scaffold. Netting was not used because the fans were considered sufficient and the potential drop-zone fell well within the site perimeter. The scaffold supervisor was reluctant to install netting because he wanted to keep the scaffold standard in its design.

As with all his projects he had paid close attention to the risks of workers falling and complied with SG4:00 regarding fall protection in the bidding, planning and work stage. Similarly close attention had been paid to prevent scaffold overloading.

He provided briefings to his workers on safety issues once a week. Sometimes he was unable to make these briefings due to other commitments but on those occasions workers knew where they could find him to ask important questions regarding the progress of their work.

The only outstanding issue had been the scheduling of work between the sub-contractors – Alpha Building being one of them. For one reason or another it was not clear until after Alpha Building had begun their work exactly when and how often Motown Scaffolds would be required to modify or begin dismantling the scaffold. Due to an increase in work in September, Motown Scaffolds had worked more closely with Alpha Building some time after they had started using the scaffold to improve their work co-ordination and improve Motown Scaffolds’s efficiency.

An inspection and reporting system for the scaffold had been planned: a specifically trained member of the team made the necessary inspections every day and week, and these were checked off each time by the scaffold supervisor. This also occurred when the scaffold was handed over to Alpha Building. Also at this point the limits of the scaffold were listed for the benefit of the user, and from experience in the trade, Motown Scaffolds had specifically cautioned against making changes to the scaffold.

When installing the fan weeks earlier, the scaffold supervisor had observed Alpha Building employees moving between lifts on the outside of the scaffold in a similar manner. At that time he had resolved to mention it to Alpha Building but in the end did not bother, partly because he was unsure who to speak with.

F.2 INCIDENT B

The scaffold structure
The scaffold was a tube-and-fitting, independent, tied scaffold, 22m in length, with four working lifts, each of five boards width. At the time of the incident it had been in place for six
weeks and was being used by a specialist renovation team to clean the façade of an historic building in Bravo. Its location was an unlit and relatively quiet street near the centre of town.

The incident
At 10am on a windy 12th March 1999, an hour after work had commenced on the scaffold, a 10m section of scaffold came away from the wall and fell across the street. Fortunately, only minor injuries were sustained. Investigations later found that the main reason for collapse was a lack of ties to the building on the section that collapsed, in combination with wind loading on the scaffold and slightly damaged lower standards. The background to the case is as follows.

Background
Close Cleaning Ltd (CC) had been contracted by the Council to undertake work from a scaffold erected by Seven-ways Scaffolding (SS). SS had commenced erection of the scaffold some one month previously after a rigorous tendering process by the Council. The brief for the work had been detailed, and supplemented by a visit to the site by SS for reasons of planning.

The scaffold was designed as a standard scaffold. On the basis of a limited brief, SS’s designer had assumed that sheeting would not be required. He had also assumed that the cleaning task on the façade would require a heavy-duty standard scaffold. Choice of scaffold was also based on an examination of the building façade (which was found to feature placements for ring ties left from a previous job). In the bid, he had also outlined the precautions necessary for the main risks of their work. CC had not been consulted on their exact requirements when the brief was given to the scaffolders.

Once the bid had been accepted, SS allocated the planning and supervision of work activities to an experienced advanced scaffolder. The scaffold was safely erected over the course of the next two weeks, then handed over to CC for the cleaning work to commence. At that point the scaffold was checked and found to be structurally sound.

The night before the collapse, a reversing vehicle had accidentally struck the scaffold. As a result of the collision, two end standards were bent slightly toward the façade. This was spotted the following morning. To the site agent the damage had seemed very limited; he decided it was safe to work on the scaffold until a scaffolder could visit two days later as part of the weekly scaffold check. He had made a request to SS for a scaffolder to attend that same morning but SS were not able to provide advice or scaffolders sooner than the agreed weekly scaffold check.

On the day before the collapse, workers of CC had removed two ties to allow access to key areas on the facade. All other ties were in place at the time and the workers believed the structure was adequately tied. CC workers claimed they were not aware that the scaffold would be made unsafe by limited removal and replacement of ties. Partly due to time pressures, they had removed the ties to allow work to continue, and they had intended to replace them the same day. In fact, they were not replaced and work commenced the following morning without the supervisor being aware of their absence. This was not the first time that ties on the scaffold had been removed. Some days previous, missing ties had been spotted during the weekly check by the scaffold company. The scaffolder had communicated his concerns to the CC supervisor at the time but the supervisor had not cautioned his workers.

In the same check, the scaffolder had also noticed that a section of sheeting had been added to the scaffold on the third lift. The CC supervisor had decided to add the sheeting to the structure because a recent change in work methods meant that the work area had to be sheltered from the wind. CC had not predicted this possibility earlier in the project, but the supervisor saw no reason why sheeting should not be installed on this limited basis.

It seems that these three factors (damaged standards, two missing ties, and wind loading on the area of sheeting) were sufficient to bring down an end section of scaffold.
APPENDIX G: SCAFPASS VERSION 2

Scaffold Planning Aid for System Safety (SCAFPASS):

SCAFPASS is a set of flow charts that makes work with scaffolds safer by providing guidance on best practice. It is designed for scaffolders, workers using the scaffold, safety advisers, site agents and planners - in short, most of the people involved with scaffolds.

SCAFPASS has three parts. Each Part has a number of Steps. You should select the appropriate Part and move through the Steps in order, ensuring that as far as reasonably practicable you can answer yes to each one.

Part A is used when Bidding for work with scaffolds or Choosing a contractor (select the appropriate version).

Part B is for Planning, erecting, using or dismantling scaffolds. It is important that Part B is used continuously during planning, erecting, using or dismantling scaffolds.

Part C is used whenever there is a Hand-over of the scaffold either from scaffold user to scaffold user, or in the opposite direction from scaffold user to scaffold user.

There is colour coding of the Steps in SCAFPASS. Blue indicates particular relevance to site agents, planners, designers and contract managers. Green indicates particular relevance to scaffolders and workers using the scaffold. Black indicates a more equally shared responsibility. The layout of SCAFPASS is shown below.

The basic layout of SCAFPASS

```
<table>
<thead>
<tr>
<th>Bidding for work with scaffolds</th>
<th>Selecting a contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used by: Only scaffold contractors and contractors intending to use the scaffold</td>
<td>Used by: Only planning supervisors, contract managers, site agents, principal contractors, or clients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planning, erecting, working from and dismantling scaffolds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used by: Both groups, including: scaffold contractors, contractors intending to use the scaffold, planning supervisors, contract managers, principal contractors, site agents and clients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hand-over of the scaffold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used by: Both groups, including: scaffold contractors, contractors intending to use the scaffold, planning supervisors, contract managers, principal contractors, site agents and clients</td>
</tr>
</tbody>
</table>
```
Choosing a contractor:
This Part is for use by principal contractors, planning supervisors and others involved in selecting contractors.

- Work at height is unavoidable
- Scaffolding is the most suitable form of access
- Experience of the contractor in similar work
- Previous experiences with the contractor
- Health and safety management strategies
- Observations at one of their sites
- Points / means of access
- Use of vehicles
- Scheduling of work and modifications to scaffold
- Type of work on the scaffold
- Comprehensiveness of risk assessment
- Methods, rules, procedures, PPE to manage risk
- Arrangements to monitor compliance among staff
- Provision of H&S information to staff
- Quality control and inspections
- Staff expertise
- Are requirements in Step A.3 satisfied

A.2 Have the potential contractors been screened on their competence to do the work?
- Yes

A.3 Has a clear brief for the scaffold been presented, including hazards for the scaffold?
- Yes

A.4 Have the bids been evaluated on health and safety content, including their risk assessment?
- Yes

A.5 Does the proposed scaffold in the bids meet the requirements of your brief?
- Yes

A.6 On the basis of Steps A.4 and A.5, is there a competent contractor at a reasonable cost?
- Yes

Go to Part B
Bidding for work with scaffolds:
This Part is for use by all contractors wishing to procure work involving scaffolds.

- Maximum loading
- Points / means of access
- Strengths of foundations
- Potential conflicts with public
- Scheduling contractors

- Reducing size or weight of material or equipment
- Simplifying the co-ordination and scheduling of work

- Location of work areas
- Number of working lifts
- Use of vehicles
- Type of work on the scaffold

- Minimum loading
- Location of work areas
- Number of working lifts
- Use of vehicles
- Type of work on the scaffold

If NO, ensure the brief is clarified

A.2 Can the brief be simplified to make the proposed scaffold or work safer?
- Yes

A.3 Is the proposed scaffold a standard scaffold (i.e. not a special scaffold)?
- Yes

A.4 Has a preliminary risk assessment considered the principal hazards and risks?
- Yes

A.5 Have preliminary controls been considered for these risks?
- Yes

A.6 Is the proposed scaffold compatible with the expected loads?
- Yes

A.7 Is the proposed scaffold compatible with the supporting structure and foundations?
- Yes

A.8 Is the proposed scaffold compatible with proposed staff?
- Yes

A.9 Will the proposed scheduling be compatible with the work of other contractors on site?

Go to Part B
Planning, erecting, using, and dismantling scaffolds:

This Part is for use by all parties when planning, erecting, using and dismantling scaffolds.

- Responsibility assigned for health and safety
- Accountability assigned for health and safety
- Information that helps in planning for safety
- Visits are frequent enough to keep up with safety issues
- Access restrictions below the scaffold / work co-ordination
- Hard hat zones in place
- Correct manual handling techniques
- Suitable harness systems
- Guard rails / temporary guard rails
- Safety nets considered
- Timely removal of material from scaffold and its base
- Minimise storage of material on scaffold
- Workers know that unauthorised alterations are forbidden
- All workers know how to request changes
- Suitable fencing around fall zones of scaffold
- Lower boards and ladders are removed from the scaffold at close of day
- Site inductions:
  - Site safety rules and emergency procedures
  - Reporting faults/ concerns
  - Requesting alterations to the scaffold
- Site safety rules and emergency procedures
- Reporting faults/ concerns
- Requesting alterations to the scaffold
- Inspection of incoming equipment by assigned person
- Daily visual and thorough weekly checks on scaffold
- Compatible technical knowledge and experience
- Number of staff sufficient at all stages and in all tasks
- Contacts for health and safety
- Information that clarifies any ambiguities in the brief
- Visits always include a site walk-around and inspection
- Safe means of moving material onto or off scaffold e.g. chute
- Housekeeping on working lifts
- Appropriate number and location of loading points
- Arrangements are made so that requested changes are made with a minimum of delay
- A schedule is agreed for scaffolders to make changes
- Consideration given to using surveillance methods
- Standards are padded and made conspicuous in the vicinity of public walkways
- Discussion of current risks/ unsafe conditions / occurrences
- Co-ordinating work safely
- Clarifications of procedures when necessary
- Clear method of reporting faults that need correcting
- Faults can be corrected swiftly
- Level of supervision is appropriate for task and staff
- Contacts for health and safety are known across contractors
- Information that clarifies any ambiguities in the brief
- Visits always include a site walk-around and inspection
- Safe means of moving material onto or off scaffold e.g. chute
- Housekeeping on working lifts
- Appropriate number and location of loading points
- Arrangements are made so that requested changes are made with a minimum of delay
- A schedule is agreed for scaffolders to make changes
- Consideration given to using surveillance methods
- Standards are padded and made conspicuous in the vicinity of public walkways
- Discussion of current risks/ unsafe conditions / occurrences
- Co-ordinating work safely
- Clarifications of procedures when necessary
- Clear method of reporting faults that need correcting
- Faults can be corrected swiftly
- Level of supervision is appropriate for task and staff

Go to Part C as appropriate
Planning, erecting, using, and dismantling scaffolds:
This Part is for use by all parties when planning, erecting, using and dismantling scaffolds

- Permanent on-site presence of scaffolder considered
- Scheduling of visits will keep up with work progress
- Checks include ties, bracing, couplers, foundations, staging
- Localised and general safe working loads are known by the user
- Other precautions relevant to the use of the scaffold are detailed
- Removing ties or bracing
- Adding sheeting
- Removing ties or bracing
- Adding sheeting

C.1 Is there an agreement for making scaffold alterations or seeking advice after hand-over?
- Yes
- IF NO, discuss and agree on this, if possible

C.2 Has a final check shown the scaffold is safe for use (or modification / dismantling)?
- Yes
- IF NO, make this final check a priority

C.3 Are you aware of the limits of the scaffold?
- Yes
- IF NO, request this information from the scaffolder

C.4 Has responsibility been accepted for the safe use (or dismantling) of the scaffold?
- Yes
- IF NO, ensure that all working on the scaffold know their responsibilities

C.5 Has the user been cautioned on making changes to the scaffold without the scaffolder's consent?
- Yes
- IF NO, provide this caution

C.6 If scaffolder and user are to work together on the scaffold, will their work co-ordinate safely?
- Yes
- IF NO, discuss schedules to ensure they are compatible

Return to Part B as appropriate
APPENDIX H: INSTRUCTIONS FOR SCAFPASS

What is SCAFPASS?
The name SCAFPASS is an abbreviation for Scaffold Planning for Access System Safety. SCAFPASS is a set of simple flow charts that include important safety considerations for planning, erecting, using and dismantling temporary access scaffold. It was designed for scaffold contractors, contractors using the scaffold, safety advisers, site agents and planners.

How is SCAFPASS different from checklists?
Accidents on or around access scaffolds usually happen because of simple errors, for example guard-rails not present or ties missing. While there are checklists aimed at identifying these faults once they occur, SCAFPASS takes a more proactive approach by improving the management of safety at an early stage and at all stages of work.

How is SCAFPASS different from published guidelines for scaffolds?
SCAFPASS includes much of the information published previously on scaffold safety, for example CIS49 General Access Scaffolds and Ladders, but it presents these and other recommendations in shortened format and a realistic sequence.

How is SCAFPASS organised?
SCAFPASS comes in a number of Parts. Each Part applies to a particular phase of the project. The decision aid “flows” in the sense that each Part consists of a sequence of Steps, and the user considers each Step before progressing to the next. It has been designed for two broad groups of people. The first group includes overseers of the work, typically site agents, principal contractors, or planning supervisors. The second group consists of persons more directly involved in the erection and use of scaffolds, typically supervisors of scaffold teams and contractors working from the scaffold.

What are the Parts to SCAFPASS?
There are three Parts to the decision aid. Each Part applies to a specific phase of the project

Part A is a sequence of Steps for bidding for and procurement of work.
There are two versions of Part A - a version for the scaffold contractor or contractor using the scaffold and a version for the relevant overseer. Only Part A is shared in this way.

Part B is a sequence of Steps for planning, using, erecting and dismantling scaffolds.
Part C is a sequence of Steps for the hand-over of the scaffold when it is being exchanged between contractors.

How is SCAFPASS used?
Within each phase of the project, beginning with the bidding / procurement phase, the appropriate Part of SCAFPASS is selected. Steps within that Part are then reviewed one by one. More detailed criteria appear to the left of each Step and serve as an elaboration and checklist. Ideally, all criteria would be considered and applied where appropriate before moving to the next Step.

