Methodologies, strategies and interactions: how best to engage industry when researching a new health and safety tool

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Abstract

Purpose : To examine and explore optimal methods of engagement between academia and industry when researching and developing an innovative technological solution for construction project health and safety. The paper aims to inform academic practice by referencing research findings against leading models of university-industry engagement, such as the Knowledge Integration Community (KIC) model of the Cambridge-MIT Institute.

Design : The paper reflects on experiences of the research team on the University of Manchester's Discovering Safety project BIM Digital Risk Library for Health and Safety. It provides details of the developed BIM-based tool and what methods/strategies have been used to engage, secure and develop ongoing industry support with the research idea.

Findings : Specific research engagement activities (e.g. steering committees workshops; software prototype development; practitioner shadowing) are discussed and reflected against existing models of university-industry engagement (i.e. the KIC of Cambridge-MIT Institute). Findings explore how the unique characteristics of UK construction and fragmented industry health and safety expert knowledge and experience affect and influence work to develop innovative solutions for widespread adoption.

Limitations : Findings and reflections are limited to the early phase of technological innovation development: a prototype proof of concept software tool.

Originality : Originality stems from: (1) Development of a BIM-based tool linking construction risks to mitigation treatments is at forefront of research in the field; (2) the Discovering Safety project is a collaborative effort with UK regulator for health and safety, the Health and Safety Executive (HSE).

Practical Limitations : The findings present useful recommendations which construction health and safety researchers could implement when engaging with industry organisations and professionals to develop technological innovations to improve safety in construction.

Keywords: *Building information modelling, Construction industry, Design for Safety, Health & Safety, Prevention through Design, Technology Innovation.*

Introduction

This paper reports on ongoing research at University of Manchester (UoM) to design and develop a new tool to connect identifiable construction project design risks with relevant mitigations/treatments based on industry expertise, official guidance and the archive of the UK regulator Health and Safety Executive (HSE). The "BIM Digital Health and Safety Risk Library" tool ultimately aims to assist designers in their work by mobilising mitigations in a BIM environment: such an approach aligns with research work that recognises risks may be identified in design phase work, called Prevention Through Design (PtD) (Hale et al. 2007; Tymvios, 2017). Such work demands several processes: proactive use of knowledge resources of the HSE; extraction of data; industry consultations; transformation of data into useable format for BIM environment; industry review, etc.

Whilst the paper briefly reviews the stages in the development of a prototype tool, the primary focus is the relationship between academia and industry to explore what methodologies, strategies and interactions work effectively when researching, designing and delivering a new health and safety tool for industry. The paper aims to inform academic practice by referencing findings against the Knowledge Integration Community (KIC) model of the Cambridge-MIT Institute, USA (a leading model of university-industry engagement).

The applicability and utility of the KIC model will be explored in relation to health and safety technology research and development in the UK, to inform our understanding of the relationship between academia and industry, the fragmented nature of health and safety expert knowledge and how different outlooks and perspectives of practitioners (often resulting from their position in the project lifecycle and the effect of different project procurement models) can effect research work evolution.

The BIM Digital Health and Safety Risk Library project

The "BIM Digital Health and Safety Risk Library" project commenced in 2019 under the Discovering Safety programme of the Thomas Ashton Institute (TAI, 2020), a collaborative research enterprise between the UK Health and Safety Executive (HSE) and University of Manchester (UoM). The project aims to assist design and construction professionals better manage their health and safety objectives via proactive use of digital technologies and mobilization of information resources via a Prevention Through Design (PtD) approach (Yuan et al. 2019). Opportunities provided by technologies such as Building Information Modelling (BIM) as well as industry standard guidance such as PAS 1192-6: 2018 (BSI, 2018) to provide digital solutions for construction health and safety, motivated the research to explore how BIM can be applied to health and safety (Hossain et al. 2019; Mordue and Finch, 2014; Ding et al. 2016). Comprehensive and continuous industry engagement was recognised as essential from the start: phase 1 of the research (January 2019 – June 2020) aiming at the delivery of a prototype Proof of Concept tool in a BIM environment.

