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## **Abstract**

One of the most pressing challenges facing humankind is climate change, but it is a wicked problem. While the complexity of this problem can be overwhelming there are means through which the problem can be understood and advances made towards a solution. This paper applies a holistic theoretical sense-making framework and an ecosystem approach to research and practice on ICT issues in the climate change problem. It demonstrates how end-user tools and Web 2.0 technologies, which are embedded in digital ecosystems that include the social context, can play a positive role in the global challenges of climate change.

## **Keywords**

change, addressing, ict, climate, digital, contribution, ecosystems

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# Digital Ecosystems: ICT's contribution to addressing climate change

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**Abstract**— One of the most pressing challenges facing humankind is climate change, but it is a wicked problem. While the complexity of this problem can be overwhelming there are means through which the problem can be understood and advances made towards a solution. This paper applies a holistic theoretical sense-making framework and an ecosystem approach to research and practice on ICT issues in the climate change problem. It demonstrates how end-user tools and Web 2.0 technologies, which are embedded in digital ecosystems that include the social context, can play a positive role in the global challenges of climate change.

**Index Terms**—climate change, ecosystems, complexity, ICT

## I. INTRODUCTION

Many of the big challenges of the current digital age come from 'wicked problems' [1, 2]. Such problems are ill-defined, with shifting definitions and multiple elements whose conflicting objectives necessitate resolution through a complex, holistic perspective. The notion of an 'ecosystem' conceptualises the current environment in a holistic, dynamic way that is appropriate for the study of wicked problems and facilitates the finding of innovative solutions. A typical example of a wicked problem, and arguably one of the most pressing challenges facing humankind, is climate change which comes with a whole raft of interrelated environmental concerns: Water, food, land degradation, species extinction, population growth, pollution etc (see eg Gore 2006, Garnaut 2008, Stern 2008). The pervasiveness of digital information and communications technologies (ICT) in all human activity make it appropriate that the concept and reality of *digital ecosystems* be considered in the climate change debate. Digital ecosystems contain a suite of technological tools, together with social and other contextual elements, that interact as part of a complex but meaningful whole. The message of this paper is that ICT and digital ecosystems are not just a part of the climate change problem but can, and should be, a critical part of the solution [6, 7].

This paper begins with a theoretical sense-making framework that is used to explore the ecosystem approach to research and practice as it is relative to ICT issues in the climate change problem. This provides a suitable perspective and analytical lens through which this issue can be understood and advanced. We then paint a picture of the kinds of digital ecosystems that our research is identifying in modern enterprises that may play a positive role in the way ICT can contribute to the challenges of climate change.

## II. SYSTEMS AND ECOSYSTEMS: A THEORETICAL PERSPECTIVE

The concept of a system, based on general systems theory [8], is central to several fields of study, eg systems thinking, systems dynamics and information systems (IS). A system can be described as a purposeful collection of interrelated elements and is more than just a sum of the parts. Computer-based information systems have been essential to organisations since they appeared in the 1960s. They process transactions where data inputs are converted into outputs which include information. Most are ordered, predictable, planned, designed and tested to be fit for purpose.

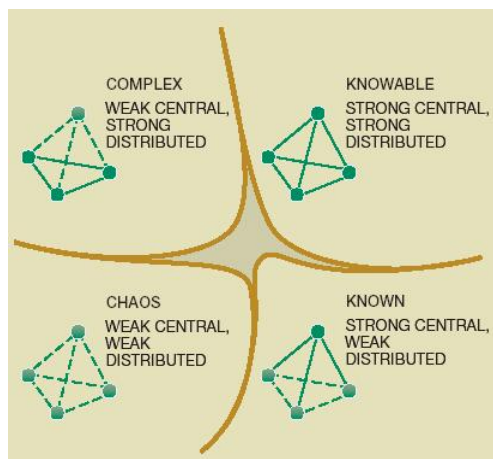
The term 'ecosystem' has been appropriated from biology and widely used to describe systems that have become more complicated, less predictable and context dependent, with softer components such as human factors and organisational culture. Ecosystems are a different way of conceptualising a problem space that is emergent and organic. They challenge traditional approaches to research as they defy most common empirical methods of data collection and analysis which seek to determine cause and effect or to create replicable models of a system. In practice it is difficult to know how to act purposefully in an ecosystem when everything is interrelated and it is impossible to predict all the ramifications of an intervention.

