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having shared *methods* for tackling tasks. Together, the shared information structures and shared methods constitute a common view or perspective of a particular subject or "domain". The development of shared mental models, essential for communication and learning, can be enhanced by such a common view.

The Enterprise ontology helps provide a gel for integrating what is currently a disparate set of modelling techniques and tools. This gel is "semantic": it helps clarify the meaning of the terms used. The existence of a gel with clearly specified properties also make it easier to design new techniques and tools with the intention of integrating them easily with existing ones.

Integration of computer tools also requires an infrastructure for communicating messages between tools — ours is based on an agent model — and a means of translating a user's needs into the demands on the tools — ours is supplied by what we call our task management.

The "task manager" guides and helps the user in accomplishing whatever task he or she is engaged in. The tool set will support the integration of distributed software tools and repositories. Communication between tools is supported by a generic agent architecture, which is coupled with the task management system.

We have adopted standards wherever possible: CommonKADS for tool set analysis and design; KIF (Knowledge Interchange Format) for encoding the ontology; KQML (Knowledge Query Manipulation Language) for communication between agents; STUDIO for user interface design. Other groups to have adopted KIF and KQML are TOVE [Fox 1993] and SHADE [McGuire 1993].

Three user groups within the project (IBM, Lloyd's Register and Unilever) are providing enterprise modelling scenarios which will be test beds for the enterprise ontology and the tool set.

Summary

All companies now operate in a rapidly changing environment. There are techniques, not yet widely used but put to very good effect by some of these highly successful companies, which help to manage the dynamic environment. Paradoxically, the manufacturing industry, which has seen the biggest decline, is the one where the lessons have been learned best by some companies such as Toyota and Analog Devices.

The scientific approach and systems thinking are key techniques. Fairly simple software tools exist to support the techniques: when integrated with information management tools and more conventional modelling tools they will combine to make powerful enterprise models.

The Enterprise project is exploring how to provide support for creating such enterprise models. Generic models, reuse and integration are key issues for Enterprise. Until these are mastered, companies can still prepare themselves and gain benefit from using the existing tools for understanding, communication and learning.

real communication and learning can be achieved when appropriate enterprise models can be built. Until then, lightweight tools will be very valuable.

Support for Enterprise Modelling

In the Enterprise project [Fraser and Macintosh 1994, AIAI 1995] we have developed an ontology for enterprises which defines both information structures and task structures. People can "buy into" and share these, and so improve their communication and learning. We are building a tool set which will support different user roles: ontology maintainer (who maintains a common set of terms and relationships); method modeller (who describes generic enterprise modelling scenarios); tool administrator (who defines which tools are applicable at certain stages in the scenario); and business analyst (who is guided in the use of the common methods as he or she follows the scenario). The activities carried out by these four user roles are depicted in Figure 2.

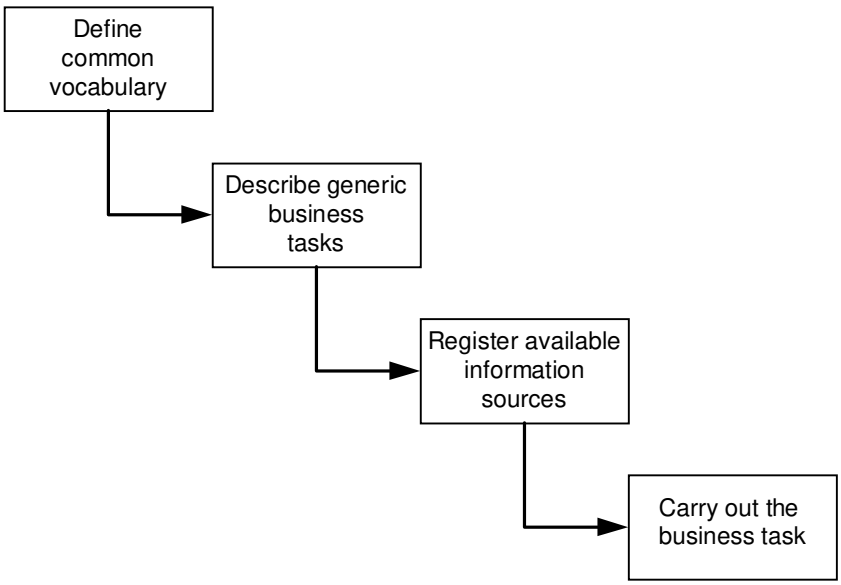

Figure 2: Support for enterprise modelling

The Issues: Generic Models, Reuse and Integration

The Enterprise tool set provides generic models, reusable components and the means to integrate the distributed tools and stores which make up the enterprise model.

Generic models are those that are not built for a specific purpose: the implication is that they can be used for different purposes at different times. There are two ways in which the Enterprise project is building reusable models.

First, we recognise the power of having *information structures* which people can share: for communication, for consistency and for understanding. Second, we recognise the power of

scientific methods such as those preached by W Edwards Deming [Neave 1990] and practised by Toyota Production Systems [Womack *et al.* 1990].