Before proceeding to detail the different stages of industry engagement employed, the paper will now describe the Knowledge Integration Community (KIC) model of the Cambridge-MIT Institute, a leading model of university-industry engagement. We seek to cross reference activities of the BIM Risk Library project against the KIC model, exploring the utility, appropriateness and suitability of the KIC model for creation of innovative technologies for construction health and safety. In so doing, we shine a light on the nature of academic/industry engagement and the realities, challenges and opportunities the construction industry presents for academics wanting to do impactful research.

The Cambridge-MIT Institute and the Knowledge Integration Community (KIC)

The Cambridge-MIT Institute (CMI) was established in 2000 by the UK government to develop and implement innovative approaches for knowledge exchange between academia and industry (Acworth, 2008, p.1242). The CMI aimed to replicate the success of the Massachusetts Institute of Technology (MIT) in collaborating with industry in a two-way flow of knowledge to strengthen research and development of innovative technologies. CMI launched its` own Knowledge Integration Community (KIC) model to enhance university-industry links; an objective being that the problems and market needs of industry effectively become the basis for defining research goals of universities. The CMI operates at the centre of an alliance of stakeholders from Research, Education and Industry communities (figure 1).

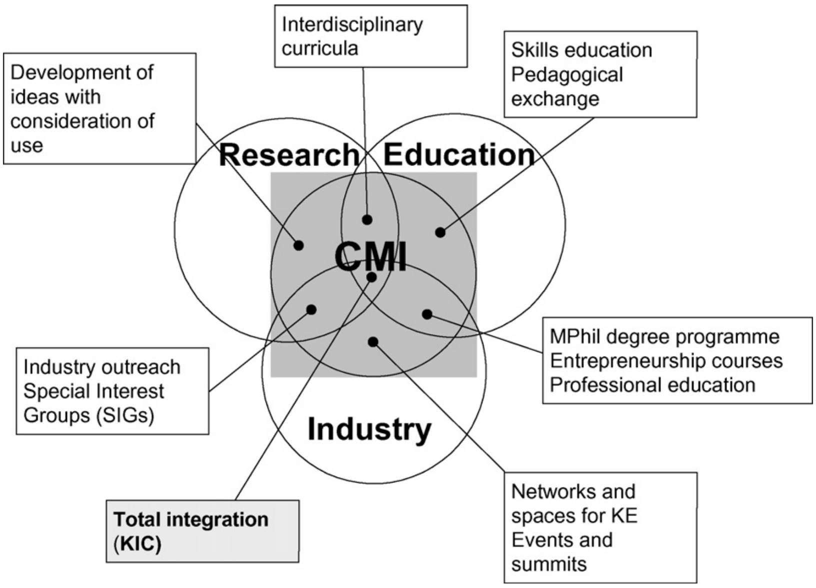

Figure 1: The Cambridge-MIT Institute model for knowledge exchange (KE) (Acworth, 2008, p.1242).

The CMI is based on the premise that positive research outputs can lead to solutions for industry that benefit society and the economy: the concept of multidirectional knowledge exchange (KE) (as opposed to unidirectional knowledge transfer) guiding its overall strategic work. For the purposes of this paper, we focus on the key components of the Knowledge Integration Community (KIC): each KIC being a "collaborative platform for development of a comprehensive and multi-faceted solution addressing technological, economics and social issues." (Acworth, 2008, p.1242).

Acworth (2008) describes the functional components, support mechanisms, organisational structure, review processes and mechanisms of a KIC, noting the importance of *intermediaries* in facilitating links between universities and potential users of knowledge, notably commercial firms. Intermediaries from industry are critical to the flow of research ideas, concepts and prototypes through intra and extra-organisational networks. They can act as gatekeepers to further contacts of importance, opening up doors for trialling, testing and refinement of research ideas and tools in real-world commercial settings.

Figure 2 visualizes the KIC model; Acworth (2008) identifying six components (four human; two concept-based):

- Human: *Research; Industry; Government; Education*
- Conceptual: *Knowledge Exchange; Study of Innovations in Knowledge Exchange (SIKE)*
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The four Human components (Government; Industry; Education; Research) are self-explanatory in meaning; each one having an important role to play in the research journey. The two conceptual elements require some explanation.

