INFORMATION TECHNOLOGY FOR CONSTRUCTION: RECENT WORK AND FUTURE DIRECTIONS

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ABSTRACT

Improving the application of information technology in construction is a major international research endeavour in scientific establishments and industry. A significant focal point for this research in terms of its dissemination and the derivation of a shared research agenda, has been the working commission concerned with IT for construction within the international council for innovation and research in building and construction (CIB). Working commission 78 of CIB has been active for almost 20 years in holding annual meetings of leading scholars in the field. These annual meetings have allowed the principal research activities from around the world to be presented to expert fora. In addition, the meetings have typically allowed debates and discussion to take place regarding the state of progress with key research themes, the emergence of new research themes, and a vision of construction activities in the future to which ongoing research could relate. This paper seeks to capture overall experiences from the activities of this working commission by reviewing the key research issues that have been addressed in recently reported work and seeking to illicit a vision of future IT-enabled construction projects that might inform future research.

KEYWORDS: Information Technology, Construction, Research Agenda, Vision.

INTRODUCTION

Working Commission 78 of CIB is concerned with Information Technology for Construction. The Commission has its origins in a meeting in Stockholm in 1983. For the last 17 years, annual meetings of leading international scholars have taken place where leading research from many countries has been reported. Table 1 lists the meetings that have been held in the period 1990-2000 indicating the conference title and some of the major themes covered. The scope of the group's work is broad in terms of the design, construction and occupancy of constructed facilities, but primarily it relates to the integration and communication of data, information and knowledge in the facility's life cycle. The mission of the group as a whole is to:

- foster, encourage and promote research and development in the application of integrated IT throughout the life-cycle of the design, construction and occupancy of buildings and related facilities;
- proactively encourage the use of IT in Construction through the demonstration of capabilities developed in collaborative research projects; and to

- organise international cooperation in such activities and to promote the communication of these activities and their results.

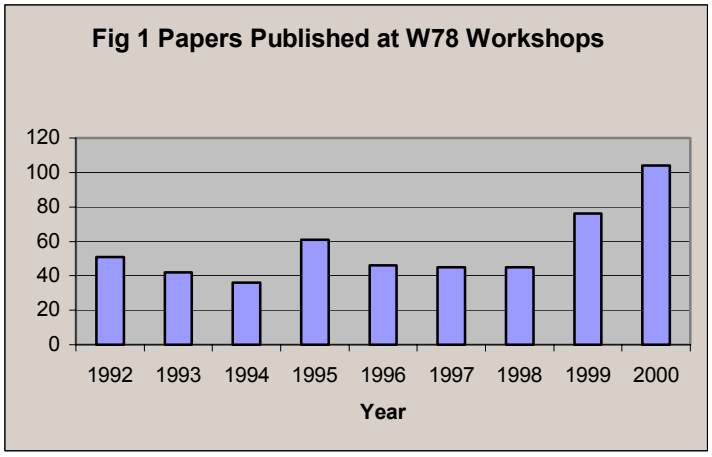
Conference Venue	Year	Conference theme
Japan	1990	Computer Integrated Construction
Holland	1991	The Computer Integrated Future
Canada	1992	Computers and Information in Construction
Singapore	1993	Management of IT for Construction
Finland	1994	Integrated Computer Aided Design
Stanford	1995	Modelling of Buildings through their Life Cycle
Slovenia	1996	Construction on the Information Highway
Australia	1997	Information Technology Support for Construction Process Reengineering
Sweden	1998	The Life Cycle of Construction IT Innovations
Canada	1999	Durability of Building Materials and Components
Iceland	2000	Taking the Construction Industry into the 21st Century

