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SAFETY AND HEALTH IN CONSTRUCTION RESEARCH ROADMAP

REPORT FOR CONSULTATION

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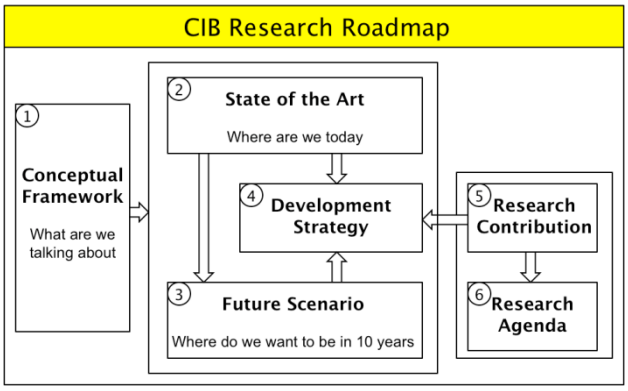

Safety and Health in Construction

CIB W099 Report for Consultation

SUMMARY

This research road map for safety and health in construction outlines the conceptual framework of the domain along with a review of the state of the art and vision for the future, both for the industry and research community. This leads to a review of the research contribution and a development strategy and research agenda for 2020.

CONCEPTUAL FRAMEWORK

WHAT IS OCCUPATIONAL SAFETY AND HEALTH (OSH) IN CONSTRUCTION?

"Occupational safety and health (OSH) is generally defined as the science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment. This domain is necessarily vast, encompassing a large number of disciplines and numerous workplace and environmental hazards. A wide range of structures, skills, knowledge and analytical capacities are needed to coordinate and implement all of the "building blocks" that make up national OSH systems so that protection is extended to both workers and the environment" (Alli, 2008).

Notwithstanding, for many people OSH is actually limited to the more immediate issues of safety caused by accidents rather than the more difficult, less immediate topic of occupational health. This is also highlighted in Figure 10 (a trend analysis of CIB W099 conference papers) where health had a much lower proportional representation than the other themes investigated.

Globally, construction is one of the most hazardous industry sectors with many thousands of workers being killed and seriously injured each year. Whilst some regions have been making progress over the years there is still a long way to go to reach the vision of an industry where people return home at the end of a shift healthier than when they arrived.

Furthermore, good health and safety management leads to project wide benefits. In a review of the success of the construction of the London 2012 Olympic Park, General the Lord Dannatt said that "health and safety was not just an annoying millstone hung around middle management's neck, but it was the enabling theme on which the project senior leadership team could form the bedrock of operational efficiency leading to completion under budget and ahead of schedule and all achieved with no fatalities."

As a relatively new domain, OSH research and practice interfaces with many other areas as indicated indicatively in Figure 1. The circles move closer to or further away from the ellipse to illustrate the current level of embednesses of each of these areas within health and safety research and development. Within the ellipse occupational safety plays a much stronger role visually (highlighted in bold). This is an attempt to highlight that while the phrase or general term Occupation Safety and

Health (OSH) is used within the industry there is in fact an uneven focus on safety. This interface feature means that many researchers enter the OSH area along with their other specialism which, in turn creates a broad spectrum of stakeholders with an interest in OSH. Examples of how some of the themes interact with OSH are given below.

Risk – is the chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard (a source of potential damage or harm). Typically, risk is assessed and managed using a risk assessment. Risk management compromises four interdependent elements: (1) hazard identification; (2) risk analysis; (3) risk control selection; and (4) risk control implementation and maintenance. Risk management has primarily been focussed on construction sites, many countries now argue that designers and preconstruction planners are in a good position to eliminate or reduce risk, prior to work starting on the site. Construction hazards are generally classified in to four distinct categories which include job site conditions (nature and physical layout); equipment and materials; human; and management factors (Pipitsupaphol and Watanabe, 2000). The importance of the human element is highlighted by the role of errors and omissions in catastrophic system failures and occupational accidents (Lingard and Rowlinson, 2005). Management hazards such as poor training and lack of appropriate safety protocols are also considered important in the causation of accidents in construction.

ICT – Innovation, planning, management and knowledge flow are important factors in continuous improvement in OSH and OSH management. ICT platforms may improve the efficiency of project planning, making it easier to consider OSH implications at each stage of a project, instead of just reactive actions to project issues. During the project, ICT has a role in improving the flow of information and improving lessons learnt by storing available information. The recent development of Building Information Modelling (BIM) is an example of this interface.

Human Factors/Ergonomics – Ergonomics is the study of work, it combines an understanding of human abilities (physical and cognitive) with knowledge of tool design, equipment and the organisation of work. Ergonomics work can involve specialists from many different disciplines, including physiotherapists, psychologists and doctors. Ergonomics principles can be used at several stages of work design including tool and equipment design, workplace layout and planning of the workplaces. Construction work is physically demanding with manual handling of heavy loads. Moreover there are constant changes in work and task design together with varying levels of technology and interface design. Construction work is often performed in restricted environments where workers are forced to observe static, awkward postures, high levels of force, repetition and vibration. There are several examples where ergonomics improvements are needed in construction. However, given the environment they are more difficult to implement in comparison to other industries.