Different types of systemic problems require different levels of understanding and analysis as well as different types of solutions. To make sense of the diverse spectrum of systems and ecosystems we advocate the use of Cynefin framework developed through the research and practice of Knowledge Management (KM) by Dave Snowden [9] when working at IBM. Cynefin is a holistic, sense-making framework that provides a perspective, language and conceptual lens that allows us to characterise problems and find suitable solutions.

The Cynefin framework has five domains reflecting the different relationships between cause and effect and different ways of working in the various domains (see Figure 1). Each domain has a different mode of community behaviour and each implies the need for a different form of management and a different leadership style with the adoption of different tools, practices and conceptual understanding. Four of the Cynefin domains set the possible contexts for collective decision making, an approach which has been used in knowledge management as well as in other applications including

conflict resolution.

## Unordered Domains    Ordered Domains



**Figure 1:** The Cynefin framework with two ordered and two unordered domains with disorder in the centre. The vertical and horizontal connection strengths of Cynefin domains are drawn from Kurtz and Snowden [10].

The four Cynefin practical domains going anticlockwise starting at the bottom right are:

- **The Known or Simple Domain**, in which the relationship between cause and effect is obvious to all. The approach suited to this context is to *Sense - Categorise - Respond* (SCR). This suits a centralised bureaucratic way of working using vertical command and control with weak horizontal links in organisations. Solutions to problems in this domain often involve the generation of best practice, standard routines, rules and regulations.
- **The Knowable or Complicated Domain**, in which the relationship between cause and effect requires analysis or some other form of investigation and/or the application of expert knowledge. The approach here is to *Sense - Analyse - Respond* (SAR). This domain is the realm of scientific research where it is assumed that all knowledge is knowable. Matrix organisational structures reside in this domain with strong relationships both vertically and horizontally.
- **The Unordered Complex Domain**, in which the relationship between cause and effect can only be perceived in retrospect, not in advance. The approach is to *Probe - Sense - Respond* (PSR) and then allow *emergent* practice. Aspects of Complexity Theory developed in biology are relevant to this domain. Community and networked structures are usually here. Solutions to problems in this domain are, in the main, the subject of this paper.
- **The Chaotic Unordered Domain**, in which there is no relationship between cause and effect at systems level. The approach is to *Act - Sense - Respond* (ASR) to discover *novel* practice. Aspects of Chaos Theory developed in mathematical disciplines are relevant to this domain. The connections between individuals and organizations working in this domain are weak. Here there is no discernable structure or obvious solutions.

The right hand domains (known/simple and knowable/complicated) are *ordered* whereas those on the left (complex and chaos) are sensibly viewed as *unordered*. As ordered or simple problems become more complicated we can either endeavour retain order by simplifying and decomposing into small problems that can be tackled more easily or we can move to the left side of the Cynefin framework, and take a holistic view where the complexity and chaos is retained. Wicked problems, that defy obvious solutions or have conflicting objectives are in the unordered domains and need to be acknowledged and treated as such.

The fifth central domain is *disorder*, which is the destructive state of not knowing what type of causality exists and thus not knowing which way of working is best. While problems may legitimately be allowed to exist in the other four domains if approached with suitable solutions, those in states of *disorder* are normally harmful and should be guided into one of the other domains. Space constraints do not allow, nor is it relevant that disorder in the context of climate change be addressed in this paper. People are usually most comfortable in one of the Cynefin domains and interpret problems through their own lens in that domain. They often try to force their interpretation on decisions to address the problem leading to inappropriate solutions.