Table 1 – CIB W78 Meetings 1990-2000

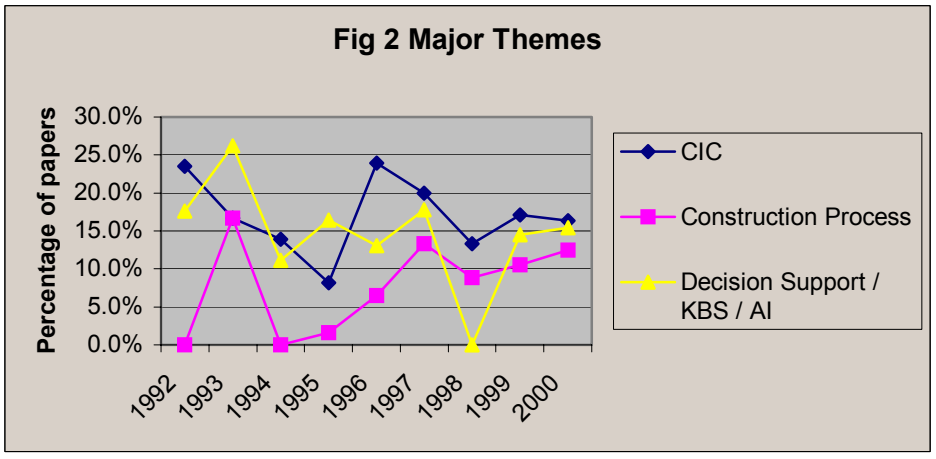
Each of these meetings has typically been attended by between 50-100 leading researchers, government policy advisors and industrialists, from 10-20 countries, reporting on extensive portfolios of institutional, national and international research projects and activities. The next section of this paper outlines an overall analysis of the breadth of research issues and major focal points within the research that has been presented at these meetings and how this has developed and evolved over time.

ANALYSIS OF RESEARCH SUBJECTS COVERED IN CIB W78 MEETINGS

The W78 workshops have covered a wide and increasingly broad range of topics in the Construction IT domain over its lifetime. With approximately 50 papers a year, until the past two years when the numbers have risen dramatically (partly due to the associated meetings the workshop was held with), researchers and industrialists in this area have covered most of the relevant IT topics. Figure 1 shows the number of papers published over the last nine years for which proceedings were produced.

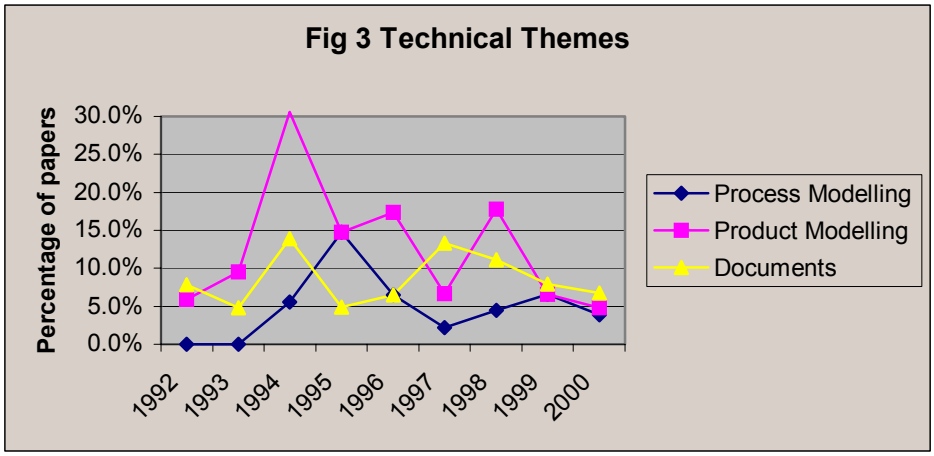


Over this period there have been a small number of major themes which are constantly covered as seen in figure 2. It would appear that there are different reasons for the constancy of each of these themes. The computer integrated construction (CIC) theme is one which hasn't settled upon a complete solution. Initial work in this area looked at bespoke, and tightly coupled, frameworks for integrated systems, usually integrating only a few very specific design tools. Over the years the scope has broadened to frameworks capable of managing loosely coupled (e.g., Internet-based) integration of design tools utilising the range of evolving data standards. Papers on the construction process have increased fairly steadily in number and importance within W78 to cover a wide variety of topics around IT supported process improvement. Usually the processes examined are for one segment of the industry, though overarching process models have also been mooted. Work on decision support, knowledge-based systems (KBS), and artificial intelligence (AI) in general, reflects construction IT researchers enthusiasm for the potential of AI techniques within the industry. Initial work was on expert systems (mostly for code checking), later papers cover newer AI techniques such as neural networks, case-based reasoning, distributed AI (e.g., agent-based systems) mostly being used for very specific domain problems (e.g., post occupancy evaluation of underground stations).