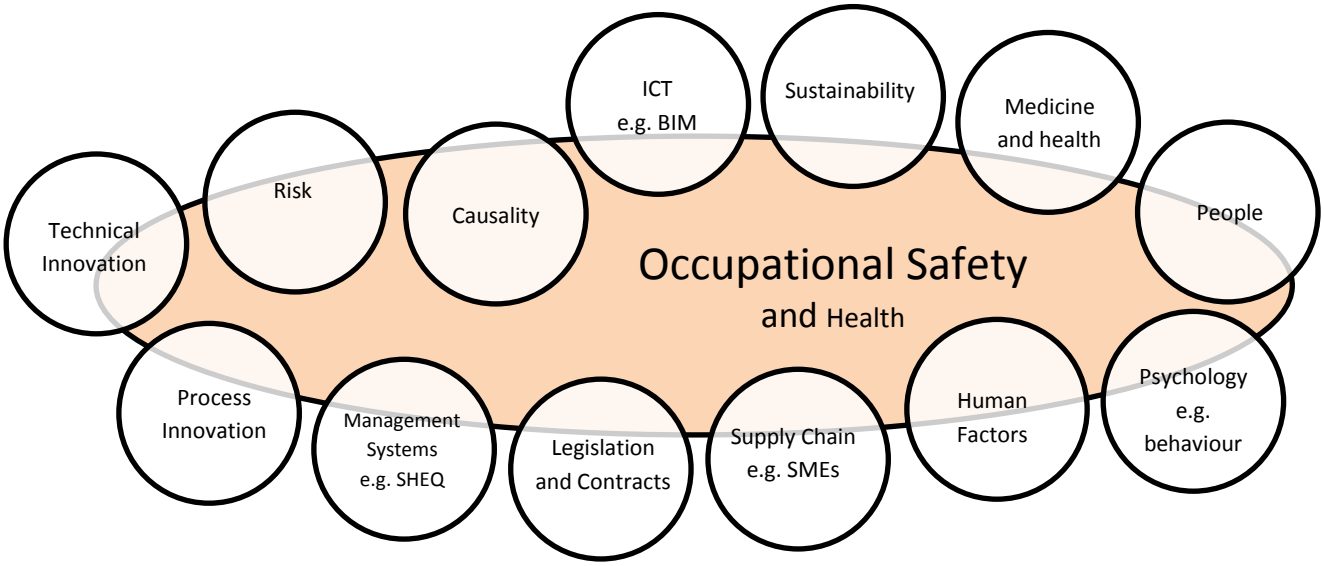

Figure 1 Indicative interfaces between OSH and other domains of research and practice

Influence of other industries

Construction is a diverse industry and projects may take place in several sectors (Figure 2) which are also high hazard or high risk, for example nuclear construction. This implies that there is an opportunity to learn and adapt health and safety standards. For example Carter and Smith (2006) compared hazard identification across rail, general and nuclear construction and found that the nuclear sector far out preformed the others in terms of risk identification. It was proposed that method statements and methods of hazard identification may be modified in rail and general construction and modelled on those used in nuclear. Choudhry et al., (2007) the term safety culture first emerged in 1986 following a review of the nuclear accident in Chernobyl. Once correct management and environmental standards in terms of tools, planning and equipment are in place, safety culture is seen as important to ensure a common sense of understanding and beliefs among everyone on site.

As standards and technology improve there is potential to introduce these technologies on site to improve the safety and health of workers. For example, the nanotechnology revolution is having a ground-breaking impact on diverse science, engineering and commercial sectors. In construction this technology has the potential to improve the usability and versatility of materials as well as strength, durability and lightness. In the final build nanaomaterials may allow the building to have improved properties such as self-cleaning glass and better health insulation. However, the long term effects of these types of materials on construction worker safety and health is still unclear. There may also be issues with the safe storage and disposal of these materials. In this instance construction health and safety professionals may need to learn from experts in health industries and materials sector to fully exploit these materials in a way that is safe for the construction worker.

These are just two examples of how different industry sectors can have an impact on OSH, given the diversity of the industry there are inherently many more.

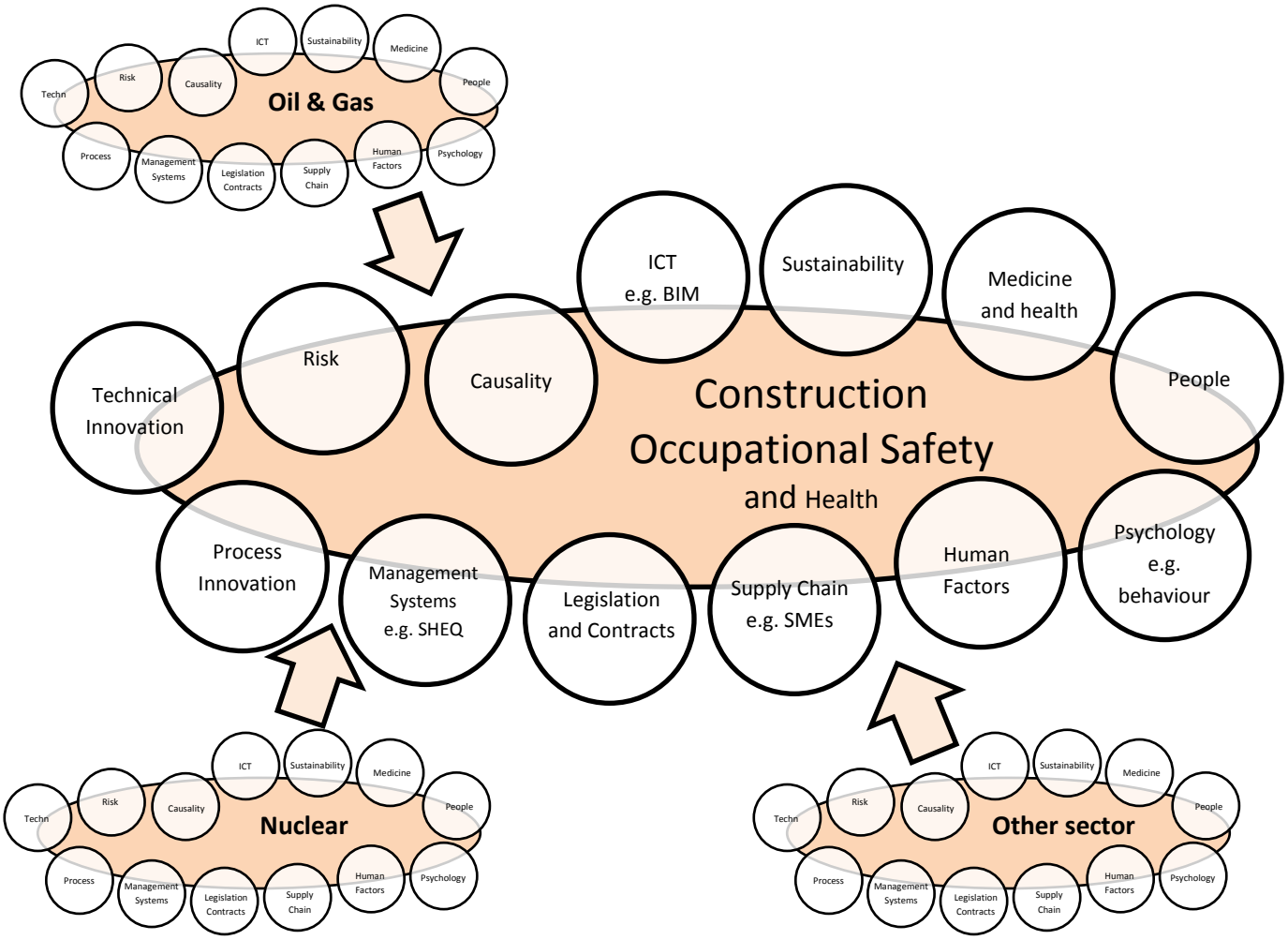

Figure 2 Influence of other sectors on Construction OSH

Construction

Worldwide occupational injury rates in construction are highest for all major industries (Lehtola et al 2008). Unlike other industries such as manufacturing, construction is composed of a transient workforce (Kadefors, 1995; Dubois and Gadde, 2002) where project personnel from different cultures and backgrounds are expected to work together in a constantly changing work organisation and structure. Construction is always risky because of outdoor operations, work-at height, complicated on-site plant machinery and equipment operation coupled with worker's attitudes and behaviours towards safety (Choudhry and Fang, 2007). From a practical point of view health and safety in construction is about using appropriate means to ensure workers are both safe and healthy. However, in a construction environment the situation is all the more challenging, where projects differ considerably in terms of size, location and complexity. Moreover, safety can impact all stages of a project from planning, operationalization to review. Construction is also made up of several organisational sizes and affiliated companies. For example, large construction companies who employ more than 250 workers and the illegal "cowboy builders" who work on an illegal,

unregistered, ad hoc basis within the industry. Further details on company size and turn over are given in Table 1.

