Emerging technologies offer new solutions to the construction industry, improving processes, enabling automation and effective decision-making mechanisms and changing current ways of work. Previous research has tended to consider a direct causal relationship between the emerging and prospective technologies and the future of construction. However, the future of construction will be influenced not only by the developments in the information technology (IT) industry, but also by other technological changes. Societal, economic, environmental and political factors will shape the future, together with emerging technologies. This paper presents a scenario-planning exercise that aimed to identify possible futures that the construction industry might face. In order to achieve the aims of the research, a literature review was carried out on scenario planning and future studies related to construction and construction IT, which was followed by a mini survey and two prospective workshops as part of the La Prospective scenario-planning approach. In a future study, it is important to understand the forces, issues and trends in order to inform and enable further thinking and action towards achieving a preferred future state whilst being prepared for what might be round the corner. Therefore, the paper first investigates the driving forces of change, main trends, issues and factors that might shape the future, focusing on factors related to society, technology, environment, economy and politics. Secondly, four future scenarios that were developed keeping these factors in mind are presented. The scenarios start from a global view and present the images of the future world in year 2030. They later focus on the construction industry, imagining how it will be shaped by the future world and trying to visualize the information and communication technology implications for construction. Finally, a preferred future scenario for 2030 is introduced based on the principle that the future can be influenced if we know what we want it to be. Focusing mainly on the IT vision, the paper concludes with

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recommendations in the areas related to innovation, communication and collaboration, education and training, process improvement, interoperability, user-centred IT and sustainability, in order to reach the desired state determined by the vision.

Keywords: scenario planning; society, technology, environment, economy and politics; information technology vision; construction industry

1. Introduction

Advances in information technology (IT) continue to offer new solutions to the construction industry, improving processes, enabling automation and effective decision-making mechanisms and changing current ways of working. As a key driver of change in the construction industry, much attention has been paid by researchers to the ways in which it will be adopted and help shape the future of the construction industry. Much of the previous research in this area considered a direct causal relationship between the emerging and prospective technologies and the future of construction. Hence, attempting to picture possible future states of construction focused on state-of-the-art IT and how specific technologies may shape construction processes in future. Examples include an $n$ dimension ($n$D)-enabled construction vision (Lee et al. 2003), an $n$D modelling roadmap proposed for the time span of 2004–2012 (Lee et al. 2005) and a scenario for a mobile IT-enabled future construction site (Bowden et al. 2006). Some research focused mainly on IT implementation in construction and developed an IT vision for the construction industry. Sarshar et al. (2000) developed a vision for construction IT for the years 2005–2010 following a research methodology based on a literature search, academic experts’ workshops, industrial experts’ workshop and feedback from industry. In order to inform future research, Amor et al. (2002) tried to draw a vision of future IT-enabled construction projects by reviewing the activities of the working commission of the International Council for Innovation and Research in Construction (CIB) until 2002 and the key research issues addressed in these activities. The Strategic Roadmap towards Knowledge Driven Sustainable Construction (ROADCON) project developed a vision for agile, model-based, knowledge-driven construction and prepared a roadmap (Hannus et al. 2003). The Strategic Actions for Realizing the Vision of ICT in Construction (Strat-CON) project identified the strategic actions in the short, medium and long term in order to achieve the ROADCON vision (Kazi et al. 2007). Processes, products, projects and enterprises were the four thematic areas addressed in the project.

The research presented in this paper was also aimed at identifying possible futures of the construction industry with a particular focus on construction IT. However, this approach is distinguished from the others based on the two major principles on which it was built. The first principle is that the future of construction IT cannot be foreseen without investigating the possible futures of the world and the construction industry. Therefore, driving forces for change and related main issues and trends should be investigated starting from the global level, then reducing the focus on the construction industry and, finally, on construction IT. Secondly, the future of construction IT is not only influenced by advancements in the IT arena, but also by other technological developments. The societal, economic, environmental and political factors will be shaping the future,
together with the emerging technologies. Depending on its aid to understand the nature and impact of the driving forces affecting the world, a modified version of the La Prospective scenario-planning approach was adopted, which used a combination of different methods such as strategic conversations, surveys, prospective workshops and horizon scanning. The interest in this research was on long-term planning. Scenario planning allows long-term planning for up to 25 years ahead, which provides a time scale that is too distant to realize that simply extrapolating current trends is insufficient, but is near enough to be imaginable. Year 2030 was chosen as the target since it was the most memorable target that could be investigated using scenario planning.