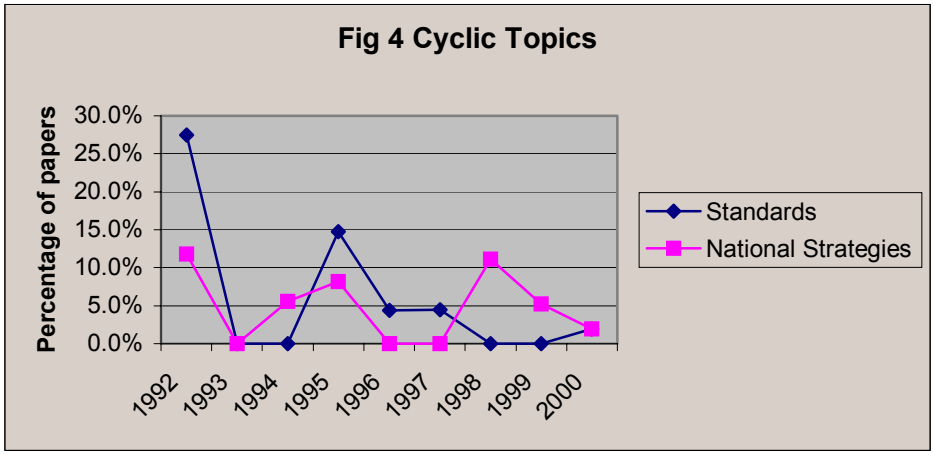


Alongside these major themes there has been a suite of technical themes which are constantly addressed. Figure 3 shows papers in product and process models and modelling as well as documentation and information management. Earlier workshops

discussed techniques and strategies for product and process modelling before moving more towards papers looking at the development of models for specific areas, often within the bounds of international standardisation efforts. It is interesting to note the continued presence of papers on documents within the construction process. Product models have not managed to usurp the place of documents and work currently presented is concerned with the appropriate handling of documents (albeit in electronic form) for a construction project. While technical themes are still important within W78 workshops there has been a trend to cover a wider set of issues and examine overarching perspectives on Construction IT.

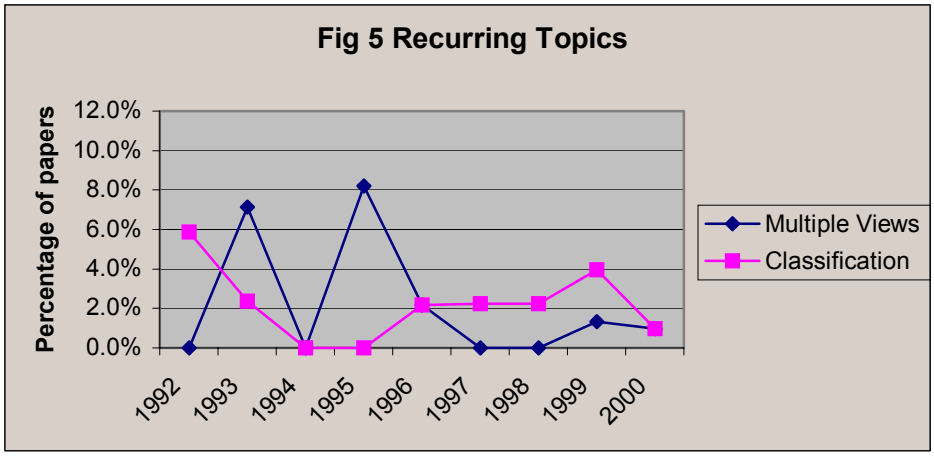


W78 workshops have included a small number of review topics which are canvassed periodically at workshops. Figure 4 shows the periodic occurrence of papers on national strategies for Construction IT (including national surveys on Construction IT usage) and on computerised standards encoding and delivery. The periodic reviews of national strategies has been beneficial in benchmarking the evolving usage of IT within the construction industries. Comparisons with these benchmarks has been useful at national levels to highlight the disparity in approach and support between similar nations (e.g., within Europe, or between Australasia and Europe).