Table 1 Size and turnover of various sized industries

Enterprise category	Headcount: Annual Work Unit (AWU)	Annual turnover	or	Annual balance sheet total
Medium-sized	< 250	≤ €50 million (in 1996 € 40 million)	or	≤ €43 million (in 1996 € 27 million)
Small	< 50	≤ €10 million (in 1996 € 7 million)	or	≤ €10 million (in 1996 €5 million)
Micro	< 10	≤ €2 million (previously not defined)	or	≤ €2 million (previously not defined)

Evolution of Safety Culture

The management of OSH requires sustained and co-ordinated effort. However, construction is a transient, global industry and therefore construction companies are often decentralised which means that a common culture or beliefs and attitudes are not easily developed among project stakeholders. Safety culture is the way in which safety is managed in the workplace, and often reflects the attitudes, beliefs, perceptions and values that employees share in relation to safety" (Cox and Cox, 1991). Pybus (1996) developed a model which has been adapted in Figure 3 to illustrate the evolution of safety culture over time as the safety culture of a construction company improves there is a correlation with the reduction in ill-health and illness. At the start of each phase a reduction in accidents or ill-health incidents is achieved, followed by a plateauing of performance before moving into the next phase. The traditional approach to OSH is essentially reactive, where hazards are dealt with as they arise and there is a strong emphasis on discipline and tactics such as enforcing the use of personal protective equipment. The transitional phase is more proactive in that hazards are considered before they arise and procedures are established in an attempt to prevent occupational illness and injury and there is an emphasis on developing effective OSH management processes and procedures. The innovative phase fully integrates OSH into all business making decisions, and every attempt is made to eliminate hazards or minimise OSH risks using technological solutions. Cultural and motivational issues are also considered in this phase, and work is organised to encourage good OSH performance (Lingard and Rowlinson, 2005). To achieve further improvement the industry needs to progress to the innovative stage of OSH management, however the complexities of the industry mean this will not be easily achieved. It is also important that the previous phases have been progressed significantly to ensure that a concentration on culture in the third phase will be effective – you can't go straight to the innovative phase.

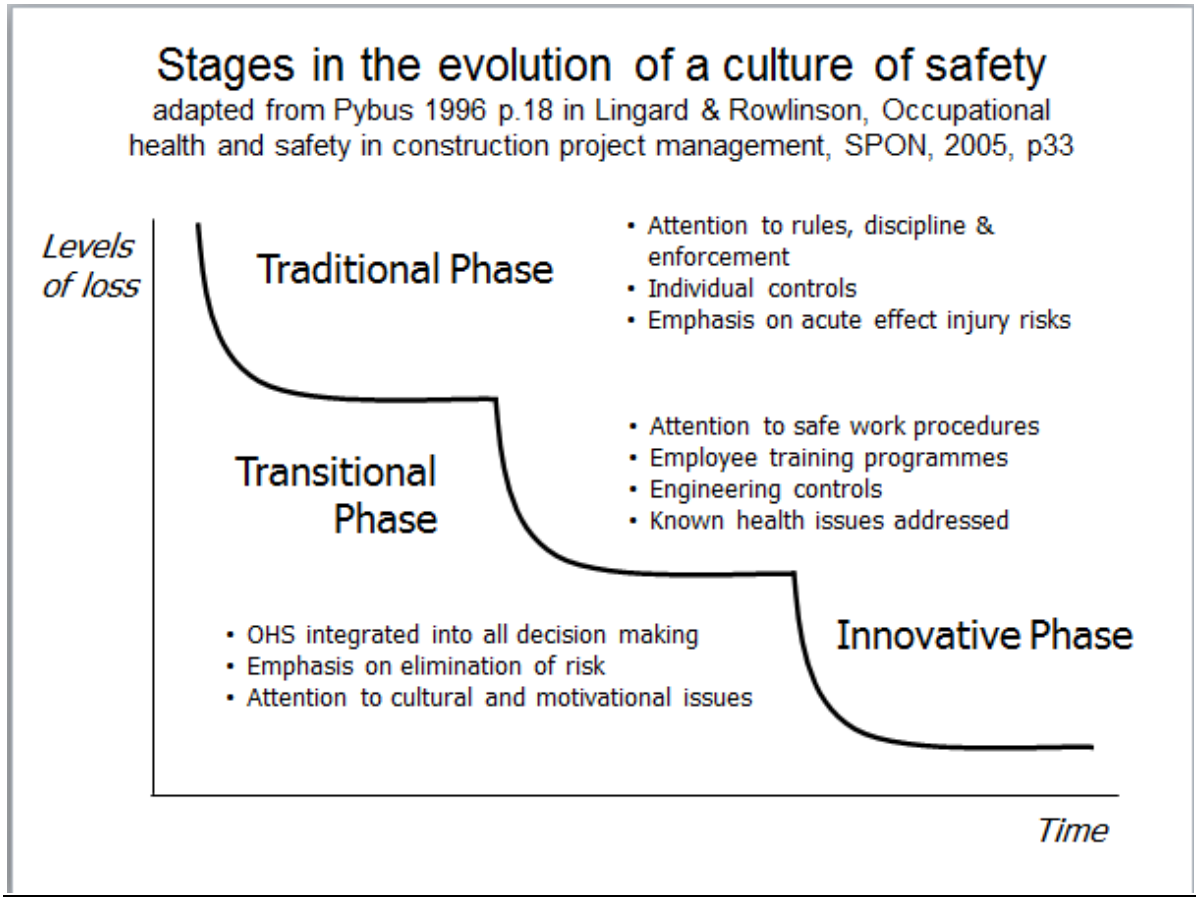

Figure 3 ***Stages in the evolution of a culture of safety***

As with many other areas of research in the built environment, OSH practice and performance differs considerably around the world, with some regions being generally accepted as leaders and others as laggards, with a considerable spectrum in between (Figure 4). Leading regions are tending to focus now on behavioural health and safety and developing an OSH culture. The time taken to move through these phases differs between regions but has tended to be measured in decades rather than years. Lagging regions still tend to be working in the traditional or transitional phases. Whilst the time taken to move between phases may be shorter now than previously, it is generally accepted that phases cannot be missed out – in other words, attention to rules, discipline and enforcement need to be embedded within organisations and individuals before much benefit will be gained by focussing on safe work procedures and, certainly, concentrating on behaviours without having the appropriate training and controls in place would be considered as inappropriate and ineffective.