All groups involved in the project will share responsibility in ensuring a particular Step is adequately considered. But some Steps will have more importance to one group than the other. For this reason, colour coding is used on each Step.

• **Green** indicates the Step has special importance to overseers.
• **Blue** indicates the Step has special importance to scaffold contractors / contractors using the scaffold.
• **Black** indicates a more equal sharing of responsibility.

All parties involved in a project may use the same decision aid. This makes it easier for each party to cross-check that the other is meeting their health and safety duties.

There are two approaches to using SCAFPASS. First, the Steps may be reviewed continually as work progresses. This is particularly important in the erection, use and dismantling phases. Second, the Steps are used to audit safety measures at the end of each work phase; this approach should be adopted only in bidding / procurement, planning or hand-over phases.

The next section explains the Steps in each Part.
The Parts of SCAFPASS

Part A. Choosing a contractor and Bidding for work with scaffolds

Part A of SCAFPASS ensures that safety issues are given priority at the earliest stage in the project. Many later problems with health and safety can be avoided by good practices in the procurement and bidding phase. The phase requires different activities for the overseer and the scaffold contractor/contractor using the scaffold. For this reason, there are two versions: Part A(i) and Part A(ii). The version for the overseer is outlined below. The version for the scaffold contractor and the contractor using the scaffold is outlined on page 5.

Part A(i) for the Overseer: Choosing a contractor

The overseer must match the requirements of the work with suitable expertise of a contractor.

A.1 Must work be done at height from a scaffold?
Working at height and from scaffolds should be avoided if the work can be done without access to height or by simpler means. For example, it might be possible to reduce the amount of work at height by using prefabricated components lifted into place; or it might be possible to use cherry-picker hydraulic platforms instead. The choice of alternative means of access will depend on time, cost and safety implications. The environment of use may also preclude the use of scaffolds. For example, poor ground conditions may mean that a scaffold cannot be sited safely.

A.2 Have the potential contractors been screened on their competence to do the work?
Many of the problems arising from work at height can be avoided by selecting safe and competent contractors before work begins. Screening contractors prior to tender can remove unsafe or less than competent contractors. The screening process need not be lengthy - often it could be an informal assessment of candidates based on their general reputation and any experience you might have had with them before.

A.3 Has a clear brief for the scaffold been presented, including hazards for the scaffold?
As the overseer of the project, you have a responsibility to ensure that a clear brief for the work and access requirements is given to the contractor prior to them bidding for the work. The scaffold contractor should be given details of the proposed work (e.g. where the access is required, scheduling, type of work, materials used), any
unusual hazards that may affect the site, and other characteristics of the site (foundations, presence of public, need for site security, use of vehicles, space restrictions).

A.4 Have the bids been evaluated on health and safety content, including their risk assessment?
The bids are evaluated once they are received. This need not be as formal as it sounds but it should include an assessment of the methods that the contractor proposes to reduce risks of the work. The criteria will probably include the thoroughness of their risk assessment, procedures and arrangements to ensure compliance with procedures, quality control of stock (including inspections of the scaffold), and the expertise and experience of staff in the team.

A.5 Does the proposed scaffold in the bid meet the requirements of your brief?
With all bids, the proposed scaffold and methods must meet the requirements of the brief in A.3. If there are discrepancies or uncertainties, you should resolve them.

A.6 On the basis of Steps A.4 and A.5, is there a competent scaffold contractor at a reasonable cost?
Competence refers to their ability to manage health and safety, as well as their technical capability. The cost of the contractor will inevitably be a major factor guiding selection, but health and safety considerations must be foremost. If the answer to A.6 is no, there are two options. The first is to negotiate with the most favourable contractor(s). The second option is to repeat procurement. Putting the work out again to tender may result in a competent contractor but there is no guarantee; there are also cost and time implications attached.

Once A.6 is satisfied, go to Part B for planning the work. Part B is shared among all parties in the project.
Part A(ii) for the scaffold contractor or contractor using the scaffold: Bidding for work with scaffolds

The scaffold contractor or contractor working from the scaffold must provide a bid for the work that includes attention to health and safety requirements. There is a balance to be met between over-investing resources in compiling a bid when its outcome is uncertain and compiling a bid with enough detail to account accurately for the financial and practical aspects of safety if the bid is accepted.

A.1 Has a detailed brief for the scaffold and/or work been established?
The quality of the bid relies on a detailed brief. The type of site and type of work will affect the type of structure that will be used for access and the safety measures necessary. The overseer should be contacted for clarification if the brief is unclear or incomplete.

A.2 Can the brief be simplified to make the proposed scaffold or work safer?
Any suggestions for simplifying the design or work method should be discussed with the overseer. This might include modifying the order of tasks, the materials used or the scheduling arrangements.

A.3 Is the proposed scaffold a standard scaffold (i.e. not a special scaffold)?
Each year there are a considerable number of scaffold collapses occurring because the scaffold was built as a standard scaffold when it should have been a special scaffold. British Standard 5973: 1993 describes the correct practices in constructing and working from special scaffolds. Listed below are the more common circumstances that require a scaffold to be built as a special scaffold. The relevant section of BS5973: 1993 appears in brackets.

• **Scaffold height will be above 50m** (Sec.2 Item 8.5.1; Sec.2 Item 9.3.2)
• **Sheeting or roofing will be used** (Sec.2 Item 8.5.2; Sec.2 Item 9.3.3)
• **The building or façade will not permit standard tie methods** (Sec.2 Item 9.1.1; Sec.2 Item 9.9)
• **Loading bays will be included** (Sec.5 Item 23.1)
• **A load rating will be required that is outside the limits of a standard scaffold** (Sec.2 Item 8.5.1).

If a scaffold has any of these properties even though it was designed as a standard scaffold there are two options:

➢ **It must be designed and erected as a special scaffold in accordance with BS 5973: 1993, Sec. 5**
The properties that make it a special scaffold must be removed and methods of working changed so that a standard scaffold is suitable.

**A.4 Has a preliminary risk assessment identified the principal hazards and risks?**
The risk assessment need only be preliminary at this point but it should identify the main hazards and their likely risks. The most important hazard will be working at height and the associated risks will include the risk of falls and the risk of being struck by falling objects. But there may be other hazards relevant to the particular site that will present risks to workers: on- and off-site vehicles; toxic chemicals; unstable ground; overhead or building-based electrical services; or risks from the public.

**A.5 Have preliminary risk controls been devised?**
This Step considers the controls to limit these risks. It is important to identify these controls at an early stage so that the bid can include them in the costing of the job. Risk controls might include: avoidance of the hazard altogether by a different technique or material; the use of personal protective equipment; the use of physical barriers; or the use of procedures for work scheduling.

**A.6 Is the proposed scaffold compatible with the expected loads?**
This Step is included because over-loading of scaffolds is one of the more common causes of scaffold collapse. The question can only be answered when a detailed description of the planned loads has been established. Safety margins should cover any momentary increases in loading during the placement of loads. An allowance of 25% of the load is recommended. Table 1 in BS5973: 1993 provides guidance in selecting the type of scaffold for the load required. The actual layout of the scaffold can influence the build-up of loads. For example, it may be necessary to plan more than one loading point or to change periodically the location of loading points so that build-up of material is kept to a minimum.

If the answer to Step A.6 is no, the alternatives are to modify the brief (e.g. change the weight of materials or order of work) or to change the proposed scaffold. Steps A.2 to A.5 should be reviewed.

**A.7 Is the proposed scaffold compatible with the supporting structure and foundations?**
The ground type and presence of underground services will affect the scaffold footings. The stability of the supporting façade may be affected by its age, quality of construction and any damage it has suffered. Where there is doubt, the case should be discussed with the overseer of the project and a site survey considered. Pull-tests on ties should be done for all jobs to check the integrity of the façade.
If the answer to Step A.7 is no, the alternatives are: to consider other methods of securing the scaffold to the façade; to consider a means of improving the stability of the foundation and/or structure; to consider an alternative means of access. Steps A.2 to A.6 should be reviewed.

**A.8 Is the proposed scaffold compatible with proposed staff?**

Staff technical knowledge and experience, as well as staff numbers, are critical in achieving safety. The proposed scaffold may not match the skills, experience and training of the proposed staff. There are tasks, for example, that a basic scaffolder is not trained to do. If the answer to A.8 is no, there are a number of options:

- **Train / re-train staff:** This may be costly and time may not permit it.
- **Hire in labour for all or some of the work:** Here, there may be difficulties in achieving control over staff on site and ensuring communication and co-ordination among staff.
- **Simplify the proposed scaffold so that it is within the capability of staff:** This may not be possible under the brief, but if it is selected then Steps A.2 to A.7 must be reviewed.
- **Reconsider bidding for the work:** This may be the least desirable option but it might be the safest and the most cost-effective strategy in the long-term.

Also note that scaffolders returning to tube and fitting systems after working exclusively with proprietary systems may need time on the job to re-learn their old skills.

**A.9 Will the proposed scheduling be compatible with the work of other contractors on-site?**

You need to make sure that the scheduling will not be too tight and that your tasks can be done safely alongside the tasks of other contractors.

After A.9, go to Part B. Part B is shared among all parties in the project.
Part B. Planning, erecting, using and dismantling scaffolds

This Part of SCAFPASS addresses ten important issues that must be considered before (planning) and during (erecting; using; dismantling) the work.

B.1 Is responsibility and accountability for health and safety established and does it remain clear?
The assignment of responsibility for health and safety is essential because it introduces accountability as a motivating force in ensuring that safety requirements are met. It also means that any health and safety issues can be addressed efficiently through key figures within and between companies. There should be a person responsible for health and safety in your company, and this person should be able to resolve health and safety problems swiftly. You should also know the names and contact details of those responsible for health and safety for all contractors in the project, or at least be in a position to contact them efficiently via the site agent should any safety problems develop.

B.2 Has the site been visited during planning? / Do persons responsible for safety visit the site regularly?
A visit may have been made to the site during the bidding stage. In any case, a visit during the planning stage is essential in ensuring that all site details are taken into account. As an example, knowledge of the site layout gained by a walk-through of the site might permit the planning of storage locations, an indication of any potential difficulties that might arise with delivery of stock, or highlight any risks to the scaffold posed by vehicles on- or off-site. Regular visits by persons responsible for safety can alert them to safety issues that need to be resolved. These visits also provide an opportunity for workers to discuss safety issues.

B.3 Are measures taken in a method statement & during work to prevent falling material?
Falling material can be one of the more common causes of injury. There are a number of measures that can reduce the risk. Toe-boards must be fitted. Brick-guards and netting should be fitted when building material or tools are present on the scaffold. The restriction of access underneath the scaffold and proper scheduling of work can prevent situations in which workers on the scaffold present a risk to people below. The handling of scaffold components and equipment in a controlled way they are moved up or down levels can reduce risk.
**B.4 Are measures taken in a method statement & during work to prevent persons falling?**

There is an ever-present risk of persons falling from scaffolds. Measures must be planned to reduce it. Edge protection (permanent and temporary) should be fitted. Fall arrest equipment should be used when erecting, altering and dismantling scaffolds. Fall arrest equipment includes harnesses and suitable attachment points for lanyards. Trip hazards on working lifts will need to be avoided by good housekeeping and by making sure that boards are flush on the working lifts.

**B.5 Are measures taken in a method statement & during work to avoid overload of the scaffold?**

Again, this is one of the more common causes of scaffold collapse. The rating of the scaffold must be compatible with the loads (this is something that was addressed earlier in A(ii)6). Of equal importance is a work method that does not require excessive temporary or long-term storage of material on the structure (scaffold components; other work equipment; material from demolition).

**B.6 Are measures taken in a method statement & during work to avoid unauthorised scaffold alterations?**

Some incidents of unsafe scaffolds occur because workers unskilled in scaffolding alter the structure. Usually workers make these alterations so that they can continue with their work unhindered. Ties are particularly susceptible to removal.

There are a number of ways to reduce the frequency of unauthorised alterations:

- Site inductions and toolbox talks can emphasise that untrained workers must not make alterations without the consent of their supervisor or site agent.
- There should be a system on site that makes it easy for workers using the scaffold to get desired alterations made by a competent person. Workers should know who to approach to request alterations. Alterations should be made quickly in response to a request.
- If there is not a trained scaffolder permanently on site then arrangements may be made with the scaffold contractor for regular modifications as required. For example, requests may be made one day and completed the next day by a visiting scaffolder.

**B.7 Are measures taken in a method statement & during work to avoid public interference?**

Scaffolds are often erected in public places where there are potential risks to passers-by. Children playing on or around the scaffold can be a problem. Public access to the scaffold can be prevented by site fencing or hoarding and by the removal of any means of accessing the scaffold at the close of work each day (e.g. removal of ladders, removal of boards on the lower lifts). When the scaffold is erected on
pavements, standards should be padded and trip hazards such as large base plates should be avoided. When scaffolds are placed close to roadways, the base of the scaffold should be protected by barriers and made conspicuous during day and night.

**B.8 Do site inductions, toolbox talks and contractor meetings include all necessary safety information?**

Toolbox talks provide an opportunity to discuss the progress of work in general and safety issues in particular. The frequency of toolbox talks and meetings will need to be sufficient to keep up with work progress and any changes in hazards on site. It is good policy to discuss safety issues first. These may include:

- Any new risks arising from the progress of work
- Scheduling and co-ordination between workers
- Clarification of any relevant procedures
- Any non-compliance with procedures that has been observed recently
- Any necessary clarification of responsibilities e.g. with respect to inspection duties
- Discussion of any recently occurring unsafe incidents or conditions and what can be learned from them

All workers coming onto site for the first time should have site inductions which include general site rules, how to report faults and how to request changes to a scaffold.

**B.9 Is an inspection and reporting system used to check equipment and scaffold for faults?**

In-house scaffold equipment and hired equipment will need to be checked for defects before use on site. The inspection programme will need to include a clear assignment of who is to make the inspections and a method of documenting inspections will be needed. Any defective equipment will need to be removed from service. The more common defects are:

- **Scaffold boards.** Defects are usually splits in the wood that reduce the strength of the board. Boards should be destroyed if there are any tyre marks or signs of excessive stress on the surface.
- **Ledgers.** Warped ledgers should be avoided because they can result in reduced overlap of transoms on ledgers.
- **Ladders.** Ladders used for access within scaffolds should be the correct rating. Ladders degrade with age due to cumulative damage to rungs and stiles through impact or exposure to the weather.
• **Staging.** The hooks on any prefabricated staging should be complete and undamaged.

Inspection should be made every seven days, whenever there has been significant structural alteration, and whenever there have been high winds. Each morning a visual check should be made before work commences on the scaffold. Ideally, there will be a notification to site personnel that the scaffold has been checked. A large proportion of scaffold companies has adopted a *Scafftag* system.

**B.10 Are the number and skills of your staff sufficient at all stages of the work?**

This question requires consideration of all phases of the scaffold lifetime. It concerns skills and experience, as well as the number of staff. A minimum number of staff is required for completing certain tasks safely. B.10 is also concerned with the level of supervision necessary to ensure workers are properly supervised. For example, will supervision be sufficient on the most difficult tasks, perhaps when supervisors themselves are involved in the work? If the answer is no, the following options apply.