In proposing the Cynefin model, initially for KM but increasingly for other areas of investigation, Snowden (2002) makes a point of strongly resisting the existence of a single or idealised model and raises an awareness and understanding of the borders between different domains and the acquisition of tools and techniques to enable border transitions when needed. In particular, problems in the complex domains require a holistic dynamic approach that allows emergence rather than planning and would benefit from an ecosystems perspective.

Wicked problems such as climate change where the context is conceptualised as an ecosystem fall into the unordered Cynefin domains. Drawing on Complexity Theory and the characteristics of the Complex Cynefin domain described above, solutions to climate change problems should rely on the detection and leveraging of emergent patterns rather than ordered pre-planning. This approach guides the analysis of digital ecosystems addressed in this paper.

### III. AN APPLICATION OF ECOSYSTEMS

Ecosystems with many interrelated and interconnected elements are suitable constructs for representing complex unordered problems for which there are usually no obvious or straightforward solutions. However, just because ecosystems are complex does not mean, that they defy research analysis or practical application leading to constructive strategies for dealing with such problems. For example KM, the field in which the Cynefin framework was developed, is a diverse, dynamic and amorphous topic, producing many wicked problems and strongly conflicting opinions. This is demonstrated by

the contradictory views of explicit and tacit knowledge that can be treated sometimes as a thing to be captured, stored and accessed, while at others knowledge is treated as a flow to be shared among people, often these days using social technology in digital ecosystems. One of the pervasive elements that introduces such complexity into KM is the difficulty of assessing or measuring the value of KM projects in a meaningful way. One reason for this is that the objectives of KM initiatives are basically to improve organisational performance in ways that cannot easily be quantified. A further challenge is to find a direct link between the KM efforts and any such improvement. Without some means of measuring success it is hard to justify the costs of potential KM projects to management. Benchmarking one organisation's KM program against another is also difficult as KM is context dependent. It is simply not possible to successfully transfer a KM initiative that works in one organisation to another because the contextual elements and culture may be unreceptive. Most KM programs include the need to create the necessary climate for change but this takes time.

KM is thus an ideal candidate topic where the concept of ecosystem can lead to creative workable solutions to wicked problems. An instance of this is the Australian Knowledge Management (KM) Standard, the final version of which [11], relies on the concept of a knowledge ecosystem to underpin a forward-looking representation of KM. Despite criticism and controversy [12, 13] this KM Standard broke new ground as an informed description of the current and emerging landscape in the area rather than a traditional prescriptive standard to be enforced by laws and regulations.



Figure 2 A visualisation of the Knowledge Eco-System from the Australian KM Standard

The development of the Australian KM Standard took place in three stages over a period of five years showing an evolution from an 'ordered' linear approach in a handbook [14] and the Interim Standard [15] to a complex 'unorder' perspective based on the knowledge ecosystem in the final version [11]. Here the elements, enablers and other KM factors are conceptualised as a knowledge eco-system as shown in Figure 2. This approach was strongly influenced by notions from the complexity quadrant of the Cynefin framework [11] where cause and effect cannot be predicted in advance

and attractors and boundaries replace rules and control. Through the knowledge ecosystem, the Standard recognises that every KM initiative is different and unpredictable because of the unique context of each organisation. It also recognises that KM processes are organic and emergent rather than mechanistic and controlled. The Standard does not promote a prescriptive, universal, linear KM process but rather a cyclic set of three phases:

- **mapping:** an audit of the current organisational KM state in the local context and culture and identifying suitable KM goals
- **building:** experiences and linkages: this is the vital phase of prototyping, trialling projects, building trust, generating champions.
- **operationalising:** initiatives and capabilities: including determination of effectiveness, measurements and performance evaluations.

The knowledge eco-system expresses the pragmatic and practical interpretation of these concepts and is reflected in the *building* phase of the KM process. The Standard also suggests possible enabling processes and technologies to support KM initiatives but warns that what works in one organisation at one time might not be appropriate at other times.