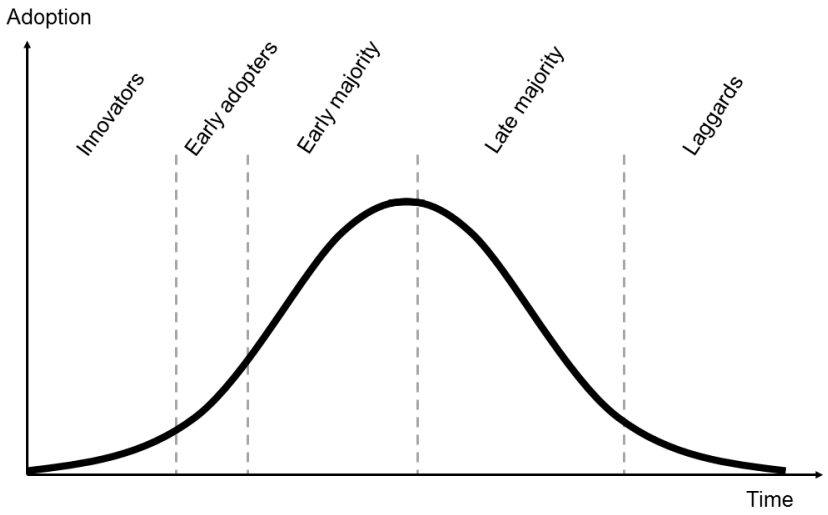

Figure 4 Approaches towards new ideas *(from Crossing the Chasm (1991) Geoffrey A Moore)*

STATE OF THE ART

At present it is theorised that the majority of small construction firms are in the traditional phase while larger companies are thought to be in the transitional phase (Lingard and Rowlinson, 2005). However, this may vary further depending on the company's geographical location i.e. whether the company is in a lagging or a leading region.

Across the globe, the construction industry uses an extended supply chain to deliver projects. Large contractors typically win the work and then subcontract to smaller companies who may subcontract again to organisations that employ the workers. Most regions also have a long 'tail' of small or micro organisations working on smaller projects or in maintenance and refurbishment. Furthermore, most regions have a considerably sizeable illegal or unregistered workforce.

Figure 5, adapted from Brace et al (2009), shows a typical situation for a leading region around 20 years ago. There was a considerable amount of poor working practices across the whole sector. This is still typical of OSH lagging regions today.

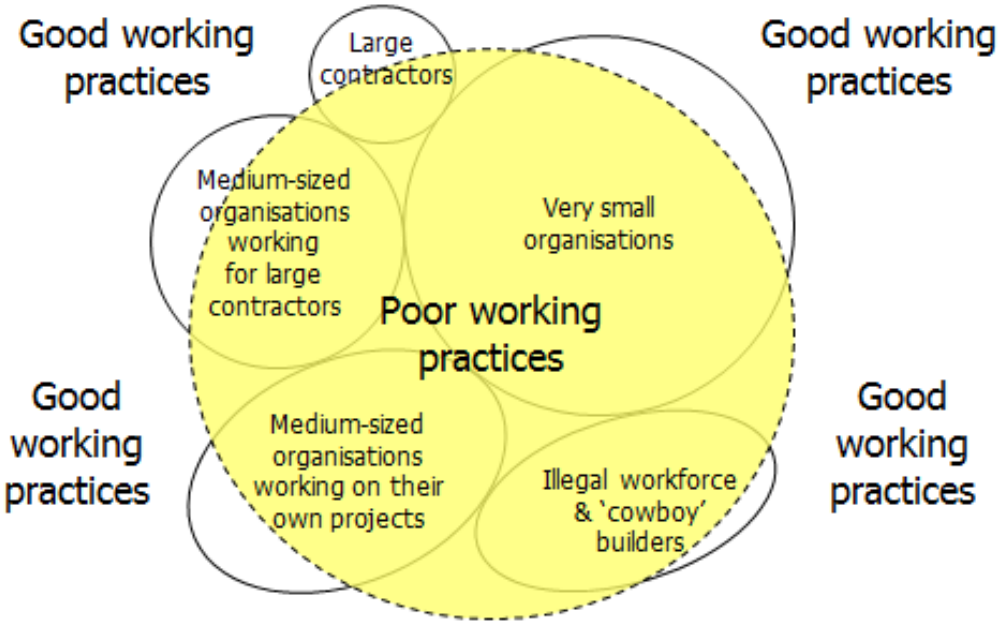

Figure 5 Typical OSH situation in leading regions 20 years ago and lagging regions today

Figure 6 shows the situation in many leading regions today, following a number of decade's concentration on OHS improvements. This also forms a viable medium term target for OSH lagging regions.