- **Provide more in-house staff:** This is a simple solution if staff are available.
- **Train/re-train staff if their expertise is insufficient:** This may be costly and time may not permit it.
- **Hire in labour for all or some of the work:** This may come with difficulties in achieving control over staff on site and ensuring communication and co-ordination among staff.
- **Simplify the proposed scaffold so that it is within the capability of staff:** This may not be possible under the brief, but if it is chosen then you should review Steps A.3 to A.8 and Steps B.2 to B.7.

After B.10, go to Part C for erecting, using and dismantling the scaffold.
Part C. Hand-over of the scaffold

In the hand-over stage the responsibility for the completed scaffold is transferred from one contractor to another. The stage is important because it offers the opportunity for exchange of information that would avoid the more common causes of scaffold collapse such as overload and unsafe alteration of the scaffold. Part C may be used whenever the responsibility for the scaffold is exchanged, including instances when the user hands the scaffold back to the scaffolder.

C.1 Is there an agreement for making scaffold alterations or for seeking advice after hand-over?
There are a large number of scaffolds that collapse each year because alterations are made by staff unskilled in scaffolding. Often contractors working on the scaffold are under time pressure and they are reluctant to wait for a scaffolder to make what appear to be simple and safe alterations. Ensuring that alterations are made swiftly on request and by trained personnel is therefore essential. As far as possible the schedule of the more predictable alterations should be agreed in advance of hand-over. In addition, a simple procedure should be adopted on site so that requests for alteration are made to a nominated person, who passes that information on to the scaffold contractor. The frequency of visits necessary by a scaffolder will depend upon the number and urgency of requested changes. On projects where the scaffold is continually changing there may be a need for a scaffolder to remain on site throughout particular periods.

C.2 Has a final check shown the scaffold is safe for use (or modification / dismantling)?
The scaffold must be checked before being handed over for use or before dismantling or modification begins. The check should be thorough.

C.3 Are you aware of the limits of the scaffold?
The scaffold user should be in no doubt about the safe working load of the scaffold. The scaffold contractor should provide information about local and overall safe working loads. The same applies to any other precautions relevant to the use of the particular scaffold. Ideally the safe working load would be expressed in a meaningful way in terms of the safe maximum amount of building material (e.g. number of blocks / bricks) or number of workers that the scaffold can support. When the scaffold is being handed-over to the scaffold contractor for dismantling or modification, the scaffold contractor should be given any information about changes to the scaffold that may have affected its performance.
C.4 Has responsibility been accepted for the safe use (or dismantling / modification) of the scaffold?
Whichever contractor(s) is / are working on the scaffold must be in no doubt that they have responsibility for its safe use.

C.5 Has the user been cautioned on making changes to the scaffold without the scaffolder’s consent?
The contractor using the scaffold and the site agent should be aware that alterations to the scaffold must not be made without the consent of a person trained in scaffolding. Ideally, the scaffold contractor would make this clear at the time of hand-over and provide cautions against the following:

- Removal of ties or bracing
- Moving / removing hop-ups
- Adding extra working lifts
- Fitting extra hoists
- Moving any access points
**PocketSCAFPASS:**

*Scaffold Planning for Access System Safety*

PocketSCAFPASS is a pocket-sized set of flow charts that makes work with scaffolds safer by providing guidance on best practice. It is designed for scaffolders, workers using the scaffold, safety advisers, site agents and planners - in short, most of the people involved with scaffolds.

PocketSCAFPASS has three parts. Each Part has a number of Steps. You should select the appropriate Part and move through the Steps in order, ensuring that as far as reasonably practicable you can answer yes to each one.

Part A is used when **Bidding for work with scaffolds** or **Choosing a contractor** (select the appropriate version). Part B is for **Planning, erecting, using or dismantling scaffolds**. It is important that Part B is used continuously during planning, erecting, using or dismantling scaffolds.

Part C is used whenever there is a **Hand-over of the scaffold** either from scaffoldor to scaffold user, or in the opposite direction from scaffold user to scaffoldor.

The Steps in SCAFPASS are colour coded. Blue indicates particular relevance to site agents, planners, designers and contract managers. Green indicates particular relevance to scaffolders and workers using the scaffold. Black indicates more equally shared responsibility.

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### Part A(i)

**Choosing a contractor**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1</td>
<td>Must work be done at height from a scaffold?</td>
</tr>
<tr>
<td>A.2</td>
<td>Have the potential contractors been screened on their competence to do the work?</td>
</tr>
<tr>
<td>A.3</td>
<td>Has a clear brief for the scaffold been presented, including hazards for the scaffold?</td>
</tr>
</tbody>
</table>

**Puts out to tender**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.4</td>
<td>Have the bids been evaluated on health and safety content, including their risk</td>
</tr>
<tr>
<td>A.5</td>
<td>Does the proposed scaffold in the bids meet the requirements of your brief?</td>
</tr>
<tr>
<td>A.6</td>
<td>On the basis of Steps A.4 &amp; A.5, is there a competent contractor at a reasonable cost?</td>
</tr>
</tbody>
</table>

**GO TO PART B**

### Part A(ii)

**Bidding for work with scaffolds**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1</td>
<td>Has a detailed brief for the scaffold and/or work been established?</td>
</tr>
<tr>
<td>A.2</td>
<td>Can the brief be simplified to make the proposed scaffold or work safer?</td>
</tr>
<tr>
<td>A.3</td>
<td>Is the proposed scaffold a standard scaffold (i.e., not a special scaffold)?</td>
</tr>
<tr>
<td>A.4</td>
<td>Has a preliminary risk assessment considered the principal hazards and risks?</td>
</tr>
<tr>
<td>A.5</td>
<td>Have preliminary controls been considered for these risks?</td>
</tr>
<tr>
<td>A.6</td>
<td>Is the proposed scaffold compatible with the expected loads?</td>
</tr>
<tr>
<td>A.7</td>
<td>Is the proposed scaffold compatible with the supporting structure and foundations?</td>
</tr>
<tr>
<td>A.8</td>
<td>Is the proposed scaffold compatible with the proposed staff?</td>
</tr>
<tr>
<td>A.9</td>
<td>Will the proposed scheduling be compatible with the work of other contractors on-site?</td>
</tr>
</tbody>
</table>

**GO TO PART B**

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1 Based on the more detailed SCAFPASS.
APPENDIX I(a): Supervisor PocketSCAFPASS (contd.)

**Part B**
Planning, erecting, using & dismantling scaffolds

- **B.1 Know who to talk to about safety concerns?**
  - IF NO: see overleaf

- **B.2 Wish to raise any safety concerns?**
  - IF NO, make concerns known to supervisor or person in B.1

- **B.3 Prevent risk of material falling?**
  - IF NO, use netting, brick guards, no-access zones, or perimeter

- **B.4 Prevent risk of workers falling?**
  - IF NO, use harnesses, guard rails, toe-boards, or netting; use proper access.

- **B.5 Know the scaffold’s maximum load?**
  - IF NO: see overleaf

- **B.6 Non-scaffolders only:** Leave ties, hop-ups, couplers alone?
  - IF NO: report it to your supervisor
  - See Part C Overleaf

- **B.7 Prevent public access to scaffold?**
  - IF NO, use fencing, remove ladders & lowest boards at end of day

- **B.8 Attend induction & toolbox talks?**
  - IF NO, make sure you go to them

- **B.9 Inspect scaffold? Report faults?**
  - IF NO, start. If no inspection routine on site talk to supervisor/person in B.1

- **B.10 Clear about how to do the work?**
  - IF NO, talk to your supervisor

**START WORK**

**Part C**
Hand-over of the scaffold

- **C.1 Clear on how changes to scaffold are requested and made?**
  - IF NO: see overleaf

- **C.2 Inspection shows scaffold is safe for access?**
  - IF NO: do not work until scaffold is checked

- **C.3 Clear on scaffold’s maximum load?**
  - IF NO: request this information. See below

- **C.4 Contractors receiving scaffold: Know scaffold is now your responsibility?**
  - IF NO: ensure that you and all working on scaffold know this

- **C.5 Know to leave ties, hop-ups, couplers alone, unless you’re a trained scaffolder?**
  - IF NO: discuss schedules to ensure they are compatible

**MAKE HAND-OVER.**

If you have safety concerns, see:

**For changes to the scaffold, see:**

**Scaffold’s maximum load per bay:**

- 1 man + tools (inspection / very light duty)
- 2 men + 175kg (light duty)
- 1 man + 350kg (general purpose)
- 2 men + 250kg (heavy duty)
- Other:

---

**Notes**
APPENDIX I(b): USER PocketSCAFPASS

PocketSCAFPASS: Scaffold Planning for Access System Safety

PocketSCAFPASS is a pocket sized set of flow charts that makes work with scaffolds safer by providing guidance on best practice. It is designed for scaffolders, workers using the scaffold, safety advisers, site agents and planners - in short, most of the people involved with scaffolds.

PocketSCAFPASS has three parts. Each Part has a number of Steps. This version contains Parts B and C and is aimed especially at scaffolders and workers using the scaffold.

It is important that Part B is used continuously during planning, erecting, using or dismantling scaffolds.

Part C is used whenever there is a Hand-over of the scaffold either from scaffolder to scaffold user, or in the opposite direction from scaffold user to scaffolder.

The Steps in SCAFPASS are colour coded. Blue indicates particular relevance to site agents, planners, designers and contract managers. Green indicates particular relevance to scaffolders and workers using the scaffold. Black indicates more equally shared responsibility.

1 Based on the more detailed SCAFPASS.

---

Part B
Planning, erecting, using & dismantling scaffolds

8.1 KNOW WHO TO TALK TO ABOUT SAFETY CONCERNS?
IF NO, see overleaf

8.2 WISH TO RAISE ANY SAFETY CONCERNS?
IF NO, make concerns known to supervisor or person in B.1

8.3 PREVENT RISK OF MATERIAL FALLING?
IF NO, use netting, brick guards, no-access zones, or perimeter

8.4 PREVENT RISK OF WORKERS FALLING?
IF NO, use harnesses, guard rails, toe-boards, or netting; use proper access.

8.5 KNOW THE SCAFFOLD’S MAXIMUM LOAD?
IF NO, see overleaf

8.6 Non-scaffolders only:
Leave ties, hop-ups, couplers alone?
IF NO, report it to your supervisor
See Part C Overleaf

8.7 Prevent public access to scaffold?
IF NO, use fencing; remove ladders & lowest boards at end of day

8.8 ATTEND INDUCTION & TOOLBOX TALKS?
IF NO, make sure you go to them
IF NO, start. If no inspection routine on site talk to supervisor/person in B.1

8.9 INSPECT SCAFFOLD? REPORT FAULTS?
IF NO, clear about how to do the work

8.10 CLEAR ABOUT HOW TO DO THE WORK?
IF NO, talk to your supervisor

START WORK

---

Part C
Hand-over of the scaffold

C.1 CLEAR ON HOW CHANGES TO SCAFFOLD ARE REQUESTED AND
IF NO, discuss and agree on this, if possible. See below.

C.2 INSPECTION SHOWS SCAFFOLD IS SAFE FOR ACCESS?
IF NO, do not work until scaffold is checked

C.3 CLEAR ON SCAFFOLD’S MAXIMUM LOAD?
IF NO, request this information. See below

C.4 Contractors receiving scaffold:
Know scaffold is now your responsibility?
IF NO, ensure that you and all working on scaffold know this

C.5 KNOW TO LEAVE TIES, HOP-UPS, COUPLERS ALONE, UNLESS YOU'RE A TRAINED SCAFFOLDER?
IF NO, ensure that you and all others know this

C.6 CONTRACTORS WORKING TOGETHER WILL MAKE HAND-OVER.
IF NO, discuss schedules to ensure they are compatible

MAKE HAND-OVER.

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Notes

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What is PocketSCAFPASS?
The name SCAFPASS is shorthand for Scaffold Planning for Access System Safety. PocketSCAFPASS is a laminated pocket sized set of simple flow charts covering important safety points for planning, erecting, using and dismantling temporary access scaffold.

Accidents on or around access scaffolds usually happen because of simple errors, for example guard-rails not present or ties missing. While there are checklists aimed at identifying these faults once they occur, PocketSCAFPASS anticipates problems by improving the management of safety at an early stage and at all stages of work.

What are the Parts to PocketSCAFPASS?
This version of PocketSCAFPASS is for persons directly involved in the erection and use of scaffolds, typically supervisors of scaffold teams and contractors working from the scaffold.

Part B is a sequence of Steps for planning, using, erecting and dismantling scaffolds.
Part C is a sequence of Steps for the hand-over of the scaffold when it is being exchanged between contractors.

How is PocketSC AFPASS used?
Use the questions to remind you of issues as work progresses. This is particularly important when erecting, using and dismantling scaffolds.

Part B. Planning, erecting, using and dismantling scaffolds
This Part of PocketSCAF PASS addresses ten important issues that must be considered before (planning) and during (erecting; using; dismantling) the work.

B.1 Know who to talk to about safety concerns?
Check that you know who is person responsible for health and safety on site, and this person should be able to resolve health and safety problems swiftly. Make a note of this person's name on the space at the bottom of Part C.

B.2 Wish to raise any safety concerns?
This is a reminder that you, as well as your employer, have responsibilities for safety. Look at the work area, is it safe? If there are any questions speak to your supervisor or the person responsible for health and safety.

B.3 Prevent risk of material falling?
Falling is one of the more common causes of injury. Toe-boards must be fitted. Brick-guards and netting should be fitted when building material or tools are on
the scaffold. Restrict access underneath the scaffold, schedule work carefully and handle of scaffold components and equipment safely when moved up or down levels to reduce risk.

**B.4 Prevent risk of workers falling?**
There is an ever-present risk of persons falling from scaffolds. Edge protection (permanent and temporary) should be fitted. Fall arrest equipment should be used when erecting, altering and dismantling scaffolds. Fall arrest equipment includes harnesses and suitable attachment points for lanyards. Avoid trip hazards by good housekeeping and by making sure that boards are flush on the working lifts.

**B.5 Know the scaffold's maximum load?**
This is one of the more common causes of scaffold collapse. Check you know what the loads mean (see C) Reduce excessive temporary or long-term storage of material on the structure (scaffold components; other work equipment; material from demolition).

**B.6 Non-scaffolders only: Leave ties, hop-ups, couplers alone?**
Accidents occur because workers unskilled in scaffolding alter the structure. Leave well alone.

**B.7 Prevent public access to scaffold?**
Prevent public access by site fencing or hoarding and by the removal of any means of accessing the scaffold at the close of work each day (e.g. removal of ladders, removal of boards on the lower lifts). When the scaffold is on pavements, pad standards and avoid trip hazards such as large base plates. When scaffolds are placed close to roadways, the base of the scaffold should be protected by barriers and made conspicuous during day and night.