Knowledge exchange between research stakeholders is achieved via various mechanisms within the KIC (e.g. workshops; personnel exchanges; web spaces; e-newsletters; video-conferencing; professional communications; formal business development networks, etc.) (Acworth, 2008, p.1248). Such mechanisms enable interconnectedness between stakeholders, facilitating an exchange of ideas and open communication between parties. Knowledge exchange is central to the functionality of the KIC model (as indicated in figure 2).

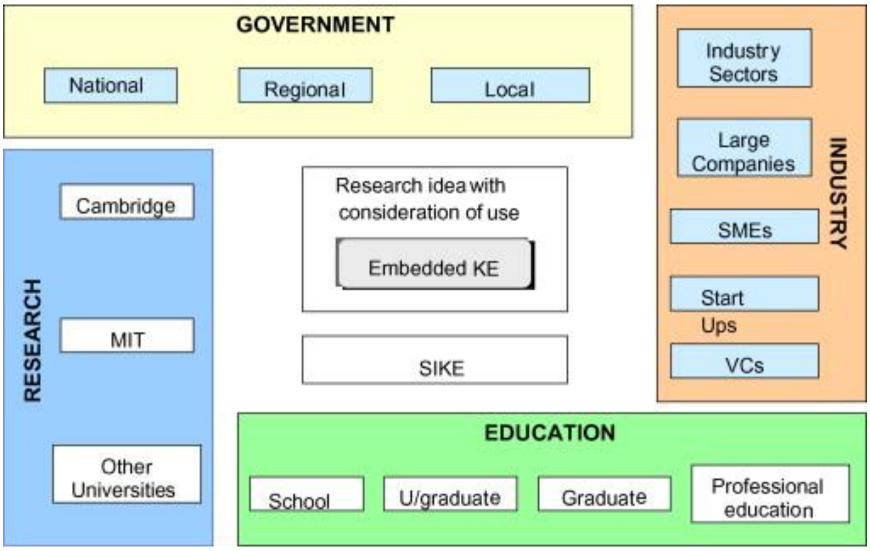

Figure 2: six-component model of a Knowledge Integration Community (KIC)(Acworth, 2008, p.1247).

Study of Innovations in Knowledge Exchange (SIKE) is effectively what facilitates reflective assessment and consideration of the knowledge exchange activities for continuous improvement. The goal here is "codification and dissemination of knowledge exchange methods within the wider community" (Ackworth, 2008, p.1248). This is important for learning and achieving more effective research work: SIKE activity clarifying how ideas/questions from industry translate into responsive research actions and continual examination of how research projects translate into practical use by industry. Again, this is a central component of the KIC.

A strength of the KIC is its` social, *non-hierarchical nature*: individuals engaging in an open forum, where individual company rank and title are set aside for the shared, common research good. Moreover, research is driven by a "consideration of use", so that future potential viability is always an important question. This latter point was identified as particularly important by UK government (2001), when noting the lack of ability in the UK to exploit the scientific results of research (DTI, 2001).

There are a number of differences between the KIC model and funded research projects commonly undertaken by university academics. For example, many academic research projects may not engage with Educational institutions or different tiers of Government, and such a difference should not be viewed as a deficiency. Each separate KIC aims to be a comprehensive model for the CMI: each KIC being a large organisational entity with its` own Manager and dedicated staff. Additionally, each KIC is not intended to be a closed-end project (unlike majority of Research Council funded grants), but is meant to develop into a long-term self-sustaining entity. So, whilst direct comparisons between the KIC model and individual funded research projects should be avoided, we aim to reflect on the KIC model itself as a useful reference for academic/industry research collaboration in construction health and safety research and to draw lessons from the model. The paper now proceeds to detail the different stages of researching and developing the prototype tool on the BIM Risk Library project together with the industry engagements employed.

BIM Risk Library research approach

Industry engagement was integral to work of the BIM Risk Library project from the start; this motivation originating in the overall project aim to:

(1) Provide industry with new tools/techniques to improve health and safety in digital BIM environment

(2) Desire of HSE to enhance and improve construction industry health and safety performance (HSE being official UK regulator or health and safety and major stakeholder and driver on the project).
Figure 3 presents the overall research approach of the BIM Risk Library project. Each of the steps in figure 3 will be briefly described prior to a closer examination of the industry engagements occurring.