The following section of the paper, explores the way that KM technologies have the potential to contribute to climate change solutions by enabling human enterprises to reduce their carbon footprint through new ways of communication, coordination and cooperation. The diversity of these contexts make it appropriate that an ecosystems approach such as that in the KM Standard be used for initiatives in this cross disciplinary area to address the needs and multiple levels of understanding, local, national and international consortia of academia, industry and government institutions.

#### IV. CLIMATE CHANGE: A WICKED PROBLEM

Environmental concerns that threaten the very existence of the human race are arguably the most important issues of our time. There is a complex range of interrelated environmental issues that currently challenge decision-makers at local, national and international levels and our Australian experience is no different. Firstly there is the large body of scientific knowledge from many disciplines which is synthesized and interpreted by others according to their needs and biases. Secondly, there is the myriad of technological and engineering R&D endeavours aiming at energy savings, clean energy generation, green urban design and so on. Thirdly, there are the logistical, business, political and informational issues that surround the science and engineering efforts and thus determine their acceptance, implementation and chances of success balanced against economic and social considerations. The IT community has a major role to play in this third category.

Despite many decades of lobbying by scientists and environmental groups, climate change has only really captured the attention of national leaders over the past

couple of years. A contributing factor has been the spread of network-centric advocacy supported by social technologies of Web 2.0. The capability of World Wide Web (WWW) to process information and knowledge and to support communication is now unprecedented. Climate change and environmental sustainability are issues where information and knowledge are vital, and social and cultural elements are critical. Advocacy groups on all sides of the debate are using ICT, the WWW and associated media to promote their causes.

The role of ICT in the climate change debate is an emerging topic in the field of Information Systems (IS) where the term 'Green IS' is distinguished from 'Green IT'. In a new IS textbook, Boudreau et al [16] record that 'Green IT' is seen to focus mainly on energy efficiency and equipment utilization. 'Green IS', in contrast, refers to "the design and implementation of information systems that contribute to sustainability of business processes". The authors give examples such as reducing transportation costs, supporting teamwork and meetings, tracking environmental information, monitoring a firm's operational emissions and waste, and providing information to consumers. Green IS as so described should therefore have a greater potential than Green IT because it tackles a much larger problem by recognising the context of an information systems as an ecosystem.

A more positive message supporting this position can be found in the work of Romm et al [17] who noted at that time that the Internet economy was generating both structural and efficiency gains leading to emission reductions. Fuhr and Pociask [18] recently reported on a study determining reduction in greenhouse emissions through the wide delivery of broadband services in the US and the work of Fernandez et al [19] on how IS design can support and coordinate a project to extract oil from green algae. This message is driven home in the Smart 2020 project [20], and a UN media release [21]. However, literature in this area is scarce and there is certainly potential and need for more.

Climate change is a global issue that has global consequences. As IT and IS professionals we can continue to be introspective focussing our research effort on technologies and systems or take a responsible view as world citizens using our knowledge and skills outside our narrow discipline boundaries on something important to all. It is with this message in mind that the remainder of the paper is written.

## V. ICT AND CLIMATE CHANGE IN CYNEFIN

Previous sections of the paper have presented, firstly, the Cynefin framework as a theoretical lens through which to make sense of an ecosystem and, secondly, a demonstration of a practical application of an ecosystem perspective in the KM Standard. A wicked problem, climate change, has then been introduced as one where the Cynefin framework and the ecosystem perspective can be used to make sense of the place of digital ecosystems in a meaningful solution. A distinction was made above between the term Green IT, which sees ICT

in a negative light as a major contributor to carbon emissions in their construction, use and disposal as waste, and Green IS which looks positively to ICT as a provider of solutions that reduce the carbon foot print of human enterprise. In this section of the paper we deal with the latter, briefly discussing some ordered solutions, and then, in more detail, solutions to climate change problems that reside in the unordered Cynefin domains and involve the use of digital ecosystems. Ordered solutions consist mainly of systems that process information or see knowledge as a thing. Unordered solutions are more likely to deal with a flow of knowledge for communication and collaboration at work and in society in general through Web 2.0 social technologies.

