Organisations as complex adaptive systems : implications for the design of information systems

Thesis

ORGANISATIONS AS COMPLEX ADAPTIVE SYSTEMS: IMPLICATIONS FOR THE DESIGN OF INFORMATION SYSTEMS

A thesis presented for the degree of

DOCTOR OF PHILOSOPHY

of

THE OPEN UNIVERSITY

in the

DEPARTMENT OF DESIGN & INNOVATION

by

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September 1998

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Abstract

Today a paradigm shift in the field of organisation and management theories is no longer disputed and the need to switch from the Command-and-Control to the Learning Organisation Paradigm (LOP) in the area of organisational theory is well understood. However, it is less well appreciated that learning organisations cannot operate effectively if supported by centralised databases and tailor-made application programs. LOP emphasises adaptability, flexibility, participation and learning. It is important to understand that the changes in organisational and management strategies will not on their own be able to produce the desired effects unless they are supported by appropriate changes in organisational culture, and by effective information systems. This research demonstrates that conventional information system strategies and development methods are no longer adequate.

Information system strategies must respond to these needs of the LOP and incorporate new information systems that are capable of evolving, adapting and responding to the constantly changing business environment. The desired adaptability, flexibility and agility in information systems for LOP can be achieved by exploiting the technologies of the Internet, World Wide Web, intelligent agents and intranets. This research establishes that there is a need for synergy between organisational structures and organisational information systems. To obtain this desired synergy it is essential that new information systems be designed as an integral part of the learning organisational structure itself.

Complexity theory provides a new set of metaphors and a host of concepts for the understanding of organisations as complex adaptive systems. This research introduces the principles of Complex Adaptive Systems and draws on their significance for designing the information systems needed to support the new generation of learning organisations. The search for new models of information system strategies for today's dynamic world of business points to the 'swarm models' observed in Nature.

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Acknowledgements

A PhD is never the work of a single individual. A number of people help and support the author so that s/he may perform the necessary research. An Information System research project such as this is no exception. I would like to thank everyone who has been involved in helping me in any capacity over the course of this project.

My first and foremost sincere thanks go to my supervisor, Professor George Rzevski for his time and support. I owe much more to him than I can ever possibly find words to express.

I wish to thank all my academic colleagues at Kingston University especially Brian Saxby, Stuart Marks, Dr. Karel Riha, Chris Tompsett and Graham Alsop for their support and understanding. Thanks also to Dr. Martin Robson who collaborated with me on the preparation of the design workshops.

I would like to express my gratitude to my former colleague Dr Anthony Lucas-Smith for his continued support and assistance. I have benefited greatly from his valuable suggestions.

In a project that relies so heavily on sharing and exchanging ideas I am grateful to the members of the Complexity Research Group at London School of Economics and Political Science. My thanks to Eve Mitleton-Kelly for her support over the years.

A very special thank-you to all my family. Taking up an academic project of this nature is never easy and doing so later in life gets much harder. I owe it to my son Tony, in helping me take that first step; to Juhi, my daughter and closest friend, for her infinite support, particularly during the trying period of research, and for the preparation of this thesis. Thank you.

Dedication

To my Parents and Suman

Research Papers and Publications

1. Journal publications

Rzevski G., and Prasad K., (forthcoming) *The Synergy of Learning Organisations and Flexible Information Technology.* Accepted for publication in AI and Society Journal.

2. Papers given at refereed conferences

Prasad K. and Rzevski G., *Organisation as Complex Evolving System: Implication for the Design of information Systems.* 'Organisations As Complex Evolving Systems' Conference, University of Warwick, 4 - 5 December 1998.

Rzevski G. & Prasad K., *New Information Technology for Learning Organisations.* UKAIS Annual Conference, Lincoln. 15 - 17 April 1998.

Rzevski G. & Prasad K., *The Synergy of Learning Organisations and Flexible Information Technology.* 6th IFAC Symposium on Automated Systems Based on Human Skill. Joint Design of Technology and Organisation. 17 - 19 Sept. 1997 Slovenia.

3. Other conference papers

Prasad K., *Complexity Theory: Offering New Insights and Relevance for Information System Strategy.* Operational Research Society Annual Conference. Bath University, Bath. 9-11 Sept. 1997.

Prasad K., *Learning Organisation Paradigm: Relevance and Role of New Information Technology.* Operational Research Society Annual Conference, Lancaster University, Lancaster. 8-10 Sept. 1998.

Chapter 1 - Overview

1.1 Introduction

This research is concerned with the investigation into a paradigm shift in the area of information systems design and development methods. Information Systems (IS) have always been the life-blood of any organisation and conform by closely mirroring the needs of the organisational structure and the needs of its management. Today a paradigm shift in the field of organisation and management theories is no longer disputed. It is being increasingly realised that traditional management practices and information systems that support them are out of synchronisation with today's business environment. Conventional IS strategies and development methods are also being seriously questioned because of their limitations in handling only structured data and text.

The approach taken in this research is unusually broad for the following main reasons:

1. Following Kuhn's (1962) assertion, that paradigms are affected by paradigm shifts in adjacent fields, the research considers how changes in social, cultural, economic and technological environments of business organisation affect information systems and the conceptual principles that underpin the theory of information systems design.

2. In order to study organisational change and to gain useful insights into the factors leading to a shift in organisational paradigm, a genealogical analysis was carried out in organisational and management theories of the industrial and post-industrial era. The interpretation of the historical processes of social

and organisational transformations and associated theories provides an insight into their significant implication for prevailing IS development practices.

3. The history of science has demonstrated that prevailing scientific paradigms can be an important source of theories, analogies, metaphors and mental models in organisational and management theories (Kumar, 1987). A study has therefore been carried out into new scientific discoveries, the emerging Complexity Theory in general, and Complex Adaptive Systems (CAS) theory in particular. The aim here is twofold: firstly to assess the impact of CAS theory on emerging organisational and management theories, and secondly to see if CAS theory can serve as an underpinning for new types of information systems.

The major concern of most organisations and senior management today is focused on how to handle uncertainty arising from a turbulent business environment. Ability to change is a much-prized quality in business these days. It is usually needed in enabling the company to achieve a better 'fit' with its environment. (Lloyd, 1995).

The new organisational paradigm emphasises adaptability, flexibility, participation and learning. A number of labels, such as 'Intelligent Organisation', 'Knowledge-based Organisation', 'Learning Organisation' and lately 'Living Organisation' are currently being used to define the emerging organisational form, of these Learning Organisation[1] (LO) being the most widely accepted. Information system strategies must respond to these organisational needs and result in new information systems that are capable of evolving, adapting and responding to constantly changing

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[1] This is the paradigm shift in the organisational and management theories from the Command-and-Control model to participative organisational model commonly referred to as the 'learning organisation' in management literature.

business environments by exploiting the technology of the Internet, the Web, multimedia, and intelligent agents.

The interest that has been generated in the study of organisations as 'complex systems' is phenomenal. Complex Adaptive Systems (CAS) theory is providing new knowledge and the complexity metaphors have been instrumental in developing a whole new vocabulary to describe this new understanding. CAS theory suggests a radically new way of thinking. It points out that, in generic terms, complexity lies between the two extreme phases of complete order and utter chaos in any complex system. Complex systems are endowed with an inherent capability for coping with 'uncertainty' based on *emergent behaviour* in the form of *self-organisation, creativity,* and *innovation.* The knowledge of how Nature deals with complexity provides new insights for managing business organisations as 'complex adaptive systems'.

This research is mainly concerned with the search for guiding principles on which the new theory for IS design strategy should be based: a theory which is capable of supporting the IS development in the dynamic and change-oriented world of business. Here too the science of complexity offers new insight and guidelines. It demolishes the view put forward by the rational approaches that information systems can be engineered. Rather, it invokes an image of a 'swarm model', such as a colony of ants, or a neural network in a brain, that achieve survival in a changing environment by evolving and adapting. Complexity theory thus not only provides a new set of metaphors and a host of concepts for enriching our understanding of organisations as complex adaptive systems but also is a possible source for the foundation of the IS strategy required to support the new generation of organisations.

1.2 Research contribution: linkage amongst interdisciplinary theoretical perspectives

This research has developed a systematic and scientific linkage between both currently dominant and emerging organisational theories and information system design theories. This theoretical bridge between closely interdependent disciplines of organisations and information systems is very important. The UK Academy for Information Systems (UKAIS), in trying to provide a general definition of the domain of academic study of information systems, has acknowledged that:

> The study of information system and their development is a multi-disciplinary subject and addresses the range of strategic, managerial and operational activities involved in the gathering, processing, storing, distributing and use of information, and its associated technologies, in society and organisations. (UKAIS, 1995)

There is further evidence of growing consensus amongst academics and researchers in the field of information systems that understanding organisational structure, management behaviour and culture is vitally important during the information definition and development process (Mingers and Stowell, 1997). Despite every indication that there is a very close and critical relation between organisational structure, culture and management, and the kind of information system needed in support, little attention has been paid to this particular epistemology.

This research provides useful insights and a way forward towards conceptualising the complex relation between Learning Organisations and the Computer-based Information Systems (CBIS) that are needed to support the new generation of organisations. Without this linkage it is not just difficult but impossible to develop the important integrated theoretical framework. In order to achieve this it was necessary to undertake a genealogical analysis of the organisational and management theories with a view to assess their implications for the design of CBIS. "This history *must* be developed; it is not adequate to use extant "standard" history......." (Probert, 1996).

The research helped understanding of the paradigm shift in technology and philosophy and exposes new trends just becoming visible in both these areas. The combined effect of these changes is going to revolutionise how the business world will function. The research offers a better understanding of how to design IS. It helps designers to develop dynamic and flexible information system which can align closely to changing business environments and information requirements.

Another important contribution of this research has been the revealing of the mismatch that exists between theory and practice in the field of CBIS design. There always existed a non-alignment between the theory of organisation & management and its application. Practice in industry lags behind by staying out of touch with the thinking of the academic circle of the time. For example it took more than a century for the principles of scientific management to be put into practice. Once the theory of scientific management did take root it has had such a stronghold that it is still being practised in spite of a total change of scene.

This mismatch between theory and its adoption in practice is equally applicable to CBIS but in a reversed order. Industry is moving ahead in employing the new technology of the Internet and the Web, but as yet no theoretical framework exists to guide IS practitioners.

The findings of this research are presented in the form of a new conceptual framework for the development of information system.

Chapter 2 - Research Hypotheses and Objectives

The research hypotheses which this thesis sets out to test are as follows:

2.1 Research hypotheses

i. Centralised database oriented information systems are only suited for the traditional hierarchical structure of organisations and 'Command-and-Control' style of management.

ii. A Learning Organisation (LO) cannot be supported by centralised, database oriented information systems. Learning organisations require a radically new type of information systems characterised in particular by flexibility, that is information systems which are capable of evolving and adapting to meet constantly changing requirements.

iii Top-down structured methodologies that were designed to develop centralised database information systems are not suitable for the design of flexible, evolving information systems.

iv The theory of Complex Adaptive Systems (CAS), as expounded by John Holland (1995), is a suitable theoretical basis for both LO and IS that support them.

v The academic community continues to teach conventional IS design and IS design methodologies whilst at the same time industry is forced to introduce new information technologies such as Intranets and Extranets without any theoretical underpinning.

2.2 Research objectives

In order to test the above hypotheses the following research objectives were specified:

i. To conduct a scientific enquiry aimed at understanding the synergy between organisational structure, its management style, and the design of computer-based information systems.

ii To explore and report on the feasibility of achieving synergy by means of currently available technology.

iii To search for a theoretical underpinning of dynamic, ever-changing, evolving organisational structure, and supporting information systems.

Chapter 3 - Research Methodology

3.1 Introduction

This chapter consists of a two part discussion of the research methodology. The first part, section 3.2, aims to provide an outline of current thinking and philosophical trends in information systems (IS) research. The second part, section 3.3, specifies the underlying *ontological and epistemological assumptions* on which this research is based, as well as the research approaches and techniques that have been adopted in collecting data and conducting the research.

Although concerns regarding the limitations of the methods used in IS research is much older, it was the famous Manchester Colloquium in 1984 (Mumford et al 1985) which provided the first forum for airing the concerns and for the ensuing debate. A review of literature on information systems research methods, resulting from the colloquium, shows quite a diversity of current ontological, epistemological, and methodological trends in the field of information systems (Mumford et al 1985; Galliers and Land, 1987; Nissen et al 1991; Mingers and Stowell, 1997). It is therefore felt necessary for these trends to be outlined here in order to provide the necessary background, and for explaining the strategy that has been devised and followed in this research.

Most complex research problems, as Mumford (1991) points out, tend to be multidisciplinary and not unidisciplinary. This research also addresses a complex interdisciplinary problem concerning the issues of organisational change and the implication of these changes for IS design and development theory. There has been an increasing awareness amongst the prominent academics concerned with the field of IS research that there is a need to "broaden perspectives and recognise the importance of interdisciplinary research" (Mumford, 1991). Chapter 1, the Overview of the thesis states the necessity for this research to straddle two disciplines namely: organisational and management disciplines, and the discipline of information systems. The main concern of this research is to understand how organisational IS are affected by the paradigm shift in organisational structure and management theories, and the implication this has for the design of IS.

Due to both the broad context and the complex interdisciplinary nature of this research, it was found necessary to adopt an integrated, interpretive research approach, incorporating different methods and techniques for collecting information and the data needed to test the research hypotheses.

3.2 IS research: 'poverty of scientism' and lack of diversity

It has been recognised that for research in IS to reach maturity the issues concerning the research philosophy and research methods, which are closely related, need close attention. In contrast to most mature scientific disciplines, information systems research methodologies are still in the process of development. The discipline of Information Systems is relatively young and needs to go through formative years in order to mature. In its infant years the IS field has suffered from a lack of diversity in both research philosophy and research methods (Galliers and Land, 1987; Orlikowski and Baroudi, 1991), and consequently results in a 'poverty of scientism' (Klein and Lyytinen, 1985). This, according to Kuhn (1970), is normal for a new discipline. He points out that each of the currently established sciences/disciplines has emerged from a previously more speculative branch of natural philosophy, medicine, or the crafts at some relatively well defined period in the past. Other fields will surely experience the same transition in the future. Only after it occurs does progress become an obvious characteristic of the field

In the past, classical natural science has placed a high value on the positivist view of science and on the role of the researcher as uninvolved and dispassionate observer (Baskerville and Wood-Harper, 1998). Logical positivism, or simply positivism, is the philosophical perspective which has guided scientific research in the past 100 years. Vitalari, (1985) provides the basic tenets of the positivist scientific philosophy as follows :

- Researchers can obtain objective value-free facts about social reality which are independent of the researcher.
- The hypothetical deductive method provides for a unified approach to scientific inquiry.
- The search for causal relationships is the pre-eminent concern of science.
- Empiricism and measurement are essential for scientific discovery.

Great concerns have been expressed against this positivist view of science (Orlikowski and Baroudi, 1991) as it "failed to appreciate the fundamental experience of life in favour of physical and mental regularities. They neglected meaningful experience which was really the defining characteristic of human phenomena." (Hirschheim, 1992).

Historically, the research philosophy in IS has also been based on a rather strict interpretation of the logical positivist philosophy of science. In 1984, at the IFIP Working Group Colloquium entitled '*Information Systems Research - a doubtful science?*' the applicability of traditional approaches to research in IS was seriously questioned and criticised. Klein and Lyytinen(1985) presented a paper at this colloquium in which they made two claims:

1. The current orthodoxy in information system research tries to implement the Hobbesian programme by believing in the possibility of a scientistic engineering theory of information systems design.
2. This is bound to fail.