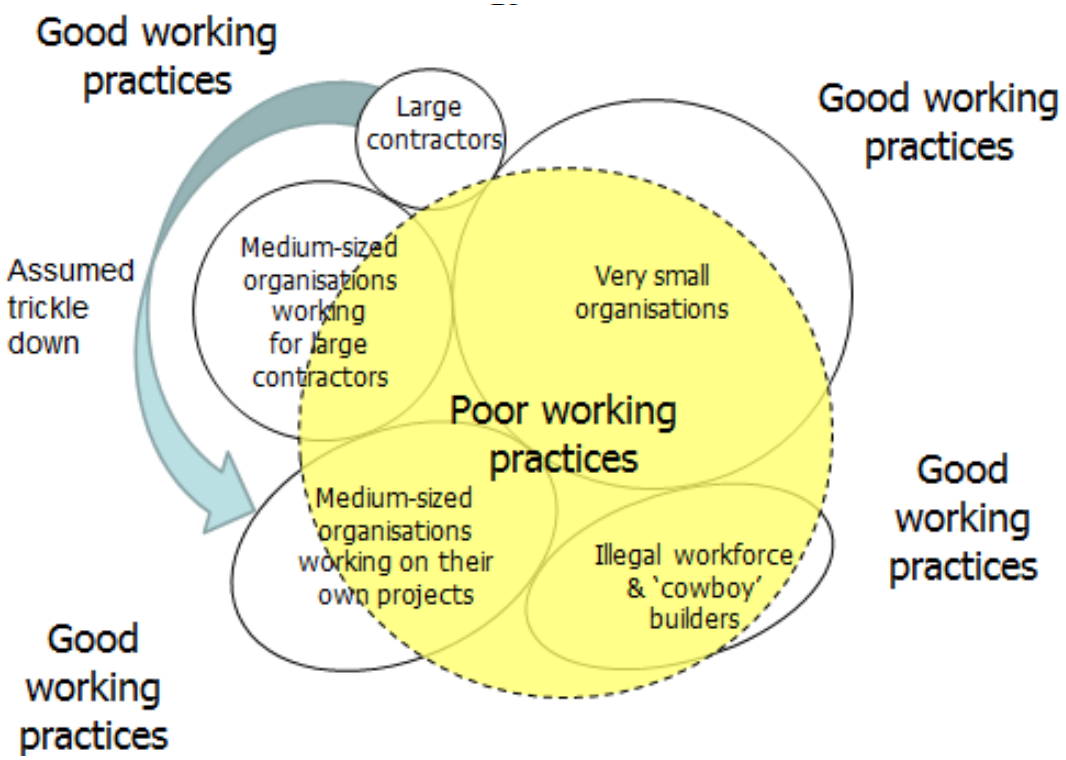

Figure 6 Improved situation for many leading regions today and realistic medium term target for lagging regions

The larger contractors have moved on considerably, along with the medium-sized organisations that are part of their networks. There is an assumed trickle down to such organisations working on their own projects. However, there are still poor working practices, especially amongst the smaller organisations and particularly within the illegal workforce

Figure 7 offers a realistic medium term target for leading regions where the large contractors and medium-sized firms working within their networks have all but eliminated poor working practices, as have many medium sized and micro organisations. However, there is still an illegal workforce and poor practice in many smaller organisations.

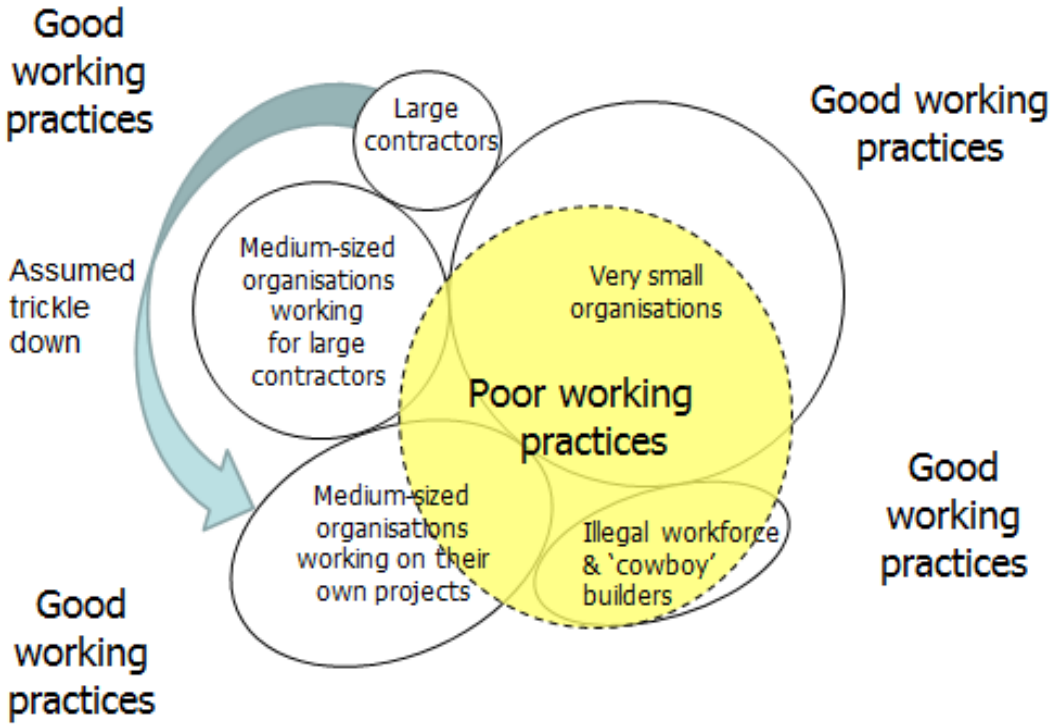

Figure 7 ***Realistic medium term target for leading regions***

FUTURE SCENARIO

Figure suggests the challenging vision for all regions where the illegal or unregistered workforce is removed and all organisations operate with good working practices and, in theory at least, zero accidents and even zero harm targets are achieved and all companies are in the innovative stage of safety culture.

Figure 8 ***Idealistic vision for all regions – no illegal workforce and no poor work practices***

Figure 3 showed the traditional, transitional and innovative phases of OSH management It was said that small and micro organisations tend to lag behind larger organisations in this development. For instance, in leading regions, large organisations may well be concentrating on the innovative phase whereas smaller organisations may still need to focus on traditional aspects. Figure 9 shows a somewhat over-simplistic indicative time line with medium, small and micro organisations following larger organisations in this development. It also suggests where the leading and lagging regions are currently focussing and provides a 10 year goal for each.