The paper is structured as follows: firstly, driving forces of change, main trends, issues and factors that might shape the future are investigated, focusing on factors related to society, technology, environment, economy and politics (STEEP). Secondly, four future scenarios that were developed keeping these factors in mind are presented. The scenarios start from a global view and present the images of the future world in year 2030. They later focus on the construction industry, imagining how it will be shaped by the future world, and try to visualize the information and communication technology (ICT) implications in construction. Finally, a preferred future scenario for 2030 is introduced based on the principle that the future can be influenced if we know what we want it to be, together with associated action areas to be enacted in order to achieve this vision.

2. Driving forces of change, main issues and trends

Whilst developing a future vision, it is important to understand the forces, issues and trends that might shape the future. For this reason, the main continuities, major trends, most important change processes, most serious problems, new factors and main sources of inspiration and hope were investigated using a number of methods. Firstly, similar previous research was investigated and the forces proposed in those were noted. Secondly, through a pre-workshop questionnaire, the views of the key actors in the sector were obtained, regarding which forces might play an important role in shaping the future. Thirdly, scanning of newspaper headlines was carried out. Finally, during the first prospective workshop, the forces determined in the previous methods were revised and finalized. In line with the second major principle of this research, which contends that the future of construction IT is not only influenced by advancements in technology, but also by factors related to society, economy, environment and politics, the workshop aimed to bring together academics and industry professionals with expertise in these areas. Academics were therefore invited according to their research profile and specialism, whereas industry professionals were chosen according to their background, industry experience and their current position. This workshop, named the ICT Vision Planning Workshop, brought together 28 world-leading experts from different disciplines who are technical and non-technical researchers and industry professionals from Australia, Canada, Denmark, Finland, the Netherlands, Norway, Turkey, UK and USA. The aim was to benefit from the synergy between the different expertise and working cultures of the attendees.
The driving forces of change were considered at the global level in five main areas indicated in the STEEP categorization: society, technology, economy, environment and politics. Societal forces focused on changes in demographics, lifestyles, education and age distribution of the population, as well as changes that might be seen in society due to better communication enhanced by technology, effects of the credit crunch. Technological forces mainly focused on the emerging technologies that are assumed will create a big impact on the future. They also included some forces related to certain characteristics to improve the use of technology, such as interoperability, user-friendliness and standardization, as well as forces related to legacy and regulation. The economic forces included many different perspectives ranging from the new US President’s effect on international capitalism to technological breakthrough and from recession to resource scarcity. Environmental forces focused on global warming, and some responsive actions to global warming, as well as the changes observed in people’s behaviour and attitude towards environmental issues and related technological advancements. Political forces mainly concentrated on current legislation, the US presidency, European Union politics and energy problems. A total of 78 forces were identified.

After the identification of the driving forces, the aim was to determine the main issues and trends that might shape the future as a result of these forces. Like the previous stage, a literature review, short questionnaires and prospective workshops were the methods adopted for this stage. The issues were examined by looking at three levels: meta, macro and micro, which reflect the issues related to the global, construction industry and IT in construction perspectives, respectively. The issues and trends were also investigated using the STEEP categories, and a total of 128 trends and issues were identified.

The third stage involved clustering the forces, main issues and trends in order to categorize them into a number of high-level concepts. Eight main themes were agreed on that will shape the future

— global environmental change,
— future financial framework,
— seismic power shift (west to east),
— demographic change,
— knowledge generation/education,
— behavioural change,
— technological progress, and
— law and order/political stability.

3. Scenarios for year 2030

Scenario building is a key technique used by futurists to develop future models in order to develop strategic action plans and policies or to create a vision for the future. The term ‘scenario’ is a fuzzy concept with many different definitions and many different meanings attached to it. According to Porter (1985), a scenario is ‘an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome’. Selin (2006) defines scenarios as stories describing different but equally plausible futures that are developed using methods that systematically gather perceptions about certainties and uncertainties.
According to Godet (1987), scenarios should aim to detect the key variables that emerge from the relationship between many different factors describing a particular system, especially those relating to the particular actors and their strategies. For this research, the eight themes explained in the previous section were identified as critical to shaping the future. When these themes were reinvestigated, global environmental change, future financial framework and seismic power shift were found as the most critical ones and therefore were used as the scenario logics, which refer to a logical rationale and structure for scenarios enabled by intuition, insight and creativity (Ratcliffe 2000). After some thinking on how these three themes can be best reflected, the two scenario axes were identified as ‘Economic model’ and ‘Environment and resource management’, where the economic model takes values as interventionist or market driven; and environment and resource management as fragmented and integrated (figure 1).