They warned that - "Information Systems will remain a dubious science as long as it tries to emulate the so-called scientific method as the only ideal of academic inquiry. The most visible symptoms of the poverty of scientism are paradigmatic anomalies - crucial research issues which cannot be resolved within the scientistic tradition because they transcend its paradigmatic assumptions. The need for affirmative pluralism is offered as a fruitful avenue to improve the status of information systems in academia and practice."

With specific reference to the problems in, and criticism of IS research Vitalari (1985) identified two root causes:

1) A mismatch between the research methodologies and the features of IS research settings.

2) The use of limited and seriously criticised research philosophy that is highly dependent upon positivist research principles. Each of these root problems has affected both the quality of IS research and its ability to make reliable statements about computing phenomena.

Hirschheim (1992) expresses similar concerns against the limitations of the positivist methods for IS research when he writes: "the present accepted research methods are no longer appropriate for the subject - indeed, they never have been. ...information systems - because they are largely human or social in nature - share the difficulties associated with social sciences." From the perspective of organisational issues what is considered most problematic is the absence of research methods for the study of change, an issue at the heart of this research. Social sciences are undergoing a rethinking process about paradigms and research methods. Vitalari (1985) identifies some of the rethinking in certain social science fields such as psychology, sociology, social systems and management. The positivist view of scientific research is undergoing a re-evaluation in the social sciences and a new view is emerging - the post-positivist view of social research.

3.2.1 Post-positivist research philosophy

The '*Post-positivist*' debate and '*Methodological Pluralism*' refer to a body of philosophical works and a belief about knowledge that has emerged in response to the movement that re-examines the role of the positivist approach in social science research.

From the review of IS research literature one is led to conclude that post-positivism cannot really be classed as a particular school of thought with clearly agreed and defined set of propositions or tenets (Hirschheim, 1992). However, from the standpoint of the researcher, the need to understand and to incorporate the major tenets of post-positivism is highly recommended and considered a valuable approach. Vitalari (1985) suggests the five tenets of post-positivism as follows:

- The instability of social systems and human behaviour.
- The limits of the stimulus-response paradigm.
- Problems with transhistorical generalizations.
- Problems with the concept of observer neutrality.
- The limits of research method.

3.2.2 Alternative stances on epistemology and ontology

While there is a clear distinction between positivist and non-positivist tradition in scientific research, as outlined above, within the non-positivist approach to research there is no clear definitive answer as to what precise philosophical position should be adopted by the interpretive IS researcher (Walsham, 1995b). Alternative epistemological and ontological stances are summarised in Table 2.1.

Epistemology	Ontology
Positivism: Facts and values are distinct and scientific knowledge consists of facts	External realism: Reality exists independently of our construction of it
Non-positivism: Facts and value are intertwined; both are involved in scientific knowledge	Internal realism: Reality-for-us is an inter-subjective construction of shared human cognitive apparatus
Normativism: Scientific knowledge is ideological and inevitably conductive to particular sets of social ends	Subjective idealism: Each person constructs his or her own reality

Table 2.1 Epistemological and ontological stances on knowledge and reality
Source: Walsham (1995b)

In fact Walsham argues that interpretive research approach is capable of accommodating all assumptions except for the positivist epistemology and the external realism ontology. As a consequence methodological pluralism has resulted and received considerable support in recent years. Pluralists take the view that "searching to find a correct research approach, contingently or absolutely, is mistaken. Different research approaches can perhaps be brought to bear on the same problem domain but each can only be judged in terms of its own, internal standards." (Klein et al 1991).

3.2.3 Methodological pluralism in IS research

Methodological pluralism in IS research is the result of two main causes: firstly, it is in response to the criticism against positivist approach to scientific research, particularly in social sciences, and secondly, from an increasing awareness and acceptance of the fact that there is *no one correct* method of scientific research.

Kuhn (1962) has strongly argued in favour of this second point, as follow:

> The pull towards a single methodological perspective, with its clearly defined tools, needs to be resisted because this single perspective designed for research in "normal science", overlooks the anomalous quality of human experience. The difficulty for human science arises not from the need to change from one paradigm to another but the need to resist settling down to any single paradigm.

Acceptance of methodological pluralism in IS research has brought with it numerous ways of classifying the research methods, as well as sharply defined dichotomies. Myers (1997a) reports on the multitude of terms used to classify and distinguish between these research methods. The most general distinction is made between qualitative and quantitative research method. Other distinctions include 'objective' versus 'subjective' approach, 'nomothetic' versus 'idiographic' approach, where the former is concerned with the discovery of general laws and the latter is concerned with the uniqueness of each particular situation. Another classification is based on outsider (etic) versus an insider (emic) perspective. The former is aimed at prediction and control whilst the latter is aimed at explanation and understanding.

3.2.4 Interpretative research methods

In response to the calls for methodological pluralism, interpretative research methods have increasingly gained acceptance and prominence within the IS research community in the last few years. Walsham (1995a) has explored in some detail the emergence of interpretivism in IS research in an attempt to investigate the claim "that interpretivism is a valuable approach to studying IS in organisations or, more strongly, that it is a better method than positivism for this purpose."

Denzin and Lincoln (1994) state that qualitative research consists of a set of interpretive practices, where no one practice is seen as either 'better' or 'privileged' over another. The literature on approaches used to conduct qualitative research is extensive. At the root of the interpretive research philosophy lies the desire to study problems in the richness of their real-life setting as contrasted with the artificial context of laboratory studies (Walsham, 1993, 1995a; Myers, 1997b). A wide variety of interpretive research strategies has been reported in the IS research literature, and some of the more prominent of these are: interpretive in-depth case studies (Walsham, 1995b). Development of research methods based on grounded theory which draw on the work of Glaser and Strauss (1967). The ground breaking work by Zuboff (1988) has made ethnography a widely used approach (Harvey and Myers, 1995; Myers, 1997a). Other strategies include phenomenology (Boland, 1985), hermeneutics (Lee, 1994), and critical hermeneutics (Myers, 1994, 1995).

The choice of method is not solely guided by epistemological or methodological consideration. Context-relatedness also plays a central role in IS research. Baskerville and Wood-Harper (1998), along with many others commenting on the diversity of approaches in IS research, state that each of the qualitative research methods in IS reference a different genre. In addition Walsham (1995b), commenting on the role of theory, which is also a key question in any research, quotes Eisenhardt, stating three distinct uses of theory as follows:

- As an initial guide to design and data collection
- As part of an iterative process of data collection and analysis
- As a final product of the research

In contrast to the quantitative approach to research, with well established procedures which can be described, learnt and practised, the qualitative research approach requires each researcher to reflect upon the particular research context and research agenda, decide upon the best research method/s to use and explicitly state the chosen strategy. The "researcher must have a theory of reality and of how reality might surrender itself to their knowledge-seeking" (Zuboff, 1988). Of course, as one might expect, considerable controversy still continues to surround the use of these terms, but any further discussion on this topic is declined.

The important conclusion that has been drawn from the review of the literature on IS research, for the purpose of this thesis, is that there is acceptance of the full range of diverse forms within each of the non-positivist methods. Furthermore, this is considered beneficial for IS research overall, allowing different models to be developed, to enable the achievement of goals. However, IS researchers must reflect upon and choose a research approach that is most suited to the research topic, and must explicitly state the epistemological and ontological stances adopted. The next section presents the research strategy that was adopted in this research.

3.3 Research strategy and process of this thesis

The research strategy devised for this study is based on the belief that the interdisciplinary phenomena and broad range of issues that this research addresses cannot be investigated by any one single approach. To achieve comprehensiveness Mumford's (1991) suggestion has been followed, that methods are only means to an end and that the *end* product is the greater understanding of the question one is seeking to answer or the problem one is trying to solve by research. This study adopts a number of research methods. In effect this means methodological pluralism, as discussed in section 3.2.3 and 3.2.4, which as an approach has received considerable support for IS research in recent years. Pluralists take the view that "searching to find a correct research approach, contingently or absolutely, is mistaken. Different research approaches can perhaps be brought to bear on the same problem domain but each can only be judged in terms of its own, internal standards." (Klein et al., 1991).

The following sections provide a discussion of the key research methods adopted in this research, including their justification in terms of relevance to research hypotheses and in meeting the research objectives. A summary of various data collection approaches and modes of analysis employed is also provided, to show how they contribute to the achievement of the research objective.

3.3.1 Contextualist research using genealogical analysis

There is general agreement in IS research literature that organisational information systems cannot be viewed in isolation, but must be addressed by considering the much wider perspective of business. The core concern of this research is to investigate the need to align information systems with the paradigm shifts in organisation structure and management theories. Pettigrew (1985), arguing the case for 'processual studies of organisational change', has stressed the importance of history in research concerned with integrated relationship and interaction between IS, IT and organisations. This implies first, to fully comprehend the nature of these paradigm shifts, and thereafter to look into the feasibility of matching computer-based IS to the new Learning Organisation paradigm. This research needs to trace both, the organisational history and the history of IS development methods from their roots in the past to the present, and to understand the conceptual principles which led to changes.

In order to find evidences to collaborate or refute the research hypotheses stated in Chapter 2 of the thesis, this study involves an understanding of contemporary organisational and management theories and their origins. A major portion of the research was concerned with tracing and understanding the transition from the command-and-control paradigm to new trends towards 'Learning' and 'Intelligent' organisational structures. Understanding the historical evolution of societies in general, and organisations in particular, became imperative for understanding the causes, effects and direction of the radical change. A research methodology, based on the various works of Michel Foucault, called 'genealogy' was adopted for this task. Interpretation of the historical process of organisational and management theories covered in Chapters 4 and 5, and to some extent in Chapter 6 has taken much of the inspiration from the genealogical studies conducted by Miller and O'Leary (1987, 1990)[2]. Probert (1996), who has also used this approach to provide a critique of Soft Systems Methodology, advises against the use of extant "standard" history as one might find in textbooks, promoting the main advantage of genealogical analysis as "being its ability to produce new, and *critical,* insights into old problems and arguments - and thereby to create new possibilities for practical action in the real world." Foucault (1977) himself wrote stressing the point:

> Even if I have referred to and used many historical studies, I have always tried to conduct at first hand the historical analyses in the fields that interested me.

3.3.2 Methodological triangulation and reflexivity

Given the complexity and the exploratory nature of this research project, an emphasis on methodological triangulation and reflexivity seemed necessary to gain an in-depth understanding of the issues involved. Methodological triangulation implies gathering qualitative data about 'the same' phenomena by different methods. Morse (1994) highlights the relevance of the approach:

> Because different "lenses" or perspectives result from the use of different methods, often more than one method may be used within a project so the researcher can gain a more holistic view of the setting.

Orlikowski and Baroudi (1991) have argued in strong terms against one single research perspective for studying information systems phenomena, calling it

[2] Miller and O'Leary use genealogical analysis to study contemporary accounting practices.

'unnecessarily restrictive'. The phenomena being studied and investigated in this research, i.e. *the synergy between organisational structure and the information systems that support it,* needed a plurality of perspectives. Contextualist research and genealogical analysis was useful from a historical perspective. With reference to table 2.1 on page 13, both the *internal realism* and *subjective idealism* ontological positions were not just relevant for the research but became intertwined, and an ethnographic approach was taken where these were concerned.

It was also considered useful that a number of qualitative data collection and analysis approaches be adopted. An ethnographic research approach was found to be most useful for the three empirical studies. Analysis of empirical material collected by the participative observation approach largely determined the next set of data requirements and/or research questions that needed to be answered. When the scope and context became more defined, as the research progressed, both the data needed to collaborate or refute the hypotheses, and the means of collecting it were refined and amended.

The traditional approach to research defines data collection and data analysis as two separate activities. In practice, such an approach is not sustainable in research of this nature, in which the evolutionary process of data collection and analysis determined the next set of direction as well as the data required.

The reflexive approach allowed refocusing, making changes, and an evolutionary progression in the research itself. There were times when these two activities became entwined and the distinction became blurred. This was particularly the case with the interviews conducted during participative observation, discussed in section 3.3.3.2.

3.3.3 Data collection methods used

Because of the complex and multidisciplinary nature of the study a number of data collection methods were employed in the course of the research, using both secondary and primary data sources as follows.

3.3.3.1 Secondary data sources

Literature review Review of literature concerning the context of the study was the first step taken to form the background for the research. The research domain on the one hand consisted of organisational changes, with particular reference to the turbulent environment in which organisations operate, and the resulting paradigm shifts in organisational structures, management styles, and changing working patterns, cumulatively resulting in the establishment of Learning Organisations. On the other hand there was a need to absorb the broad picture pertaining to development, use, implementation and management of computer-based information systems (CBIS), with particular emphasis on the extent of user satisfaction from those CBIS that were in place in the business organisations.

The first step was to read enough on organisational and management literature, both past and contemporary, to gain familiarity and then to be able to analyse and synthesise the findings from the perspective of the research questions.

Secondary data sources on organisational and management literature are extensive. Making the task manageable was achieved by setting a target date within which to complete the study and the approach provided a number of benefits. Apart from a big saving in time, it kept the research on track, enabling enough understanding of the key aspects while complementing the primary data obtained from other research approaches.

Each subsequent literature search was guided by the direction of the research, which was allowed to evolve to a certain extent.

Membership of a mailing list Participation in the Learning Organisation mailing list[3] provided a valuable source of discussion and cross fertilisation of ideas and viewpoints.

3.3.3.2 Primary data sources

Participative observation Baskerville and Wood-Harper (1998) suggest two uses of participant observation. In the first instance participatory observation can be used as the central organising principle for a research method. This use of participatory observation is "crucial to effective fieldwork" where culturally immersive research methods like action research and ethnography are being used (Fetterman, 1989).

The second use of participative observation is that of a supporting data collection technique for possible use within other types of research design. It is in this sense that participative observation was used in the research. The main objective was to achieve a better understanding of the factors under study and to see the reality behind the written descriptions of them in journals and other sources.

Participative observation was used to collect empirical material for textual analysis from three very different organisations - one was a multinational information technology firm, and the other two were indigenous public sector organisations. In each case, document analysis was an important source of information. Document analysis also preceded the open-ended interviews, with a wide selection of

[3] Learning-org-Hosted by Rick Karash <rkarash@karash.com>
Public Dialog on Learning Organizations - <http://www.learning-org.com>

employees in the first organisation. In this way it was possible to compare and contrast direct, personal experience with what was learnt from the literature search and other secondary sources. The analysis and interpretation of material collected helped to identify a number of issues relevant to the research such as:

- Predominant organisational structure and managerial style
- The extent to which each organisation was affected by the phenomenon of change
- The level of awareness amongst employees concerning the turbulent business environment and the need to change
- The organisational approach to achieve change
- Awareness amongst employees (largely middle and senior IT/S managers) concerning:

  The synergy between organisational structure and organisational information systems

  The need to match information systems to organisational structure and management style

In addition to investigations of paradigm shift, research involved observation of IS development at work i.e. observing information system analysts and designers involved in practical work. The observations carried out were not formal, but informal by being part of the teamwork as explained below.

Empirical study 1 This was based in one of the UK branches of a large multinational computer firm. It was a full time study and lasted four months. The project involved the development of a proprietary IS development methodology. During this period there was also an opportunity to research and document the proposals for the testing and validation phase of the methodology. The methodology developed was essentially based on the principles of top-down structured system development. It was launched in October 1992 and superseded all previous system development methods and procedures used within the organisation concerned, both in the UK and USA, as well as in all its other offices abroad.

Empirical study 2 This was a part-time study, three days a week, and lasted for a period of three months. The primary aim of the study was to observe the development process of an information system in a real life situation using top-down Structured System Analysis and Design (SSADM) which is the UK Government's mandatory methodology for all public sector projects. The project involved a large UK Government database project. During the period of observation, participation also included documenting the design of the database.

Empirical study 3 This study was also part-time and lasted for one year. This project was concerned with assisting in developing an information strategy for the A & P Fund-holding Consortium. The consortium consisted of six general medical practices (3 group practices of 3 doctors each, and 3 single-handed practices) in the NHS.