**B.8 Attend induction & toolbox talks?**
Go to the Toolbox talks and listen for safety issues such as:
- Any new risks arising from the progress of work
- Scheduling and co-ordination between workers
- Clearing up any questions about parts of work
- Checking responsibilities e.g. with respect to inspection duties
- Discussing any recent unsafe incidents/ conditions and lessons to be learnt

**B.9 Inspect scaffold? Report faults?**
If there is no inspection, speak to supervisor. Check for the more common defects:
- **Scaffold boards**: usually splits in the wood. Destroy boards with tyre marks or signs of damage on the surface.
- **Ledgers**: Avoid warped ledgers - reduced overlap of transoms on ledgers.
- **Ladders**: correct rating of ladders Check for ageing, damage to rungs and stiles or by exposure to the weather.
- **Staging**: The hooks on any prefabricated staging should be complete and undamaged.
Inspections should be made every seven days, with any significant structural alteration, and whenever there have been high winds. Each morning a visual check should be made before work commences on the scaffold.

**B.10 Clear about how to do the work?**
If there are any questions about the job, ask. Its better to ask than be hurt or hurt someone else.

*After B.10, go to Part C for erecting, using and dismantling the scaffold.*

---

**Part C. Hand-over of the scaffold**

The hand-over stage is important because of exchange of information that would avoid more common causes of scaffold collapse such as overload and unsafe alteration. Part C is used whenever the responsibility for the scaffold is exchanged, including when the user hands the scaffold back to the scaffolder.

**C.1 Clear on how changes to scaffold are requested and made?**
Who do you need to talk to get alterations made? Know what needs to be done to request the alteration.

**C.2 Inspection shows scaffold is safe for access?**
The scaffold must be checked before being handed over for use or before dismantling or modification begins. The check should be thorough.

**C.3 Clear on scaffold’s maximum load?**
You should be in no doubt about the safe working load of the scaffold. If in doubt ask and make a note at the bottom of Part C.

**C.4 Contractors receiving scaffold: Know scaffold is now your responsibility**
Whichever contractor(s) is / are working on the scaffold have responsibility for its safe use.

**C.5 Know to leave ties, hop-ups, couplers alone, unless you’re a trained scaffolder?**
You must not make alterations to the scaffold without the consent of a person trained in scaffolding. Do not:
- Remove of ties or bracing
- Move / remove hop-ups
- Add extra working lifts
- Fit extra hoists
- Move any access points

**C.6 Contractors working together will co-ordinate safely?**
Check who is doing what near to you.
How was PocketSCAFPASS for you?

The laminated flow-chart cards, called PocketSCAFPASS, that you have just used is a summarised version of the detailed aide called SCAFPASS (provided as a reference) and was designed for all people working with scaffolds. Heriot-Watt University and the Health and Safety Executive developed it to put across the basic safety issues when working at height with scaffold structures. There are fifteen questions below that will take only a few minutes to answer, and will reward you with a £5 postal order when returned in the stamped addressed envelope provided. Your answers will help us with improving the flow-chart and people’s safety.

Please provide the following information then please tick the box or boxes below that apply in each question.

Building trade experience..............years Scaffold training Level............Job Title..............................................
Name..........................................................Address (for Postal Order)......................................................

<table>
<thead>
<tr>
<th>First Impressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Which part(s) of the flow-chart were you using? <em>(This is the letter in the top right of the card)</em></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

|   | Very simple |
|   | Simple |
|   | Some bits complicated, some simple |
|   | Complicated |
|   | Very complicated |

Have you any Comments?

|   | Very difficult |
|   | Difficult |
|   | Some bits difficult, some easy |
|   | Easy |
|   | Very easy |

If you experienced any difficulty with the instructions, which bits were difficult? Write the phrase(s) below.
### How You Used The Decision Aid

4. Although it may be hard to remember, how often in a week would you say you looked at the flow-chart during work?
   - Never - Go to question 8
   - Only once or twice in a week
   - Every other day or so
   - Every day
   - More than once a day

Have you any Comments?

5. The flow-chart can be used in different ways. Which of the following best describes how you used it?
   - Continually as I progressed in work
   - As a checklist at the end of a period of work
   - Occasionally to jog my memory
   - Only once because I knew most of the issues already
   - Other - Please state here:

Have you any Comments?

6. Could you remember information from the flow-chart without having to look at it?
   - Yes
     - No - Go to question 8 after giving reason if possible

If No, any reason?

7. How often did you apply issues in the flow-chart without having to look at it? (If you had problems using it because of the work during the trial, please say why)
   - More than once a day
   - Every day
   - Every other day or so
   - Only once or twice in a week
   - Never

Have you any Comments?
8. How do you rate the ease or difficulty of use of the flow-chart(s)?
   - Very easy to use
   - Easy to use
   - Some difficulty in use
   - Difficult to use
   - Very difficult to use

   Which steps, if any, did you find difficult to use? *(List the letter and number, e.g. A2, B6)*

9. How do you rate the length of the flow-chart(s)?
   - Much too short
   - Too short
   - About right
   - Too long
   - Much too long

   Have you any Comments?

10. How do you rate the content of the flow-chart(s)?
    - All important issues are included
    - Nearly all the important issues are included
    - Some of the important issues are included
    - Only a few of the important issues are included
    - Very few or none of the important issues are included

    Have you any Comments?

11. Were there any phrases or terms that you think are not appropriate or you didn’t understand?
    - Yes
    - No

    If yes, please list them here:
### Effects Of The Decision Aid

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 12. Do you think the flow-chart(s) would improve safety in scaffold work for you and your company? | - Definitely yes
- Probably yes
- Unsure
- Probably no
- Definitely no |
| Have you any Comments?                                                   |                                              |

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 13. Do you think widespread use of the flow-chart(s) in scaffold companies would improve safety on sites with scaffolds? | - Definitely yes
- Probably yes
- Unsure
- Probably no
- Definitely no |
| Have you any Comments?                                                   |                                              |

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 14. Would you recommend the flow-chart(s) to others?                     | - Definitely yes
- Probably yes
- Unsure
- Probably no
- Definitely no |
| If unsure, no or not, why not?                                           |                                              |

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 15. The HSE is considering publishing a set of flow-charts like the one you used. Scaffold companies would be invited to use them on a voluntary basis. If one was published do you think your company would use it? | - Definitely yes
- Probably yes
- Unsure
- Probably no
- Definitely no |

Thank you for your time in helping us with our work and enjoy the £5 postal order.
APPENDIX J: MODELLING THE RELIABILITY OF A SIMPLE SCAFFOLD USING EXPERT JUDGEMENT

J.1 AIMS AND INTRODUCTION

SCAFPASS includes a section advising proper checks on the scaffold. A scaffold checklist is an indispensable tool for making the inspections. The checklist should prioritise the types of faults most likely to compromise the integrity of the structure. In larger scaffold structures where it can take a day or more to check the entire structure prioritisation within the checklist becomes increasingly important.

The following sections examine a simplified scaffold structure and attempt to put an order of prioritisation on faults and combinations of faults. This data may be used to construct a scaffold checklist that can be used as part of the SCAFPass package.

Modelling failures in scaffolds can supplement accident data in identifying where the major risks exist in scaffolds. The use of expert opinion may facilitate the modelling process by providing overall estimates of the likelihood of operators committing different errors and the likely consequences of the errors for the safety of site staff and public. The aims of the modelling exercise were to provide indices of:

a) relative importance of specific faults for the scaffold, and,
b) the likelihood of specific faults leading to injury

J.2 SIMPLIFICATION OF SCAFFOLD FAULTS

As a simplification, scaffold-related faults categorised:

a) Faults within the integral structure of the scaffold that cause the scaffold partially or completely to collapse, i.e. structural faults.

b) Faults within the sub-structure, which allow an object or person to fall from the scaffold or an external element (person, vehicle) to interfere with the scaffold. These could be called barrier faults.

J.2.1 Structural faults

Generally, scaffolds collapse due to more than one structural fault distributed within the scaffold, and which have a negative effect on structural integrity that is greater than the sum of the individual faults had they occurred singly. On this basis, certain combinations of structural faults can be assumed as more likely to result in scaffold collapse. Collapses occurring due to structural faults can be divided into mutually exclusive categories which we will call peeling and lozenging collapses. Peeling collapses involve the scaffold toppling over in an initial direction that is normal to the façade: the overall force is in a direction away from the façade. Lozenging collapses involve the scaffold folding with a movement along the façade: the overall force is in a direction parallel to the façade. The division of potential causes according to the type of collapse limits the number of fault combinations that must be examined and makes the modelling exercise manageable.

Peeling collapse
- Foundations subside
- Load exceeds safe working load
- Unstable supporting structure
- Tie(s) is/are insecure or absent

Lozenging collapse
- Foundations subside
- Load exceeds safe working load
- Unstable supporting structure
- Longitudinal brace(s) is/are insecure or absent

Ledger brace(s) is/are insecure or absent
J.2.2 Barrier faults

The principal barrier failures include faults or omissions in harnesses, edge protection, netting, and traffic restrictions. Certain component defects are also included, notably broken scaffold boards. The effect of these faults is regarded simply as additive: the effects of two faults occurring together will not have a disproportionate effect on safety in the same way as structural faults.

J.3 PROBABILITIES USED IN THE ANALYSIS

To make an analysis, two sets of estimates were required. The first set concerns the likelihood of a specific fault or combination of faults being present on the scaffold, \( P(fault) \). The second set concerns the likelihood that a fault or combination of faults, when present, will result in injury, \( P(injury/fault) \), i.e. the probability of injury given (/) that the fault is present. The probability that a scaffold will have a specific fault and that it will then lead to injury is the product of \( P(fault) \) and \( P(injury/fault) \), referred to as \( P(overall) \).

Assuming statistical independence of faults, \( P(fault) \) for a two-fault combination may be calculated as the product of the two single fault probabilities. Independence of faults assumes that for two faults A and B, the presence of fault A does not effect the likelihood of finding fault B. That assumption may not be accurate in reality and some level of dependence between faults will exist.

J.4 METHOD

J.4.1 Participants

Eight experts were selected to provide estimates for a list of faults. Their area of expertise was health and safety management in construction; together they held 130 years of experience in the construction industry. All participants had experience with inspecting scaffolds and working on sites involving scaffolds. They were not paid for their participation.

J.4.2 Procedure

A postal questionnaire requested estimates of \( P(fault) \) for 22 single faults and ratings of the riskiness for 37 single faults or fault combinations. The questionnaire is shown in Appendix K. Estimates were requested with reference to an independent, tied, tube-and-fitting scaffold of four lifts (one working lift) and four bays. The faults that were examined were drawn from a range of faults previously compiled in a HAZOP study, as well from the faults represented in the accident and incident analyses.

Respondents selected their estimates of \( P(fault) \) from a list of 18 discrete decimalised probabilities, each with a corresponding 1 in X statement, e.g. 0.01 was accompanied by the explanation “one in a hundred scaffolds”. This list is given in Appendix L. Only estimates for single faults were requested.

Due to the difficulty of making 37 estimates of \( P(injury/fault) \), figures for \( P(injury/fault) \) were calculated indirectly from estimates of the riskiness of faults and fault combinations. These ratings were made on an 11-point scale from 0 (“not at all risky”) to 10 (“extremely risky”) – a scale adapted from Slovic, MacGregor, and Kraus (2001) who used the same anchor points to address the risk of a selection of automobile faults.

The estimates for riskiness were assumed proportional to the logarithm of \( P(injury/fault) \), so that:
Log $P(\text{injury/fault}) = a \, R_{\text{injury}} + b$, where:

where $R_{\text{injury}}$ is the mean rating on the scale 0 to 10 of the risk of injury given that the fault is present; and $a$ and $b$ are constants.

For six specific faults the absolute probability $P(\text{injury/fault})$ was requested, allowing log-linear regression to estimate $a$ and $b$, and subsequently the 37 values for $P(\text{injury/fault})$. The method avoided a large number of absolute probability judgements and replaced them with the easier task of rating risk on an 11-point scale.

**J.5 RESULTS**

**J.5.1 Consistency Among Experts and Differences in Ratings Across Fault Types**

The set of $P(\text{fault})$ for 22 faults was submitted to two factor analysis of variance with factors expert and fault type. Statistically significant differences were apparent for fault type [$F(21, 147)=2.64; \, p<0.001$] suggesting that $P(\text{fault})$ differed according to the type of fault – as would be expected. Significant differences existed for expert [$F(7,147)=7.97; \, p<0.001$], suggesting a lack of unanimity across the eight judges in the estimates they provided.

An analysis of variance on the set of estimates for riskiness of 33 faults and fault combinations again showed statistically significant effects for fault type [$F(32,224)=7.79; \, p<0.001$] and a significant effect for expert [$F(7,224)=8.82; \, p<0.001$]. Once again, this suggested there were differences in estimates for riskiness across faults and a lack of unanimity among experts in the estimates they provided.

**J.5.2 Converting Estimates of Riskiness to Probabilities**

The estimates of riskiness may be viewed as the rated likelihood that injury to workers or the public will occur given that a fault or a combination of faults is present. As mentioned above, six absolute estimates for $P(\text{injury/fault})$ had been sought in order to convert risk ratings to probabilities by log-linear regression. The geometric means for these six estimates were:

- 1 tie is missing (0.00345);
- 1 longitudinal brace is missing (0.00259);
- All longitudinal braces are missing (0.05157);
- Safe working load of any part or all of the scaffold is exceeded by 50% (0.03867);
- Edge protection is not fitted (0.01778);
- Traffic margins for work and public vehicles are not considered (0.03448)

Log-linear regression used the log of these six points as the dependent variable and the mean estimates of riskiness as the independent variable. The regression was statistically significant [$F(1,5)=26.8; \, p<0.001$], providing a better fit (higher $R^2$) than a linear model. Values of $a$ and $b$ were estimated as 0.23 and –3.59. Values for $P(\text{injury/fault})$ were calculated accordingly for all mean ratings of riskiness.

**J.5.3 Geometric Means for $P(\text{fault})$ and Arithmetic Means for Riskiness and $P(\text{injury/fault})$**

Table XX shows the estimates provided by the eight experts. The geometric means for $P(\text{fault})$ of single faults are generally very low, ranging from 0.16 (a defective scaffold board) to $1.1 \times 10^{-4}$ (no ties are fitted during erection of the scaffold). For two-fault combinations $P(\text{fault})$ appears in brackets because it has been calculated as the product of two probabilities under the assumption of independence. Here $P(\text{fault})$ ranges from $7.30 \times 10^{-4}$ (1 tie missing and 1 ledger
brace missing) to \(2.1 \times 10^{-7}\) (all ties missing and all ledger braces missing). \(P(\text{fault})\) for fault combinations are very low, and possibly unrealistically low, because of the assumption of independence.

The ratings of risk in Table XX are arithmetic means of eight individual estimates for each fault. They range from 10.00 (all ties missing with all ledger braces missing; all ties missing with significant resettlement of foundations) to 4.00 (one tie being removed; one tie not being fitted).