The Place for Enterprise Modelling

Part of the scientific approach is an attention to detail:

> *Holistic manufacturing systems ... benefit from close attention to details, order and discipline... In sailing, good crews maintain meticulous standards and discipline for sails, halyards, ropes, tools, nautical instruments, and safety equipment in order to concentrate on the creative parts of the adventure, respond to unpredictable shifts, and meet emergencies promptly. The same applies in manufacturing. [Berggren 1994]*

What is often missing in management of organisations is a holistic approach, which acknowledges that changes in one location or one aspect of the enterprise can cause effects which will only be observed at a distance in time and space. Much of management is fixated on events, such as

> *last month's sales, the new budget cuts, last quarter's earning, who just got promoted or fired, the new product our competitors just announced, the delay that was announced in our new product, and so on. [Senge 1993]*

The key to holistic modelling is to allow different views on the model while keeping the whole model intact, as opposed to fragmenting the model and running the danger of breaking important dependencies.

Many of the enterprise modelling efforts over the last 5-10 years have failed to do this: they adopt reductionist (divide and conquer) methods in which the important thing is to construct detailed models of data and how it should be structured. As [Davenport *et al.* 1992] point out when discussing "technocratic utopianism" as one of five models of information politics:

> *... utopians focus on all information throughout the corporation - at least all that can be captured by a computer. A common example is the creation of an "enterprise model" - a structured inventory and categorization of all data elements used throughout the firm. Such modeling exercises often take years and yield vast amounts of detail. Although their purpose is often to eliminate redundant data storage, they often yield little real business value.*

The trouble with this kind of enterprise modelling lies in the tacit assumptions that the information modelled is all of high value in making decisions and that the information will be made available by individuals when it is required. An alternative view which I propose is that the "enterprise model" consists of whatever information is needed to take a holistic view, reduce the complexity but still pay attention to relevant detail. Typically the relevant information varies from issue to issue; typically much of it resides in people's heads, and

Systems thinking can help to identify the real points of leverage for effective change. Systems thinking [Kauffman 1980] challenges the reductionist approach in which a complex thing is assumed to be no more than the sum of its parts. Systems thinking encourages the study of how the parts are organised and the identification of patterns which recur in many different kinds of system. Real influences which are distant in time and space can then be identified and understood. Peter Senge, of the Sloan Management School, describes systems thinking as the "fifth discipline" which highly successful organisations such as Shell, Analog Devices and Hanover Insurance have adopted in order to become learning organisations [Senge 1993].

Several software tools exist to help in systems thinking (*e.g.* ithink, PowerSim, VenSim and Model Maker). Many have evolved from what we would describe as scientific fields (ecology, demographics etc.), so it may come as a surprise to find them being applied to the woolly, divergent problems that abound in the business world. But one of the strengths of systems thinking is that it allows you to understand and think about issues which have no "right" answer: we can model complexity and work out the consequences of proposed actions before we actually carry them out.

Managing the Complexity - the Scientific Approach

How fast you can learn is the key to managing complexity. To learn fast you need a good understanding of the current context; tools to help you visualise change and think about change; and better ways of getting fast feedback on operational behaviour. The car industry provides well-documented examples [*e.g.* Womack *et al.* 1990] of those organisations, like Toyota, who have been able to take a scientific approach and see the real issues (such as cutting out batch jobs and cutting out queues) and those, like General Motors, who have gone down blind alleys by taking actions which did not take the whole picture into account (such as going for full automation of production plant). In a recent talk by Dan Jones, one of Womack's co-authors, an example was given of an American aircraft engine manufacturer who cut down the production time of an engine from 3 weeks to 3 days by taking the advice of an ex-Toyota manager and replacing a sophisticated high-tech robot with several simpler tools [Jones 1995].

A recurring theme in successful companies is that they put more effort up front in early design. That is what good management of complexity should be seen as: the careful design of systems to handle and reduce complexity. With the software tools available, we can start thinking of "computer aided design (CAD) for business".

Another recurring theme is that the successful companies follow a scientific approach: not only do they set out their strategy ("**theory**"), they then set out **operational definitions** for carrying out the strategy and then, most importantly, they perform **controlled experiments**, gather data and feed them back to test the strategy. Business process reengineering (BPR) and total quality management (TQM) are strong on the first, but weak on the second and non-existent on the last. Marshall Industries, an $800 million public corporation which has doubled its workforce, doubled its profits and trebled its share price in the space of two years, has achieved it by a dramatic change [Rodin 1995] to the scientific methods such as those preached by W Edwards Deming [Neave 1990] and practised by Toyota Production Systems [Womack *et al.* 1990].

interdependencies of all the component parts. The emphasis is less on information engineering – detailed modelling and categorisation of data – and more on information management – ensuring that information is shared, reused and easily accessible.