This study, although a failure in terms of both the consortium as well as the fund-holding scheme itself, did provide, from the point of this research, an interesting opportunity to observe the interaction of a group of knowledge/expert workers (the doctors) who, though professionals, lacked experience of team working, organisational and financial planning, and in addition exhibited lack of mutual trust, hidden agendas and the inability to resolve differences of opinion.

Appendix 1 provides more detail on each of these case studies.

3.3.3.3 Action/activity research

This consisted of the development of computer-based information system for a real-life client. Since these were developed in a controlled manner (laboratory experiments) it is suggested that they be called 'activity research' rather than 'action research'.

As part of first and second year undergraduate studies, students of IS at Kingston University develop an information system. The unique feature of these workshops is that it involves a "real" client with a real computer-based information requirement/problem. The duration of the workshop is 12 weeks. The final products are a complete design specification for the system, and a documented working prototype which fulfils part of the specification.

Appendix 2 provides examples of some of the recent workshop clients and the case studies.

3.3.3.4 Questionnaires

The three empirical studies and design workshops described under action research above provided a rich source of information and findings. It was felt however, that there was a need to further elaborate the findings of these studies by collecting data from a much larger group. Questionnaires seemed to be the most appropriate choice for targeting a much wider organisational community and collecting data to support or refute the findings from the analysis of data from the participative observation of the three firms, as well as analysis of data from other sources. This was achieved by the use of three questionnaires.

Questionnaire 1 The first was a detailed 9 page questionnaire comprising three sections. This was sent to 425 business organisations in the UK operating at local, national and global level. 65 usable responses were received and analysed (for analysis of results see Appendix 3, Questionnaire 1).

Questionnaire 2 The second questionnaire was circulated after the UK Academy for Information Systems' (UKAIS) annual conference in April 1998. At the conference one of the plenary speakers, Mr. Rob Wirszyck, Director of Communications and Alliances UK, addressed the topic of 'The skills required to achieve a successful match' between the new generations of organisations and the information systems needed to support them. During his talk he put forward the idea that:

> industry is accepting and implementing the new Information Technology but, the *problem lies with academics who are slow in providing the underpinning theory* for the new paradigm of Information Systems.

A brief questionnaire was sent to 60 delegates (academics only) and 27 responses were received of which 26 were usable.

Subsequently, a brief survey using the second questionnaire was conducted on the Internet[4] to assess the extent to which the above statement may be correct, firstly for all UK universities and then for the 300 Universities world-wide which teach computing and information system design courses. However, the response on the Internet was almost negligible (under 1%) and therefore abandoned. The responses received via the Internet were combined with the responses received by mail and a

[4] The questionnaire is located at the following URL:
http://tompsett.king.ac.uk:591/KPSurvey/enterdetails.html

total of 30 responses were analysed. For analysis of the results see Appendix 3, Questionnaire 2.

Questionnaire 3 In the third questionnaire the objective is the same as for the second questionnaire, except that the target audience is those organisations that are involved in developing IS for their own needs, or as consultants involved in advising and/or developing IS for clients. The questions of course needed to be framed slightly differently from the second questionnaire but with the same aim of finding out the extent to which new IT is being harnessed. For analysis of the results see Appendix 3, Questionnaire 3.

3.3.3.5 The London School of Economics' complexity study groups

The LSE research programme on complexity, which started in October 1995, provided a forum for the study of organisations as *complex evolving systems*. The programme hosts regular seminars given by leading researchers in the field. A two day colloquium on '*Autopoiesis*' with Maturana and other scholars, who have contributed to the theory took place in May 1998. It has two academic Study Groups (SG):

i) The Learning Organisation SG is studying organisational learning from a complexity perspective.

ii) The Complexity SG is exploring the application of generic characteristics of complex adaptive systems to organisations.

Membership of these two Study Groups from their inception and attendance at the seminars and the colloquium have provided a rich and unparalleled source of information, exchange and cross-fertilisation of ideas on the new science of complexity.

3.4 Conclusions

To conclude then, the underlying philosophy which has guided the research strategy is that the problem, its context, and the research objectives together influence the choice of research methods. This research has evolved and is by definition 'explorative research'. It was therefore necessary to adopt a strategy which allowed shifting from one line of enquiry to another. The whole purpose of the research is to move towards a clearer understanding of the principles that must underpin the new theory of IS design. A single research method would have failed to meet the objectives of this study, due to the limited access to research material, data, and evidence needed for testing the hypotheses.

Paradigm shifts cause discontinuities. A study concerned with paradigm shifts, such as this, cannot afford to neglect the historical process of change. One of the criticisms made of the interpretive approach to research is that it fails to acknowledge and explain historical change. Therefore, the processual study of shifts, concerning organisational and management theories, was not just useful but imperative to understand present trends and their implications for future design of CBIS.

Chapter 4 - Industrial Era: organisational and management theories

4.1 Introduction

This chapter is devoted to setting out, in some detail, the principles and ideology on which the organisational and management theories of the industrial age have been based. The set of principles that underpinned these theories (some of which are still dominant in existing business organisation and management practices) were laid down around two centuries ago.

These principles have served business organisations and their management well in the past, but have now reached the end of their useful life (Hammer 1990; Hammer and Champy, 1993; Davenport 1993; Drucker 1988 a, b, 1990, 1992 a, b, 1993, 1994). An 'end of ideology' has been declared by a number of post-industrial theorists. Their discussions generate a keen awareness that the study of past and future are clearly indissolubly linked. To understand and act upon future trends it is essential to understand the linkage between the past and the present. In such an undertaking one is inevitably directed back to the central tenets of the formative period of organisations. An analytical historical perspective of existing organisational and management theories was pursued from the early stages of the industrial age.

4.2 Proprietorship model of the early industrial era

With the advent of the early industrial era, around 1750, Western society faced its first major period of discontinuity when the feudal organisational model became obsolete and the new industrial model was in the development stage. Methods based on agricultural era principles and concepts, and the feudal model, proved totally inadequate to cope with the demands of mechanical technology.

Adam Smith (1723-1790) postulated that the then emerging age of commerce would follow the three earlier stages of society, namely, hunting, pasturing and farming. He put forward two simple conceptual principles which provided the foundation of capitalism and the industrial era: *the detailed division of labour* and *self-interest.* In a famous passage from his book *The Wealth of Nations* (Smith 1987, (first published in 1776)) Adam Smith presents the following argument in favour of the division of labour:

> The great increase in the quantity of work, which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances: first, to the increase of dexterity in every particular workman; secondly, to the saving of time, which is commonly lost in passing from one species of work to another; and, lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many.

It was the *detailed* division of labour that Adam Smith advocated, not just division of labour, as illustrated by the example of making pins. The third principle: *pay for narrowly defined tasks* was added later (Babbage, 1963, (first published in 1832)). It took 50-60 years for these concepts to germinate and take roots before large-scale private capitalist enterprises developed in the West. It was Taylor, with his scientific management theory, who later developed these concepts to sort out how individuals and work units are to be linked into industrial organisations and how the division of labour is to be implemented.

Until the middle of the nineteenth century the volume of industrial activity was not large. The enterprise remained small and personal, usually run as a family business, employing family and friends to help run the business. The owner was normally capable of administering the business himself, the main task being co-ordination of resources. Codes of practice gradually became necessary for the factory to deal efficiently with increasing numbers of workers, but these were introduced in a piecemeal fashion by the owner as and when the need arose. With regards to the management aspects of the business during this period Tillet et al. (1970) write:

> Management was not recognised as being an important element in the success or failure of a firm until there were enough firms with common problems to enable administration to be picked out as a specific skill, independent of a particular firm or industry. It was found for example, that size brought certain problems, and as firms grew in size they were confronted with the same type of difficulties. Management information, once it began to be communicated, was not confined to a single industry or even to countries. There was a widespread exchange of books and journals between Britain and the United States, and as the United States began to take the lead in industrial innovation, so its management practices came increasingly to the attention of British industrialists.

The fifty years before the outbreak of World War I have been called the 'Heroic Age of Invention'. With the exception of computers, most industrial technology in use today is an extension or enhancement of the inventions of this remarkable half-century. During the 1850s and 1860s Siemens produced the electric generator. Ten years later in the 1870s, Edison invented the electric bulb and the phonograph. In the same decade the typewriter and telephone were invented, transforming communications within the office. 1880s brought the automobile and 1890s saw the advent of Marconi's wireless. The first synthetic drug, aspirin was also produced in the 1890s and marked the beginnings of the pharmaceutical industry. The Wright brothers gave us the aeroplane in 1903 (Drucker, 1969).

It was in the decades of the late nineteenth and early twentieth century that the most characteristic features of industrialism came to fruition. Systematic application of division of labour using scientific management techniques became all pervasive. Newer technologies necessitated the accumulation of resources, which in turn created the need for rationalisation of work. In the words of Landes (1969):

> seen from the hindsight of the mid-twentieth century, scientific management was the natural sequel to the process of mechanization that constituted the heart of the Industrial Revolution: first the substitution of machine and inanimate power for human skills and strength; then the

> conversion of the operative into an automaton to match and keep pace with his equipment.

Landes called the peaking of technological innovation and the transformations that followed suit as 'consummation of the Industrial Revolution'. All these factors along with the separation of ownership and control created an atmosphere ready for a genesis in management thought. Kumar (1987) writes:

> The coming of Taylorism or 'scientific management' illustrates this particularly well. As we have seen, employers until the end of the nineteenth century were remarkably casual about the organization of labour, apparently content with spectacular results achieved by mechanization alone. But sooner or later they were bound to realize that the advances of mechanization would be held back if the organization of work itself lacked the 'rationalization' and science that had gone into machinery. And F. W. Taylor was on hand to help them see this the more readily .

The classical theories which laid the foundation of the command-and-control model of the organisation are discussed in the next section.

4.3 Command-and-control model of the industrial era

This section considers the background influences which caused the paradigm shift from the proprietorship model to the command-and-control model. This is followed by a brief review of the diverse approaches to organisation and its management theories, with the aim of drawing together the major themes of the command-and-control model of organisation.

4.3.1 Technological innovations

As mentioned earlier the fifty years before the first world war was called the 'Heroic Age of Invention'. In the years following, new technologies created the need to manage resources effectively with the aim of enhancing production efficiency. By the

1880s some of these scientific inventions, particularly the telephone, telegraph, electric motor, steamboat and the railway opened new markets for the producers (Chandler, 1977). The resulting expansion of the economy paved the way for important changes in organisational structures. The proprietorship model, which was developed in the early industrial era, was replaced by the command-and-control model, resulting in deep hierarchical organisational structures.

4.3.2 The changing business environment

The business environment amongst industrial nations varied a great deal even in the late nineteenth and early twentieth century. Capital was plentiful in Britain in the nineteenth century, for it had a flourishing international trade and a large Empire. Yet Britain, which had the lead in the industrial revolution was beginning to lag behind its competitors by the end of the nineteenth century. The main reasons for this was an attitude of complacency - "lag in technique, and lack of concern with innovation, even discounting new industries like motor cars and electricity, was noticeable in most sectors" (Tillett et al., 1970).

The firms in most other industrialised countries, during this period, were expanding to take advantage of the larger markets. Expansion was achieved either by increasing in size or by aggressive mergers, particularly in America. As mentioned earlier, in the nineteenth century, firms were mainly manufacturing factory-type of family businesses but by the late nineteenth and early twentieth century, vertical integration had created a new pattern of business aggregation introducing Limited Liability and Joint Stock Companies, both in Europe and America. These expansions resulted in large increases in workforce. A combination of these factors led to an important consequence: *separation of ownership from management.* It increasingly became apparent to those involved that the skills required to manage these new types of organisation were distinctly different to those needed before. In addition, these industrialised nations did not enjoy the affluent conditions that existed in Britain. As such, the firms in these countries borrowed from banks which gave the banks the right to supervise performance of the firm in order to maintain credit. As a result, closer attention to performance became necessary. (Tillett et al., 1970).

4.3.3 The demographic transitions

Industrialisation, amongst other things, also resulted in population growth and urbanisation. Although the population of the entire world increased from about 1750 onwards, demographic revolution took place in countries from where the industrial revolution originated and in the countries to which it spread, i.e. Britain, followed by North-Western Europe and the United States. The population of Europe doubled between 1750 and 1800. From then on there was an increase of 43% for the period 1800 to 1850, and a 50% increase for the period 1850 to 1900 (Kumar, 1987). A large number of people left rural life and came to cities in search of work, but the vast majority of these people were illiterate, unskilled labourers. They needed to be trained quickly and efficiently to become productive.

4.3.4 Classical organisation theory

The early foundation of the command-and-control model was laid by two groups of theorists - *Classical Organisation Theorists* and *Neo-classical Organisation Theorists.* The classical theories and their main proponent are summarised in Figure 4.1 on the following page. Classical organisational theory deals almost exclusively with the *anatomy of formal organisation* and is built around four key pillars (Litterer, 1969). The four major and related elements in the theory were:

- The division of labour
- The scalar and functional processes
- Structure (two basic structures: the line and staff)
- The span of control

Theories	Proponent
Classical Organisation Theory	
Scientific Management School	F. W. Taylor Frank & Lillian Gilbreth Henry L Gantt
Administrative School	Henri Fayol James Mooney Lyndall F. Urwick Max Weber
Neoclassical Organisation Theory	Elton Mayo Rensis Likert Chris Argyris

Fig. 4.1 Organisation and management theories and their proponents

4.3.4.1 Scientific management

The American quest for national efficiency lies at the heart of scientific management. The notion of efficiency was used as a convenient label for grouping all kinds of assumptions, beliefs and demands concerning government, industry and social organisation in the early years of this century (Miller and O'Leary, 1987). Taylor (1911) himself states in the introductory pages of his celebrated *Principles of scientific management,* that the core issue for him was to advance national efficiency:

> We can see our forests vanishing, our water-power going to waste, our soil being carried by floods into the sea. We can see and feel the waste of material things. Awkward, inefficient, or ill-directed movements of men, however, leave nothing visible or tangible behind them. Their appreciation calls for an act of memory, an effort of imagination. And for this reason, even though our daily loss from this source is greater than our waste of material things, the one has stirred us deeply, while the other has moved us but little.

The other foundation of scientific management was *division of labour through detailed planning*. Taylor's approach in itself was an extension of the principles established by (Smith 1987, (first published in 1776)) and (Babbage, 1963) (first published in 1832)) nearly over a century earlier. The studies Taylor and his followers carried out were designed to understand and facilitate planning of routine tasks. The emphasis was on the physiological aspects of workers. The major theme of scientific management, to begin with, was the blue collar work. Taylor was not alone in his mission of scientific management. Henry Gantt (1916) a contemporary and associate of Taylor devised a production charting tool and a wage incentive scheme. Frank Gilbreth, assisted by his wife Lillian Gilbreth, a trained psychologist, took Taylor's ideas and developed the principles of time and motion study by applying scientific method (Gilbreth and Gilbreth, 1917). Later developments in ergonomics, particularly during World War II, owe much to him.

Taylor devoted all his efforts to improve the efficiency and productivity of industrial workers. More recent management writers such as Peter Drucker (1991) believe that Taylor certainly turned round the fortunes of the workers. In the 1850s a labourer was a hired hand, paid meagrely and expected to work very long hours. Animosity between workers and their managers was the rule rather than the exception. Peter Drucker maintains that Frederick Taylor's contribution of scientific management was the prime reason for averting the class war in the West.

The success of Taylor's management principles, when applied in practical business situations, was so great that he not only averted the revolution of the proletariat, but instead turned the proletariat into the bourgeoisie. His methods allowed industrial workers to earn middle class wages and achieve middle class status despite their initial lack of skills and education. Soon after World War II, blue collar workers were transformed from being the under-privileged class to becoming the dominant class in society, with job security, pension schemes and union powers behind them (Drucker, 1991). It is somewhat unfair that Taylor's contribution to the principle of the separation of thinking from doing, is often remembered, summed up by Robert

Reich (1983) as: "This separation of thinkers from doers was the apogee of specialisation: planning was to be distinct from execution, brain from brawn, head from hand, white collar from blue collar".