The transformed estimates of riskiness in the form of \(P(\text{injury/fault})\) range from \(4.7 \times 10^{-2}\) (all ties missing and all ledger braces missing; all ties missing and significant resettlement of lower standards) to \(2.1 \times 10^{-3}\) (a tie is removed when it should not be; a tie is not fitted during erection of the scaffold). Finally, the fifth column, \(P(\text{overall})\), shows absolute probabilities of injury for faults and fault combinations; it is calculated as the product of \(P(\text{fault})\) and \(P(\text{injury/fault})\). The highest values of \(P(\text{overall})\) belong to single faults such as a defective scaffold board \((3.4 \times 10^{-3})\), 50% overload \((1.6 \times 10^{-3})\), a defective attachment of scaffold board \((1.1 \times 10^{-3})\), deficient traffic margins \((7.4 \times 10^{-4})\), and poorly fitted edge protection \((6.5 \times 10^{-3})\).

With reference to Table J.1, the main findings of the modelling exercise were:

The top five probabilities of occurrence were rated as:
- Defective scaffold board
- Defective attachment of staging
- A ledger brace is not fitted
- The safe working load of any part or all of the scaffold is exceeded by 50%
- Edge protection is poorly fitted

The top five risks were associated with:
- All ties missing AND significant resettlement of lower standards
- All ties missing AND all ledger braces missing
- All ties are removed when they should not be
- No ties are fitted during erection of the scaffold
- All ties missing AND 1 ledger brace missing

The faults most likely to cause injury were rated as:
- Defective scaffold board
- The safe working load of any part or all of the scaffold is exceeded by 50%
- Defective attachment of staging
- Traffic margins for work and public vehicles are not considered
- Edge protection is poorly fitted
<table>
<thead>
<tr>
<th>Fault</th>
<th>Fault: Peeling Lozenge or Barrier</th>
<th>Effect (calculated values in brackets)</th>
<th>Risk</th>
<th>P(fault) calculated from risk rating</th>
<th>P(overall)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ties missing AND significant resettlement of lower standards</td>
<td>P</td>
<td>(3.43E-06)</td>
<td>10.00</td>
<td>4.71E-02</td>
<td>1.61E-07</td>
<td>38</td>
</tr>
<tr>
<td>All ties missing AND all ledger braces missing</td>
<td>P</td>
<td>(2.10E-07)</td>
<td>10.00</td>
<td>4.71E-02</td>
<td>9.90E-09</td>
<td>39</td>
</tr>
<tr>
<td>All ties are removed when they should not be</td>
<td>P</td>
<td>1.30E-04</td>
<td>9.88</td>
<td>4.41E-02</td>
<td>5.72E-06</td>
<td>29</td>
</tr>
<tr>
<td>No ties are fitted during erection of the scaffold</td>
<td>P</td>
<td>1.06E-04</td>
<td>9.88</td>
<td>4.41E-02</td>
<td>4.68E-06</td>
<td>31</td>
</tr>
<tr>
<td>All ties missing AND 1 ledger brace missing</td>
<td>P</td>
<td>(1.18E-05)</td>
<td>9.88</td>
<td>4.41E-02</td>
<td>5.22E-07</td>
<td>34</td>
</tr>
<tr>
<td>All ledger braces are not fitted</td>
<td>P</td>
<td>8.92E-04</td>
<td>9.75</td>
<td>4.13E-02</td>
<td>3.69E-05</td>
<td>22</td>
</tr>
<tr>
<td>All ties missing AND general overload of the scaffold by 50%</td>
<td>P</td>
<td>(9.94E-06)</td>
<td>9.75</td>
<td>4.13E-02</td>
<td>4.11E-07</td>
<td>37</td>
</tr>
<tr>
<td>The safe working load of any part or all of the scaffold is exceeded by 50%</td>
<td>L/P</td>
<td></td>
<td>2.22E-02</td>
<td></td>
<td>1.63E-03</td>
<td>2</td>
</tr>
<tr>
<td>The wall or building supporting the scaffold is locally or generally unstable</td>
<td>L/P</td>
<td></td>
<td>1.83E-03</td>
<td></td>
<td>7.08E-05</td>
<td>19</td>
</tr>
<tr>
<td>All façade braces are not fitted</td>
<td>L</td>
<td>7.95E-04</td>
<td>9.63</td>
<td>3.87E-02</td>
<td>3.08E-05</td>
<td>24</td>
</tr>
<tr>
<td>All ledger braces missing AND general overload of the scaffold by 50%</td>
<td>P</td>
<td>(3.76E-05)</td>
<td>9.63</td>
<td>3.87E-02</td>
<td>1.46E-06</td>
<td>32</td>
</tr>
<tr>
<td>All longitudinal braces missing AND general overload of the scaffold by 50%</td>
<td>L</td>
<td>(3.35E-05)</td>
<td>9.63</td>
<td>3.87E-02</td>
<td>1.30E-06</td>
<td>33</td>
</tr>
<tr>
<td>All longitudinal braces missing AND significant resettlement of lower standards</td>
<td>L</td>
<td>(1.16E-05)</td>
<td>9.63</td>
<td>3.87E-02</td>
<td>4.48E-07</td>
<td>36</td>
</tr>
<tr>
<td>1 tie missing AND all ledger braces missing</td>
<td>P</td>
<td>(1.33E-04)</td>
<td>9.50</td>
<td>3.63E-02</td>
<td>4.83E-06</td>
<td>30</td>
</tr>
<tr>
<td>All ledger braces missing AND significant resettlement of lower standards</td>
<td>P</td>
<td>(1.30E-05)</td>
<td>9.50</td>
<td>3.63E-02</td>
<td>4.71E-07</td>
<td>35</td>
</tr>
<tr>
<td>Significant resettlement of lower standards AND general overload of the scaffold by 50%</td>
<td>L/P</td>
<td>(6.13E-04)</td>
<td>9.25</td>
<td>3.19E-02</td>
<td>1.95E-05</td>
<td>25</td>
</tr>
<tr>
<td>Defect in lifting apparatus such as a hoist</td>
<td>B</td>
<td>1.94E-02</td>
<td>9.13</td>
<td>2.98E-02</td>
<td>5.79E-04</td>
<td>6</td>
</tr>
<tr>
<td>1 tie missing AND general overload of the scaffold by 50%</td>
<td>P</td>
<td>(6.29E-03)</td>
<td>9.00</td>
<td>2.80E-02</td>
<td>1.76E-04</td>
<td>12</td>
</tr>
<tr>
<td>Traffic margins for work and public vehicles are not considered</td>
<td>B</td>
<td>2.82E-02</td>
<td>8.88</td>
<td>2.62E-02</td>
<td>7.39E-04</td>
<td>4</td>
</tr>
<tr>
<td>Edge protection is not fitted</td>
<td>B</td>
<td>4.60E-03</td>
<td>8.75</td>
<td>2.45E-02</td>
<td>1.13E-04</td>
<td>14</td>
</tr>
<tr>
<td>1 longitudinal brace missing AND general overload of the scaffold by 50%</td>
<td>L</td>
<td>(3.55E-04)</td>
<td>8.63</td>
<td>2.30E-02</td>
<td>8.15E-06</td>
<td>27</td>
</tr>
<tr>
<td>Defective scaffold board</td>
<td>B</td>
<td>1.59E-01</td>
<td>8.50</td>
<td>2.15E-02</td>
<td>5.42E-03</td>
<td>1</td>
</tr>
<tr>
<td>1 ledger brace missing AND general overload of the scaffold by 50%</td>
<td>P</td>
<td>(2.11E-03)</td>
<td>8.50</td>
<td>2.15E-02</td>
<td>4.56E-05</td>
<td>20</td>
</tr>
<tr>
<td>1 ledger brace missing AND significant resettlement of lower standards</td>
<td>P</td>
<td>(7.29E-04)</td>
<td>8.50</td>
<td>2.15E-02</td>
<td>1.57E-05</td>
<td>26</td>
</tr>
<tr>
<td>1 tie missing AND significant resettlement of lower standards</td>
<td>P</td>
<td>(2.17E-03)</td>
<td>8.38</td>
<td>2.02E-02</td>
<td>4.38E-05</td>
<td>21</td>
</tr>
<tr>
<td>Significant resettlement of lower standards occurs</td>
<td>L/P</td>
<td>1.45E-02</td>
<td>8.13</td>
<td>1.77E-02</td>
<td>2.58E-04</td>
<td>10</td>
</tr>
<tr>
<td>1 longitudinal brace missing AND significant resettlement of lower standards</td>
<td>L</td>
<td>(3.55E-04)</td>
<td>8.13</td>
<td>1.77E-02</td>
<td>6.28E-06</td>
<td>28</td>
</tr>
<tr>
<td>A coupler has not been tightened or is omitted between a ledger and standard</td>
<td>-</td>
<td>1.22E-02</td>
<td>8.00</td>
<td>1.66E-02</td>
<td>2.03E-04</td>
<td>-</td>
</tr>
<tr>
<td>Edge protection is poorly fitted</td>
<td>B</td>
<td>3.45E-02</td>
<td>7.88</td>
<td>1.89E-02</td>
<td>6.52E-04</td>
<td>5</td>
</tr>
<tr>
<td>Netting or sheeting is not fitted when the situation requires</td>
<td>B</td>
<td>3.08E-02</td>
<td>7.88</td>
<td>1.56E-02</td>
<td>4.78E-04</td>
<td>7</td>
</tr>
<tr>
<td>Defective attachment of staging</td>
<td>B</td>
<td>7.50E-02</td>
<td>7.75</td>
<td>1.46E-02</td>
<td>1.09E-03</td>
<td>3</td>
</tr>
<tr>
<td>Defective transom</td>
<td>B</td>
<td>5.96E-03</td>
<td>7.63</td>
<td>1.37E-02</td>
<td>8.14E-05</td>
<td>17</td>
</tr>
<tr>
<td>Defective ledger</td>
<td>B</td>
<td>6.69E-03</td>
<td>7.50</td>
<td>1.28E-02</td>
<td>8.55E-05</td>
<td>16</td>
</tr>
<tr>
<td>1 tie missing AND 1 ledger brace missing</td>
<td>P</td>
<td>(7.48E-03)</td>
<td>7.38</td>
<td>1.20E-02</td>
<td>8.97E-05</td>
<td>15</td>
</tr>
<tr>
<td>There are sufficient number of ties but they are not distributed correctly</td>
<td>-</td>
<td>9.17E-03</td>
<td>6.75</td>
<td>8.65E-3</td>
<td>7.93E-05</td>
<td>-</td>
</tr>
<tr>
<td>A ledger brace is not fitted</td>
<td>P</td>
<td>5.01E-02</td>
<td>5.88</td>
<td>5.48E-03</td>
<td>2.75E-04</td>
<td>9</td>
</tr>
<tr>
<td>A façade brace is not fitted</td>
<td>L</td>
<td>2.44E-02</td>
<td>5.88</td>
<td>5.48E-03</td>
<td>1.34E-04</td>
<td>13</td>
</tr>
<tr>
<td>A tie is removed when it should not be</td>
<td>P</td>
<td>1.33E-01</td>
<td>4.00</td>
<td>2.06E-03</td>
<td>2.75E-04</td>
<td>8</td>
</tr>
<tr>
<td>A tie is not fitted during erection of the scaffold</td>
<td>P</td>
<td>1.59E-02</td>
<td>4.00</td>
<td>2.06E-03</td>
<td>3.27E-05</td>
<td>23</td>
</tr>
</tbody>
</table>

Table J.1

Probability estimates of scaffold faults from eight experts – faults assumed independent

Note: The probabilities are calculated based on expert estimates and are presented in descending order of risk.
J.5.4 DISCUSSION AND SUMMARY

The modelling of the overall probability of failure of scaffolds relied on expert judgement of both the likelihood of different faults and the riskiness of those faults once they occurred. We converted ratings of riskiness to a probability, and defined the overall probability as the product of that probability with fault likelihood.

The top five probabilities of occurrence did not contain reference to ties but highlighted defects in the platform, ledger brace, safe working load and edge protection. These probabilities concern how likely it is that the faults occur. The ratings of riskiness addressed the risks posed by the faults once they have occurred. Here, ties feature in all top five risks and in three cases they appear in combination with other faults (resettlement of foundations; all ledger braces missing; one ledger brace missing).

When the overall probability of injury is calculated from these probabilities, defects in platforms again emerge as the leading cause. Overload, non-consideration of traffic margins and edge protection also appear in the top five. Ties do not feature in this list because of their low rating of probability of occurrence. Such low ratings are in stark contrast to the comments in the consultations reported earlier.
APPENDIX K: QUESTIONNAIRE USED IN EXPERT JUDGEMENT

Reducing injury on scaffolds

Statistics from the Health and Safety Executive (HSE) show that accidents on and around scaffolds account for a high proportion of injuries within the construction industry.

Researchers at Heriot-Watt University and Aberdeen University together with the HSE are researching methods of reducing accidents involving temporary access systems, particularly scaffolds. As part of the research we need estimates of the frequency of specific faults in scaffolds and the severity of the faults for the safety of workers and public.

We are asking people with experience in working on or around scaffolds to provide these estimates.

In answering the questions on the following pages, you should make any estimates with reference to a section of general-purpose, tube and fitting, independent tied scaffold 8m high, 8m long and four boards wide, with four bays and four lifts (two of which are working lifts). All ties are rated 6.25kN (ring ties, lip ties, through ties or reveal ties set behind a feature). Where the location of particular faults can vary, make your estimates with reference to the location where the severity of the fault is at a maximum.

Please read the questions carefully and rely on your experiences in the scaffold trade. In Parts 1 and 4 it is important that you use the accompanying Table entitled Probabilities and frequencies to select your estimates.

If you have any queries please feel free to call me. When completed please use the envelope provided to send the forms to:

Sean Whitaker  
School of Management  
Heriot-Watt University  
Edinburgh EH14 4AS

s.m.whitaker@hw.ac.uk  
Tel: 0131 451 3043  
Fax: 0131 451 3296

Once all participants have returned the booklet we may send out a second blank booklet with a list of the other participants’ estimates. This provides everyone the opportunity to revise their original estimates should they so wish.

Thank you for helping with this work.
**Part 1: Likelihood of finding particular faults in scaffolds**

This section asks you to estimate how often particular types of faults will occur in a large randomly selected group of scaffolds in the UK. You should make your estimate from the accompanying Table, *Probabilities and frequencies*, and write it in the respective box below. As an example, if after consulting *Probabilities and frequencies* you estimated that 2 out of any 100 scaffolds would have fault X, then you would write 0.02 next to fault X.