Four scenarios for year 2030 were portrayed over these two axes following the scenario guidelines identified by Vanston et al. (1977) and Kelly et al. (2004) in order to achieve plausible, self-consistent, divergent, useful and creative scenarios that include all critical, relevant factors. Although the two axes were used to frame the scenarios, all eight themes obtained during the clustering process were addressed in the scenarios. The initial scenarios were developed in the first prospective workshop. The workshop participants worked in four groups, where each group was assigned to develop a scenario in one of the quadrants based on different economic and environmental futures. Participants were asked to visualize what the construction industry and IT within it would be like in the year 2030, the most important changes that would have taken place up to this year, major opportunities and threats the construction industry would have had since 2009.
and any shocks or wildcards that would have impacted upon the development of the industry. Each scenario was given a memorable name describing the essence of the scenario and included an approximate timeline of the most important changes that will have taken place up to 2030. Each scenario developed was presented to the other groups for feedback and discussion. These scenarios were revisited and have been finalized in a second workshop. The final versions of the scenarios for 2030 are presented below. They start from the global view and present the images of the future world and then narrow down to the construction industry, and finally down to IT in construction.

(a) Scenario 1: cuddly dictatorship

This scenario pictures a possible future when there is an integrated resource and environmental management system and an interventionist economic model. Since the scenario assumes a regulated regime with an attitude that puts people in first place, it is named ‘cuddly dictatorship’. At the heart of the scenario lies some form of global entity developing visions, setting goals and objectives that cascade down to national and to local levels.

The whole process starts with the recognition of the environment and climate change amongst a number of countries. They then decide to work together and set up a forum. The Kyoto agreement and global carbon trading are some early indicators of this attitude. This roadmap will continue and an organization such as the United Nations will be established to set out goals for climate change and to develop a shared objective, vision and mission. The organization will have a reward-and-penalty system to encourage the countries to follow the shared vision. Although there will be countries that do not want to be involved in environmental changes since they have other problems which are more critical to them. Those that can comply will be rewarded for their contribution. Likewise, there will be sanctions on countries that do not comply.

In the 2020s, the focus will be on converting the shared objective into legislations and standards, and planning for implementation. In 2030, there will be well-defined local action plans and legislation that will have cascaded down from the forum that was set up in the first phase.

In 2030, it is expected to see a regulating regime that sets timelines and plans on the intervention on the economic front. This will have many effects on the construction industry and its IT implementations.

The planned approach will mean that the construction industry will be more focused on off-site construction. It will be possible to include the customers/clients in the design process—through a Lego-style fashion pick and mix approach—providing them with modular design components that will be constructed cheaply and defect-free off site, brought together on site following just-in-time principles and assembled on site. These modular components will be built in such a way that enables disassembly for reuse elsewhere as demographics change and people move around. A seamless supply chain is targeted.

New technologies will be a part of the construction process. Technologies such as nanotechnology will be used to establish a maintenance-free environment (i.e. self-cleansing glass, self-repairing concrete). Interactive three-dimensional models will be created prior to building. Technologies enhancing the built environment and robots will be a part of the construction process.
The regions will have their own energy sources and will develop their infrastructure to enable a self-sustainable energy system. Each building might also have its own power sources such as clean nuclear, fuel cells or biomass boiler associated with it. Intelligent buildings will be mainstreamed.

The construction industry’s ability to keep up with the pace of change, generally, and in IT, might be a threat. The industry is still not open to new ideas and changing work practices. The need to keep up with the skills and skilled personnel who are able to deliver the buildings will be another major threat. Training needs to be considered more thoroughly in this sense.