4.3.4.2 Administrative theorists

Taylor was concerned with efficiency at the level of the shop floor and did not address the broader question of organisation design. Administrative theorists like Henri Fayol (1949), James Mooney (Mooney and Reiley, 1931), Urwick (1943) and others devoted their attention to the task of organisational management.

At the same time as administrative theorists were developing their theories in the United States and Britain, Max Weber (1946), in Germany, was developing a theory of bureaucracy. His work was not translated until after World War II and did not reach America until 1947. He described bureaucracy as having (Narayanan and Nath, 1993):

- A well-defined hierarchy of authority
- A division of work based on functional specialisation
- A system of rules covering the rights and duties of position incumbents
- A system of procedures for dealing with work situations
- Impersonality of interpersonal relationships
- Selection for employment and promotion based on technical excellence

4.3.5 Neo-classical organisation theory

The Neo-classical theory of organisation addressed the task of compensating for the shortcomings of the classical approach and is commonly identified with the human relation movement. One of the main contributions of the neo-classical school is the introduction of the behavioural sciences in an integrated fashion into the theory of organisation. Through the use of these sciences, the human relationists demonstrate how the pillars of the classical doctrine are affected by the impact of human action. Further, the neo-classical approach includes a systematic treatment of the 'informal organisation' showing its influence on the formal structure. (Litterer, 1969).

Thus the neo-classical approach to organisation theory provides evidence that while it accepts the classical doctrine, it superimposes on it modifications based on individual human behaviour as well as the influences of the informal group. The fundamental principles of neoclassical theory remain the same as those of the classical theory. "Generally the neoclassical approach takes the postulates of the classical school, regarding the pillars of organizations as givens. But these postulates are regarded as modified by people, acting independently or within the context of the informal organization." (Litterer, 1969). Woodward (1965) provides a comprehensive perspective:

> At first sight it appears that the approach of the traditional social scientists is in conflict with the approach of the classical management theorist. Certainly two bodies of knowledge have been built up which to a considerable extent cancel out each other. But classical management theorists and social scientists managed on the whole to live quite happily together. There were dogmatists on both sides always sniping at the other; but as management education got under way in this country, both approaches were represented in the syllabuses of courses, and the contribution of the social scientists came to be regarded as compensatory rather than contradictory to classical management theory. The human relations movement which grew out of the Hawthorne researches did not question the ideas and theories of the classical approach, but took the view that modifications had to be superimposed to allow for the fact that people act in response to other pressures. If the rules of the classical management theory failed to work, the failure was due either to imperfections in the way that they were applied or to the capacity of human beings to disrupt even the most carefully laid organizational plans. It was therefore important for managers to know about the factors underlying human interaction and to increase their sophistication and skill in dealing with human behaviour. Management could look to the social scientists for help in making the rules work.

4.4 Conclusions

A number of important conclusions are drawn from the above analysis:

Firstly, that there always existed a non alignment between the theory of organisation and management and its practical application. Practice in industry lagged behind by staying out of touch with the thinking of the academic circle of the time. It took more than a century for the principles of scientific management to be put into practice. Once the theory of scientific management did take roots it had such a stronghold that behaviour management theory of the Human Relations movement was used just as an overlay, and was never implemented in its true sense and spirit. This mismatch between theory and its adoption in practice is illustrated in figure 4.2 on the following page.

Secondly, the hierarchical command-and-control model was developed incrementally and the main impact of this model on society was felt only when practitioners began to apply it and extend its principles. Examples are: when Ford introduced production lines and mass manufacturing, and Sloan of General Motors Company established a divisional functional structure which persisted until recently as the only viable way of organising big business.

Thirdly, until very recently concepts of scientific management such as: division of labour, deep management hierarchies, limited span of control, rigid production lines, the use of unskilled and semiskilled labour (to carry out precisely specified procedures), functional organisational units and vertical integration have been accepted as essential building blocks supporting every successful organisation. Indeed these concepts formed the basis on which the United States of America built its industrial supremacy until challenged by Japanese competition from the 1970s onward. Virtually all prognosticators of this period failed to perceive and predict the critical role Japan was to play in revolutionising industrial organisation theory and structure since the 1960s. Today it is being realised that the other countries of the Pacific Rim will have an equally important influence in the world market of this decade and beyond. The organisational model based on these concepts is considered as the departing paradigm and will be referred to it as the *command-and-control paradigm*.

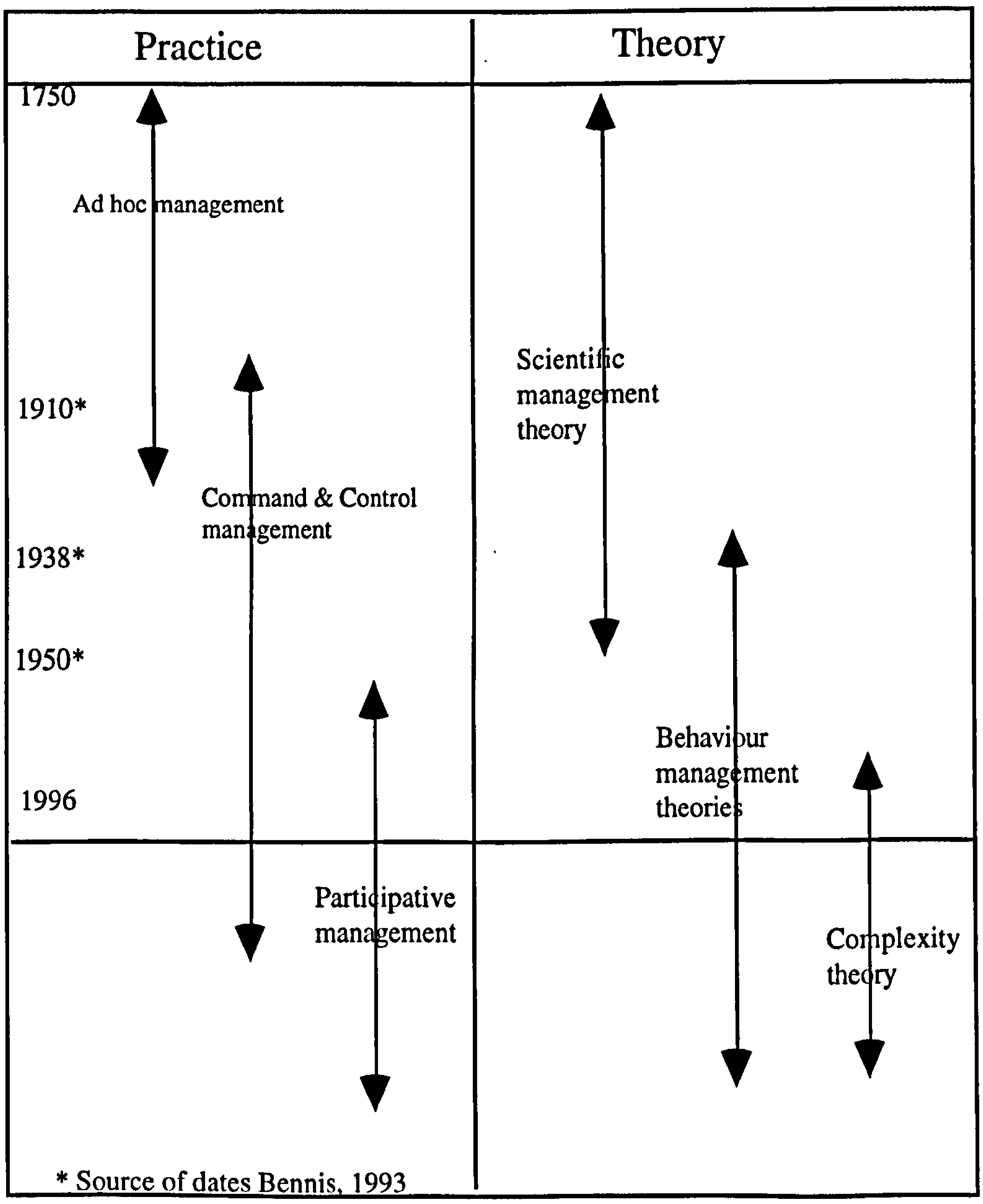

Fig. 4.2 Mismatch between management theories and practice

In spite of the fact that many authors as early as the 1920s and 1930s (Follett, 1924), (Barnard, 1938) have written about severe limitations of this model, in practice, it has dominated the industrial scene for more than a century. "The ideas of F W Taylor continue to suffuse much of management thinking but have had overlaid upon them the doctrine of human co-operation advanced by Elton Mayo..." (Torrington and Weightman, 1994). Mayo's (1933) work was continued by human relation theorists (e.g. Argyris, 1957a; McGregor, 1960; Likert, 1961; Maslow, 1968). Its demise came only very recently after leading large companies such as General Motors and, in particular, IBM incurred enormous losses and began re-examining the foundations of their organisational structure and culture. Pushed by market forces and encouraged by management consultants of high profile, e.g. Hammer (1990), Hammer and Champy (1993), Drucker (1988 a, b, 1992 a, b, 1994), Western companies began serious restructuring under the name of Business Process Reengineering, abandoning almost all features of the command-and-control model.

The causes of the downfall of the command-and-control paradigm, which was at the heart of unprecedented Western industrial success for more than a century, can be traced to recent global oversupply of goods and services due to a steep increase in competition, primarily from countries of the Pacific Rim. Unexpectedly, demand and supply conditions changed. Vendors are now expected to deliver products and services of both high quality and low cost. Customisation (rather than mass production), incremental innovation, responsiveness to rapid changes in demand and supply and short concept-to-market lead times became the main critical success factors - features that large command-and-control organisations could not provide.

The new system of concepts defining participative organisational structures and cultures has emerged (Zuboff, 1988; Savage, 1990; Scott Morton, 1991; Hammer and Champy, 1993; Davenport, 1993; Drucker, 1969, 1993). These concepts provide the basis for an emerging paradigm and will be referred to as the *Learning Organisation Paradigm.* (LOP). The LOP encompasses: shallow hierarchies, small power distances, interdisciplinary teams of well educated employees, process-oriented organisational units and global partnerships between independent companies along supply chains. The nature and the consequences of the discontinuities that are responsible for this paradigm shift is the topic of the next chapter.

Chapter 5 - Post-Industrialism: heralding major paradigm shift in organisation theory

5.1 Introduction

The principles underpinning the classical and neo-classical management and organisational theories, as discussed in the previous chapter, were appropriate primarily for the conditions prevailing in the nineteenth century. Today these principles no longer have much relevance; they have reached the end of their useful life if not stagnation point. The general conditions prevailing in the world, and the environment in which business organisations operate today have changed dramatically, particularly in the post World War II decades. Latest technological developments and the new concepts of the 'Information' and 'knowledge' around which the organisation, its management and its workforce have to conform, cannot be understood, let alone mastered and exploited, if organisations choose to remain tied to the past way of thinking.

The aim of this chapter is not an exposition of the theories of post-industrialism *per se*, as this would be outside the scope of this research, but rather the intention is to draw on them in order to gain an understanding of discontinuities and changes which have ushered in the post-industrial society. These changes have cumulatively signalled a major shift in organisational theory, from the command-and-control model discussed in the previous chapter, to the Learning Organisation Paradigm

5.2 Change as a natural phenomenon

There is nothing extraordinary about the phenomenon of revolutionary changes taking place in society. Change always has been a constant feature of the lives of our forefathers and is guaranteed to be so for the generations to come. One of the earliest recordings of the concept of continuous change is found in the writings of the Greek philosopher Heraclitus (540-475 BC). A considerable number of fragments of his thoughts remain, one of them being....all things are in flux, changing in such a way that it is not possible to step into the same river twice; for "other and yet other waters are flowing on".

The pre-eminent management thinker of our time, Peter Drucker (1993) in his book '*Post Capitalist Society*' reconfirms this fact when he writes....."every few hundred years in the western history there occurs a sharp transformation....... Within a few short decades, society rearranges itself- its world view; its basic values; its social and political structures; its art; its key institutions. Fifty years later there is a new world........".

We are currently living in such a period of radical and unprecedented change, a technological and social revolution is taking place in our midst today, compared in scale and consequence to the industrial revolution. Three decades ago Drucker (1969) had anticipated these turbulent times when he wrote :

> Measured by the yardsticks of the economists, the last half-century has been an *Age of Continuity* - the period of least change in 300 years or so, that is, since world commerce and systematic agriculture first became dominant economic factors in the closing decades of the seventeenth century.
>
> The growth during this period of continuity has been great, especially in the countries that were already well advanced before 1913. But the growth has been largely along lines that had been laid down well and truly in those distant days of our grandparents and great-grandparents.................. The towering economic achievements of today, the affluent, mass-consumption economies of the advanced countries, their productivity and their technological powers, are built four-square on Victorian and Edwardian foundations and out of building blocks quarried then. They are, above all, a fulfilment of the economic and technological promises of the Victorian and Edwardian eras and testimony to their economic vision.

> Now, however, we face an *Age of Discontinuity* in world economy and technology. We might succeed in making it an age of great economic growth as well. But the one thing that is certain so far is that it will be a period of change - in technology and in economic policy, in industry structures and in economic theory, in the knowledge needed to govern and to manage, and in economic issues.

All around the world, particularly in the developed nations of the world, there are clear signs that the ecology of the world business environment is changing dramatically. Geographical boundaries and protected market niches no longer exist. New market conditions created by increased competition, changed patterns of demand, altered attitudes of work-force, environment protection issues and regulation are all putting great pressure on today's businesses, but at the same time are also opening up new and exciting avenues for commercial success.

There are however, some very significant differences in the way the changes taking place today are affecting us as individuals and as a society in comparison to the changes that took place in the past. With the passing of time, the time taken, first in realising that a new reality has emerged, then accepting it, and finally responding to it, is getting shorter and shorter. Today both individuals and organisations can no longer afford to ignore changes for even a few years let alone a generation or two, as was the norm in the not too distant past. Furthermore, the change being experienced in all walks of life today is not in response to some theory which emerged some 50-60 years ago. *The two seem to be concurrent. Both are happening here and now.* It is our generation, not the next or the one after that, that must respond to it. Unlike past changes, the changes are taking place at an increasing pace today and cannot be ignored for a generation or two.

5.3 Post-industrialism: the theoretical perspective

A great deal has been written on the new age based around Information Technology (IT) since the 1960s, and a number of different theories of social and organisational transformation have also been proposed. Krishna Kumar (1987) a thorough surveyor of recent literature provides this synopsis:

> The diversity of names for the new society similarly indicates both variety and convergence: variety in the bases from which the changes are viewed, as well as in the singling out of the principal forces promoting the change; convergence of the idea that the industrial societies are entering on a new phase of their evolution, marking a transition as momentous as that which a hundred years ago took European societies from an agrarian to an industrial social order. Thus Amitai Etzioni speaks of 'the post-modern era', George Lichtheim of 'the post-bourgeois society', Herman Kahn of 'post-economic society', Murray Bookchin of 'the post-scarcity society', Kenneth Boulding of 'post-civilized society', Daniel Bell simply of the post-industrial society'. Others putting the point more positively have spoken of 'the knowledge society' (Peter Drucker), 'the personal service society' (Paul Halmos), 'the service class society' (Ralf Dahrendorf), and 'the technetronic era' (Zbigniew Brzezinski). Taken as a whole, these labels tell us what it is in the past that has now been or is being suspended- e.g. scarcity, the bourgeois order, the predominance of economic motive; and also what can be expected to be the main principle of the future society - e.g. knowledge, personal services, the electronic technology of computers and telecommunications.