<table>
<thead>
<tr>
<th>Ties:</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>- a tie is removed when it should not be</td>
<td></td>
</tr>
<tr>
<td>- all ties are removed when they should not be</td>
<td></td>
</tr>
<tr>
<td>- a tie is not fitted during erection of the scaffold</td>
<td></td>
</tr>
<tr>
<td>- no ties are fitted during erection of the scaffold</td>
<td></td>
</tr>
<tr>
<td>- there are sufficient number of ties but they are not distributed correctly</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coupler:</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>- a coupler has not been tightened or is omitted between a ledger and standard</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bracing:</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>- a ledger brace is not fitted</td>
<td></td>
</tr>
<tr>
<td>- all ledger braces are not fitted</td>
<td></td>
</tr>
<tr>
<td>- a façade brace is not fitted</td>
<td></td>
</tr>
<tr>
<td>- all façade braces are not fitted</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A defective component is used:</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>- a scaffold board</td>
<td></td>
</tr>
<tr>
<td>- for attachment of staging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- a ledger</td>
</tr>
<tr>
<td></td>
<td>- a transom</td>
</tr>
<tr>
<td>- in lifting apparatus such as a hoist</td>
<td></td>
</tr>
</tbody>
</table>

| Significant resettlement of lower standards occurs |  |

| The safe working load of any part or all of the scaffold is exceeded by 50% |  |

| The wall or building supporting the scaffold is locally or generally unstable |  |

<table>
<thead>
<tr>
<th>Edge protection:</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>- is not fitted</td>
<td></td>
</tr>
<tr>
<td>- is poorly fitted</td>
<td></td>
</tr>
</tbody>
</table>

| Netting or sheeting is not fitted when the situation requires |  |

| Traffic margins for work and public vehicles are not considered |  |

122
Part 2: The severity of particular structural faults

This section asks you to rate the severity of particular faults in the scaffold in terms of the risk it represents to the safety of workers and/or the public.

Please first read through all the different faults and combinations of faults listed on this page and overleaf (i.e. Part 2) to get an idea of the types of faults or combinations of faults that are included and the range of risk.

Then using a scale from 0 not at all risky to 10 extremely risky (the mid-point being at 5), rate each scaffold fault or combination of faults on the level of risk it represents for workers and/or public on or around the faulty scaffold.

Put a tick in the box to make your estimate.

<table>
<thead>
<tr>
<th>Fault Description</th>
<th>NOT AT ALL RISKY</th>
<th>EXTREMELY RISKY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a tie is missing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-all ties are missing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-there are sufficient number of ties but they are not distributed correctly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coupler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a coupler has not been tightened or is omitted between a ledger and standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bracing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a ledger brace is not fitted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-all ledger braces are not fitted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a façade brace is not fitted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-all façade braces are not fitted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A defective component is used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a scaffold board</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-for attachment of staging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a ledger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a transom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-a coupling in a piece of lifting apparatus such as a hoist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The safe working load on part or all of the scaffold is exceeded by 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The wall or building supporting the scaffold is locally or generally unstable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant resettlement of lower standards occurs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part: 2 Continued: Combinations of faults

<table>
<thead>
<tr>
<th>NOT AT ALL RISKY</th>
<th>EXTREMELY RISKY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>▼</td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 tie missing AND 1 ledger brace missing</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 tie missing AND all ledger braces missing</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 tie missing AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 tie missing AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All ties missing AND 1 ledger brace missing</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All ties missing AND all ledger braces missing</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All ties missing AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All ties missing AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 ledger brace missing AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 ledger brace missing AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All ledger braces missing AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All ledger braces missing AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>Significant resettlement of lower standards AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 longitudinal brace missing AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>1 longitudinal brace missing AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All longitudinal braces missing AND general overload of the scaffold by 50%</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>All longitudinal braces missing AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>General overload of the scaffold by 50% AND significant resettlement of lower standards</td>
<td>□ □ □ □ □ □ □ □ □ □</td>
</tr>
</tbody>
</table>
**Part 3 The severity of other faults**

This section asks you again to rate the severity of particular faults. Please first read through all the faults on this page to get an idea of the range of risk.

Then using a scale from *0 not at all risky* to *10 extremely risky* (the mid-point being at 5), rate each scaffold fault or combination of faults on the level of risk it represents for workers and/or public on or around the faulty scaffold.

Put a tick in the box to make your estimate.

<table>
<thead>
<tr>
<th></th>
<th>NOT AT ALL RISKY</th>
<th>EXTREMELY RISKY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Edge protection:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-is not fitted</td>
<td>□ □ □ □ □ □ □ □</td>
<td>□ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td>-is poorly fitted</td>
<td>□ □ □ □ □ □ □ □</td>
<td>□ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td><strong>Netting or sheeting is not fitted when the situation requires</strong></td>
<td>□ □ □ □ □ □ □ □</td>
<td>□ □ □ □ □ □ □ □</td>
</tr>
<tr>
<td><strong>Traffic margins for work and public vehicles are not considered</strong></td>
<td>□ □ □ □ □ □ □ □</td>
<td>□ □ □ □ □ □ □ □</td>
</tr>
</tbody>
</table>
Part 4: Judging the likelihood of injury for four structural faults and three other faults

This section asks you how often a particular fault, when it is present in the scaffold, will result in injury to workers or the public.

For each fault below, imagine a large sample of scaffolds of the type described all with that fault. Use the Table *Probabilities and frequencies* to select your estimates and write them in the boxes below.

As an example, if you estimated that out of 100 scaffolds all with fault X, an injury would result on 2 of these scaffolds *because* of fault X, then 0.02 would be written in the box for fault X.

<table>
<thead>
<tr>
<th>Fault</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 tie is missing</td>
<td></td>
</tr>
<tr>
<td>1 longitudinal brace is missing</td>
<td></td>
</tr>
<tr>
<td>All longitudinal braces are missing</td>
<td></td>
</tr>
<tr>
<td>The safe working load of any part or all of the scaffold is exceeded by 50%</td>
<td></td>
</tr>
<tr>
<td>Edge protection is not fitted</td>
<td></td>
</tr>
<tr>
<td>Traffic margins for work and public vehicles are not considered</td>
<td></td>
</tr>
</tbody>
</table>

Part 5: Some details about yourself

This short section asks you about your experience and job title.

1. Approximately how many years experience do you have working on scaffolds or inspecting scaffolds?  
   
2. What is your current job title?  
   
3. Please briefly describe your job responsibilities?  
   
THANK YOU FOR FINDING TIME TO COMPLETE THIS BOOKLET
APPENDIX L: PROBABILITIES TABLE USED IN EXPERT JUDGEMENT

Table Probabilities and frequencies

This Table is to be used when completing Part 1 and Part 4

<table>
<thead>
<tr>
<th>Probability</th>
<th>Chances of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>One in every scaffold</td>
</tr>
<tr>
<td>.5</td>
<td>One in every 2 scaffolds</td>
</tr>
<tr>
<td>.2</td>
<td>One in every 5 scaffolds</td>
</tr>
<tr>
<td>.1</td>
<td>One in every 10 scaffolds</td>
</tr>
<tr>
<td>.05</td>
<td>One in every 20 scaffolds</td>
</tr>
<tr>
<td>.02</td>
<td>One in every 50 scaffolds</td>
</tr>
<tr>
<td>.01</td>
<td>One in every 100 scaffolds</td>
</tr>
<tr>
<td>.005</td>
<td>One in every 200 scaffolds</td>
</tr>
<tr>
<td>.002</td>
<td>One in every 500 scaffolds</td>
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<tr>
<td>.001</td>
<td>One in every 1000 scaffolds</td>
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<td>One in every 5000 scaffolds</td>
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<tr>
<td>.0001</td>
<td>One in every 10,000 scaffolds</td>
</tr>
<tr>
<td>.00005</td>
<td>One in every 20,000 scaffolds</td>
</tr>
<tr>
<td>.00002</td>
<td>One in every 50,000 scaffolds</td>
</tr>
<tr>
<td>.00001</td>
<td>One in every 100,000 scaffolds</td>
</tr>
<tr>
<td>.000005</td>
<td>One in every 200,000 scaffolds</td>
</tr>
<tr>
<td>.000002</td>
<td>One in every 500,000 scaffolds</td>
</tr>
</tbody>
</table>

THIS END OF THE SCALE IS FOR A **HIGH** LIKELIHOOD OF OCCURRENCE
APPENDIX M: MODELLING THE RELIABILITY OF A SIMPLE SCAFFOLD USING COMPUTER SOFTWARE

M.1 INTRODUCTION AND AIMS

In the previous section we looked at reliability of scaffold systems using expert judgements. In this section a software package is used to model the structural integrity of a simplified tube and fitting scaffold structure when basic faults are introduced into the system.

The aim was to set an order of priority on the common faults that are encountered in steel frame tube and fitting scaffolds, allowing a comparison to be made with the results of the modelling, reported previously, that used experts to provide the probabilities.

M.2 METHOD

M.2.1 Software used

The NAF (Non-linear Analysis of Frames Series)- Non-linear Integrated Design and Analysis (Nida) computer program (Chan et al.,) was used to perform the analysis of a four-bay-one-row-four-storey scaffold system as shown in Figure M.1. The software is aimed at linear and geometrically non-linear analysis, combined design and analysis of framed structures.

M.2.2 Design of the Scaffold System

The scaffold system shown in Figure M.1 is designed according to the British Standards BS5973: 1993 and BS1139 -2.1: 1991. It is an independent tied scaffold consisting of two lines of standards spaced at 0.8m. The lift height or height of each storey of the scaffold is 2m. The scaffold consists of four bays, the length of each bay is 2m, and the total scaffold length therefore 8m.

The steel tubes that were used for the formation of the elements of the scaffold are tubes of outside diameter 48.3mm and wall thickness 4mm, i.e. standard steel scaffold tubing. Steel tubes of lengths 16 and 21 feet (4.88 and 6.4m respectively) were used. One steel tube of length 4.88m and one of length 6.4m were connected in order to form the standards and ledgers of the system. For the very left standard of the inner line of standards, the 4.88m steel tube was supported vertically to the ground and the 6.4m steel tube was placed vertically above the shorter to form a longer standard. The second standard of the same line of standards was formed in a similar way, but with the 6.4m steel tube at ground level. Exactly the same method was followed for the outside line of standards but this time starting the erection with the installation of the long tube on the ground. This arrangement is standard practice to avoid the existence of excess joints in the same lift.

The steel tubes of standards and ledgers were connected together with sleeve couplers. The joints in standards and ledgers were positioned at a distance not greater than 1/3 of the span between adjacent ledgers and standards respectively. Thus, joints were made by overlapping the two lengths of the tube by a distance of 0.5m. This type of formation of standards and ledger designates the exact height and length of the scaffold system respectively, calculated as follows:

\[
\text{Height} = 6.4+4.88-0.5 = 10.78m \\
\text{Length} = 6.4+4.88-0.5 = 10.78m
\]
Also, the position of the sleeve couplers was calculated to be:

6.4-0.5/2 = 6.15m or 4.88-0.5/2 = 4.63m above the foundation of the scaffold for the standards, and,
6.15m or 4.63m beyond the first pair of standards to the right of the scaffold, for the ledgers.

Since 8m is enough for the purpose of the particular scaffold, boards were placed only up to 8m. The rest 10.78-8=2.78m of steel tubes were used for guardrails.

Two working platforms were formed using four boards of the standard 225m width, located at the second and fourth (top) lifts. These boards, forming the working platforms designate the width of the scaffold. Steel tubes of length of 0.9m were used in order to get the appropriate length of transoms.

Ledger bracing was fixed at alternate pairs of standards, i.e. at the first, middle and last pairs. Ledger bracing follows a zigzag pattern from the inside base to the full height of the scaffold forming triangles, as shown in Figure M.1. Longitudinal bracing takes the form of a continuous slope of steel tube. The outside longitudinal brace of the scaffold has its bottom fixed at the first outside standard and its top at the fifth (last) outside standard, while a continuous slope of steel
tube in the opposite direction is used for the inside of the scaffold. Two 6.4m tubes were needed to form the longitudinal bracing on both the inside and outside of the scaffold, since the diagonal distance that is to be braced is:

\[
\text{Length of longitudinal bracing} = \sqrt{8^2 + 8^2} = 11.31\text{m}
\]

These steel tubes were joined together with sleeve couplers making an overlap of 300mm. Hence, the available length of the long steel tube to be used as longitudinal bracing was:

\[6.4 + 6.4 - 0.3 = 12.5\text{m}\]

Sleeve couplers were located at a distance 6.25m (6.4-0.3/2) diagonally from the very left front bottom point of the scaffold for the front brace and at the same distance diagonally from the very right inside bottom point of the scaffold for the inside longitudinal brace.

If the scaffold was to be constructed actually on site, the scaffold could be connected with the building using ring bolt ties in order to resist inward and outward movement of the system. Twenty ring bolt ties were used with their steel tubes located very close to the transoms of the scaffold and parallel to them. These tubes should extend beyond the inner standards of the scaffold to attach the ring bolts. The position of the ties is shown in Figure M.1.

Standards, ledgers, transoms, braces and ties are connected together using the couplers specified in the British Standards. The inside and outside ledgers were fixed to the adjacent standards with right angle couplers, and the same was true for transoms and ledgers. As far as concerns ledger bracing, the top of each brace was fixed to the ledger with a right angle coupler and the bottom of the brace is fixed to the standard with a swivel coupler. Longitudinal bracing tubes were fixed to the extended transoms of every lift with right angle couplers. The ties of the scaffold are connected to both the inside and outside ledgers with right angle couplers.

It was assumed that the ground underneath the scaffold is made with concrete, which forms a hard surface and penetration by the standards is not possible. Base plates were located under each standard.

**M.2.3 Modelling the Scaffold System**

The NIDA model is shown in Figure M.2 and consists of 124 members and 78 nodes.

Each node represents the point of intersection between elements of the scaffold. The point at which transoms and ledgers intersect and the point of intersection between ledgers and standards do not exactly coincide in reality because a small length of the steel tube is occupied by the couplers. However, for modelling purposes it was assumed to be one point corresponding to a single node.

The numbering of the nodes is shown in Figure M.2. In the model, each node has boundary conditions related to ability of the system to move at the particular point. Nodes 1-5 and 30-34 are the points of contact between the front and back bottom standards and the baseplates. In the model, baseplates were represented by fixing these nodes, making them unable to move in X, Y and Z directions. However, they are free to rotate in all directions. Thus, “restraint” and “free” was selected for the “displacement in X, Y, Z” and “rotation at X, Y, Z” respectively, for the “boundary condition” in the “node properties” box. The same boundary conditions were selected for nodes 6-29 in order to represent the ties of the scaffold, which in site are fixed at the points of their contact with the building. All the remaining nodes of the model are free to displace and rotate in every direction and hence “free” was selected for the “boundary condition” in the “node properties” box of these nodes.
Members 1-20 represent the inside standards, 41-60 the outside ones, having a length of 2m. Members 21-40 and 61-80, corresponding to the inside and outside ledgers of the scaffold, do not have the same length because the elements of the horizontal bracing were added before the completion of all the ledger members. Thus, members 21-32 and 61-72 have length 2m and the length of the remaining ledgers, i.e. members 33-40 and 73-80 is 1m.

The numbering of the members representing the transoms is not continuous since the horizontal braces of the scaffold are placed between the transoms of the top working platform. Hence, elements 81-96 represent transoms of the scaffold but elements 98, 100, 102 and 104 also represent the remaining transoms of the system with length 0.8m. Similarly, elements 97, 99, 101 and 103 represent the horizontal bracing of the scaffold with the same length.