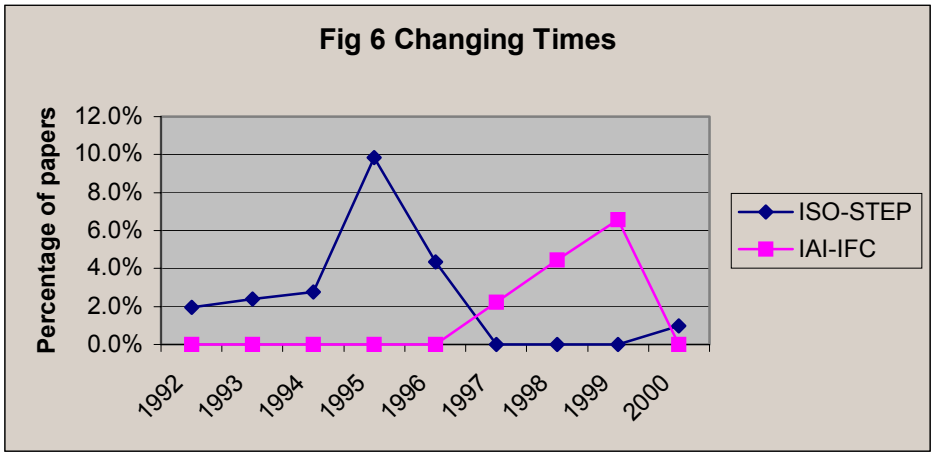


There are a range of topics where there are only a small number of researchers working and presenting. This tends to give bursts of activity in the topic as is illustrated in Figure

5. Reports on classification systems (national and transnational) and classification development frameworks appear in small numbers, though fairly regularly. Work on provision of multiple views and mapping between views has identified different approaches and the scope of the problem, but never gained wide interest or fully addressed the issue.

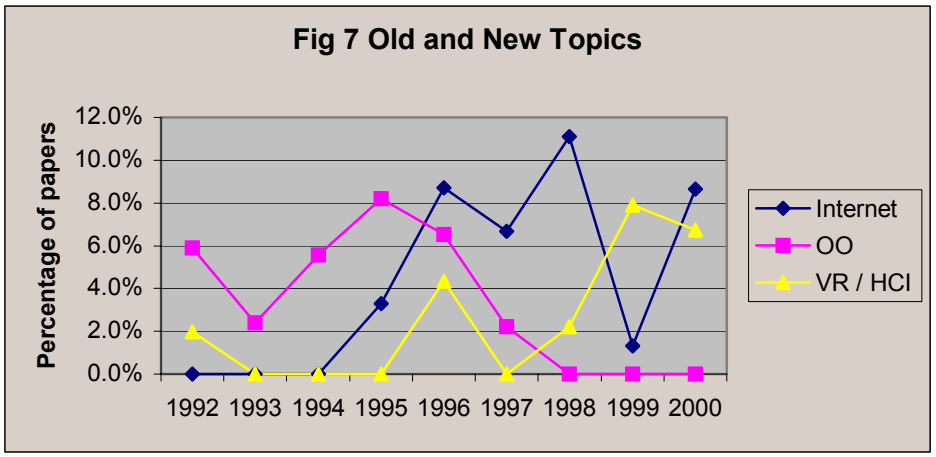


Within this period it is interesting to note the changes in approach and favour of international standardisation efforts. Figure 6 shows a fairly constant stream of papers regarding the progress of ISO-STEP standards for construction, which is displaced by the recently formed, and fairly universally supported, IAI initiative. Note, that while several papers in the 2000 workshop described projects utilising the IAI's IFCs none of them were primarily on the IFC standard and its evolution. The impression is of a fairly broad acceptance of the IFC standards across construction IT projects, with a few groups still working with the ISO-STEP standards which have been formally ratified.



Research results presented in W78 have reflected, and mirrored in popularity, the wider issues being confronted in the IT world. Figure 7 shows the demise of papers tackling the issue of object-oriented (OO) representations of construction information, or the application of OO to system development, which is now an established and widely recognised technique within the industry. Interestingly, the applicability of VR to construction was reviewed in 1992, but it isn't until 1996 that we see research and

applications in the use of VR becoming evident. The impact of the Internet and its potential for construction industries was noted in 1995 and has elicited an increasing stream of research since then, reflecting the continued interest in the Internet within all domains.



It is difficult to draw hard conclusions from this review of papers over the past nine years of W78 workshops given the small population of papers to work from. However, an overall trend appears to be a move from addressing a range of narrow technical issues to a wider consideration of IT and its impact on the construction industry and its working methods. Technical papers are still in evidence and they cover an increasingly wider range of topics often mirroring major technology thrusts and breakthrough areas from the general IT arena.