1. Academic Literature Review
A review of the academic literature relating to BIM and health and safety concentrated on the design phase of projects. There is a large and growing body of work in this area (Tymvios, 2017; Gambatese et al. 2008; Yuan et al. 2019; Morrow et al. 2015); recent research highlighting the need for designers to enhance their safety knowledge and expertise via digital solutions (Hayne et al. 2017; Hare et al. 2019). Findings of the literature review were synthesised and coded using Nvivo software to produce a rich file of published work in the field. The review provided insights into the implementation of any IT tool for better safety management in construction project design. This work stream was considered an essential foundation for the research project.

2. Industry Software Review
Specific construction industry software packages were identified and reviewed by the research team. Specific workshops and webinars were subsequently attended, so the potential for hosting a pilot tool on different platforms could be explored. Following a number of further meetings, one specific software platform was selected as the most appropriate for our research work. It should be noted that the software providers were very accommodating to engage in the research discussions. Following the selection of one specific platform provider, a separate contract was set-up so that our research concepts could be integrated with and hosted on the BIM software platform. An important insight here is the need to reserve project funds for software development work (if the expertise/capability is not within the academic research team).

3. Research Centres
Several national and international research centres of excellence in the field were identified for subsequent contact in future project work.

4. BIM 4 H&S Group
University of Manchester (UoM) was invited by HSE to engage with the BIM for Health and Safety group (BIM4H&S), a body of industry experts in the field. The BIM4H&S group were instrumental in work leading to the industry standard PAS 1192-6: 2018 “Specification for collaborative sharing and use of structured health and safety information using BIM” (BSI, 2018); a working link with the BIM4H&S group therefore being important for the research project. A working link was subsequently established and several meetings attended, with ongoing work being presented at periodic intervals. This link was important for the research project, giving a direct communication link with industry figures managing construction health and safety in their organisations.

5. Industry Workshops
Two industry workshops were held at UoM to review research work done and scope out directions of the research project. Industry figures were invited and contributed positively to the research work tasks conducted. The research work was also presented at several national events (e.g. Digital Construction Week 2019; BIM for Water event 2019), with potentially useful collaborative contacts being made.