Ledger and longitudinal braces correspond to elements 105-116 and 117-124 of the model, having length of 11.31m and 2.15m, respectively. Additional steel tubes are used for the ties of the scaffold system constructed in site. However, in the model there are no separate elements representing the ties. Since the location of the tubes of ties is very close to the transoms of the scaffold, ties appear to coincide to the transoms in the model. The method by which the ties of the scaffold are represented by the model was mentioned previously.

The determination of the stiffness of each type of coupler that would be used in actual construction of the scaffold system was necessary, since these values were used for the “spring stiffness” in the “spring” of both the node and member properties box. The values needed were taken from a study carried out by McCann and Rush [9] related to the evaluation of slip characteristics and performance envelope of right angle couplers. This study involves the tests of prototype right angle couplers according to the British Standards. The values were used in the program as the spring stiffnesses under both member and node properties. In particular, the
"connection stiffness" in the "spring" of the "member properties" was taken as 52000KN/m for both ends of each member of the model and about both Y and Z axis which are the local axes of each of the members, since the all elements are connected either by right angle or sleeve couplers having the same values of stiffness. It should also be noted that the 52000kN/m value was used in this way, assuming that for modelling purposes each element has two springs one at each end located near to the connection with the other elements as shown in Figure M.3. The stiffness of each of these springs represents the stiffness of the coupler located at the closest intersection.

Sleeve couplers were added after all the elements were numbered, so they do not split the element on which they are located into sub-elements. Thus, the ends of each such element are linked to the stiffness of either right angle or a swivel coupler as before.

The value 3429kN/m, i.e. the stiffness due to rotation for right angle and swivel couplers, was used for the "rotation" at X, Y and Z directions for the "spring stiffness" of the "node properties" box for all nodes apart from nodes 59-78.

For the "displacement" in X, Y and Z directions in the spring stiffness of the same box the value of 52000kN/m was not used since it was already included in the "member properties" box.

For nodes 59-78 the value of 13000kN/m was used because these nodes represent the sleeve couplers. For nodes 59-68 this value was used for the displacement in Y direction only, in the "spring" of the "node properties" box, since it is assumed that the stiffness of a sleeve coupler located on the standards of the scaffold is represented by a spring that can displace only in the direction of the standards, i.e. the Y direction as shown in Figure M.3. Similarly, for nodes 69-76, 13000kN/m was the spring stiffness for X direction only, because these nodes represent the sleeve couplers on the ledgers of the scaffold and the assumed spring can displace in this direction only is shown in Figure M.3.

Figure M.3
Springs representing couplers at a node (a) and sleeve couplers on standards(b), ledgers(c) and longitudinal bracing (d).
Nodes 77 and 78, which represent the sleeve couplers of the longitudinal bracing can obviously displace in more than one directions. In this case, the spring is assumed to be located diagonally having the direction of the braces, moving along their length as shown in Figure M.1. This motion can be analysed into one displacement parallel to x-axis and one parallel to y-axis, considering the global system of axes. Thus, for 77 and 78 nodes, 13000kN/m was used for the spring stiffness in displacement in X and Y directions.

**M.2.4 Scaffold loading**

The load applied on the scaffold was calculated according to the British Standards [2], assuming a scaffold of light duty and considering the width of the working platforms. It was found by multiplying the 1.5kN/m² distributed load (given in British Standards )[2] by the width of the platforms 0.9m. For the model, the resulted 1.35kN/m was divided by 2, since two are the lines of ledgers adjacent to each working platform. The resulted load 0.675kN/m was applied on the appropriate members, as point loads having in total the same magnitude as the distributes load. This method of application of the load was considered for modelling purposes. The members on which this load was applied are: 25-28, 65-68, 33-40 and 73-80 that represent the inside and outside ledgers that are located adjacent to the boards forming the working platforms of the scaffold. The point load applied on each of these elements was depended upon its length.

On members 25-28 and 65-68 having length 2m the point load applied was:

\[0.675\text{kN/m} \times 2\text{m} = 1.35\text{kN at the middle of each member}\]

Members 33-40 and 73-80 being of length 1m, the applied point load was:

\[0.675\text{kN/m} \times 1\text{m} = 0.675\text{kN at the middle of each member}\]

Figure M.4 shows the application of this loading on the scaffold.

A wind load of 1.125kN/m² was also considered to be applied on the front surface of the scaffold system. In the model this wind load was applied on nodes 39, 44, 49 and 58 as point loads. Detailed calculations of the wind distributed load were made (Mavridou, 2002). The equivalent point load applied on the scaffold was:

\[1.125\text{kN/m}^2 \times 14.3\text{m}^2 = 16\text{kN}\]

(14.3 m² is the area loaded by the wind and is calculated in detail in appendix A)

Hence, each of the four nodes is loaded with a point load of magnitude:

\[16\text{kN} / 4 = 4\text{kN}\]
The application of both loads mentioned above is shown in figure M.5.
M.3 CONSIDERED CASES

The structural model described above was used to investigate the performance of the scaffold system described earlier when one particular type of fault is involved. Eight different types of faults were considered and the model, including each time one of the these faults, was analysed. The system without any faults was also analysed for comparison reasons. The faults considered in the scaffold system are:

1. Single missing tie (in critical place)
2. All ties missing
3. Single ledger brace missing (in critical place)
4. All ledger braces missing
5. Single longitudinal brace missing (in critical place)
6. All longitudinal braces missing
7. Foundations sink on one standard (in critical place)
8. Foundations sink on all front standards

Ten different cases considering the loading and the types of faults were analysed using the NAF-Nida computing program. The first load described above was applied on all cases, hence it is not mentioned in each case separately. The analysed cases were:

1. Scaffold system without any fault
2. Scaffold system without any faults including the wind load
3. Scaffold system including the 1st fault.
4. Scaffold system including the 2nd fault
5. Scaffold system including the 3rd fault
6. Scaffold system including the 4th fault
7. Scaffold system including the 5th fault
8. Scaffold system including the 6th fault
9. Scaffold system including the 7th fault
10. Scaffold system including the 8th fault.

The ten different cases of scaffold systems were analysed using the NAF-Nida computer program [8]. 20 load cycles were selected for the second linear analysis of every case. This program calculates stresses, sectional force and moments at every section along members, allowing the effect of member slenderness. Therefore, it can be used to perform the design by section capacity check. The equation used to check the capacity of the members was:

\[
\frac{P}{A_y \cdot p_y} + \frac{M_y + P(\delta_y + \Delta_y)}{M_{ry}} + \frac{M_z + P(\delta_z + \Delta_z)}{M_{rz}} = \phi \leq 1 \quad [8]
\]

where:

- \( p_y \) is the design strength normally taken as the yield stress of the section
- \( P \) is the external force in the section
- \( A_y \) is the cross sectional area
- \( M_y \) and \( M_z \) are the external moments about the x and y axes
- \( M_{ry} \) and \( M_{rz} \) are the moment resistance about the y and z axes
- \( P(\delta_y + \Delta_y) \) and \( P(\delta_z + \Delta_z) \) are \( P - \delta \) and \( P - \Delta \) moments due to change of member stiffness under load and the large deflection effects of which the consideration allows to include automatically the effect of effective length. All these values where filled in the appropriate
boxes of the program and therefore the value for the capacity factor $\phi$ for the members of the structure for each case was automatically calculated by the program.

The critical load for each case was evaluated considering the maximum load factor so that no member of each of the cases achieved maximum stress. The resulted stresses on the members are represented by their section capacity $\phi$. The negative sign in the value of $\phi$ indicates that the member is in compression while the positive in tension.

The representation of the scaffold system in the program corresponding to the first case has already mentioned earlier. The structural model of case 1 under loading is shown in Figure M.5.

In relation to cases 3, 5, 7 and 9, the critical tie, ledger brace, longitudinal brace and standard respectively which should be missing had to be identified. For this purpose case 1 was first analysed finding its critical load. While this critical load was kept constant, the number of load cycles was increased until one of the members representing the bottom inside or outside standards achieved maximum stress. It was found that the most critical tie, ledger brace, longitudinal brace and standard were members 97, 107, 120 and 53 respectively. The numbering of the members is shown in Figure M.2.

The model analysed for each case was derived considering the first case. Hence, for case 3 the missing critical single tie was represented by setting free all the boundary conditions of the node of member 97 placed at the inside of the system, (node 22), making this node able to move at any direction. This node represents the point of contact between the tie and the building.

Case 5 corresponds to a model in which the critical single ledger brace identified before as member 107 is missing from the model of case 1, while case 7 was represented by removing the critical single longitudinal brace, i.e. member 120 is missing from the model of case 1.

Case 9 corresponds to the same model as case 1 but this time the boundary conditions of the bottom node (node 33) of the critical standard numbered as 53 are all set free. Hence, the standard corresponding to member 53 can now penetrate the ground and providing a sinking foundation situation. It was decided to fix sinking foundations at 20cm below ground level, to represent the case of having 20cm penetration by the scaffold system into the ground. Consequently, the y-coordinate of each of the nodes lying on the critical standard and the standards above was decreased by 0.2m. These nodes are: 33, 43, 48 and 56.

The models analysed for cases 6 and 8 were the same as the model of the first case, the only difference being no ledger bracing or longitudinal bracing respectively. Finally case 10 was represented in a similar way as case 9 but this time nodes 30-34, which are the bottom nodes of the front bottom standards, were set free to move in all directions. As before, the foundations were fixed at 20cm of sinking. Hence, the y co-ordinates of nodes located at the front face of the model apart from nodes 51, 33, 55 and 57 were decreased by 0.2m, representing the situation where the scaffold’s foundations sink on all front standards.

**M.4 RESULTS**

The resultant critical loads form the modelling for all cases are summarised in Table M.1.
Table M.1
Results of the modelling with NIDA

<table>
<thead>
<tr>
<th>Case</th>
<th>Critical scaffold load as a factor from NIDA</th>
<th>Critical load on scaffold (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaffold without faults</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Scaffold without faults, with wind loading</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Single missing tie in critical position</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Foundations sink on all standards</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>All ties missing</td>
<td>1.52</td>
<td>1.14</td>
</tr>
<tr>
<td>Single ledger brace missing in critical position</td>
<td>1.52</td>
<td>1.14</td>
</tr>
<tr>
<td>All ledger braces missing</td>
<td>1.50</td>
<td>1.125</td>
</tr>
<tr>
<td>Single longitudinal brace missing in critical position</td>
<td>1.50</td>
<td>1.125</td>
</tr>
<tr>
<td>Foundations sink on one standard in critical position</td>
<td>1.49</td>
<td>1.118</td>
</tr>
<tr>
<td>All longitudinal braces missing</td>
<td>1.46</td>
<td>1.095</td>
</tr>
</tbody>
</table>

The values in the third column were calculated by as follows:

For example, consider case 1:

\[
\text{Critical load} = 1.53 \times 1.35 \text{kN} = 2.0655 \text{kN}
\]

Converting the point load to distributed load:

\[
\frac{2.0655 \text{kN}}{2 \times 0.9 \text{m}} = 1.15 \text{ kN/m}^2
\]

where, 1.35kN is the maximum applied point load on member, which designates the maximum load for the entire scaffold system, 2m is the length of this member and 0.9m is the width of each working platform. This means that a different method was used for determining the critical load compared to calculating the point load applied to the scaffold earlier. The rest of the critical loads were calculated in similar way.

M.5 DISCUSSION

From the above table it can be seen that the critical loads for all cases were less than the maximum value recommended in the British Standards, which is equal to 1.5kN/m². Hence, it can be said that generally these values are acceptable as maximum loads for these scaffold cases. However, the comparison of the cases showed that in some of them the resulted critical loads were not reasonable.

The maximum (critical) stresses for all cases were of the same magnitude and were observed in the middle of the scaffold and particularly in members 25-28 and 65-68 but at different critical loads. This is logical, since these members, placed adjacent to a working platform, were loaded with maximum load as shown in Figure M.5 and they also sustained a significant part of the load applied on members 33-40 and 73-80, located adjacent the top working platform. All cases were compared to case 1 in order to evaluate the effect of the considered faults and the wind loading.
In case 1, the distribution of stresses is almost symmetrical about an axis having the direction of the Y-axis at middle of the model. This is because the scaffold is an almost symmetrical structure under the effect of a symmetrical applied loading. Due to the method of installation of the longitudinal bracing, i.e. one at the back and one the front of the scaffold, the system is not exactly symmetrical. However, the width of the scaffold is relatively small compared to its other dimensions and thus the divergence is just for a few members. Members 44 and 60 that are placed at the same distance from the centre of the scaffold and have values which mean that the difference in the stresses of these two members is very small. The same happens for members 3 and 19 and members 86 and 90. It should be noted that all critical loads were given to two decimal places. This might be the reason why the distribution of stresses is not symmetrical for all members.

The critical load for case 2 was 1.15kN/m², which is the same as the one found for case 1. Hence, it can be stated that the wind load has no effect on the scaffold. This result was to be expected, since the area on a scaffold onto which the wind load is actually applied is very small, i.e. only half of the external area of the outside tubes. Between the steel tubes there is no surface to take this load. From the modelling, it was found that the stresses of the members were not exactly the same as the ones in case 1. The differences occurred in members 104, 116, 19 and 114. Taking into account the fact that the wind load was applied at nodes 39, 44, 49 and 58 that lie on these members or are located very close to them, it can be concluded that these differences are reasonable but that the difference in the stresses is very small.

The critical load of case 3 was found to be the same as the one for cases 1 and 2. Case 3 represents a scaffold where a single tie in critical place is missing and it should be expected to give a lower critical load. It should be noted that the minimum number of ties required for the particular type of scaffold according to the British Standards[2] is two. However, for extra safety reasons 24 members were used in the model as ties, which is 12 times more than needed. Hence, it is logical that the removal of one of these ties is provides less critical loadings and does not affect the performance of the system.

Another reason for the similar results of cases 1 and 3 may be the method selected to represent the ties for the model in the program. No additional tubes were used for the ties but the existing transoms were just fixed at their inner node. From a structural point of view, probably it does not make any difference if one of the transoms is not fixed. If the ties had been represented by additional tubes then in this case one of them would have been removed and this could give a lower critical load for case 3.

In case 4 the critical load was found to be 1.14kN/m², which is very close to the value of the critical load of case 1. It would be expected to be much lower than the critical load of cases 1 and 3, since in this case all the ties in the scaffold are missing. This may happen due to the method of representing the ties in the program as mentioned for case 3. The stresses were much higher in the case where all ties are missing. It was found that members 4, 33-36 and 73 located at the very top inside and outside of the scaffold were under stresses with higher values compared to all other elements, and also compared to the corresponding members of cases 1 and 3. The remaining elements have the same magnitude of stress as cases 1 and 3 but some of these elements were under compression and some under tension.