LINKS WITH OTHER GROUPS AND OTHER CIB WORKING COMMISSIONS

Beyond its own annual meetings, the working commission has been extensively involved as a collective group, and through its individual members with other CIB working commissions, other scientific and research fora and with international standardisation work. Joint meetings have taken place with other working commissions concerned with construction management, futures studies in construction, information management, information standardisation and transfer, computer representation of design standards, concurrent engineering, virtual reality, building pathology, service life of building materials and components, and others. Links have also been forged with groups concerned with applications of artificial intelligence in civil engineering, computer aided design, the durability of building materials and components, and structural engineering. The links with standardisation work have been with the STEP community, ISO groups and more recently with the International Alliance for Interoperability. These links have allowed the research issues described above to be shared with broader groups and for research issues of a more general construction product and process nature to inform the research in IT for Construction.

The working group has primarily been made up of members from Universities and Research Institutes. There has been an increase in participation by industrialists and

policy makers. At the same time, inputs from the scientific community have increasingly demonstrated the close links that have developed between scientific and industrial communities as research in this area has reached a state of maturity and the issues it covers have become recognised as important by construction practice.

A VISION FOR THE FUTURE ARISING FROM THE WORK OF W78

As we can see from the review of key issues arising from recent meetings of the group, research in IT for construction has typically embraced a number of discrete research challenges of a technological and managerial nature, together with issues of application and implementation, and relationships to construction process and product performance.

As technologies and research approaches have developed in this area an implicit vision underlies the overall research approach. This vision is not fully shared by all the research reported and many points of detail within it would be disputed and have been debated by groups. Differences in visions have led to alternative paradigms that have driven elements of the research presented. As we look forward, there would not be a single shared vision of the nature of construction process and product delivery that all future research would relate to. However, for the benefit of making our respective implicit visions more visible, it is possible to construct scenarios of the future to which our ongoing research efforts may relate. This section of the paper seeks to do that by reporting on an attempt to define a vision arising out of recent work by Construct IT in the UK and allowing this to be influenced by the review work from earlier sections of this paper. Other work reported within the group has attempted to define scenarios or visions for the future of how IT might impact on construction processes and products. The work of Walker and Betts (1998) and of Waugh et al (1996) are examples.

The Construct IT vision has been drawn from extensive literature review and exposure to industry innovation in the field. It is more completely documented and described in Sarshar et al (2000). It can be depicted in summary form as in Figure 8 below.

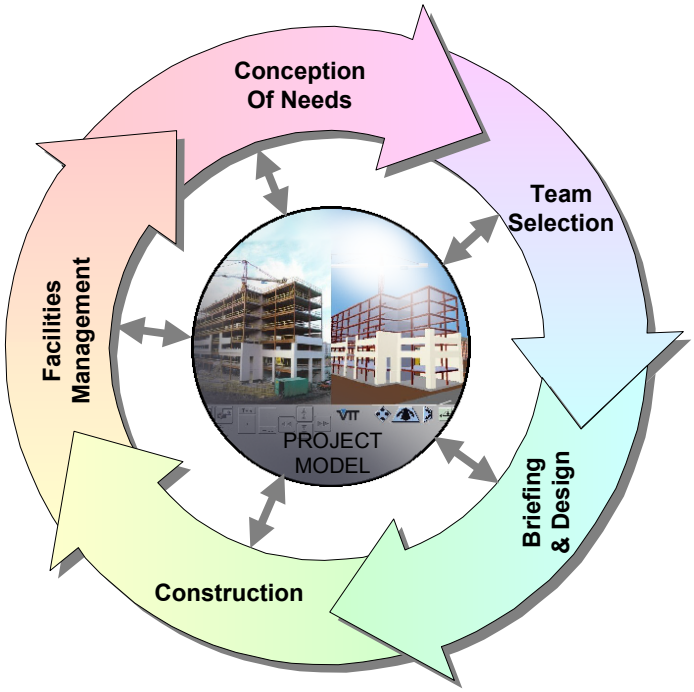


Fig 8 An IT-Enabled Future Construction Process

It contains 6 key themes of how further developments in IT may enable projects to be executed differently in the future. These themes are:

- *Model driven as opposed to document driven information management on projects:* Currently construction project information is captured in documents. The construction parties may share these documents using the electronic environment. But problems arise as the volume of documents and their versions increase. The model driven approach is a means of sharing project information, via a shared conceptual product / process model. Model driven construction does no imply a large unique database, but it implies a shared conceptual model, which is implemented on different applications.
- *Life cycle thinking and seamless transition of information and processes between life cycle phases:* In current construction projects, there is a little communication and knowledge sharing between the phases. IT is the major element that allows seamless information sharing between the phases of the life cycle.
- *Use of past knowledge (information) in new developments:* In construction, it is essential to rely on past project knowledge and information when dealing with new projects. The implication of this theme is that the industry will require strategic systems, which allows capturing of previous knowledge.
- *Dramatic changes in procurement philosophies, as a result of the internet:* The increased use of the internet opens new business opportunities for construction organisations such as 'Project Information Exchange', 'e-Trading' and 'e-Tendering'. In the new era, just-in time procurement strategies will be more prevalent.
- *Improved communications in all life cycle phases, through visualization:* Communication between the construction parties relies mainly on drawings and specifications. Visualisation, on the other hand, makes communications more effective

and accessible. For more effective results, visualisation is best combined with a model driven (integrated) construction environment.

- *Increased opportunities for simulation and what if analysis:* Simulation is an important tool that helps the construction manager to analyse productivity measurement, risk analysis, resource allocation, site planning etc. Moreover, simulation in construction will improve feasibility, planning and scheduling.
- *Increased capabilities for change management and process improvement:* To achieve all the items above, construction organisations will need to implement fundamental structural changes to processes and organisational management as well as address issues of human resource development.

Based on these major themes, a new scenario was developed. This scenario aims to interpret the seven proposed themes in terms of construction projects. The scenario describes a lifecycle consisting of five main stages in a project with ways in which IT would allow them to be executed differently described as in Table 2.

Stage in Life Cycle	**IT-enabled Process Changes**
Conception of needs	• Developments in technologies will have a major impact on the reuse of previous project knowledge and experience. • Facility managers will take a more proactive role during the conception of needs. • GIS will assist in site selection and physical positioning of buildings. • Visualisation will offer a better understanding of the project.
Tendering and team selection	• Long-term partnering relations will be commonplace. E-tendering and e-business will be major technologies linking the supply chain. • If a model-based approach is to be realised, there will be an ease of information sharing between the parties. Capability in information sharing, will be an important team selection criteria. • There will be long-term relations with other project participants
Design and briefing	• Visualization tools will improve communications. • Simulation tools will be used. This will allow feasibility studies on usability, environmental impact and constructability of buildings. "what if" analysis can be performed on construction programmes. • Greater reuse of previous, and industry best practice, design solutions will be enabled through knowledge management and organisational learning strategies. • Project models will improve information consistency and enable active notification of design changes for participants. • The use of internet applications such as e-procurement will change business relations. Many of the manufacturing philosophies of material procurement can be adopted.

	Manufacturers and material suppliers will supply materials just in time by refereeing to the web-based project information board, and will also enable parameterised selection of their products.
Construction	• 3rd generation mobile phones –that can transmit images – will help to visualize the different components of the building in the construction phase. • Intelligent tagging such as bar coding will improve material movement and tracking. • Last minute changes in the construction phase will be captured and submitted to the client. • Integrated performance management on site will reduce non-value adding activities and enhance possibilities for waste reduction and reuse.
Facilities management	• Electronic as built information is used for operations and maintenance of the facility. • Intelligent tagging will become part of the project and form a base for FM activities. • Facilities managers will use their experience and knowledge for the development of conception of needs in future.

Table 2. IT-Enabled Changes to Project Processes

CONCLUSIONS

The group CIB W78 is a mature group of international scholars concerned with IT for Construction who for almost 20 years have shared research progress, outcomes and challenges. Over that time considerable progress has been made in our understanding of how IT can support improved construction processes and products. From this platform it is possible to construct a scenario or vision of how IT may enable construction products and processes to be more competitively procured in the future. One such vision is presented here in this paper. This vision is currently informing ongoing research and innovation within IT for construction. It has a relevance to research much more widely in building and construction. Researchers in many of the other areas covered by CIB and other research organisations might look to examine this vision to identify the extent to which it informs and influences their own research agenda. In doing so, their own work would further enrich the vision for others.

ACKNOWLEDGEMENTS

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