Safety and design: on-site insight

Using digital design models to improve planning for safe construction

Our research and development programme

IOSH, the Chartered body for safety and health professionals, is committed to evidence-based practice in workplace safety and health. We maintain a Research and Development Fund to support research, lead debate and inspire innovation as part of our work as a thought leader in safety and health.

In this document, you'll find a summary of the independent study we commissioned from the University of Reading and Technion – Israel Institute of Technology: 'Building safely by design'.

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What's the problem?

Construction is one of the world's major industrial sectors, and also one of the most hazardous. The number and severity of accidents could be reduced through design change, and site safety could be improved by designers and builders working closely together during the design phase of projects.

However, research has identified challenges in transferring knowledge between the site and the design office. Co-operation between designers and builders, particularly when it comes to improving safety performance, is hampered by a clash between different forms of knowledge. In the professions, the dominant form of knowledge is through written reports and documentation; in the trades, this is through experiential learning. This clash is an obstacle to designers adequately anticipating health and safety issues in construction.

With the advancement of technology, digital tools have been developed for construction safety, but less attention has been paid to digital tools that support safety by design. The increasing use of building information models (BIMs) in construction raises new opportunities, as well as questions, about how digital models can be used to build safely by design.

We commissioned Professor Jennifer Whyte from the University of Reading, and Associate Professor Rafael Sacks from Technion – Israel Institute of Technology, to look into the issue of how builders and designers can interact effectively, with the aid of a virtual reality tool, to design safe construction processes. We asked them to:

- develop a method for assessing the safety implications of a detailed design model of a building
- develop techniques for use in this assessment
- trial the process with designers and construction workers on a virtual construction project.

What did our researchers do?

The team reviewed the latest statistical data and policy reports to identify construction safety issues, and carried out research on digital tools that support safe construction processes.

The researchers brought together designers and builders at a digital laboratory (known as the 'CAVE') in the University of Reading to record their interactions and discussions while viewing digital models of a construction project. The researchers analysed data from reviews of the model by designers and builders, and their co-discovery of issues using virtual reality.

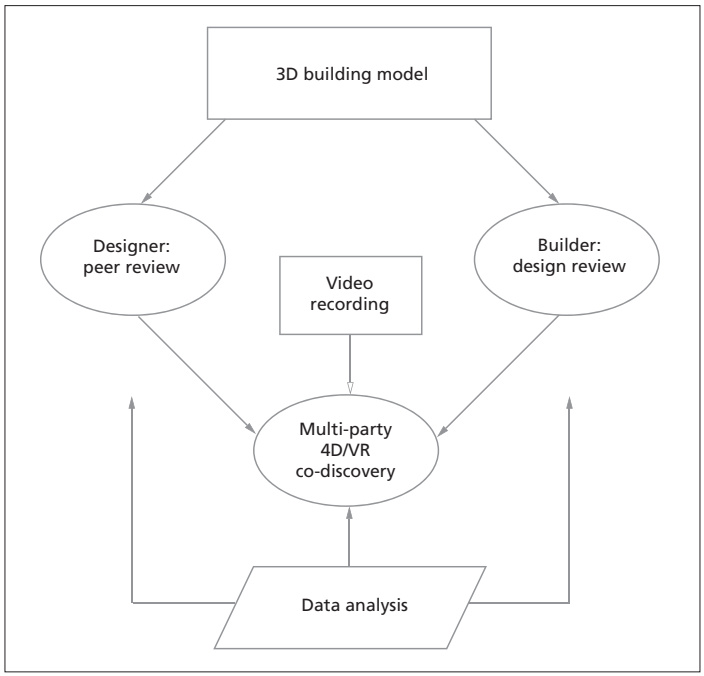

Figure 1
Experimental procedure

Then, experiments were conducted with industry partners and graduate students in construction management.

The team's work included:

- 11 visits to and from industrial collaborators
- two recorded sessions with industrial partners, who, having completed an initial assessment, viewed a model in the laboratory in order to assess the safety implications of a detailed design
- 47 individual assessments by graduate students, followed by 10 pairs of students viewing a model collaboratively to assess the safety implications of a detailed design.

What did our researchers find out?

Assessment of the safety implications of a detailed design

In the CAVE, the safety professionals carried out stereoscopic viewings of 3D models. The research team found that the link between safety and design is more subtle and problematic than earlier studies suggest.

The researchers' critical reading of the research literature on construction safety and design, and their assessment of the safety implications of a detailed design, highlighted the difficulty of establishing causal links, as many factors were involved, such as momentary lapses of judgment, inadequate training, and the institutionalised practices of the design and construction industries.

Development of techniques for use in an assessment

The researchers' interactions with the safety professionals highlighted the many practical challenges of building safely by design and using models to encourage conversations between builders and designers. One finding from the experiments with novice users was that they found it difficult to imagine things that were not represented within the model, such as prefabricated building methods.

Trial of the process with designers and construction workers

In the digital laboratory, the experienced safety professionals discussed hazards relating to edge protection, voids, stairs, scaffolding, cladding, cranes and roofs. They were able to plan scenarios around the design issues and incompleteness of the model.

The professionals drew attention to a wider range of possible solutions to safety issues than graduate students. For example, the professionals identified that using prefabricated building components would reduce or eliminate the hazards posed by working at height.

What does the research mean?

The project suggests a new direction for research on digital tools that promote 'mindful' practices, and the rich interactions associated with these practices.

The findings of the experiments suggest that:

- rich models are needed that direct attention to relevant safety aspects, as well as allow professionals to discover and clarify further contextual information about the project and see it within the context of the site and construction process
- the relationship between safety and design is complex and needs to be actively investigated in work to visualise and use models to develop an evidence base that shows how conversations around design models can improve building safely
- work is needed on models aimed at teaching construction workers about on-site safety issues. An option here would be for the research team to model a wider set of alternatives for permanent and temporary works; and for prefabrication and building on site.

Figure 2
Safety professionals inspecting a scaffolding scenario in the CAVE

Don't forget

Like many studies, this one had some limitations. Virtual reality enabled professionals to collaboratively explore issues and was most useful where attention was directed to key safety concerns. However, the model used in the experiments did not provide users with enough context about the project. Because of this, when the safety professionals and graduate students asked the researchers questions about the model, the information they provided, on occasion, had to be improvised.

The researchers had difficulty bringing together industrial collaborators, ie pairs of designers and builders, to take part in the experiment under controlled conditions. Therefore, some construction management MSc and PhD students with industrial experience were used. The team also engaged with whole-industry project teams, which included safety professionals, by hosting visits to the CAVE and discussing models of their own projects.

What's next?

Further research is needed to extend this study and examine the extent to which health and safety issues can be identified and addressed in the design phase using virtual reality displays of BIMs that provide relevant contextual information.

A follow-up study with designers and builders involved in a real-life construction project, where there is access to both the project design model and safety data from the site, is currently being undertaken.

Our summary gives you all the major findings of the independent project report by the University of Reading and Technion – Israel Institute of Technology. If you want to read about the study in more depth, you can download the full report from **www.iosh.co.uk/designsafely**.

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