While theories of social transformation are concerned primarily with changes at the level of global, national and regional society, organisational theories consider the transformation of the work environment occurring at the level of the workplace. Although some of the theories mentioned above seek to provide a broader perspective by incorporating society, polity, workplace, and cultural levels, others are largely concerned with only one level. From the point of this research the concern is mainly confined to contemporary theories of organisational change. However, it needs to be borne in mind that a clear cut distinction between social and organisational transformation theories is not always possible, since social changes do influence the work place and changes at the organisational level no doubt constitute an element of social change.

The origins of a number of the theories of forthcoming social transformation can be traced to the theories of post-industrialism popular in the sociological literature of the 1960s and 1970s in general, and to Daniel Bell's (1973) *The coming of the Post-Industrial Society* in particular. Daniel Bell, and other eminent experts in the field of business management, for example Peter Drucker (1988 a, b, 1990, 1992 a, b) foresaw the changes that are taking place today, over two decades ago. Bell's work has gained high respectability as it displays an erudite knowledge of conventional and radical social theory in explaining his observations of changes taking place in the USA during the early 1970s. He says a society comprises three components: the social structure, the polity, and the prevalent culture. During the industrial era a common value system united these three areas of society. However, according to Bell, in *modern* western society "the three realms - the economy, the polity, and the culture are ruled by contrary axial principle: for the economy, efficiency; for the polity, equality; and for culture, self realization (or self-gratification). The resulting disjunction has framed the tensions and social conflicts of Western society" (Bell, 1973). There is an ever increasing disjunction amongst the three, and this will continue to widen. The concept of post-industrial society deals primarily with change in the social structure, yet it has important significance for business organisations and the work environment of the future. Bell specifies five dimensions, or components of the term 'post-industrial society'-

Economic sector:	the change from goods production to service economy.
Occupational distribution:	the pre-eminence of the professional and technical classes.
Axial principles:	the centrality of theoretical knowledge as the source of innovation and of policy formulation for society.
Future orientation:	the control of technology and technological assessment.
Decision making:	the creation of a new 'intellectual technology'.

The main contributions of Bell's theory to current thinking on social and organisational transformation is the *'emphasis on technology as a motor of change'*, and in the present context it means computer and telecommunication based information technology.

Bell's theory introduced two further key concepts: *'Importance of knowledge and knowledge workers in the post-industrial society'*, and the other is the promotion of what Bell terms *'intellectual technology'* (Jones, 1991).

Bell believed that the first and simplest characteristic of a post-industrial society is that the majority of the labour force will no longer be engaged either in agriculture or manufacturing but in the service industry. With the expansion of the service economy, and its emphasis on office work and education, he predicted a natural and marked shift from blue collar jobs to white collar occupations. Bell (1973) writes "In 1956 the number of white collar workers, for the first time in the history of industrial civilisation, out-numbered the blue-collar." Furthermore, industrial society was the co-ordination of machine and men for the production of goods. In comparison, post-industrial society will be organised around knowledge, for the purpose of social control and the directing of innovation and change.

Some of these key tenets are debatable today for example, the first characteristic of a post-industrial society was the change predicted in the economic sector, i.e. from a goods producing to a service economy. This prediction has not come about. Manufacturing industry has not been replaced by the service industry as Bell predicted. Nonetheless, there are marked differences in the principles on which the manufacturing industry is to be based in the 1990s and the early 21st century. Today's global markets are dynamic and customer driven. Economy of scale has been replaced by economy of scope. The emphasis has moved from competition based on price, to quality. Jones (1991) explains the 'Theory of Second Industrial Divide' as put forward by Piore & Sabel (1984):

> Industrial economies are at an historical cross-roads at which two alternative paths lie open to them. The first is a continuation of the techniques of mass production developed during the first industrial revolution. This would be based on a policy of multinational Keynesianism to stimulate mass consumption through co-ordinated international relation. The alternative is based on flexible specialisation through a regional network of federated enterprise using extensive subcontracting. The importance of this theory ... provides for an understanding of IS is its identification of the importance of historical and cultural factors in shaping social and technological development.

Principles and methods of manufacturing may be changing but there is no evidence to suggest that service industry has either replaced or even taken over manufacturing industry. This view finds support from leading academics and consultants such as Peter Drucker (1993) who confirms that: "American manufacturing production remained almost unchanged as a percentage of GNP in the years of the 'manufacturing decline'. It stood at 22% of GNP in 1975 and 23% in 1990. During those 20 years GNP increased two and a half times. In other words, total American manufacturing production grew more than two and a half times in these 20 years".

What is significantly noticeable is that manufacturing employment has not increased at all; in fact it has shed jobs and a lot of mundane repetitive jobs have been taken over by robots.

5.4 The paradigm shift in organisational theory

Following the discussion above there is little doubt about a radical change taking place both on the social and organisational front. The growing turbulence in the business world in general, and particular events like the stock market crash in 1987, are making it clear that the conventional thinking on which organisation and business management theories have been based are somehow no longer adequate. The mental model and the paradigm supported by the hundred year old theories is being increasingly questioned. There is a growing body of opinion that the classical theories of the past era can only be applied to a limited set of problems. They are certainly not adept in dealing with the *uncertainty* and *complexity* with which post-industrial organisations are faced today. Most practitioners and academics agree that what is really needed is a new set of guiding principles to lay down the foundation for new theories to deal with the current situation. As yet no consensus has been reached.

In the interim, business organisations faced with discontinuity, have made every effort to draw on the classical theories for guidance but without much success. A whole host of trendy solutions in the form of down-sizing, right-sizing, outsourcing, and experimentation with a variety of concepts imported from Japan, such as Total Quality Management, Just-in-Time and Lean Production, have been on offer, based on the ideals published after the experiments of practitioners and the observations of theoreticians. Western organisations, large and small, are making a serious effort to remake themselves. The outcome is still far from satisfactory with few successes and many failures. The problems with most of these solutions fall into two main categories:

(1) either the approach itself is still largely based on the command-and-control principles and demands no radical change in business practices, organisation structures, management styles, attitudes to work etc. They therefore, fail to reflect the changes in demography, technology, business objectives, and new consumer ethics. As a result some initial improvements are observed but no long-term gains are achieved.

or

(2) the approach itself is radical but its new philosophy fails to penetrate and change the mind-set of the organisation, bound by shackles of a bygone age.

Not surprisingly, when these efforts to bring about change eventually fail to live up to the overblown expectations, they are followed by a backlash, one that is often so heightened in its intensity that even such merit as there may have been in the ideas get snuffed out, leaving more confusion and disillusionment in its wake.

Most organisations are still accustomed to organising work linearly i.e. as a sequence of tasks and sub-tasks, and construct elaborate organisational structures, all the time thickening the bureaucracy with steep management hierarchy merely to monitor, control and provide feedback on tasks in progress. Michael Hammer (1990) alerting of the dangers writes:

> These patterns of organising work have become so ingrained that, despite their serious drawbacks, it's hard to conceive of work being accomplished any other way. Conventional process structures are fragmented and piecemeal, and they lack the integration necessary to maintain quality and service, They are breeding grounds for tunnel vision, as people tend to substitute the narrow goals of their particular department for the larger goals of the process as a whole.

A majority of organisations still function in this way and those likely to continue on this path will lose out. The roots of conventional work organisation were embedded in the early days of the industrial revolution with the principles of scientific management, both of which have no place in the emerging paradigm. A whole new system of concepts defining organisational structure and culture is gradually emerging and is discussed in the next section.

5.5 Emerging concepts: likely to dominate future organisational and management theories

This section highlights some of the emerging concepts, along with contributory factors, that are playing a dominant role in bringing about a paradigm shift in organisational theory.

5.5.1 Today's businesses must become information based

That information technology (IT) is an indispensable tool for modern business is self-evident and, at a very high level, one could describe the effect or impact of computer technology as extrinsic and intrinsic to business organisations. The first phase of IT had only an extrinsic impact, in the form of data processing. All it did was automate what businesses had always done, i.e. it computerised transactional and other clerical operations.

As a consequence, in its first phase, IT had a direct impact only on clerical and operational level jobs and business processes, a less direct impact on skill and staff requirements, and only later an indirect impact on organisation structures and business management strategies.

In its second phase, IT is intrinsic in its impact as it influences the structure of the organisation, by providing the capacity to produce and manage information. In doing so it almost immediately cuts down on both the hierarchies of management and the numbers of managers, i.e. middle management levels and managers whose main function is to serve as synthesiser and relayer of information. That is, those management activities that constitute communication and information channels in a traditional organisation. In the context of emerging trends this is disturbing since it rocks the foundations by casting doubt on the rationality of age old management tasks and practices.

According to Charles Savage "...Throughout the industrial era it has been possible for the organisation to absorb each new wave of mechanical technology. Yet as wave after wave of computer technology beats against our traditional ways of doing things, we find ourselves in the backwaters of confusion and uncertainty..." (Savage, 1990). Computer-based Information Technology (IT) is on the one hand contributing to making obsolete the familiar notions of hierarchical organisational structures and established business management practices but, on the other hand is also offering some of the most effective means of taking advantage of new opportunities.

Major research was conducted by the Sloan School of Management at the MIT, by the 'Management in the 1990s research program', in collaboration with 12 industrial and government sponsors from the United States and Britain which included names like: American Express, Digital Equipment Corporation, Eastman Kodak, British Petroleum, MCI Communications, General Motors, US Army, ICL plc, Ernst & Young, BellSouth, and CIGNA Corporation.

The results of the research have been documented in two books. The first: *The Corporation of the 1990s: Information Technology and Organizational Transformation,* (Scott Morton, 1991). The second book, *Information Technology and the Corporation of the 1990s* (Allen and Scott Morton, 1994) makes available the research on which the first book was based.

The six major finding of the research (Scott Morton, 1991) are as follows:

- IT is enabling fundamental changes in the way work is done.
- IT is enabling the integration of business functions at all levels within and between organizations.
- IT is causing shifts in the competitive climate in many industries.
- IT presents new strategic opportunities for organizations that reassess their missions and operations.
- Successful application of IT will require changes in management and organizational structure.
- A major challenge for management in the 1990s will be to lead their organizations through the transformation necessary to prosper in the globally competitive environment.

The decline of the traditional "big" company, with its bureaucracy and hierarchy, has enormous implications for both the future structure of organisations and for their employees.

5.5.2 Changes in the workforce

Great changes in the structure of the society have been taking place as a consequence of technological advancement and consequent industrialisation. The cumulative effects of over two centuries of change on the workforce in industrialised nations are phenomenal.

5.5.2.1 The workforce of the early industrial era (domestic servants and farmers)

At the beginning of this century the majority of people earned their living either by being a domestic servant or by working on farms, a norm which is still discernible in the underdeveloped countries of the world. Drucker (1992a), with reference to the Western world, reports that in 1913, 30% of all wage earners were domestic servants; today this class has all but disappeared in Western society. In the USA nearly 50% of the labour force tilled the soil in 1900. By the end of World War ll, this figure was reduced to almost one-third of the population. Today there is no developed country in the world in which farmers constitute more than 8% of the population.

5.5.2.2 The workforce of the late industrial era (blue-collar workers)

It was the blue-collar worker who emerged out of the disappearing ranks of the two classes mentioned above. In the 1850s a labourer was a hired hand, paid meagrely and expected to work very long hours. Marxism arose out of a response to the plight of these workers. That a class war was imminent was a view shared by many thinkers and philosophers of the time. This was around 150 years ago when people like Karl Marx and other intelligent observers like Benjamin Disraeli were obsessed with the spectre of class war. "What defeated these prophecies, which seemed eminently reasonable, indeed almost self-evident to the contemporaries, was the revolution in productivity set-off by Frederick W. Taylor in 1881, when he began to study the way a common laborer shovelled sand." (Drucker, 1991).

Taylor was quite concerned with the animosity between workers and their managers. He too was fearful of a class war and devoted all his efforts to improving the efficiency and productivity of industrial workers. His success was so great, that in spite of all the criticism levied against him, he not only averted the revolution of the proletariat, but instead turned the proletariat into the bourgeoisie. His methods allowed industrial workers to earn middle class wages and achieve middle class status despite their lack of skill and education.

Fredrick Taylor's principles of scientific management not only averted a class war but also turned round the fortunes of these workers; so much so that soon after World War ll, blue collar workers were transformed from being the under-privileged class to becoming the dominant class in society, with job security, pension schemes and union powers behind them.

5.5.2.3 The workforce of the post industrial era: knowledge workers

Today another metamorphosis is transforming these workers into the class of knowledge workers. The workforce has entered a third period of change, or rather it might be more appropriate to say that it is in the midst of a transition - a computer-based Information Technology revolution heralding an era of unprecedented uncertainty. It is challenging the foundations on which theories of business organisations and management have been based (some of these effects were mentioned in section 5.5.1 of this chapter).

Demographically, the centre of gravity in employment is shifting fast from clerical/manual to knowledge workers. The new workers resist the command-and-control model that businesses took from the military over a century ago.

Today's organisation comprises far more specialists than conventional command-and-control structure based companies. These specialists do not work locked up in some ivory tower of corporate headquarters but at the operational levels of the organisation where real work is done. Furthermore, these specialists do not require layers of management to direct and discipline their performance. This is in complete contrast with conventional organisational structures where knowledge, information and the task of communicating with them, tends to be concentrated in 'service staff', i.e. middle management.

The control approach model no longer fits today's needs as the pendulum is moving away from people being totally managed to people having to take responsibility for themselves. The term commonly used to define the concept is 'empowerment'. The role of management is caught halfway between managing staff and facilitating empowerment. Managers need to learn to manage and be effective in situations where no command and authority model exists i.e. employees will neither be managing and controlling their subordinates nor will they be managed in the conventional sense by their superiors. In the words of Chris Argyris (1994):

> Twenty-first century corporations will find it hard to survive, let alone flourish, unless they get better work from their employees. This does not necessarily mean harder work or more work. What it does necessarily mean is employees who've learned to take active responsibility for their own behaviour, develop and share first-rate information about their jobs, and make good use of genuine empowerment to shape lasting solutions to fundamental problems.

5.5.3 Changes in organisation structure

An information-based organisation tends to become an organisation of specialists of all kinds as opposed to managers of different operations. There is a move away from functional units to process-oriented organisational structures (Majchrzak and Wang, 1996). The need for "service staff" i.e. people whose role is only to advise, counsel, or co-ordinate data/information reduces drastically. As a result of this, large information based organisations result, having a flatter structure, not much different from the structures with which industrial organisations started out at the beginning of the industrial era over a century ago.

At the start of the organisational era some two centuries ago, information and/or knowledge was held by a few at the top, usually the owner/s of the business. As time passed and management hierarchies became prevalent this knowledge/information descended, but lodged itself in the middle, i.e. at tactical levels, between the strategic and operational levels, of organisations. The new base for this organisational knowledge tends to descend further down to the operational level, and to the minds of skilled specialists.

With reference to IT as an indispensable tool for modern business in section 5.5.1, an organisations with computer-based information systems, tends to operates quite differently by transcending physical as well as temporal boundaries. The new terms being used to refer to such organisations are 'virtual organisation', 'virtual factories' run by teams of workers on a project but geographically dispersed as 'virtual teams'. Traditional departments such as sales and marketing only serve as guardians of standards, as centres for training and the assignment of specialists. The actual work is no longer done within these departments but rather in specially constructed task-focused teams which are brought together for a project and disperse once the task is completed.