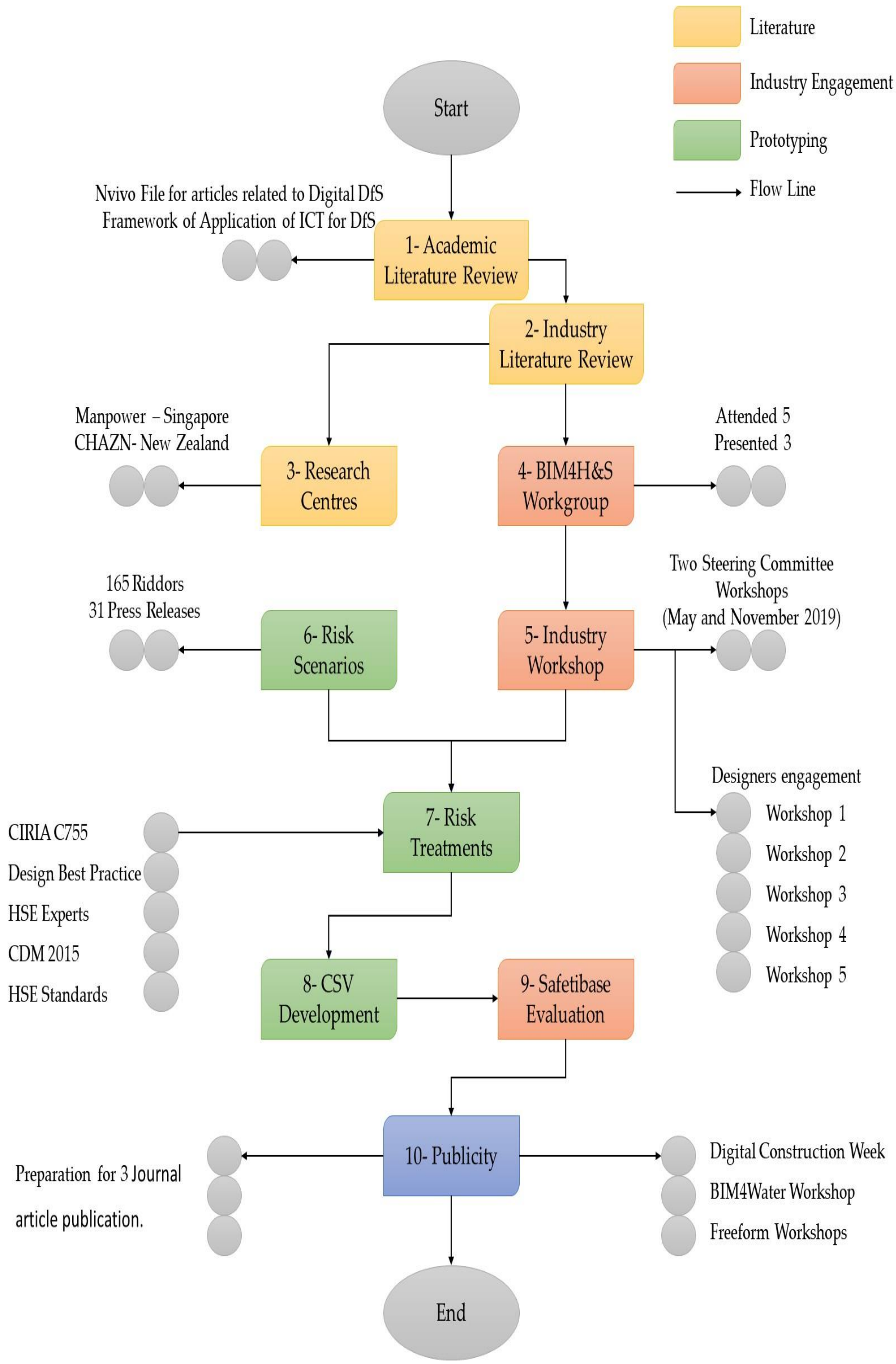

Figure 3: research approach: BIM Risk Library project

7. Treatment Actions
Treatment actions for the 9 scenarios were identified from a combination of industry workshop events (see above), official industry guidance documents (CIRIA C755; CDM 2015), HSE expert opinion and the Design for Best Practice Website (www.dbp.org.uk). Treatments were then placed into a matrix, classifying treatment actions based on treatment type and phase of implementation: Treatment Type (eliminate; reduce; control; inform); Project Phase (preliminary; detailed; preconstruction; site management).

For each scenario, several treatment actions were identified and placed in the appropriate matrix slot. These Treatments were then validated in one to one meetings with industry experts. The work led logically to the creation of a csv file showing all different combinations of seven concepts for the proof of concept risk.

8. CSV development
It was determined that a csv file could contain relations between the different concepts and several mitigation plans based on several scenarios; the csv file then being uploadable to the new software interface development work (see above).

9. Tool testing and evaluation
With the creation of the new interface on the BIM platform that could host the csv file, the scenarios and treatments tool could then be tested and refined with an industry audience. This work began at the end of phase 1, to be subsequently expanded in further work.

Discussion

The above activities are now discussed with reference to the KIC model of the CMI to inform understanding of conducting research in construction health and safety. To do this, each of the KIC components are reviewed in turn, as well as the overall KIC characteristics of *intermediary roles* and its` *non-hierarchical nature*.

Human components (Government; Research; Education; Industry)
The BIM Risk Library project has several Human component stakeholders. UoM, as appointed research partner, belongs in the *Research* category. The project sponsor (Lloyds Register Foundation), as a global charity, straddles both *Industry* and *Research* components: Lloyds Register providing funds to the HSE, which in turn, commissions research work. Whilst the BIM Risk Library project has no *Education* components, the potential of using the BIM Risk Tool in educational settings was noted by several stakeholders during project work. The HSE, as government agency, falls into both *Government* and *Research* components. Having the HSE as research partner greatly assisted the project in several ways: the HSE opening up communication links with industry more easily than an independent academic team could achieve. Several companies became involved in research work, either as software providers or construction industry companies: these falling into the *Industry* category of the KIC model.

