'The City as a Complex Adaptive System: Lessons from the ATLAS Experiment at the LHC'

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Glossary

CERN: The European Organization for Nuclear Research - one of the world's largest centres of scientific research. Founded in 1954, the CERN Laboratory straddles the Franco–Swiss border near Geneva. It was one of Europe's first joint ventures and now has 20 member states. Its main interest is in fundamental physics, finding out what the Universe is made of and how it works. At CERN, the world's largest and most complex scientific instruments are used to study the basic constituents of matter ie the fundamental particles. By studying what happens when these particles collide, physicists learn about the laws of nature. The instruments used at CERN are particle accelerators and detectors. Accelerators boost beams of particles to high energies before they are made to collide with each other or with stationary targets. Detectors observe and record the results of these collisions.

Large Hadron Collider: The Large Hadron Collider (LHC) is a particle accelerator at CERN. It is used by physicists to study the smallest known particles – the fundamental building blocks of all things. The LHC sends two beams of subatomic particles called 'hadrons' (either protons or lead ions) in opposite directions inside the circular accelerator, gaining energy with every lap. Physicists use the LHC to recreate the conditions just after the Big Bang, by colliding the two beams head-on at very high energy. Teams of physicists around the world will analyse the particles created in the collisions using special detectors in a number of experiments dedicated to the LHC.

ATLAS detector: ATLAS is one of two general-purpose detectors at the LHC. It will investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, and particles that could make up dark matter. ATLAS will record sets of measurements on the particles created in collisions including their paths, energies, and their identities. The detector is 46 meters high, 25 meters wide and weighs 7000 tonnes. It involves over 3000 scientists, in 174 research institutes in 38 countries.

Boundary Object: An object which enables order to be created in uncertain circumstances, for example where there are overlaps or gaps in responsibilities etc.

Complex Adaptive Systems: These are special cases of complex systems which are dynamic networks of interactions and relationships and not aggregations of static entities. They are 'adaptive' because their behaviour, individual and collective, changes in the light of experience.

Adhocracy: a form of organisation which acts in the opposite way to a bureaucracy.

Overview

Study of the ATLAS experiment at CERN suggests that more informal networked forms of knowledge and organisation work better than more formal bureaucratic forms, in navigating the complex adaptive system which the experiment represents. Such informal approaches may also be useful in understanding other complex adaptive systems such as cities. How is such co-ordination achieved and what lessons might the ATLAS experience hold for other complex adaptive systems like cities?

Summary

Key features of decision making processes in ATLAS

In considering the extensive collaboration among such a large number of scientists and institutions it is interesting to ask how this is achieved. How is it possible in such a complex experiment to organise effectively and to perform tasks never before undertaken?

Several features of the system are noteworthy. Firstly, none of the scientists working on the experiment is employed by CERN: each tends to be employed by a participating institution. Moreover, within the experiment, there is no one 'boss' or 'head' scientist. Similarly, no organisational 'superiors' from participating institutions interfere with this set up. The operational model is therefore more one of peers collaborating together on a set of complex tasks towards specific purposes. This is reflected in the fact that each paper published from the experiment has every one of the 3000 authors listed on it in alphabetical order. There are also no formal contracts holding the collaboration together. This is done by memoranda of association.

Decision making within the experiment is mostly bottom up, with decisions about what to do being forged in significant numbers of meetings in which each participating scientist has an equal say, the currency being the strength of the idea rather than seniority. Decision making is therefore distributed, with ideas being taken up or not based on the collective perception of their strength.

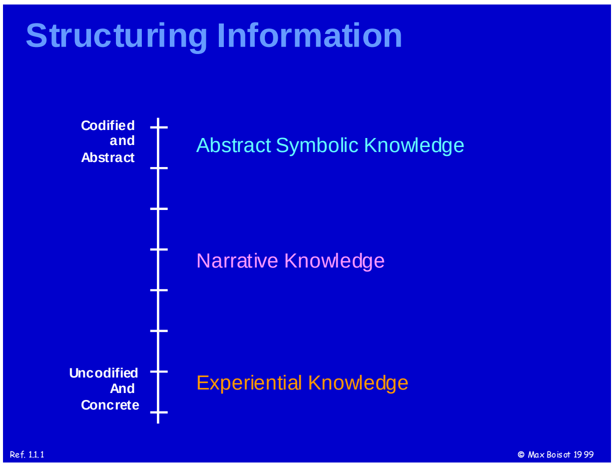
What are the lessons from this for others?