Entire layers of managerial and support functions are thus being eliminated. Even entire segments of some companies may be eliminated as companies identify and refocus on their core business. Traditional ideas about a "span of control" where a manager or supervisor was needed for every four, five, or six employees are being discarded (Simon, 1995). Instead of a narrow span of control, companies are now beginning to look at a broader span of communication or span of information as the basis for establishing the number and levels of management. No longer are the number of employees per manager constrained by how many he or she can "control". Rather, the constraining factor is *how many he or she can communicate with effectively*. Lower-level supervision for control purposes will no longer be needed or desired as businesses realise that world-class quality, superior customer service, continuous innovation, and flexibility cannot be obtained through control. Monitoring of performance is no longer measured by physical quantities of production but by the overall effectiveness of workers. This kind of monitoring can be accomplished through use of technology that allows senior management, perhaps thousands of miles away, to instantaneously examine the status of some project and an employee's contribution/performance to it (Boyett and Conn, 1992).

Organisational theorists and experts predict that within the next couple of decades, neither the organisation structure, nor its management's problems and concerns, will bear any resemblance to the business organisation with which we are familiar today. According to Peter Drucker (1988a, 1992b), the structure of a large business, in the coming decades, is more likely to resemble that of a *university*, a *hospital* or a *symphony orchestra*.

5.5.4 Changed business objectives

Today there is an unprecedented pressure on businesses to be innovative and to be entrepreneurs. This is increasingly necessary for mere survival of the business let alone for thriving and gaining any competitive edge.

Multinational corporations are quickly going out of fashion. Business expansion, either at the grassroots level or by acquisition, has been appropriate to hierarchical organisational structures and the resulting command-and-control models. New modes of business expansions in today's business world are to grow through alliances and joint ventures. Major companies disintegrate and refocus on a core business e.g. a car builder no longer tries to make its own steel as Ford once did. The new corporate model will be more like a solar system, or an orchestra, than a pyramid.

The rejection of vertical integration represents a significant departure from prevailing notions about how businesses should seek competitive advantage. Vertical integration brought with it standardisation. Today the trend away from vertical integration towards solar system, or partnering with suppliers, is a direct response to overcoming the disadvantages of vertical integration while retaining the advantages. For example, Ford improved its overall quality and gained competitive advantage by relinquishing manufacture of paint to the competent supplier du Pont, while retaining the same benefits that it would enjoy through vertical integration, of single sourcing, just-in-time inventories, vendor certification of quality and co-development. In such an arrangement, all parties of a partnership retain the flexibility to reach partnership agreements with other customers or suppliers, and to terminate the partnership if it is no longer advantageous.

5.6 Conclusions

There is fermentation of ideas, there is interest, but a paradigm, in the sense of a conceptually articulate framework that can compete with the classical and neo-classical in explanatory scope, as yet has not been formalised.

Once again organisations find themselves at the threshold of a transition from known to unknown. Indeed they are experiencing what Thomas Kuhn (1962) calls a *paradigm shift.* Kuhn argues that in any given discipline or field of knowledge, scientists, researchers and practitioners share a set of conceptual principles and beliefs. This set constitutes the *paradigm* under which the work of researchers and scientists, which he terms *normal science,* proceeds placidly. According to Kuhn (1962): "All crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research. In this respect research during crisis very much resembles research during the pre-paradigm period, except that in the former the locus of difference is both smaller and more clearly defined."

The transition from a 'paradigm in crisis', to one from which a new tradition of normal science can emerge is far from a cumulative process, and cannot be achieved just by a revised articulation or extension of the old paradigm. Rather it is the reconstruction of the field from *new fundamentals, new philosophy, and new conceptual principles.* This reconstruction changes some of the field's most elementary theoretical generalisations as well as many of its paradigm methods and applications. "......during the transition there will be a large, but never complete overlap between the problems that can be solved by the old and by the new paradigm. But there will also be a decisive difference in the modes of solution. When the transition is complete, the profession will have changed its view of the field, its methods and its goals" (Kuhn, 1962).

The observation that IT in conjunction with other factors is transforming the way businesses operate is unanimous. The challenge exists in deciphering and predicting how new businesses will emerge following this transformation. At this point in time it is difficult to state with certainty and authority how organisations will structure themselves in the future and how the structure itself will influence the management style. The key lies in observing the trends and making informed judgements and predictions. One such trend is towards a workforce comprising knowledge workers capable of engendering *self-transformation,* and *expanding capacity* into their workplace and thereby creating a 'Learning Organisation'. The next chapter is devoted to understanding this trend.

Chapter 6 - Learning Organisations: the emerging paradigm for the next generation of organisations

6.1 Introduction

This chapter introduces the *concept of learning* as the key to organisational transformation. The perception of the need for radical reforms in organisational and management theories is not sudden but was in the making for more than 40 years. The changes in organisational environment, both internal and external (as discussed in the previous two chapters) cumulatively amount to a major paradigm shift from the *Command-and-Control* model to a *Participative* model of organisations. A dichotomy between thinkers and doers was created by the scientific management and reinforced by the command-and-control model of organisation. According to Argyris (1991), transcending this dichotomy into a new synthesis is the central philosophical challenge for the new theory of organisations, when he writes:

> Any company that aspires to succeed in the tougher business environment of the 1990s must first resolve a basic dilemma: success in market-place increasingly depends on learning, yet most people don't know how to learn. What's more, those members of the organization that many assume to be best at learning are, in fact, not very good at it. I am talking about the well-educated, high-powered, high commitment professionals who occupy key leadership positions in the modern corporations.

'Learning Organisation', along with similar other labels currently being used such as: 'Intelligent Organisation, 'Knowledge-Creating Company' (Nonaka, 1991), Knowledge-Based Business (Davis, 1994), and lately 'Living Company' (De Geus, 1997), refer to the process and product of deep organisational changes in theory and practice.

This chapter provides a summary of the early academic thoughts which have helped to lay the foundations of the Learning Organisation Paradigm (LOP) and is followed by a brief review of the current contributions by some of the prominent writers on the subject. The LOP, still in the early stages of development, is based on principles which are quite different from the command-and-control paradigm, requiring a radically new conceptual framework which is capable of offering fresh theoretical insights and practical tools, to improve organisational performance.

6.2 Learning as the key to organisational transformation

The new system of concepts defining organisational structures and cultures is gradually emerging under the name of *Learning Organisation* (LO). It comprises: shallow hierarchies, small power distances, interdisciplinary teams of well educated employees, process-oriented organisational units and global partnerships between independent companies, along and across value chains. It is useful to define an LO by the manner in which it interacts with its environment. A LO is capable of learning about (and from) its environment and adapting itself to it. An advanced LO is, in addition, capable of changing its environment with a view to achieving desired goals. A competently designed organisation can exhibit more intelligent behaviour than the sum of intelligence of its employees. This enhanced intelligence, obtained through the rich interaction of people who constitute the organisation, is referred to as *emergent intelligence.*

The participative model of organisation has been in the making since the early decades of this century but over the last four decades it has picked up great momentum. The founding conceptual principles of the LO also have been around for some time, referring to which Hampden-Turner (1994) writes: "Never in the field of corporate consulting has so much repackaging been done by so many from the ideas of so few".

The emphasis on learning however is very recent. The awareness and definition of emergent intelligence is even newer. It is important to note that the learning organisation model, very much like the earlier command-and-control model, has developed incrementally, the development being led by academic researchers. Practical implementation has lagged behind and occurred in earnest only when drastic changes in market conditions made the change in organisational structures unavoidable.

Until recently, learning was something that was usually seen as achieved by individuals. In fact learning was seen as an activity suited to children at school and the young in higher education, while training was considered more appropriate for people at work. If an organisation was in need of specific knowledge it was obtained by hiring an expert.

> There was a time when a company simply took whatever knowledge was already available from professional bodies or research departments and put it to production. The learning was "brought in" by hiring experts and then ground out by the factory. Employees learned up to a point, but organisations simply exploited what was known, buying new expertise when appropriate. (Cunningham, 1994).

Today, based on recent developments in our understanding of the needs of modern business organisations, the emphasis is shifting from training oriented approaches to learning oriented approaches in organisational development. "The goal of the learning organisation is to generate a process of continuous change and self-transformation from within the organisation" (Pearn et al 1995). The emphasis on learning for organisations has resulted from suggestions of management experts like Drucker (1988a) who have noted that a major change is taking place in the perception of 'organisation' and 'management' with a shift occurring from a model of resource-based organisations adding value to the resources at their disposal towards a model of information-based organisations constructed around knowledge specialists. Drucker (1993) points out that "possession of knowledge and the ability to apply it to desired ends is supplanting capital as the mainspring of economic and social advance."

Since the 1980s recognition of the importance of learning as the basis of organisational development and competitive advantage has found favour amongst not only strategic management thinkers, but also industrialists. Arie de Geus (1988), the head of Planning for Royal Dutch/Shell, captured the essence and urgency for creating a learning organisation when he stated "the ability to learn faster than your competitors may be the only sustainable competitive advantage".

Today the environment has changed and the organisation's ability to survive depends on its ability to quickly perceive and understand the shift/s in the environment and adapt effectively and profitably to change. This largely explains why some organisations are able to survive over many decades while others disappear after a short period. Much depends on the ability of management to quickly comprehend and absorb the changing situation in the business environment and to act appropriately. Once a crisis sets in, the need to change is visible to all, leaving little time and few options and as a result many companies fail to survive. The *intelligent* organisation is one that behaves like a living system, that is it senses and reacts to environmental change.

> Today everything is simply moving too fast. The market environments are in ever more rapid evolution, while science develops faster than commercial applications can be generated.
>
> In such circumstances there has to be a network who can learn simultaneously from changing markets "outside" and burgeoning technology "inside", and bring to customers the latest satisfaction which new knowledge makes possible. This can only be achieved by a culture that continuously learns from several sources: that is the much discussed "learning organization". (Cunningham, 1994).

In a learning organisation the implicit knowledge of each learner becomes a building block of the institutional model. Institutional learning begins with the calibration of existing mental models. How much and how fast this model changes will depend on the culture and structure of the organisation, (De Geus, 1988).

This thinking has been reinforced by researches into Japanese companies and their management style. Nonaka (1991) contrasts the approach to knowledge and learning of Japanese and Western organisations. He demonstrates that Japanese companies take a pragmatic view of learning in that, *learning is inseparable from taking action and applying knowledge to real situation.*

In the 1980s a series of books e.g. Peters' (1992) *Liberation Management* written in a more popular fashion, some describing Japanese experiences in somewhat over enthusiastic manner, contributed to the greater awareness of practitioners to the major weaknesses associated with the command-and-control model under new volatile market conditions (Rzevski, 1993). They also triggered the need of organisational transformation for *'search of excellence'*, *'core competencies'* and *'competitive advantage'*. In the USA, the final push was provided by articles of Drucker (1992b) and Hammer (1990) making the acceptance of the need for a radical change almost universal.

6.3 Theoretical underpinnings of LO paradigm

The origins of the concept of the learning organisation can be traced by following the philosophical and theoretical development that has evolved to deal with organisational effectiveness in a turbulent and changing environment.

6.3.1 Early academic contributions

Kurt Lewin's contribution as a psychologist and founder of social psychology fundamentally altered the course of social science since the early decades of this century but the influence of his work has extended well beyond the bounds of social psychology. "In the application of behavioral-science concepts to management methods, such authorities as McGregor, Likert, Argyris, and Bennis, among others, have built many of their formulations on Lewin's concepts and experiments." (Marrow, 1977). The need for situational analysis in social psychology was advanced by Lewin. He believed that an individual's behaviour is determined jointly by the person's personality and the prevailing psychological climate.

Lewin created the field of group dynamics and action research (Lewin, 1935, 1963) and was the founder of the Research Center for Group Dynamics at Massachusetts Institute of Technology. Lewin's influence was seminal in behavioural theories and the theory of organisation development (OD).

> Organizational development grew out of experiments that utilized principles of group dynamics: the T-group training at National Training Laboratories and survey feedback at Michigan in the United States, and the group dynamics work pioneered by Bion in the Tavistock Institute in the United Kingdom. Unlike strategic planning, where practitioners led academics in developing the field, the credit for developing the field of OD goes to academicians and social thinkers like Kurt Lewin and Douglas McGregor. (Narayanan and Nath, 1993).

Human relations approaches The early work on building foundations of the new paradigm of LO began under the title of 'Human Relations Approaches' Mayo (1933) and later, 'Neo-Human Relations Approaches' by McGregor, (1960); Likert, (1961); Maslow (1968), Argyris (1957 a) and others. The proponents of these approaches expressed concerns on the limited understanding of human behaviour in work situations, for example, to use the words of Argyris and of McGregor:

> How is it possible to create an organization in which the individuals may obtain optimum expression and, simultaneously, in which the organization itself may obtain optimum satisfaction of its demands? (Argyris, 1957 b).

> We have not learned enough about the utilization of talent, about the creation of an organizational climate conducive to human growth. The blunt fact is that we are a long way from realizing the potential

> represented by the human resources we now recruit into industry. (McGregor, 1960).

Two competing approaches to research on explaining employee behaviour in the workplace arose. The first, cognitive approach (Maslow, 1968; Herzberg, 1966; Vroom, 1964) focused on understanding and responding to employee needs. It suggested that employees' behaviour was merely the result of their effort to meet their needs. The second, behavioural approach, (Skinner, 1953) was grounded in operant psychology. This latter approach raised a great deal of controversy but was nevertheless influential.

The human relations approach was heavily influenced by the social psychology and sociology of the early 1960s and was proposed in protest to the scientific management model. It advocated close co-operation between employees and management.

> In a large sense the human relations school of management reflected the social ethic. More importantly, however, it was a reaction to the mechanistic, impersonal world inherent in the application of scientific management and administrative theories ..... The human relationists retained the notion of universality of management, though they now saw the task of management as more complex: consisting of attention to the social aspects of organization in addition to economic and production requirements. (Narayanan and Nath, 1993).

The research into the psychology of employee behaviour also established the importance of effective communication, information sharing and feedback to motivate employees and improve their performance.

Organisation as dynamic open systems Later as economic expansion brought about an increasingly dynamic environment and the problems this presented for management, it gave rise to the concept of *organisations as dynamic open systems in interaction with the environment.* This theme has been expressed in various versions of open system models of organisations, and contingency theory (Lawrence and

Lorsch, 1970) is one of them. Contingency theory, which developed as an offshoot of open systems theory, attempted reconciliation between the rational traditional school of management on one hand, and human resource theorists on the other. Contingency theory placed great emphasis on congruence as the key to effectiveness and strove to prescribe organisational designs and managerial actions most appropriate to specific situations. The contribution made by the contingency perspective to organisational change however had limitations. It proved useful as an *orienting strategy* but still needed to be augmented with a theory of change. The main reason for this was that contingency theory provided an incomplete picture: only a partial view of an organisation, as it did not deal with the issues pertaining to important organisational subsystems e.g. informational, social and cultural. The open systems theory's success lies in it providing a much needed, alternative organisational perspective to the closed systems perspective.

> At the turn of the century, scholars working from a closed systems perspective advanced the concept of efficiency, which pertained to the internal workings of an organisation...... When the open systems view of organisations gained prominence as a concept for guiding managerial action, efficiency was replaced by effectiveness. Open system theorists suggest that since the prime goal of an organisation is adaptation to the environment, it is far more important to do things that are appropriate to survival of an organisation. Efficiency pertains to doing things right whereas effectiveness pertains to doing the right things. (Narayanan and Nath, 1993).

Organisational efficiency lies at the core of LO

Although such terms as 'Knowledge-based Company', 'Intelligent Organisation' and 'Learning Organisation' have appeared in the research literature comparatively recently, as discussed above, their roots can be traced to the early 1950s and 1960s. It were the concepts of *notion of efficiency, organisational effectiveness* and *organisational development* that provided the necessary link between organisational theory and organisational change.