(b) Scenario 2: long march

This scenario pictures a possible future when there is a fragmented resource and environmental management system and an interventionist economic model. The effects of the recession will continue until 2015. All countries, regardless of whether they are in the west or east, will be affected during this period. It is expected that traditionally strong economies will be affected by the recession more than others. Although the emerging economies will also be affected by the recession, they will also manage to take advantage of the situation. When the recession is over, high public investment will occur everywhere, resulting in some new economic partnerships formed in the middle term. These partnerships will shape a new global financial framework. With the intervention and global government investment, some robustness will return to the economy and long-term sustainable economic growth will start.

Due to the fragmented approach, companies will be developing their own tools and technologies for their own interests that will create a power game across the technology process. The increase in public-sector funding will result in the development of new methods and technologies around public-sector contracts. Since the government sets the scene, there could be more punishment for non-conforming clients.

The traditionally strong economies recovering from the recession will put more thought into technologies such as CO₂ scrubbing. Emerging technology will enable the clean-up of waste gases, and hence will be used by countries having traditionally strong economies. On the other hand, the countries with emerging economies that benefited from the recession period will not put much thought into this, and they will not have enough infrastructure or equipment for scrubbing since they will have used all their earnings for further investment to grow more.

(c) Scenario 3: business as usual

This scenario pictures a possible future in which there is a fragmented resource and environmental management system and the economy is market driven. Since this situation is very similar to the economy and resource management system today, this scenario was called ‘business as usual’. The scenario expects the current recession period will continue until 2012, with other possible boom and bust periods to 2030. During this period, companies will be more focused on survival. The recession will affect most small and medium enterprises, and the future will be left to strong large-scale companies only. Since the focus will be more on survival, environmental issues will get worse each year.
The future will be driven by money; therefore, the only value considered by the construction business will be the price. Likewise, individuals will be considered as a commodity and the big institutions will lead the future. Everything will be at the power of big corporations, mainly strong specialized contractors. This can be interpreted as an opportunity as well as a threat. On one hand, it will be clear which contractors are experienced in which area and the quality of the work will be better since they are specialized in that area. On the other hand, these strong contractors will be working in a kind of silo system. Small and medium enterprises will be having really difficult times if they survive until 2030, considering the supply and demand situation during the boom and bust period.

In the same context, client power—whoever is on the top of the supply chain tree—will have a huge power over the others since everybody will serve and take orders from strong clients.

There will be fragmented ways of looking at sustainability since the environment and resource management is also fragmented. Each company will have their own methods to define and measure sustainability, as well as different ontologies. If compared to the extent of sustainability approaches in construction today and their efficiency and effectiveness, it is very unlikely that the construction industry will move forward with these issues by 2030. On the contrary, there will be a huge increase in environmental problems because of the different ontologies, different interpretations of what is meant by the environment and different methods of measurement. Lots of problems will be compounded in the years to come.

(d) Scenario 4: lean and mean

This scenario pictures a possible future when there is an integrated resource and environmental management system and a market-driven economic model. Part of the vision seen in this scenario is a merger between the integrated global carbon economy and the market-driven economic model. This merge inspired the title of ‘lean and mean’.

In terms of the timeline, the first prospective workshop held for this research is considered as a crucial point in time that starts the whole process. In the very near future, the financial markets will entirely collapse, creating a major shock. Following this, changes will be carried out in development policy in terms of constructing the balance of resources associated with the construction industry. These changes will lead to tension in resources, development and generation of knowledge, and real-time assessment and control of carbon involvement. The picture seen in 2030 is a construction industry operating in a global carbon economy, which has developed related interoperable processes.

The entire collapse of the financial markets and other major change driving forces will lead to the development of an international framework of a carbon economy. It will start with carbon trading goods and have a small environmental footprint that will be developed more and more every coming day following the better understanding of the concept and the conception of its importance. A small energy footprint will be maintained and processes will become more streamlined and effective.
There will be an increased localization of the factors for potential stages of design and manufacture use. Decommissioning will occur if these elements need to be in particular locations. This localization refers to the goods only, that is, geographically closed products. The teams involved in the design can be globally dispersed. Free access to information will start to emanate from society and from the industry. Collaborative workspaces will enable sharing knowledge between people with knowledge throughout the world. Analysis tools and decision-making tools can help to decide what to do with the knowledge within the context of the carbon-market trading scheme coming into existence.