### *A. Ordered activities: from the paperless office to e- and my- everything*

There are many straightforward uses of ICT that obviously and simply reduce carbon emissions and mitigate against climate change. Most routine human activity, located in the Cynefin ordered domains, has either been automated by an information system, such as an ERP, or is supported by standard ICT packages. There needs to be more attention paid to the way these systems provide means of paperless creation, storage and availability of information and content knowledge. Curbing the urge to print hardcopy, we should encourage more use of digital document readers, digital editing capability (eg use tracking and commenting facilities in wordprocessors), and online data collection, store, manipulation and display (eg online surveys).

Specific software such as carbon calculators can be used to forecast and monitor the carbon emission from all we do. Systems can be optimized to make manufacturing systems, logistics, supply chain etc more efficient thus saving energy, modelling business systems and processes to include environmental costs and benefits.

Web services also have a positive environmental impact when online transactions replace the need for paper documents and the energy needed to move people to the shop-front. Trends in business and government are to electronic business, (e-commerce e-business e-government, e-health) where customers initiate, drive and manage transactions. This is not just a matter of getting the technical aspects right but motivating people to work this way, by winning over hearts and minds. For example, a sense of personal ownership and control comes through the prefix 'my': I register my car at my-rta and choose TV programs through my-abc etc. This is becoming accepted and widespread for simple ordered activities, it is a challenge for unordered ones as will now be discussed.

### *B. Unordered activities - communicating, conferencing, coordinating, collaborating and advocating*

For any human enterprise to perform effectively, it needs to develop social capital as people meet, communicate and collaborate. Traditionally, people have preferred to meet face-to-face (F2F) and to have a daily

routine where they 'go to work'. However we now recognize that such activities have a significant carbon footprint, travelling, commuting and producing of all manner of paper documentation. Potential IT solutions to these problems have been around for some time, namely teleconferencing, telecommuting, the virtual office, group decision support systems, and digital document management. Despite research showing their benefits, their take up has not been particularly widespread as people have resisted the combination of technical, economic, social and cultural changes to the way things are done. Putting the 'C' (communication) into ICT, together with the new imperative to take environmental concerns into account, and the ICT-enabled conferencing and collaborating tools are now firmly back on the agenda. However, the challenges are particularly acute now that social technologies are being considered as tools to support work in formal organisations whose culture is the antithesis of the type of ecosystem of communities who use these technologies socially. This development concerns knowledge as a flow which places it in the unordered Cynefin domain. It poses a cultural challenge to organisations that can only be met with initiatives that suit the unordered domain and whose successful outcomes are judged accordingly [22].

## VI. TECHNICAL, SOCIAL AND CONTEXTUAL ELEMENTS OF DIGITAL ECOSYSTEMS SOLUTIONS

ICT can play a beneficial, environmentally friendly role in re-organizing and transforming the ways we work if an ecosystems approach is taken. The issues and activities we describe here can reduce our use of paper and our need for travel while improving performance.

Our research in this area [23] takes a holistic approach to the complex issues of human activity in modern social-technical systems. The research integrates the technical, economic, social and cultural issues of working in the modern digitally networked world, understanding organizations as complex evolving eco-systems and finding ways to prepare managers and staff for a new way of working in this environment. Without this generation of new human capability and will, no amount of technical innovation is sustainable. Findings from our research suggest the following:

- form work teams and units of diverse members with complementary, not similar skills,
- replace some F2F with online when appropriate and with suitable training,
- set up teams with F2F to build trust and social capital and meet again from time to time to celebrate success and renew team bonds,
- use appropriate groupware, communications and social technologies under the guidance of those who know how, with moderators and facilitators,
- build capability in virtual social skills, encourage community spirit,
- develop ways to create, store and access information digitally,

- allow/trust people to work/collaborate virtually in less formal ways, self-organized, self-directed, letting team roles emerge,
- allow workers to use technologies of their own choosing, and
- provide appropriate incentives and rewards