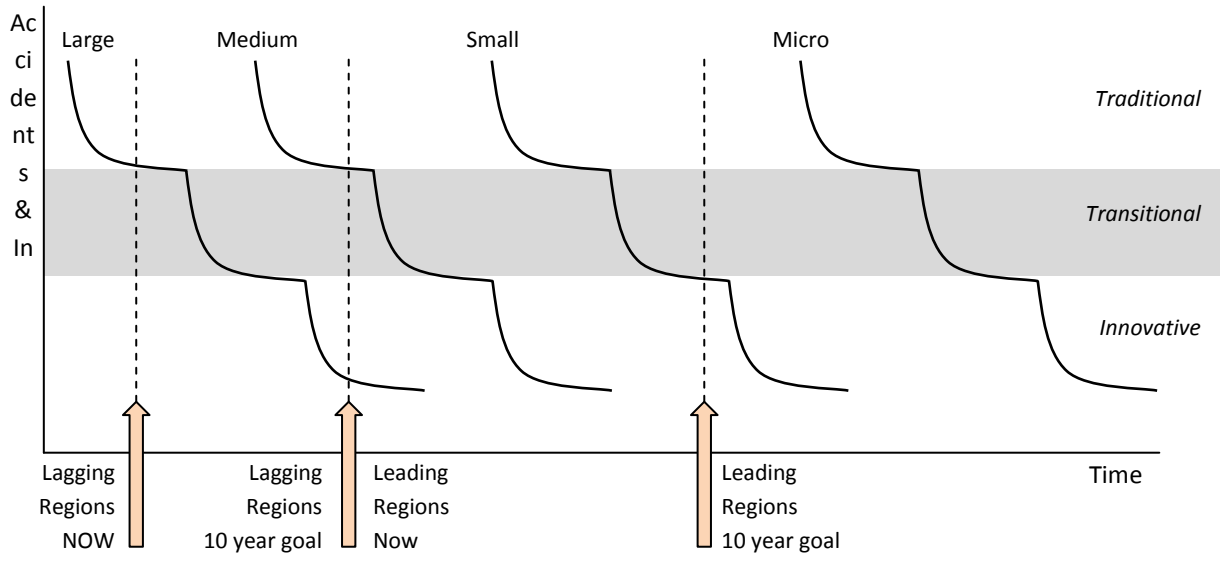

Figure 9 Traditional, transitional and innovative OSH management phases varying with organisation size and region

DEVELOPMENT STRATEGY

A survey of industrialists and researchers from leading regions identified the following three areas that were seen as key to moving from the current situation to the ideal OSH state. They were:

(1) More responsible client behaviour – to adopt procurement approaches that support the integration of health and safety into project decision making and drive this so that it happens. The green building analogy comes to mind. If clients want environmentally sustainable buildings they get them. Why not healthier and safer building techniques and processes too?
(2) Health and safety becomes a professional responsibility of everyone in the industry. At the moment it is perceived to be the health and safety professional's job. Health and safety professionals are generally not architects, engineers etc. They don't make decisions. They act as advisors. The decision makers need to step up and take professional responsibility.
(3) Closer and more effective links between industry and academia. There is a need for a more evidence-based approach to construction health and safety. Companies need to know with certainty what works and what doesn't. Managers are easily persuaded when there is evidence but sceptical when there is none.

RESEARCH CONTRIBUTION

In order to investigate the role of CIB W099 in facilitating OSH research, data from previous conferences was analysed to investigate if any trends existed over time in each of the key factors and themes identified by the researchers based on frequency. These results give an overview of:

1. Conference locations (Table 2).
2. Average paper submission per continent (Table 2).
3. Types of papers submitted, i.e. academic or otherwise (Figure 10).
4. Methodologies and study designs used by authors (Figure 11).
5. Data collection methods used (Figure 12).
6. Data analysis methods used (Figure 13).
7. Pertinent themes and trends (Figure 14).

Table 2 illustrates that the majority of conferences were held in OSH leading regions (Europe and North America). Moreover, Europe and North America were the most prolific contributors to the conference. South America was very much underrepresented at the conferences. However, where the conference was held in South America the majority of papers were from that region. Oceania, Africa, and Asia were also better represented as a region when conferences were held there.

Table 2 ***Conference locations and average paper submission***

Year	Continent	Country	#Papers	%Host nation	Collaboration	Asia	Europe	Nth America	Sth America	Africa	Oceania
1994	Nth Am	USA	26	50	0	3.8	38.4	54	0	3.8	0
1996	Europe	Portugal (WC)	13	7.6	0	0	46.2	53.8	0	0	0
1999	Europe	Milan, Italy	122	45.1	4	15	27	45	0.8	6	3
2000	Europe	England	28	28.5	0	3.6	67.8	14.3	0	10.7	3.6
2001	Oceania	Nw Zeald (WC)	10	10	0	10	40	10	0	20	20
2002	Asia	Hong Kong, Ch	36	36.1	5	34	30	5	2	13	11
2003	Sth Am	Brazil	36	38	5	5	33	11	38	8	0
2004	Nth Am	Canada (WC)	6	0	33	0	25	26	0	16	0
2005	Africa	South Africa	69	23	6	12	43	6	5	23	5
2006	Asia	China	72	22	2.7	44	14	18	0	8.3	13
2008	Nth Am	USA	54	48	3	12	11	47	0	24	3
2009	Oceania	Australia	71	38	8	14	22	24	0	2	30
2010	Europe	England	25	16	6	16	44	16	6	4	8
2011	Nth Ame	USA	81	43.2	3.7	16	18.3	43	0	11	8
2012	Asia	Singapore	80	10	21.25	31.25	16.25	11.25	0	7.5	12.5

In Figure 1010 it can be seen that the majority of the papers submitted were academic. This may be a cause for concern as a survey of industrialists and researchers (Development Strategy) highlighted the need for better industry-academic links to improve case studies and verify and validate results.

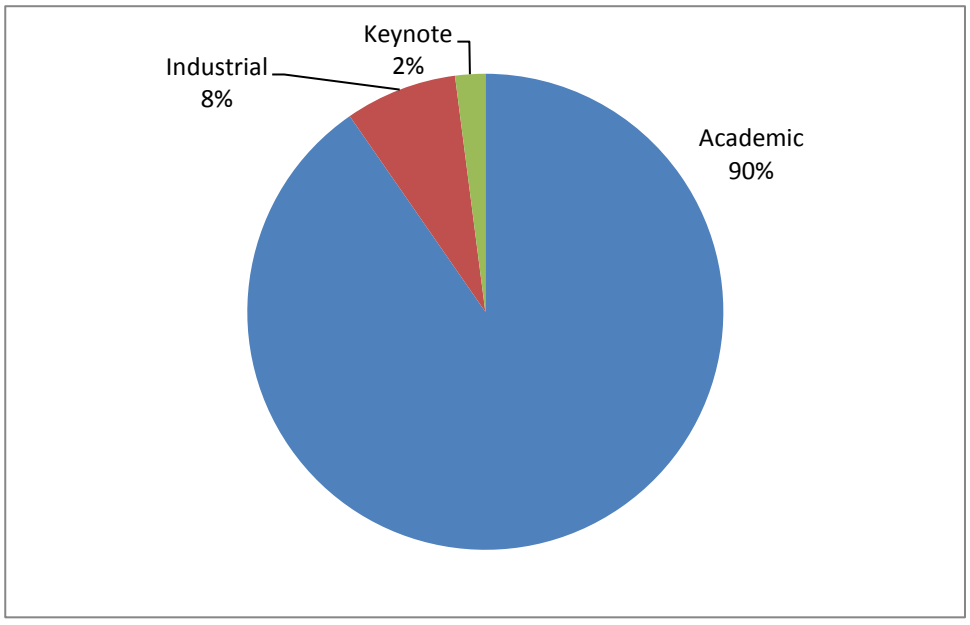

Figure 10 ***Types of papers submitted***

Study design (Figure 11) has focused on the development of models or the enhancement or modification of existing data and methods. A theoretical perspective has also been taken in a majority (16%) of the papers investigated. This may suggest that researchers are following popular

trends in terms of the types of studies they are preforming.