We may conclude that having active players in each of the *Research*, *Government* and *Industry* categories definitely helped the project. Having both the HSE and Lloyds Register Foundation straddle several categories also strengthened the overall research project: industry organisations being more interested in becoming involved in our work. Therefore, it can be stated that for research teams aiming to produce innovative health and safety technical solutions, having representation in each of the human component categories is beneficial for the research project.

Knowledge Exchange

Knowledge exchange was facilitated in a number of ways on the project. Active membership of the BIM4H&S group, the setting up of a research project steering committee and regular attendance of industry events allowed opinions and thoughts of industry leaders to be obtained. This was vitally important for research project progress.

Software provider expertise and opinion was also essential for the prototype tool development. As noted, one BIM software provider enhanced their own software interface to allow integration of the UoM concepts and csv file. This followed formulation of a separate Contract between the HSE and the company to do so. The insight illustrates how it may be expedient to employ external expertise to complete a task which the internal team may not have the capacity or capability to undertake themselves. Although a financial cost was incurred, considerable time and effort was saved as result. Therefore, for research project managers, it may be expedient to budget in for possible software development work on a project, especially if the internal team lacks the expert knowledge. In terms of digital technology development, this may well be an issue of importance.

Knowledge exchange was also facilitated by the industry workshops. These were held for risk scenario completion, and were important in several respects. Not only did they facilitate the necessary knowledge exchange, but the organisation, management and running of the workshops had a cumulative effect on participants. Composition of each workshop was carefully considered beforehand (6 workshops were conducted with different companies to fill the treatment plans for the 9 identified scenarios); the meetings consisting of safety experts, design engineers and construction managers to fill the scenarios with different mitigation plans. During several workshops, a spreadsheet was uploaded onto the Cloud to allow simultaneous access and concurrent inputting of data (with shared viewing).

The workshops also facilitated knowledge exchange between industry stakeholders who commonly do not meet or communicate with each other in their professional lives. For example, in one workshop, a leading design and engineering consultancy worked closely with a Tier 1 contractor on the scenario task, obtaining a unique, holistic view of an integrated design in the process. There was thus added value for the participants in attending the workshop. No less important to the running of a successful industry workshop are its` organisation, venue, travel arrangements and food/refreshment provision, which all feed into the opinion of the academic partner by the industry practitioners. The above mechanisms were key to effective knowledge exchange on the research project.

Study of Innovation in Knowledge Exchange (SIKE)

SIKE activity was limited as the bulk of effort went into prototype tool concept and development work. However, the authors believe SIKE activity will be critical in future as SIKE is effectively what facilitates reflective assessment and consideration of the knowledge exchange activities for continuous improvement, as noted by Acworth (2008), who states,

"The goal here is "codification and dissemination of knowledge exchange methods within the wider community" (p.1248)

The research team at UoM have certainly laid the groundwork and conditions for fruitful SIKE activity in further research work.

Intermediary roles

There were several important intermediaries who provided a vital link between the academic team, construction industry companies and potential users of the tool. These were persons from the HSE and individual construction companies.

As noted by Ackworth (2008), these intermediaries are critical to the flow of research ideas and concepts, acting as gatekeepers to further contacts of importance, opening up doors for trialling, testing and refinement of research ideas and tools in real-world commercial settings. For the BIM Risk Library project, these intermediaries were very important to the eventual success of the project.

The authors conclude that a research project should try and identify such intermediaries very early in the research project lifecycle, probably at the research proposal stage. A project lacking intermediaries would experience more difficulties in making the important connections between industry, academia and government.

Non-hierarchical nature

The research was conducted in a non-hierarchical fashion from the start. Different companies were treated equally, with the BIM4H&S group meeting being non-hierarchical in nature. The workshops were open and non-hierarchical in nature, and the participants enjoyed this set-up, more readily contributing their thoughts and opinions as a result. It may be concluded that treating research participants equally is of benefit to a research project.