The critical load found for case 5 was 1.14kN/m² as in case 4. It was expected to have a lower critical load in this case, since the member representing the critical ledger was removed from the original model. It was not expected to be much lower than 1.14kN/m² since the width of the scaffold was not very large compared to the other dimensions of the system. Hence this width does not generally require many steel tubes in order to be braced. Therefore, when one single ledger brace is removed from the scaffold, the critical load decreases but does not become much lower than the critical load of the original scaffold.
The stress of the member corresponding to the ledger placed just below the missing one, i.e. member 106 was higher compared to the stress of the same member of the scaffold in case 1. This can be seen as a “transformation” of stress towards the bottom of the scaffold, since one member above is missing. The remaining members have the same stresses. In addition, the distribution of stresses was not symmetrical since the scaffold was not longer symmetrical with one missing element.

The critical load for case 6 was found to be 1.125kN/m^2, which is lower than the critical loads of every other case discussed above. This result is reasonable since all ledger bracing was removed from the original case. The distribution of stresses on the members is symmetrical. This is also reasonable since, by removing all the ledgers from the original scaffold, the structure remains symmetrical. Comparing this case with case 1 the stresses are generally higher in the case of the missing ledgers, especially for the members at the top of the scaffold.

As far as case 7 is concerned, the critical load was 1.125kN/m^2. This value is the same as the critical load for case 6, indicating that the effect of the missing ledger bracing and the effect of the single missing longitudinal brace is the same. This result is reasonable for the particular scaffold, since its width is not very large compared to its length and height. Therefore, the braces across its width can be as important as one single brace across its diagonal dimension. The stresses of the members for case 7, are almost the same as the stresses for case 6. It appears, however, that the same members for these different cases in the other. Comparing the critical load for case 7 with the one found for case 1 it can be concluded that there is a reasonable difference, since longitudinal braces are important elements in a scaffold, especially when they are located to brace a relatively long distance as here.

The critical load for case 8 was found to be 1.095kN/m^2, which is even lower than all the cases discussed until now. Of course, this was expected, since all longitudinal braces were removed from the original scaffold. Hence, it can be concluded that their contribution to the strength of the entire system is critical. The distribution of stresses on the elements of the scaffold was symmetrical, since after removing all the longitudinal braces the system is still symmetrical. Comparing these stresses to the stresses of the scaffold for case 1 it can be seen that they are generally higher. Also the comparison of case 8 with all the other cases gave similar result in relation to the stresses of the members of the scaffold.

The critical load for case 9 was 1.118kN/m^2. This value is lower than the critical load of case 1, since one of the boundary conditions for node 33 were set free. Hence the standard located above this node may possibly penetrate the ground surface, making the all the standards located above it able to move towards the ground. This can happen in actual construction when the baseplate for this standard is removed. Thus, the resulted critical load is reasonable.

The distribution of stresses on the elements of the scaffold was compared with the model for case 1 and it was found that the stresses were higher in the original. In particular, the stresses of members 78 and 79 were higher in case 1. This may be due to the method of representation of this case in the program. The movement of the standards in the y direction by decreasing the values in the y-co-ordinate may not be correspondent to the sinking of foundations of the real scaffold. The loading on the top front members 78 and 79 in case 9 was not applied because the y-co-ordinate of node 56 was decreased, making these members move downwards, and away from the point of application of the scaffold load. Hence, less loading was applied in this case and therefore these stresses had the lowest values compared to all the cases up until now. Considering the modelling in the program these results may be reasonable. However, during if one of the baseplates is removed actual construction, the standards located on this base plate will sink and will carry less stress, but the stresses on the rest of the elements will probably increase.
Finally, for case 10 the critical load was 1.15kN/m$^2$. This is the same value that was found in case 1. However, the stress distribution for the two cases was not the same because cases 9 and 10 are represented in the same way in the program. Overall, the magnitudes of the stresses for cases 1 and 10 are the same but they are distributed differently in the elements. This may be happening because the original scaffold was changed in order to correspond to this case, by lowering the front nodes of the model.

**M.6 CONCLUSIONS**

The critical loads for all cases were lower than the maximum value recommended in the British Standards. Hence, it can be said that generally these values are acceptable as maximum loads for these cases. The maximum (critical) stresses for all cases were of the same magnitude and were observed in the middle of the scaffold and particularly in members 25-28 and 65-68 but at different critical loads. This is logical, since these members, placed adjacent to a working platform, were loaded with maximum loads and they also sustained a significant part of the load applied to members 33-40 and 73-80, located adjacent the top working platform.

All cases were compared to case 1 in order to evaluate the effect of the faults or wind loading. From the above results it can be seen that the lowest value of critical loading was observed in case 8 where all longitudinal braces were removed from the original scaffold. This indicates that the longitudinal bracing is a very critical element of a scaffold system.

An second most important part of the scaffold was found to be the ledger bracing. This shown from the value of the critical load for case 6, corresponding to the scaffold without ledger bracing, being second lowest. Cases 9 and 10 are problematic but indicate the choice of the models that can be analysed in future studies.

Case 7, which represents the scaffold system without the critical longitudinal brace, gave the same critical load as case 6, verifying once more the importance of the longitudinal bracing. Cases 4 and 5, corresponding to the scaffold system without ties and the system with the critical ledger brace missing, gave the same value for the critical load and were lower than cases 6, 7 and 8. This result was not expected, with the prediction being that a scaffold without ties would give a much lower critical load.

A missing single ledger brace did not significantly affect the critical load of the scaffold. Comparing the performance of the scaffold without ledger bracing (case 6) and the scaffold without longitudinal bracing (case 8) it can be concluded that for the particular type of scaffold the longitudinal bracing is more important than the ledger bracing. This is because the width of the scaffold is not very large relative to its other dimensions. Therefore, it is more important to make sure that the scaffold is braced diagonally rather than across its width.

The opposite could happen in a case of a scaffold with more than two rows, e.g. a 4-bay-3-row-4 storey scaffold system, where in this case the scaffold would be wider. In case 3, where the critical tie was removed from the original scaffold, the critical load was the same as in case 1 which can be assumed to be reasonable, since much more than the required number of ties were used in the scaffold. Finally, the wind load did not affect the performance of the scaffold system as expected, because the surface to which it was applied was very small.

In summary, the results showed that the most serious fault has all longitudinal braces missing, then sinking of one standard, and then a single longitudinal brace missing. Ties have very little effect on the maximum working load of the scaffold. It is likely that, had forces away from the building been assessed, ties would have had a more significant effect. Clearly more complex interactions would be need to considered to reflect real life situations. It is known that if the design is pushed to the limits by a combination of faults, there will be scaffold failure.
APPENDIX N: DESIGN OF A SCAFFOLD CHECKLIST

See over-page.
## SCAFFOLD INSPECTION CHECKLIST

These details to be completed by the person making the inspection

Your name: ____________________________ Date of inspection: ______/_____/____

Name of your company: ____________________________ Scaffold type: ____________________________

Name of company requesting inspection: ____________________________ Scaffold location (and/or section): ____________________________

<table>
<thead>
<tr>
<th>Foundations</th>
<th>Yes</th>
<th>No</th>
<th>Comments</th>
<th>If fault is corrected, tick here</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Ground beneath standards is compact and level</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Platforms</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Working lifts fully boarded</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Boards are undamaged &amp; flush</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Boards overhang transoms by 50 to 150mm</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Boards span less than 1.5m see note 1</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Edge protection</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Guard-rails are present on all working lifts see note 2</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Toeboards are fitted to all working lifts see note 3</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Brickguards / fans are present when necessary</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Standards</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Joint pins or sleeve couplers connect standards</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Distance between standards within guidelines</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Joints in adjacent standards in alternate lifts</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>No more than three standards jointed in same bay</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Baseplates fitted</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Sole plates fitted if on soft ground</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>If on public walkways: standards are padded &amp; lower lift clearance sufficient; no trip hazards</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Transoms</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Transoms on every pair of standards</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Bracing</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Ledger bracing on alternate pairs of standards</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Longitudinal bracing at no more than 30m intervals</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Ties</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Correct number of ties; distributed evenly see note 4</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Ties are sound?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Ties have not been altered</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Overall</td>
<td>Yes</td>
<td>No</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Scaffold erected to design (where appropriate)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Risk of vehicle collision minimised</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Scaffold loading safe see note 5</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>*Secure fencing around scaffold; public protected</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

* Means the item is particularly important

**Signature of person making inspection**
I have inspected the scaffold and found the faults (if any) listed above: signature here

**Signature of agent**
I confirm inspection of the scaffold and the correction of faults listed above: signature here

**Date:** ______/_____/____
1. This applies to boards 38mm thick. For other boards, use the data below (from Table 3, Sec. 15.2, BS5973: 1993)

<table>
<thead>
<tr>
<th>Board thickness</th>
<th>Maximum span</th>
<th>Min. overhang</th>
<th>Max. overhang</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 mm</td>
<td>1.5 m</td>
<td>50 mm</td>
<td>150 mm</td>
</tr>
<tr>
<td>50 mm</td>
<td>2.6 m</td>
<td>50 mm</td>
<td>200 mm</td>
</tr>
<tr>
<td>63 mm</td>
<td>3.25 mm</td>
<td>50 mm</td>
<td>250 mm</td>
</tr>
</tbody>
</table>

2. Guardrails must be present and must be set at a height from the working platform of between 910mm and 1150mm, with no more than 765mm gap between the lowest guard rail and the toeboard. A second guardrail should be installed if the gap is larger than 765mm. (from Sec. 15.6, BS5973: 1993). Correct couplers should be used to connect guardrails.

3. Toeboards must have a minimum of 150mm height and be attached to the inside of the standards (from Sec. 15.5, BS5973: 1993)

4. The number of ties will affect the area of façade per tie. The maximum area per tie should be less than the following (adapted from Table 1a, Sec. 9.3.1, BS5973: 1993)

<table>
<thead>
<tr>
<th>Ties</th>
<th>Per tie</th>
<th>Per tie</th>
<th>Per tie</th>
<th>Per tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5kN</td>
<td>6.25kN</td>
<td>Up to 50%</td>
<td>More than 50%</td>
<td></td>
</tr>
<tr>
<td>(such ties are usually box ties)</td>
<td>(such ties are usually lip ties, through ties, ring bolts, cast-in and drilled anchorages)</td>
<td>3.5kN ties</td>
<td>3.5kN ties</td>
<td></td>
</tr>
<tr>
<td>Unsheeted, independent scaffolds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-with movable ties</td>
<td>32 m²/tie</td>
<td>32 m²/tie</td>
<td>25 m²/tie</td>
<td>Not recommended</td>
</tr>
<tr>
<td>-with non-movable ties</td>
<td>40 m²/tie</td>
<td>40 m²/tie</td>
<td>31 m²/tie</td>
<td>22 m²/tie</td>
</tr>
<tr>
<td>Sheeted, independent scaffolds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-with movable ties</td>
<td>25 m²/tie</td>
<td>12.5 m²/tie</td>
<td>Not recommended</td>
<td>Not recommended</td>
</tr>
<tr>
<td>-with non-movable ties</td>
<td>32 m²/tie</td>
<td>16 m²/tie</td>
<td>Not recommended</td>
<td>Not recommended</td>
</tr>
</tbody>
</table>

5. Load rating and maximum bay length must be according to the following (adapted from Table 1, Sec. 6.4.1, BS5973: 1993).

<table>
<thead>
<tr>
<th>Duty</th>
<th>Use of Platform</th>
<th>Distributed Load on Platform</th>
<th>Example Load per Bay</th>
<th>Max. Number of Platforms</th>
<th>Commonly Used Widths</th>
<th>Max. Bay Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection/ very light duty</td>
<td>Inspection, painting, stone clearing, light cleaning, access</td>
<td>0.75 kN/m²</td>
<td>1 MAN + TOOLS AND NO MATERIAL</td>
<td>1 working platform</td>
<td>3 boards</td>
<td>2.7 m</td>
</tr>
<tr>
<td>Light duty</td>
<td>Plastering, painting, stone cleaning, glazing, pointing</td>
<td>1.50 kN/m²</td>
<td>2 MEN + 175KG OF MATERIALS</td>
<td>2 working platforms</td>
<td>4 boards</td>
<td>2.4 m</td>
</tr>
<tr>
<td>General purpose</td>
<td>General building work including brickwork, window and mullion fixing, rendering, plastering</td>
<td>2.00 kN/m²</td>
<td>1 MAN + 350KG OF MATERIALS</td>
<td>2 working platforms and 1 at very light duty</td>
<td>5 boards or 4 boards and 1 inside</td>
<td>2.1 m</td>
</tr>
<tr>
<td>Heavy duty</td>
<td>Blockwork, brickwork, heavy cladding</td>
<td>2.50 kN/m²</td>
<td>2 MEN + 250KG OF MATERIALS</td>
<td>2 working platforms and 1 at very light duty</td>
<td>5 boards or 5 boards and 1 inside or 4 boards and 1 inside</td>
<td>2.0 m</td>
</tr>
<tr>
<td>Masonry or special duty</td>
<td>Masonry work, concrete blockwork, and heavy cladding</td>
<td>3.00</td>
<td>1 working platform and 1 at very light duty</td>
<td>6 to 8 boards</td>
<td>1.8 m</td>
<td></td>
</tr>
</tbody>
</table>

Your notes:
APPENDIX O: ROOFMATE VERSION 1

This is the version of ROOFMATE that was used in the user trials. It is shown actual size. In the trials it was laminated with flexible laminate. The instructions appeared on the reverse.¹

¹ Note that only a pilot study has been undertaken with these versions of ROOFMATE. These may be modified further, so care should be taken if used in work situations.
ROOFMATE’S SEVEN ANSWERS

(1) Before commencement of roof work you should have been directed by your supervisor/foreman, i.e. someone who is competent in all aspects of roofing work. If in doubt seek his/her advice.

(2) For ascent and descent to and from the roof, access/egress must be safe, i.e. secured ladders within scaffolding, and a safe working platform at eaves level. If unsure refer to (1).

(3) Assume all roof coverings to be fragile unless otherwise informed. If unsure refer to (1).

(4) If at all possible, full edge protection should be in place, i.e. scaffolding at eaves and gable ends with adequate guard-rails and toe-boards in place; holes covered and guard-rails surrounding sky-lights and other fragile areas. Demarcation areas should be clearly mapped out. If unsure refer to (1).

(5) If (4) cannot be achieved, safety netting (particularly on industrial roofs) and/or personal protective equipment (PPE) will be necessary alternatives, i.e. harness & lanyards with good anchor points. If unsure refer to (1).

(6) All materials should be adequately loaded and distributed tidily and evenly across the working area. This will cut down on travel time across the roof and ensure the roof is free of trip hazards. If unsure refer to (1).

(7) If at all possible, do not work in adverse weather conditions, i.e. high winds, heavy rain, or ice. If unsure refer to (1).

When you can answer yes to all relevant questions start work.
This is the amended version of ROOFMATE following the user trials. Once again it is shown actual size. The instructions are exactly the same as ROOFMATE Version 1 and would appear on the reverse.

APPENDIX P: ROOFMATE VERSION 2

Note that only a pilot study has been undertaken with these versions of ROOFMATE. These may be modified further, so care should be taken if used in work situations.
Developing a prototype decision aid for determining the risk of work systems at height when using temporary access systems.