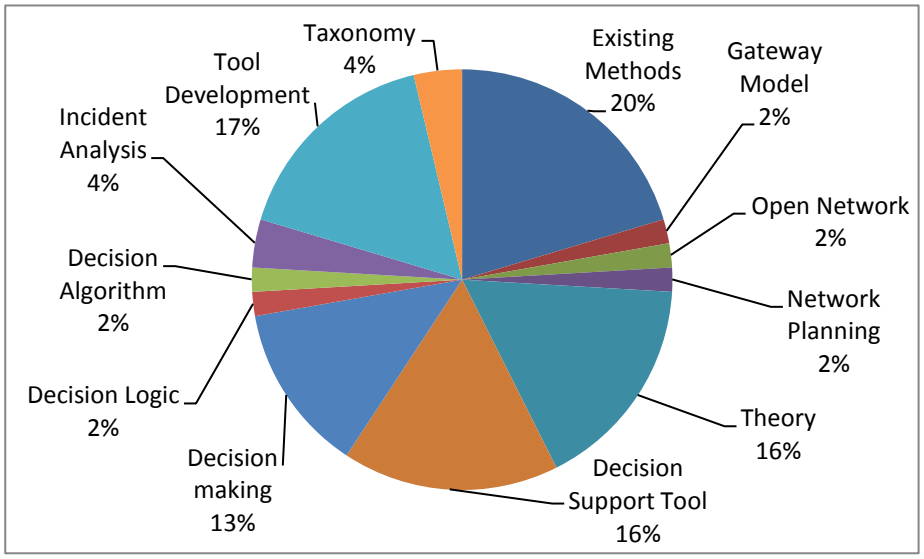

Figure 11 ***Study Design***

The majority (37%) of data collection methods (Figure 12) have involved a review of previous studies or related literature. Questionnaires were used by 27% of papers reviewed as a data collection method.

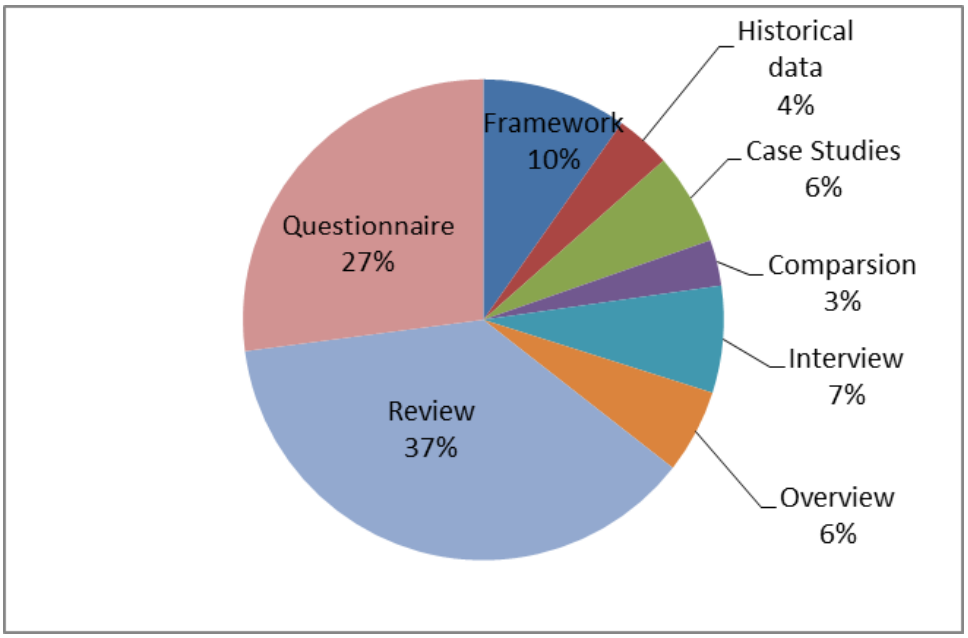

Figure 82 Data collection methods

In general data analysis (Figure 93) focused on the identification and variability of factors related to accident causation and modelling this data.