The adoption of Web 2.0 in some organisations is happening under the label of Enterprise 2.0 although it is noticeable that organisations find it hard to break away from an ordered mode of implementation – restricting access, imposing structure, and strictly monitoring content. This is evident from the discussion by KM experts on ActKM<sup>1</sup> on the use of Sharepoint in organisations for whom they consult and our research with Confluence<sup>2</sup> as an organisational wiki. Hopefully management will learn from the way society at large is connecting in Web 2.0. Some enlightened companies are enlisting help from digital ecosystems involving their customers and clients to improve their business, while at the same time lowering costs and being environmentally responsible. Examples of this include the online Lego user community that proposes new designs for their product [24], and CNN<sup>3</sup> which has instigated a program, i-report, where viewers supply news stories extending the operation of their business to the customer and client communities.

From the enterprise perspective, our research shows that the IT function may now encompass not only basic network infrastructure and traditional business information systems but also a myriad of possible end-user tools including those of Web 2.0. It is no longer a matter of developing or buying applications but allowing workers to choose from those freely available and setting up appropriate policies of use. For example, a the Marketing Department might use Youtube and Facebook to reach young customers, virtual teams might use Google Groups or Ning to coordinate activities or all employees might use a wiki to participate in creating the corporate memory. Such organisational changes pose challenges, but they also bring new opportunities for innovation and sustainability. As the new generation of knowledge workers bring the capability to create these digital ecosystems with them into the workplace they and the digital ecosystems they create can play a significant role in creating enterprises with a more social organisational culture and a reduced carbon footprint.

## VII. CONCLUSION

Solving the wicked problems associated with climate change can be facilitated by the holistic theoretical sense-making framework and an ecosystem approach to research and practice as described here. A research agenda is needed that incorporates the social and

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<sup>1</sup> [www.actkm.org](http://www.actkm.org)

<sup>2</sup> <http://www.atlassian.com/software/confluence/>

<sup>3</sup> <http://www.cnn.com/iReport/>



technical aspects of the big global issues such as climate change. This is where the descriptive sense-making of the Cynefin framework, in particular the attributes of the unordered complex domain, can guide us. Wicked problems need not be simplified or diluted but considered as whole ecosystems. Following the example of the KM Standard, problems can be tackled through the map, build and operationalise phases, and not be constrained to the need to meet strict objectives and deadlines. Rather enough promising interventions can be made and meaningful incentives given to provide fertile ground so that progress will emerge from the ecosystem, be recognised and then nurtured even developments that were not anticipated when the initiative began.

There are several topics where research is still needed into the relationship of social issues and technology. Examples include:

- Getting the work/life balance right for people telecommuting from home when their managers may have concerns that employees work less and employees may find themselves overworking.
- Meeting virtually: The widely used teleconferencing is a rather poor medium but can have support facilities such as common whiteboards, slide shows. On the other hand, video conferencing was once very costly but is now cheaper and available on the desktop over IP. Some companies now support meeting in richer virtual worlds such as second-life.
- The virtual office: In some organizations, sales teams no longer use a central office, meeting in cafes with laptops and wireless internet connection; many client meetings take place in homes.

Digital ecosystems on the Web are also giving a strong collective public voice on environmental issues and climate change that is multidisciplinary and cross cultural, with different languages and jargon and foci. Supported by Web 2.0, the balance of power with respect to knowledge is now shifting away from the 'official versions' in the hands of governments, big business, media moguls, formal libraries and publishing houses. Now if anyone wants to 'know' something they are more likely to go to Google or Wikipedia. Many, particularly young, consumers of news are cynical about what they read in newspapers or see on television. They read blogs from people on the scene, discuss current events on Twitter, get personal opinions from postings on Myspace or Facebook, become immersed in virtual worlds on Second Life, see pictures on Flickr or videos on Youtube, often with detail of news stories before they are picked up by the traditional news media.

This has democratized knowledge and provided a form of network-centric advocacy which is changing the political landscape. Voters are now exposed to new perspectives on issues and are able to collaborate with others to get new messages out there. This phenomenon is almost certainly helping the environmental movement with knowledge sharing and network-centric advocacy.

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