Obviously, context of study is a very important factor here: the BIM Risk Library being "project-neutral" in that our research work was not connected to one specific project, examining health and safety work from an objective, independent viewpoint. Conducting research work in a project setting might compromise the non-hierarchical ideal we experienced, as different companies/individuals would be sensitive to how their responses to research questions would be interpreted by other stakeholders on the project.

Conclusions

The paper reviewed the UoM BIM Risk Library project, discussing what methods, strategies and interactions were employed by the research team and referencing the CMI KIC model of research in the process. Whilst there are obvious alignments between the KIC model and the BIM Risk Library project (i.e. the Human components, importance of intermediaries), the authors believe that the characteristics of the construction industry and how health and safety expertise and knowledge is held makes conducting research in the field uniquely different.

For example, the fragmented nature of industry knowledge and expertise means industry workshops have added value for participants: workshops allowing different professional perspectives to come together in a relaxed forum to share opinion. Additionally, construction software providers are likely to be very positive towards research teams that offer them links with industry and government agencies (as the BIM Risk Library project did), whilst a research project that has a governmental entity as part of the research team brings with it distinct advantages. For research teams about to engage in health and safety research work, recognising the unique differences of construction industry and catering for them, can result in more fruitful research outputs and longer sustaining relationships.

The research project has now (Sept. 2020) proceeded to a further stage of industry engagement, with several pilot projects being planned to test and refine the tool in real construction design work settings on multiple projects with multiple design and construction organisations. These closer industry interactions will bring further issues forward and highlight more lessons regarding academia and industry engagements.

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References

Acworth, E.B., 2008. University–industry engagement: The formation of the Knowledge Integration Community (KIC) model at the Cambridge-MIT Institute. Research Policy, 37(8), pp.1241-1254.

British_Standards_Institution, 2018. PAS1192-6: 2018 Specification for the Collaborative Sharing and Use of Structured Health and Safety Information Using BIM. London :BSI Standards Limited.

DTI (Department of Trade and Industry), 2001. UK innovation performance: strengths, weaknesses, opportunities, threats and main problems. DTI: HMSO.

Ding, L. Y., et al. 2016. Construction risk knowledge management in BIM using ontology and semantic web technology. Safety Science, 87, pp.202-213.

Gambatese, J. A., Behm, M. and Rajendran, S., 2008. Design's role in construction accident causality and prevention: Perspectives from an expert panel. Safety science, 46(4), pp.675-691.

Guo, H., et al., 2017. Visualization technology-based construction safety management: A review. Automation in Construction, 73, pp.135-144.

Hale, A., et al., 2007. Safe by design: where are we now? Safety Science, 45(1-2), pp.305- 327.

Hare, B., et al., 2019. Improving designer`s knowledge of hazards, IOSH.

Hayne, G. et al., 2017. Design hazard identification and the link to site experience, Proceedings of ICE: Management, Procurement and Law, 170(2), pp.85-94.

Hossain, M.A., et al., 2018. Design-for-Safety knowledge library for BIM-integrated safety risk reviews. Automation in Construction, 94, pp.290-302.

Kasirossafar, M., Ardeshir,A. and Shahandashti, R.L., 2012. Developing the sustainable design with PtD using 3D/4D BIM tools. World Environmental And Water Resources Congress, May 20-24, Albuquerque, New Mexico, United States.

Mordue, S. and Finch, R., 2014. BIM for Construction Health and Safety. NBS Publishing.

Morrow, S., Cameron, I. and Hare, B., 2015. The effects of framing on the development of the design engineer: Framing health and safety in design. Architectural Engineering and Design Management, 11(5), 338-359. [online]

TAI (2020) Thomas Ashton Institute. Available at: https://www.ashtoninstitute.ac.uk/programmes/discovering-safety/

Tymvios, N., 2017. Design Resources for Incorporating PtD. Practice Periodical on Structural Design and Construction, 22(4), p.6.

Yuan, J.F., et al., 2019. Accident prevention through design (PtD): Integration of building information modeling and PtD knowledge base. Automation in Construction, 102, pp.86-104.