The concept of LO, as mentioned earlier in this chapter, has evolved and some of the work on the subject which has been particularly influential from the 1970s includes Bateson's (1973) original work on the theory of 'deutro-learning', that is double loop learning, which is the same as learning to learn. Gardner's (1963) concept of 'self-renewal' and Lippitt's (1969) framework of 'organisational renewal', along with concepts of 'action learning and 'systems thinking', were all equally important in contributing to the concept of LO. These concepts, when applied to organisations, allowed them to be viewed as systems capable of, amongst other things, *learning* and *intelligent* behaviour. These concepts are very much at the centre of current thinking on the subject e.g. systems thinking has been influential in Senge's (1990) framework for LO and indeed represents the integrating force for the creation of a learning organisation (Leitch et al, 1995). Moss-Jones (1992) also confirms both the eclectic nature of the concept of LO and the dual influence of sociology and human resource development when he states that the origins of the concept lie in "the family of ideas which attempts to help organisations cope with the turbulence of rapid, difficult to predict and complex change."

6.3.2 Current academic contributions

Contemporary literature on learning organisations is diffused. A plethora of definitions with a number of distinct frameworks and perspective exist. Some of this can be attributed to the fact that *learning* can be both an activity of acquiring knowledge as well as the product of knowledge itself, and hence a range of perspectives has been adopted. Huber (1991) is particularly critical about the lack of theory concerning learning organisation and the lack of cross-fertilisation of ideas amongst different perspectives.

This section reports on three contemporary academic writers - Chris Argryis, Peter Senge and George Huber who have contributed to the concept of "learning" in the context of organisational effectiveness, predominantly from a management science and human resource development perspective. An outline of these authors' respective frameworks is given below.

Argyris' framework

Some of the earliest work on organisational learning amongst contemporary writers has been done by Chris Argyris (1977). Chris Argyris and Donald Schon (1978) modified Bateson's (1973) work on 'deutro-learning' and founded the theory and practice of 'Action Science'. According to Argyris (1977) organisational learning is the process of detecting and correcting errors that inhibit learning. Single-loop learning occurs when the organisation learns to do better what it is currently doing. Double-loop learning is the learning that results from questioning organisational goals and policies, and this is the learning that organisations must have for future success. Argyris claims that double-loop learning is inhibited because people in organisations have a 'theory-in-use' which leads to information being withheld, or being vague and ambiguous. To change these behaviours, individuals must change their private assumptions, or theories-in-use. The change involves:

- becoming aware of private assumptions
- understanding how these assumptions inhibit double loop learning
- developing new assumptions to facilitate learning
- developing the skills necessary to implement the behaviour which follows from the new set of assumptions

The capacity for double-loop learning comes from:

- reliable information
- competent people
- continually monitoring the effectiveness of decisions

When Royal Dutch/Shell Group surveyed 30 firms that had been in business for more than 75 years they attributed the success of survival to "their ability to live in harmony with the business environment, to switch from a survival mode when times were turbulent to a self-development mode when the pace of change was slow." (De Geus, 1988). This mode of behaviour is not automatic. According to Argyris most organisations become adept at single-loop learning but to deliver organisations from a crisis situation requires double-loop learning. De Geus (1988) head of planning at the time, describes how Royal Dutch/Shell benefited from double-loop learning through being prepared when oil prices plummeted in the spring of 1986. Organisations that have to cope with rigid procedures and centralised information systems, learn and act more slowly than those with flexible, open communication channels.

Senge's framework

Another very widely cited frameworks for organisational learning is Senge's 'Five Disciplines' (Senge, 1990; Senge et al. 1994). According to Senge the learning organisation is still at an "invention stage" that is the principles of learning organisation hold promise in controlled "laboratory conditions". These ideas can become "innovative" only when these principles can be applied on a meaningful scale, with successful results in a real life situation.

Senge takes a behavioural view of learning and the foundation of his framework is built on a combination of systems theory, which grew out of the pioneering work of the theoretical biologist Ludwig von Bertalanffy in the 1950s, and systems dynamics, a form of systems theory which was developed for modelling purposes by Jay Forrester (1961). Forrester developed an early application of systems theory to the business world, in this case to the study of industrial dynamics. His approach achieved fame when it was used as the basis of the MIT project that resulted in the book by Meadows (1972) *The Limits to Growth*.

The goal of a learning organisation from Senge's point of view concerns all employees, at individual level, group/team level and corporate level, to internalise the 'Five Disciplines' with the intent of increasing individual, group and corporate knowledge and thereby efficiency. The five disciplines inherent in Senge's (1990) framework of Organisational Learning are:

- Personal Mastery
- Mental Model
- Building Shared Vision
- Team Learning
- Systems Thinking

Senge's framework aims to provide a blend of the soft and difficult to define issues that play a significant role in learning, such as emotion, aspiration and vision, along with the analytical concerns such as systems thinking.

> [T]he five learning disciplines differ from more familiar management disciplines in that they are "personal" disciplines. Each has to do with how we think, what we truly want, and how we interact and learn with one another. In this sense, they are more like artistic disciplines than traditional management discipline. Moreover, while accounting is good for "keeping score", we have never approached the subtler task of building organizations, of enhancing their capabilities for innovation, of crafting strategy and designing policy and structure through assimilating new disciplines.

Senge believes that these five "component technologies" are gradually converging to innovate learning organisation. Senge explains the use of the term "component technologies" saying that in engineering innovation, the components are called *'technologies'* whilst the components of innovation in human behaviour are seen as *'disciplines'*. Though each of the above listed disciplines/technologies are developed separately, the contribution of each provides a vital dimension in creating a learning organisation.

Senge calls 'systems thinking' the fifth discipline- the discipline that performs the vital task of integrating and fusing all of the first four components of the framework. Senge postulates that the process of change leading to organisational learning will only take hold once managers start systems thinking.

> Building learning organizations involves developing people who learn to see as system thinkers see, who develop their own personal mastery, and who learn to surface and restructure mental models, collaboratively. Given the influence of organizations in today's world, this may be one of the most powerful steps toward helping us "rewrite the code", altering not just what we think but our predominant *ways of thinking*. In this sense, learning organizations may be tools not just for the evolution of organizations, but for the evolution of intelligence. (Senge, 1990)

Systems thinking, he explains involves "a shift of mind - seeing interrelationships rather than linear cause-effect chains, and seeing processes of change rather than snapshots." (Senge, 1990). Senge highlights the disparity in mental models and understanding of the concepts involved by quoting the CEO of a large insurance company: 'If the learning organization is so widely preferred, why don't people create such organizations?' The answer, he says, is leadership. People have no real comprehension of the type of commitment it requires to build such an organisation.

Senge goes on to discuss the qualities leaders need. Leaders, he says, are designers/teachers/stewards. They need new skills, the ability to build a shared vision, to bring to the surface, confront and challenge prevailing mental models. In short, leaders in learning organisations are responsible for creating and facilitating a work environment where people are continually expanding their capabilities to shape their future.

Huber's framework

Huber (1991) also takes a behavioural view and defines *learning* as a process: *An entity learns if, through its processing of information, the range of its potential behaviour is changed.* He defines *organisational learning* as acquiring knowledge that is potentially useful to the organisation. Huber believes that *learning* takes place when the range of potential, rather than actual observable behaviour is improved. He has presented an alternative framework, based on four constructs as integrally linked to learning organisations and associated processes. The four constructs are:

- knowledge acquisition
- information distribution
- information interpretation
- organizational memory

Of these, the knowledge acquisition construct is the best developed with the following five sub constructs: congenital learning, experiential learning, vicarious learning, grafting, and searching and noticing; each of which contain even further subconstructs.

Huber has argued that an organisation acquires knowledge in a number of ways including 'congenital learning' i.e. the knowledge residing at the birth of the organisation. Further knowledge sources are 'experiential learning' and 'vicarious learning', that is by direct experience and through the experience of other organisations. In addition, organisations institute programmes of directed search and design environment scanning systems to gain environmental knowledge. Knowledge can also be grafted onto the organisation as in the case of business acquisitions and mergers.

In the second construct 'information distribution', Huber explicitly specifies the role of IS in a learning organisation. He stresses that information needs to be shared to be of potential value to the organisation. Information needs to be distributed and interpreted. New information is generated by piecing together all the diverse interpretations. Finally Huber suggests that knowledge needs to be stored in "organizational memory" so that it can be called upon by a variety of individuals as required.

Author	Definition of learning	Subject of learning	Content of learning	Process of learning	Result of learning
Argyris & Schon (1978)	Organisational learning is a process of detecting and correcting error	Individual learning	Organisational theories-in-use or theories-of-action	Assumption sharing, individual and collective inquiry constructs and modified theory-in-use; exact process remains unclear	Link between learning and improved action
Huber (1991)	An entity learns through the processing of information resulting in change in the range of potential behaviour	Concept of entity includes individuals, groups, organisation, society	Information, knowledge	Information processing: acquisition, distribution, interpretation and storage. Process of organisational learning remains unspecified	Range of potential behaviour change, not necessarily resulting in *observable* change
Senge (1990)	A learning organisation is a place where people are continually discovering how they create their reality, and how they can change it	Individuals, groups, weak at developing organisational elements	Personal mastery, mental models, team learning shared vision and systems thinking	Personal mastery and mental models focus on the individual; team learning and shared vision focus on groups. Weak in developing organisational elements	Collective capacity for thought and action. Shared vision is the element of personal mastery as individuals come together in a sense of common purpose

Table 6.1 Comparison of three learning organisation frameworks
Adapted from Prange (1996)

From the brief outline description of the Argyris, Senge and Huber frameworks above, it is clear that they all offer very different conceptualisations of OL and a number of dispersed constructs. These are summarised in Table 6.1 above.

It is also clear that the concept of learning organisations is not just a management tool but a radical new way of thinking and creating a new organisational climate and culture. Furthermore, it needs to be understood that learning organisations are not achieved overnight, nor are they an end-state. What is needed is cross-fertilisation among some of the alternative perspectives, to provide a unified source for the theory.

6.4 The concept of the learning organisation and IS

In order to operate autonomously, under changing conditions, organisations must have extensive capabilities to acquire and interpret information about that part of their universe where changes are likely to occur. They must also make correct decisions even when acquired information is incomplete or unreliable. Therefore the three concepts that are fundamental to the concept of such intelligent organisation are *uncertainty, information* and *intelligence.* (Rzevski, 1995; Rzevski and Prasad, 1998)

The usual sources of uncertainty to which organisations are exposed include:

- the occurrence of unexpected external events e.g. unpredictable changes in markets, social conditions and the environment in which the organisations operate
- the occurrence of unexpected internal events e.g. unforeseen changes of personnel, or sudden loss of assets
- incomplete, inconsistent or unreliable information available to the decision maker for the purpose of deciding what to do next. This uncertainty may be caused by inadequate technology or by the speed at which unexpected events occur.

To cope with these uncertainties the last thing that members of an organisation need are precise instructions and rigid lines of command and reporting. They need instead a reasonable freedom to collect information and make appropriate decision. In this context,

information is a means of reducing uncertainty about an aspect of the universe.

Since no information is ever complete and there always is residual uncertainty, organisations need individual and collective intelligence, where

intelligence is the capability of a system to achieve a goal or sustain desired behaviour under conditions of uncertainty.

Intelligence is therefore the property which enables a system to operate effectively when available information is inadequate. The ability to recognise partially specified patterns is the key to intelligent behaviour and learning is one of its most important manifestations.

Intelligent behaviour is dependent on the ability of the organisation to quickly comprehend and absorb the changing situation in the business environment and to act on that information. The intelligent organisation is one that behaves *like a living system*; it senses and reacts to environmental change. Thus in an intelligent organisation the implicit knowledge of each learner becomes a building block for the institutional model. Institutional learning begins with the calibration of existing mental models. How much and how fast this model changes will depend on the culture and structure of the organisation. Teams that have to cope with rigid procedures and information systems will learn more slowly than those with flexible, open communication channels (De Geus, 1988).

In a world in which it is possible to eliminate uncertainty by collecting all appropriate information required for decision making, there is no need for intelligence. Today an organisation must develop the "ability to live in harmony with the business environment, to switch from a survival mode when times were turbulent to a self-development mode when the pace of change was slow." (De Geus, 1988).

6.5 Conclusions

The organisation structures and management assumptions of command-and-control associated with traditional, hierarchical bureaucracies and Tayloristic management principles have created a deep-rooted mind-set which is a considerable hindrance for businesses in today's new, unfamiliar and highly turbulent environment. Both academics and researchers, as well as practitioners, are looking for new theories to support the new paradigm: theories that will provide some coherent conceptual model, an underpinning framework that is capable of providing practical guidelines for enabing organisational survival and growth.

Western organisations, large and small, are making a serious effort to remake themselves by selecting from a number of solution on offer in the form of down-sizing, right-sizing, outsourcing, along with a variety of concepts imported from Japan, such as just-in-time, lean production, and total quality management (which although originated in USA was first put into practice in Japan). The outcome is still far from satisfactory with few successes and many failures. The discussion on efforts to create LOs, as reported in management literature, presents two extremes: the academic and consultancy end is reverential and utopian, based on philosophy; the reports from practitioners are largely critical, and express disappointment that the promised results have not materialised. There are nonetheless, some illustrious examples of achieving a LO e.g. Paul Allaires of Xerox, Gordon Forward of Chapparral Steel, Ray Stata of Analog Devices (Garvin 1993).

The complexity and uncertainty of today's business environment warrants a participatory approach to problem solving. Also, it is not just extremely difficult, but impossible to develop strategies for all the contingencies that an organisation may be faced with. In order to deal with complexities there is a need to focus on the processes of competence building at the individual and team levels on one hand, and the processes of networking organisational knowledge resources - locally, nationally and globally - on the other hand. There is an urgency to explore and research into the interrelation between the two processes, at micro-level and macro-level.

This once again, clearly indicates a mismatch between theory and practice. Only in cases where the theoretical principles on which learning organisations should be based have been grasped by the management in essence, has success been achieved. The understanding of issues such as how knowledge is created, diffused and transformed in the work environment has remained elementary in most cases.

Michael McMaster (1995) suggests the source for the basis of a new theory for the next generation of organisations:

> Models for the new theory abound in nature. We can look at living systems such as human beings. We can look at systems of living things such as rain forests. We can look at "parts" of living systems such as the immune system of a human being. We can look at evolution or large ecologies. All will tell us similar stories if we look through the eyes of the fundamental change in cosmology that is emerging. That change is a view of the world as a living system where the senior element is information (or maybe intelligence or consciousness) and the junior elements are physical. These physical elements turn out to disappear into information and energy when we get inside them or, if you prefer, down to the smallest level. *The nature of world as understood by contemporary science and philosophy has changed dramatically.*

The new theory of learning organisations, which is consistent with this thinking, requires features that are derived from the nature of the phenomena being organised and also from the principles of systems where information is the key. The point being made can be better illustrated by referring to the transformation in comprehension that has taken place in biology. The breakthrough came when the elements of genetics changed from being physical "bits" of protein molecules to a genetic *code*, and the building blocks were seen as information and the way they were put together was considered "grammar". Such knowledge provided the capacity to understand and intervene with biological entities leading to hitherto unknown possibilities, soon followed by practical results.

A comparison of the command-and-control and learning organisation paradigms is given in Table 6.2 on the following page.

PRE-PARADIGM OLD CONCEPTS	*COMMAND-AND-CONTROL PARADIGM* ESTABLISHED CONCEPTS AT THE END OF THEIR USEFUL LIFE	*LEARNING ORGANISATION PARADIGM* NEW CONCEPTS LIKELY TO DOMINATE THE FUTURE
guiding ideas: *Ad hoc* introduced in a piecemeal fashion	**guiding ideas:** *1 economy of scale* *2 division of labour*	**guiding ideas:** *1 flexibility, evolution* *2 learning, intellectual capital*
	specialists, functional organisation.	multidisciplinary teams, process-oriented organisation.
	deep hierarchies, limited span of control.	shallow hierarchies, networking.
	centralised decision making, clear reporting lines.	distributed decision making, delegation.
	avoidance of uncertainty, precisely specified procedures for performing operational tasks, predictability.	skills of handling uncertainty, empowerment of employees to decide how to perform operational tasks, learning and problem solving, flexible cells, performance not completely predictable.
	vertical integration.	(global) partnerships along and across value chain, virtual organisations.
	high power distance.	low power distance, caring culture.
	unskilled and semiskilled workforce.	skilled, well educated workforce, emergent intelligence.