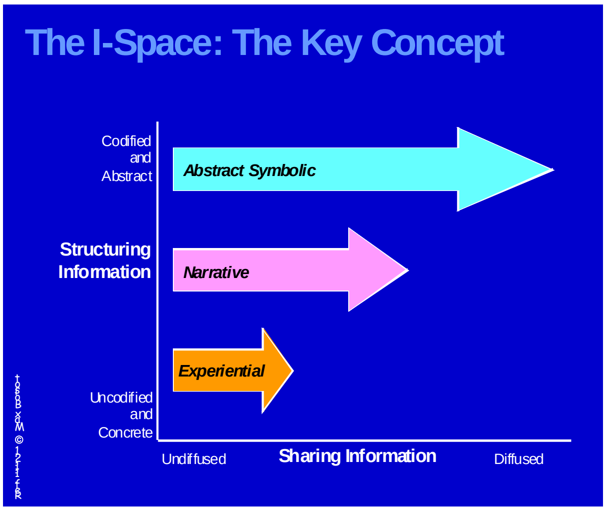
Forms of knowledge

To explore this, Prof Boisot posited three forms of knowledge.

- Experiential – what can I see, hear, touch, feel, hear, smell?
- Narrative – what can I say about it?
- Abstract symbolic – what can I extract from it which is stable and durable?

He then suggested that the first was uncodified and concrete while the latter was codified and abstract.





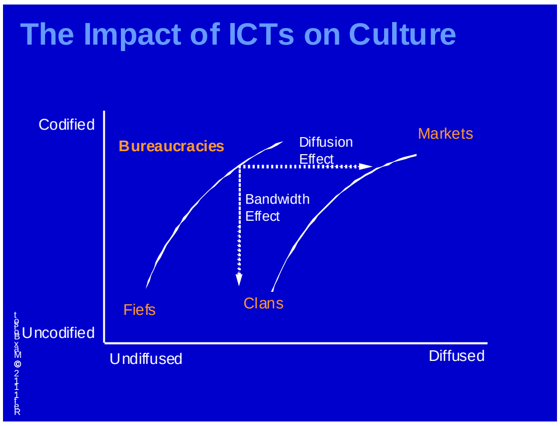
Prof Boisot suggested that these different forms of information have different limits upon the extent to which they can be easily shared and diffused, with abstract symbolic knowledge being most readily shareable. He illustrated this by use of the ‘I space’ or ‘information space’ shown here on the left.

As an example, he compared the knowledge of a Zen master (which resides in the bottom left of the I-space) with that of a bond trader (which dwells in the top right). The stock prices and purchases and sales of bonds are highly abstract concepts which can be shared around the world almost instantly. The knowledge of a Zen master is much more embodied, much less externally structured, and might take several years of study with the master before knowledge is gleaned or imparted.

A key difference between the two forms of knowledge is that abstract codified knowledge can be more readily manipulated and predicted. It can be stored, readily exchanged and form the basis of contracts. However a key disadvantage is that the more abstract knowledge becomes, the more it loses contextual richness, feeling and understanding.

He then went on to suggest that different types of institutions and associated cultures have preferences for different kinds of information.

The diagram on the right, for example, suggests that bureaucracies prefer codified information which is not widely distributed. Markets prefer highly codified and widely diffused information. There are other forms of organisation like fiefs or clans which are better able to operate with the richness of less codified data. Fiefs prefer to limit experience to just a few to maintain power, and clans prefer more widespread knowledge to foster, for example, a sense of belonging.



It should also be noted that order resides in the top left of the I-space alongside bureaucracies, and chaos in the bottom right. Information and computer technology has the effect of increasing diffusion and pushing it down into more informal space. In these circumstances the adhocracy represented by the ATLAS experiment was a very effective way of making meaning and coherence from the space at the edge of human understanding.

Prof Boisot asked the question: ‘*why then, if ATLAS operates at the edge of chaos, does it not simply fly apart at the edges of chaos?*’

He suggested that the reason this does not happen is that the ATLAS detector acts as a boundary object around which the energy and focus of the scientists involved can cohere to make meaning while engaged in a common purpose. Central to this function of the detector is that it is operated as an adhocracy rather than a hierarchy or bureaucracy. This affords scientists the freedom to respond appropriately. The ATLAS detector brings requisite order and focus, whereas the adhocracy brings the requisite variety to deal with the edge of chaos.

The detector acts as a *boundary object* which binds the cultural ecology of the adhocracy into a complex adaptive system. The elements of the system are, on the one hand, the ATLAS detector as a boundary object, and on the other, sufficient trust and shared values to overcome cognitive and affective differences.

Therefore, using this logic to describe Glasgow or the City:

- The city is a complex adaptive system that sits at the so-called *'edge of chaos'*
- Its physical, social and institutional features act as a collection of *boundary objects*
- The obstinate nature of the challenges which the city faces compared to other similar places suggests that the binding agents of trust, based on shared values and shared interactions with a boundary object, need further developing.