Ultimately, there will be a global access to resources, everyone being able to share the resources and share the understanding. Clients will be fully satisfied with products. The evaluation and measurement of behaviour will be fully integrated into the design process and the operation.

All of these will be possible because of the flexibility in construction that some industries do not have. Development of interoperable processes will make it even more advantageous.

4. A glance at the desired future

Although scenarios have a big role in strategic planning, it should never be forgotten that scenarios are only constructed models of the future and are based on what we know about what is happening and the application of imagination in order to predict what might happen in the future. Each of the four scenarios built in the previous section might come true under different circumstances. Nobody can actually know what the future will bring. However, it is believed that the process of scenario building enables the planners to become aware of different possibilities, analyse and understand the forces influencing the future, and hence see the journey between today and tomorrow from a different angle. It also encourages people to realize their preferred future and work towards achieving it, as well as being prepared for what might be round the corner.

Reinvestigating the four scenarios, a vision-planning exercise was carried out with the focus on construction IT. The vision was built from four strands: people, processes, technology and places. The ICT vision was determined broadly as

The construction industry is supported by tools and technologies which are fully compatible, developed using open standard software and that put people at the centre of focus, thus enabling creativity, creating integrated business processes that are consistent and compatible; and facilitating less geographically dependent ways of working.

It is aimed to have less geographically dependent work practices in future. Collaboration between dispersed teams will be more possible as virtual reality and possibly holograms become a common working practice. The improvements on videoconferencing and holograms that integrate with sophisticated whole life-building models will better enable design meetings and project planning between globally dispersed teams. Technologies such as second life might provide means for the interaction of the whole supply chain, design teams and the end user.

Phil. Trans. R. Soc. A (2010)
Regardless of the client type, future processes will make the most of new technologies such as wireless technologies and ubiquitous intelligent frameworks. As a result of IT, there will be a better work balance. Home working, remote working and mobile working will be much more possible and feasible.

Advancements in ICT will enable construction professionals to focus on what they do, rather than how they do it. The construction industry will be perceived as more around design and innovation to meet user needs rather than manual labouring. The future will be based on people with a broad range of skills who will use IT skills to underpin the areas in which they are not so expert. Human creativity will be boosted and supported through increasing artificial intelligence developed from current expert systems and online knowledge-management tools. Highly skilled people having in-depth knowledge will be needed in order to develop these expert systems. However, this also brings a risk factor associated with it: engineers or other users might become less and less involved and, therefore, less understand what they are actually doing because of the ‘black-box’ style IT tools. On the other hand, IT will enable people having less menial tasks, leading to more creative and more stimulating work.

The way people work in future will be different to today. Most tasks carried out by manual workers now will be carried out by robots or in factories, which will improve health and safety on site. Likewise, off-site construction will increase. A Lego-style construction will be possible through enhancements in IT. Moreover, it will be possible to move beyond the visual environment and simulate the sensory environment, integrating elements such as acoustics and odour.

Processes will become more efficient and streamlined through the help of IT. Intelligent buildings will become mainstream in 2030, and it will be possible to manage self-healing/self-correcting buildings through embedded sensors in the buildings. Smarter management of facilities and construction spaces that is responsive to people and their behavioural preferences will be seen as a result. Rather than sending maintenance people to check whether there is any problem, intelligent built environments will automatically detect the problems. Cutting down carbon, energy and cost of climate will be possible through IT systems that enable user-centred design and intelligent built environments to provide a better future for people.

Project management will be carried out more efficiently with better integration of the supply chain, resource management and online transaction processes into the project planning and management tools.

Intelligent or semi-intelligent software will improve themselves through automated double-loop learning facilities based on evidence from the actual use of buildings in operation.

IT will be used to train people in any area they need to be trained. Learning will be achieved through games and role plays. For example, site inductions providing a walkthrough in three-dimensional site models. Rather than sitting in a porta cabin and trying to work out which activity needs to be carried out when and where from a blueprint, the information will be accessed much more easily and intuitively through these techniques.

In future, IT will naturally become a part of the life of end-users. IT tools will become much more ubiquitous, pervasive, intuitive and human centred. Furthermore, they will have been familiar with IT since their childhood, so they will not need to go to IT training to understand how to use a tool.
5. Policies and actions to achieve the vision

The last stage focused on understanding what might be done to achieve the identified construction IT vision. For this reason, key areas have been identified during the first prospective, and recommendations in the areas related to change and innovation, communication and collaboration, education and training, process improvement, interoperability, user-centred IT and sustainability are made in order to reach the desired state determined by the vision.