There are already many simple software tools available which help people understand and communicate the complexity of their environments. The Enterprise project is making it possible for companies like IBM, Unilever and Lloyd's Register to bring these tools together and do real enterprise modelling.

In the rest of this paper I state that systems thinking and a more scientific approach to management can and should contribute to an enterprise model as described above. Other parts of the enterprise model are more obvious (the third box in Figure 1): process models, organisation charts, optimisation models, risk models, decision models *etc*.

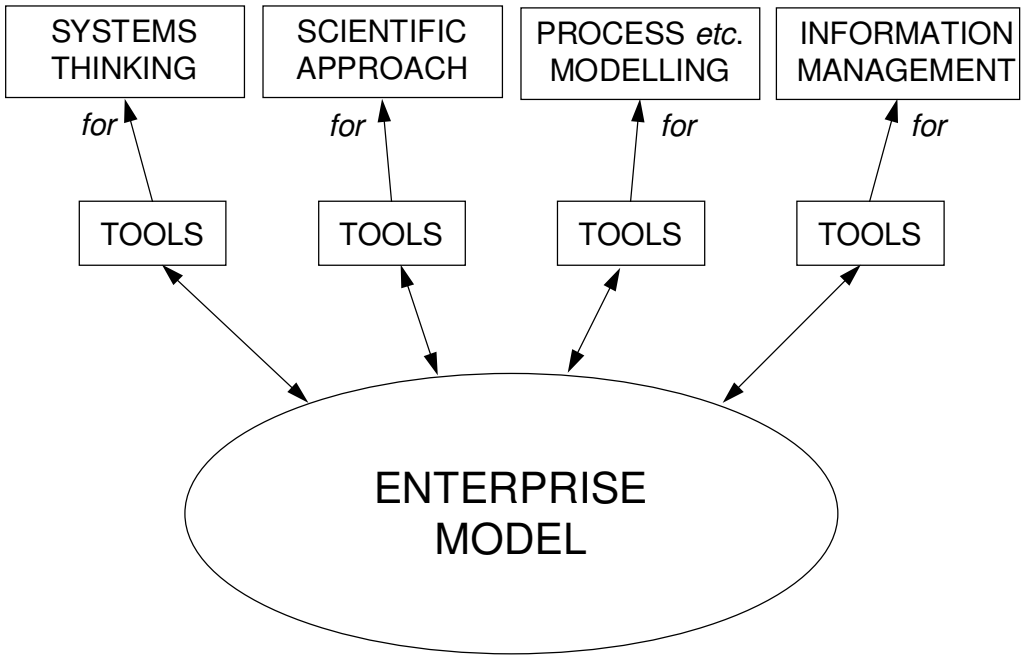

Figure 1: Main Points in the Paper

Understanding The Dynamic Environment – Systems Thinking

One very important feature of complex dynamic environments is that the pressures for change as we experience them may not in themselves reveal the real forces which need managing. Think of how the world's debt crisis is due in the main to well-meaning but disastrous World Bank lending in the 1980s: the resultant schemes have in the main been inappropriate to the recipients' needs and now they have to borrow ever more from the World Bank and the International Monetary Fund to service those loans. [Economist 1995] How much better it would have been for smaller-scale local initiatives in which the local economies could really have benefited from change.

Support for Managing the Dynamic Environment

John Fraser, AIAI

AIAI, The University of Edinburgh, 80 South Bridge, EH1 1HN

All companies, especially manufacturing ones, operate in a changing environment. There are techniques, not yet widely used but put to very good effect by some highly successful companies, which help to manage the dynamic environment. Systems thinking and the scientific approach are two of them. Fairly simple software tools exist to support the techniques: when they can be integrated with information management tools and more conventional modelling tools they will combine to make powerful enterprise models. The Enterprise project is exploring how to do this. Generic models, reuse and integration are key issues for Enterprise.

Introduction

We all live in a complex and dynamic world. The last 20 years have seen, particularly in Europe and North America, the relentless shift from manufacturing-based to knowledge-based industries, recognised as early as 1969 by Peter Drucker and emphasised by him more recently [Drucker 1992]:

> *From now on the key is knowledge. The world is becoming not labour intensive, not materials intensive, not energy intensive, but knowledge intensive.*

As a result there is growing interest in "knowledge management" [Macintosh 1994].

The semiconductor and biotechnology industries exemplify the move away from products with high raw material and energy content to those with high knowledge content. These industries too demonstrate how quickly markets, market leaders and operating conditions can change. True "service" industries, like insurance and finance, are also finding the pace of change hard to keep up with, and are beginning to wonder how they could have prepared themselves better for rapid change.

For manufacturing and other industries to handle this dynamic environment effectively, knowledge and information need to be managed so that they are readily available and can be used for learning. In this paper I propose that enterprise modelling provides some support for managing knowledge and information – but not enterprise modelling as people might already know it. I propose a holistic approach: understanding the whole and the

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