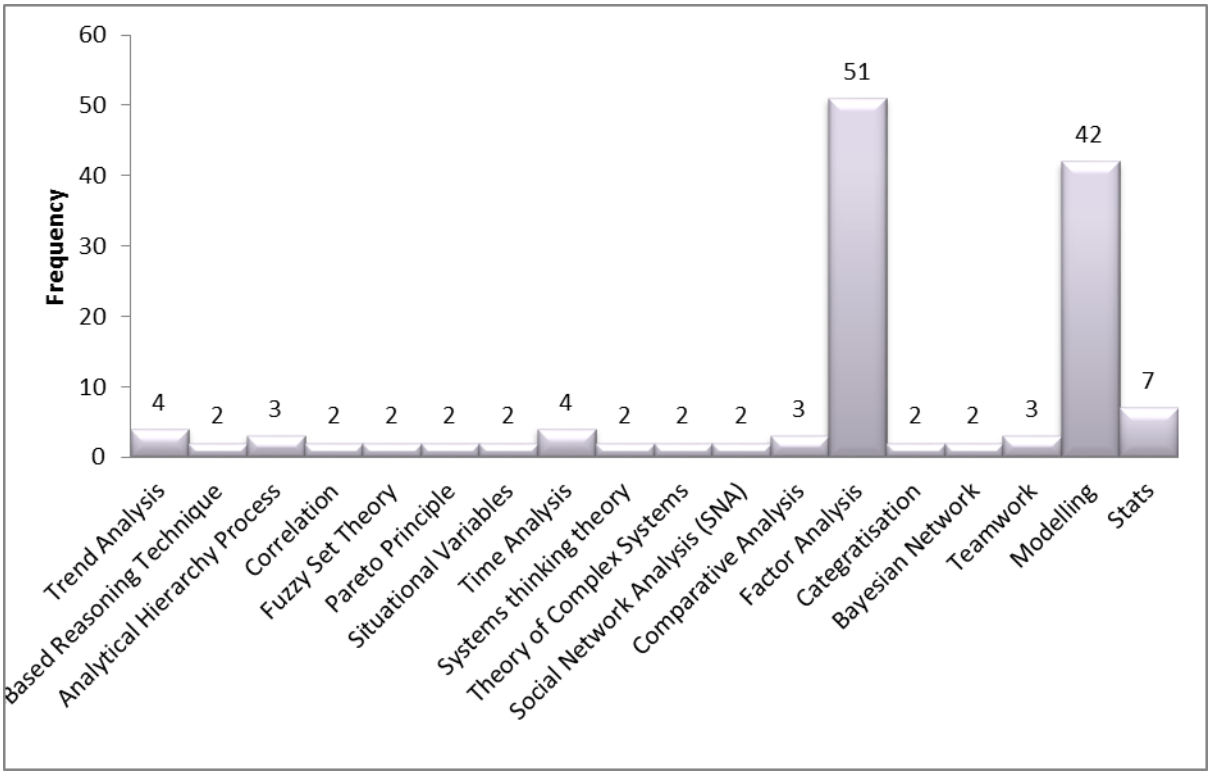

Figure 93 Data analysis methods

Pertinent themes and trends were identified (Figure 93) and further divided into major themes. While several themes appear in the data, three themes in particular showed consistent focus. Education was a very popular theme. These papers were concerned with the development of undergraduate courses, as well as training and development for on-site workers. Themes such as e-learning began to appear in the late 2000s. Administration themes which include sub-themes such as policy, procedure, legislation, planning, management and performance have also shown consistent focus. The social theme which includes culture, climate, communication and developing countries has had almost consistent proportional representation over the time period investigated. IT and technology have shown consistent importance but this has increased in recent years with a focus on simulation and BIM. Health, sustainability themes have proportionately been very under represented at the conferences.

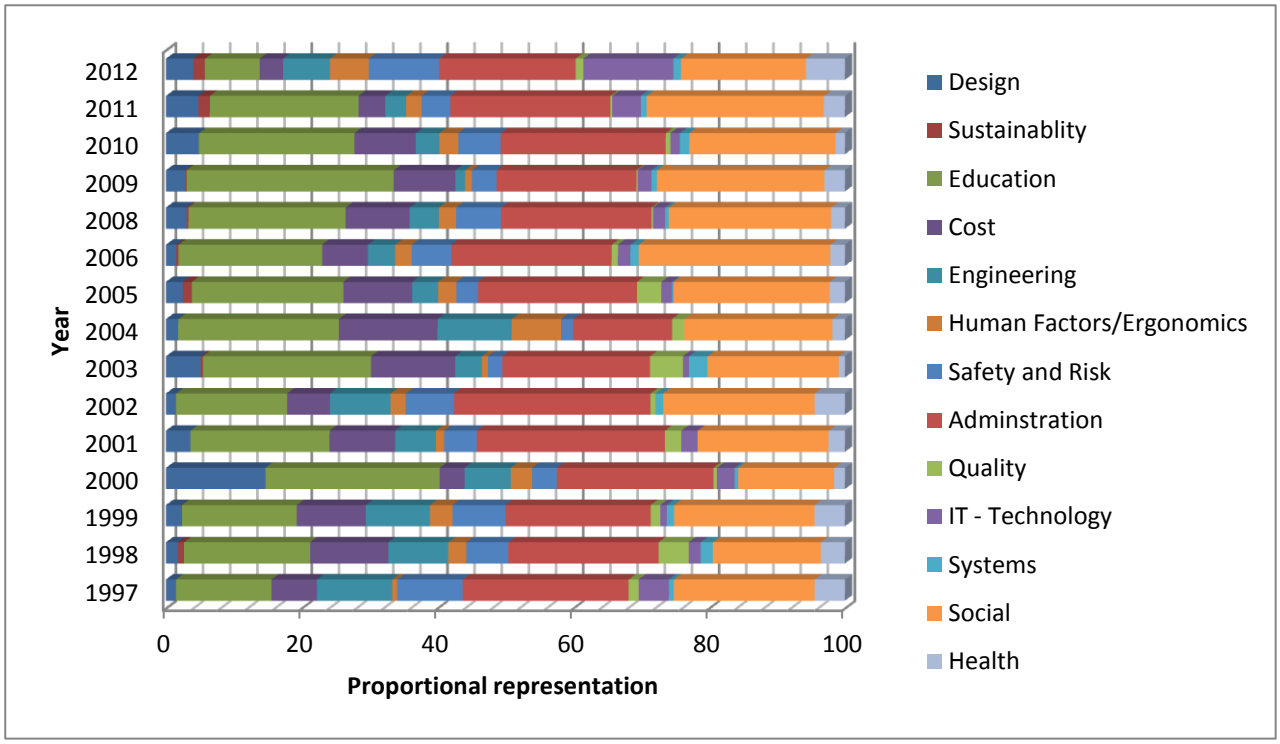

Figure 104 Paper theme trend analysis

RESEARCH AGENDA

Research and development, both within the OSH sector and in related areas has played a significant role in achieving performance improvements. OSH research is moving in the direction of multidisciplinary collaboration. While this is perhaps the best way to address many OSH issues, the research is less likely to be understood by funding agencies (resulting in difficulty in funding for research). Researchers need a better understanding of industry areas that require the most attention. For example, areas that are difficult to reach such as SMEs. There is also a need to review all elements of the system (design, management systems and the user) and not just focus on safety as a behavioural problem. In other words future work should not just focus on new and emergent themes, there needs to be a focus on how these themes affect what we already know. There is also a need to improve and review research that has been conducted in the past and integrate it with future needs. For example, while technology is an important part of site management, ways need to be found to integrate new technologies while at the same time not lose sight of what is important in terms of health and safety.

Better relationships need to be established between appropriate stakeholders in research. For example, research needs the backing of the construction industry, owners, designers, suppliers, insurance companies and regulators. Stakeholders need to focus on the same goals; the health and safety of the worker should be a priority to all. As a consequence improved tools and methods can be developed which convey lessons learnt both to industry and the wider research community. Better links with industry may mean that solutions are more practicable and testable.

There needs to be a systematic approach to the CIB research agenda. Using their expertise CIB members need to brainstorm the true problems to be solved. There may also be reason to develop and model a systematic way of performing research. There needs to be a move away from the research that is easy and a focus on the research that is important. This may be achieved through the development of conference calls and themes. CIB should encourage and develop relationships with industry to test, produce and develop networks for practical interventions; academic relationships should also be developed. CIB may facilitate this by developing further task groups which will allow direction setting and collaborative rather than competitive research. It may also be useful to facilitate research seminars which provide feedback and present lessons learnt in a structured way. The value of these seminars to academics, researchers and industrialists should also be highlighted, whether it be promoted as continuous professional development or using other means. If possible, the cooperation of a major industry group should be sought to take a lead role in OSH efforts which may offer better visibility and momentum for change.

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