(a) Manage change and foster innovation

Thinking about the future enables us to understand the need to cope with, adapt to and benefit from constantly changing scenarios, much of which are out of the control of us as individuals or of organizations. To this end, it is necessary for construction businesses (as for all businesses) to be able to effectively manage change and foster innovation. This is particularly important for the adoption and exploitation of IT, most of which requires radical and architectural innovation in business organization and processes. Action areas under this broad heading include the following.

Enhance communication and collaboration: there were many action areas under the broad heading of enhancing communication and collaboration. The scenarios illustrated a range of different drivers beyond the current considerations of conventional businesses. The construction industry is increasingly multi-disciplinary and needs to become more so in order to respond to the increasingly complex challenges posed by climate change and appropriate user-centred design in response. It already provides the ability to bring multi-disciplinary teams together, but future developments need to go beyond the current models that replicate existing processes to holistic multi-dimensional approaches that enable flexible working and bring intelligence support to cross-disciplinary solutions.

Improve education: ICT will be one of the enablers of a move from traditional craft-based industry towards a more knowledge-intensive model. The better use of ICT will, in turn, require better education. Lifelong education, as well as self-directed learning, will be the key in this regard.

Improve process: the scenario-planning process indicated that economic efficiency will remain the key driver for organizations in the construction industry. In this regard, organizations should be focusing on integrated solutions that address both IT and processes in order to increase the ability of an organization to adapt and improve upon the current process inefficiency in the industry.

Achieve interoperable, integrated and holistic IT: the scenarios illustrated the desirability in appropriate circumstances of predictability, standardization and commonly adopted and understood regulations and policies. In order for IT to play its full role within the construction industry, it is thought by many that defined and open standards should be agreed and used by all stakeholders.

User-centred IT: whilst there is much agreement on the potential benefits of IT for the construction industry, there is an equal recognition that, so far, much of this promise remains unfulfilled. Most of the action areas from the workshop participants were in response to this recognition and could be grouped under the heading of the development of user-centred IT. This goes beyond the ease of use...
of IT tools to include ubiquitous and pervasive uses of IT within the fabric of the built environment in an intelligent and adaptive manner that meets the needs and enhances the experience of individuals.

**Sustainability:** The final cluster of action areas is around the theme of sustainability. The construction industry, both during the building and use phases, is the most significant industry in terms of carbon emissions, and consequently improvements in the design and use of the built environment is the key to meeting Kyoto targets. The adoption of sustainable approaches can be a key driver to the adoption of IT in, for example, holistic urban planning and building designs that require multiple perspectives such as initial and whole-life costs and embodied energies. A focus on whole-life carbon costs can be enabled by IT tools, as can cradle-to-grave tracking of materials, intelligent control and in-use performance monitoring of buildings.

### 6. Conclusion

The scenario-planning approach has enabled the development of a vision for construction IT that is informed by an extremely wide range of drivers and factors derived from a STEEP approach. This provides a contrast to most previous approaches to predict construction IT futures, which have tended to focus on how developments in technology will shape the future of the construction industry. The consideration of different scenarios helped to stimulate original thinking, and aspects from each scenario have fed into the overall vision statement for construction IT. This vision statement places advances through technological change in a holistic statement alongside people, places and processes. The action areas suggested for working towards the vision are notable both for their range and also for their lack of technological focus.

There are, however, limitations to the work so far. Time limits during the workshops did not allow the scenarios to be developed in detail. Nevertheless, the approach and the active participation of the delegates from different disciplines produced a wide-ranging initial vision for construction IT in the workshops. It is not the claim of the authors that the approach employed is a replacement for previous approaches. Rather, the approach employed can and should be a useful methodology that is used alongside other approaches. In doing so, it will bring different thinking and perspectives from non-IT experts into future thinking processes.

The vision described in this paper is not the final vision. It needs to be revisited regularly and adapted, detecting the early signals for different futures. Further work is also needed to refine the action areas. Following this, a strategic roadmap will be developed for the construction industry. Likewise, this will be used to inform future research activities.

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