Table 6.2 Paradigm shift in the domain of organisational theory

Chapter 7 - The Science of Complexity: a source of new understanding

7.1 Introduction

The most prolific advice with which current business management literature resounds is that in order to survive and prosper in today's harsh environment, organisations need to be highly flexible and responsive to the rapid twists and turns of markets and technologies. To do this, as discussed in Chapter 6, they must adopt the path of continuous learning and transform themselves into learning organisations which have an inbuilt ability to anticipate, assess and react to change. Yet all the knowledge of organisational and management theories that has been inherited is proving to be inadequate to achieve all this, and the burning question remains: but how?

The command-and-control paradigm fails to model the real physical systems of today's business world, since organisations are no longer dealing with stable environments and predictable conditions for which the command-and-control paradigm was suited. Today's businesses are faced with an environment characterised by turbulence, unpredictability and uncertainty. Under such conditions the maxim that reality is only a step away from the approximation is neither valid nor safe. Awareness of anomalies has given rise to a situation which according to Kuhn (1962) is the prerequisite of a paradigm shift.

New scientific understanding is emerging in the form of a science of complexity which deals with the difficult problem of non-linear dynamic systems and seems set to revolutionise current scientific theories. Gleick (1988), writing about Chaos Theory, says: "Relativity eliminated the Newtonian illusion of absolute space and time; quantum theory eliminated the Newtonian dream of a controllable measurement process; and chaos eliminates the Laplacian fantasy of deterministic predictability." In the same vein, the theory of complexity eliminates the false notion that evolution is the work of a blind watchmaker and revivifies it by exposing the creative emergence, novelty and spontaneous order within evolution. Kauffman (1995) refers to it as 'order for free'.

The science of complexity is a developing scientific theory which is based on the interdisciplinary study of nonlinear systems incorporating a wide area and comprises a number of theories such as - dynamic systems theory, chaos theory, catastrophe theory, nonlinear systems theory, complexity theory, complex adaptive systems theory. It is essential to point out that although the term 'Chaos Theory' is most widely publicised, as for example in the title of James Gleick's 1987 book , "Chaos: Making a New Science", it does not represent the whole of complexity theory. As knowledge about the behaviour of complex systems accumulates, consensus is building-up fast in academic circles that these new theories provide a radical shift in scientific concepts of nature and reality, as well as in epistemology.

In this chapter the theory of complexity is discussed in three interlinked stages; the first looks at some of the reasons why the science of complexity has remained unexplored until now. A review of the literature was undertaken in order to search for any underlying reasons; however, this did not provide any. The answer, in the form of the argument presented here, takes the view that although anomalies are a prerequisite for a paradigm change they are in themselves an insufficient cause of change. A paradigm shift takes place only when anomalies lead to a *crisis* i.e. only when practitioners of a scientific discipline confront problems that cannot be solved by the existing paradigm. Kuhn's (1962) view, supported by his research into the history of science, is of great significance here in trying to explain the incongruity between the interpretations presented in this chapter and those found in the literature.

The next stage identifies the salient characteristics of complex systems behaviour. The primary objective of this is to ascertain if this knowledge could provide the research with the urgently needed platform for understanding the implication of complexity on emerging organisational forms, and the new set of tools needed to deal with the phenomenon of organisational complexity in a creative way. In short, the main objective is to assess the relevance of complexity theory in providing the philosophical foundation for the theory of the new organisational and information systems paradigm.

The final stage concludes that the science of complexity heralds an intellectual revolution which will replace currently dominant philosophies and the conceptual world view.

7.2 A paradigm switch in mathematics

Research into understanding natural and technical systems that contain uncertainty is very recent. Chaos theory is no more than three decades old and complexity theory is even younger. The interest they have generated in the nonlinear dynamics in natural sciences: in physics, chemistry, biology, evolution, meteorology and mathematics; and more recently in social, economic and technological systems, is quite phenomenal and continues to grow.

Knowledge of scientific complexity has existed for some time but has not been acknowledged. Its origins can be traced back to the mathematician and physicist, Henri Poincaré who discussed nonlinear dynamic systems with *sensitive dependence on initial conditions,* at the end of the nineteenth century. Henri Poincaré established the fact that the motion of even as few as three bodies interacting, such as the sun, moon and earth, was too complex to be captured in a neat deterministic mathematical model. There are similar other real-world problems, for example the peripatetic salesman who has to devise the most economical way to visit a set of cities. A solution can be formulated simply while the number of cities to be visited are few. However, attempts to find a solution by systematic means rapidly becomes impractical as the problem's size i.e. the number of cities to be visited is increased beyond a small number (Coveney and Highfield, 1995).

Researchers in the field of complexity tell us that chaotic behaviour and complexity are all around us and it is the science of complexity that can teach us how to make sense of it all. In accepting all this, two questions spring to mind:

> Why has the science of complexity remained unexplored for so long?
>
> What new insights do the theories of complexity offer which make them the object of so much interest?

The first question is dealt with here and answer the second question is dealt with in section 7.4. A number of explanations have been offered in the literature (Jackson, 1989; Kellert, 1993; Coveney and Highfield, 1995) to account for the situation and are as follows.

7.2.1 Non-availability of computing power

The most common explanation maintains that chaos theory relies heavily on digital computers; there was no way to study chaotic behaviour scientifically until computers were invented. (Franks, 1984). The science of complexity too is critically dependent on computer technology. It is true that computers have provided both the key and the catalyst to the exploration of the new science of chaos and complexity. The essential role played by the computer in the modern study of complex systems explains in large part why such a rich field of investigation was over-looked for so long. Kellert (1993) explains that chaos theory has been instrumental in revealing the surprising fact that *sensitive dependence on initial conditions* may well be very common in non-linear systems, but this fact "surprises us because it was invisible before the computer, but with computers it is easy to see, even hard to avoid." (Franks, 1989). Kellert (1993) writes that the "nontreatment of chaos thus should seem no more puzzling than the nontreatment of bacteria until the invention of the microscope. Until Leeuwenhoek, people saw evidence of bacterial behaviour and may even have speculated about very tiny organisms, but until there were microscopes there was no possibility of a scientific examination of bacteria." Franks makes this analogy explicit:

> The computer is a viewing instrument for mathematical models that will, in the long run, be more significant than the microscope to a biologist or the telescope to an astronomer.... It is no more surprising that numerous types of complex dynamical phenomena have been discovered in the last twenty years than would be the discovery of numerous kinds of bacteria if thousands of biologists were, for the first time in history, given a microscope.

However, writers like Kellert contend that this is only a partial answer, because alternative computational resources were available.

7.2.2 Prevailing paradigm in favour of linear systems

As mentioned above, in the view of some writers, the science of chaos and complexity could have been researched into much earlier but for the overwhelming emphasis on providing an orderly view of the world. Robert May's (1976) article in Nature pointed out this prejudice in favour of linear models in biological and social sciences:

> The elegant body of mathematical theory pertaining to linear systems (Fourier analysis, orthogonal functions, and so on), and its successful application to many fundamentally linear problems in the physical sciences, tends to dominate even moderately advanced University courses in mathematics and theoretical physics. The mathematical intuition so developed ill equips the student to confront the bizarre behaviour exhibited by the simplest of discrete nonlinear systems, such as [the logistic map].

According to Kellert there is ample evidence in the form of text books to support these allegations. He points out that a fully adequate account of the historical development of chaos theory must take into account the contributory social and cultural factors. The prejudice in favour of predictable natural processes has contributed significantly to the "nontreatment" of chaos. In his book Kellert (1993) focuses on the field of physics, but many of the issues discussed are just as relevant to general features of the history of the physical, biological and social sciences. He points out that "cultural biases can profoundly affect the historical development of physics by influencing the scientific community's notions of what counts as an interesting or worthwhile scientific phenomenon".

7.2.3 Discouragement of nonlinear dynamic

Education in natural sciences has been responsible for inculcating the mindset amongst the students that linear and solvable systems are the only one to which attention should be paid. Such a belief has been further reinforced by the professional training that scientists received and which encouraged them to ignore chaotic behaviour. Kellert explains:

> Professional instruction rendered chaos less visible in two ways: on the one hand, students were indirectly steered away from nonlinear systems (the only systems in which chaos is possible) by being taught that they were uninteresting or exceptional cases. On the other hand, when apparently bizarre

> or even chaotic behaviour was found in these nonlinear systems, it was dismissed as mere noise or experimental error.

If a study resulted in strange answers it was common to put the blame on experimental error or noise. The research into complex systems has demonstrated that the 'noise' actually contains important information about the experiment. The concept of unpredictability in complex systems is what Lorenz called "sensitivity to initial conditions" or "the butterfly effect". The concept means that with a complex, nonlinear system, for example the weather, very minor changes in the initial conditions of a system can result in dramatically different outcomes for that system.

James Gleick's (1988) book *Chaos: Making a New Science* has been influential in rekindling the interest of economists and managers in non-linearity. It is not that economists have not been aware that the linear equations at the heart of neo-classical economic models were only approximations, but it is only now that they are questioning their relevance and validity in the context of the real world. Linear equations may be computationally convenient, but they are a serious distortion of reality and also fail to exhibit other aspects of non-linear behaviour seen in the real world.

7.2.4 The fallibility of mathematics

Classical science somehow seemed to have confirmed the status of mathematics as the most secure form of knowledge. "For more than 200 years after Newton, it was thought that a complete theoretical understanding of any mechanical process could be achieved by using sufficient mathematical ingenuity to analytically solve the equations describing those processes. Methods based on pencil, paper, and thought alone have always been regarded as the highest form of mathematical thinking."(Coveney and Highfield, 1995). Not surprisingly, anyone who has received scientific education developed a deep faith in mathematics. However, in the light of developments, particularly in mathematical logic notably the works of Gödel, Turing, Church and Chaitin (Casti, 1994), cracks have appeared in the edifice of mathematics and faith is increasingly being put to test.

7.3 Kuhnian paradigm shift

All the above explanation found in literature may be partially correct but they all seem to miss a fundamental point. There exists a very simple and natural explanation for why the science of complexity remained unexplored until recently. This research uncovers the exciting fact - what we are experiencing in a number of disciplines related with the science of complexity are actually many of the attributes of a Kuhnian revolution. Kuhn is right in his explanation of the subject of paradigm shifts and revolutions - the rise and fall of major theories. He has emphasised a contrast between the bulk of what scientists do, namely, working on legitimate, well-understood problems within their disciplines (normal science), and the exceptional, unorthodox work that creates scientific revolution, which in turn results in paradigm shifts.

According to Drucker (1969) in spite of the two World Wars, this century has enjoyed a long period of very stable conditions. He writes, "the last half-century has been an *age of Continuity* - the period of least change in 300 years or so, that is, since world commerce and systematic agriculture first became dominant economic factors in the closing decades of the seventeenth century." During this period, while the world concentrated on stable physical systems, the prevailing paradigm of linear dynamics proved successful in solving the problems of the time and enjoyed the allegiance of its practitioners. Kuhn (1962) has argued "that one of the things a scientific community acquires with a paradigm is a criterion for choosing problems that, while the paradigm is a taken for granted, can be assumed to have solutions".

Extraordinary problems concerned with nonlinear dynamics were not something waiting for attention and being ignored, an allegation discussed above. These problems presented themselves, previously unencountered, as a direct result of the advances of normal research, a typical example being when Lorenz attempted to study and model weather conditions using linear dynamics. In addition, the fallibility of mathematics in recent years has no doubt proved to be a contributory factors in highlighting the fact that our understanding of the laws governing nature is seriously limited. The perception of a new paradigm is always instigated by the accumulation of anomalies under the prevalent paradigm.

Problems faced in today's business environment, for which the command-and-control paradigm is totally unsuited, are highlighted by Stacey (1993) as follows:

> When managers confront open-ended change the situation is completely different in every respect. They are faced with actions and events past, present and future that have unknowable long-term consequences. Links between cause and effect are lost in the detail of those events because small changes escalate and self-reinforcing circles develop. The key difficulty then, is that of identifying what the problems and opportunities are. The prime difficulty is not that of finding answers, but identifying *what questions to ask.* The situation is ambiguous and the responses of managers are equivocal. In these uniquely new situations, old shared mental models on how to design actions do not work and new mental models have to be developed and shared before anything can happen. We are talking about frame-breaking, extraordinary management, akin to Kuhn's notion of extraordinary science.

In the terminology of science historian Thomas Kuhn, the reigning command-and-control paradigm is now weighing heavy with anomalies. Kuhn (1962) points out "the manner in which anomalies, or violation of expectation, attract the increasing attention of a scientific community needs detailed study, as does the emergence of the allegiance of its practitioners. Kuhn (1962) has argued "that one of the things a scientific community acquires with a paradigm is a criterion for choosing problems that, while the paradigm is a taken for granted, can be assumed to have solutions".

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Thus each generation has lived according to the latest version of its knowledge as to how the universe functions. This knowledge no doubt affects their behaviour and thought. Kelly (1995) condenses man's history in the world as follows:

> The African savanna hatches human hunter-gatherers - raw biology; the hunter-gatherers hatch agriculture - domestication of the natural; the farmers hatch the industrial - domestication of the machine; the industrialists hatch the currently emerging postindustrial whatever. We are still figuring out what it is, but I'll call it the marriage of the born and the made.
>
> To be precise, the flavor of the next epoch is *neo-biological* rather than bionic, because although it may start symmetrically, biology always wins in any blending of organic and machine.

7.4 Fundamentals of complexity theory

The following discussion concentrates mainly on the theory of complexity. Nevertheless, any discussion of complexity, by its very nature necessitates some reference to the nonlinear dynamics better known as chaos theory. Complexity theory and chaos theory are to a certain extent related to each other in the sense that the former explores a system's behaviour at the edge of chaos or at the point "where the components of a system never quite lock into place, and yet never quite dissolve into turbulence either ....Chaos by itself doesn't explain the structure, the coherence, the self-organising cohesiveness of complex system." (Waldrop, 1992). A full discussion of chaos theory is not the objective of this chapter. A brief introduction to the origins of chaos theory is given below with the sole aim of providing the background and context for the discussion of complexity theory which follows.

In scientific terms 'chaos' does not refer to the dictionary definition of the word, i.e. the commonly implied meaning of utter confusion or mayhem, rather it is used to refer to the behaviour of a system which, although governed by simple physical laws, remains so unpredictable that it appears to be random.

It was in the mid-sixties that chaos theory was originally developed when a research meteorologist, Edward Lorenz (1963 a, b), attempted to predict weather patterns. His findings were published in the Journal of the Atmospheric Science. The techniques used by him abandoned the typical dynamics and tackled the more difficult problem of non-linear dynamic systems. This was heralded as a new approach and later expanded upon by others. A new way of looking at the world thus emerged, not in the form of a set of specific discoveries but rather more as a new insight. In the 1970s, Benoit Mandelbrot, a mathematician working for IBM, while studying symmetry of scale in behaviour as diverse as cotton prices and earthquake sizes, found that instead of obeying a Gaussian distribution, and following a bell-shaped curve as predicted by statistical theory, they showed a very different kind of behaviour for which he coined the term 'fractal behaviour' (Trisoglio, 1995).

One needs to make references to chaos theory from time to time as it is closely related to complexity theory. Inayatullah (1994) exemplifies the affinity between chaos and complexity:

> For complexity theorists, chaos is focused on order and disorder and merely one dimension of complexity, since chaos theory does not explain the mechanisms of change. Complexity is similar to chaos in that both are concerned with non-linear systems, both focus on inter relatedness, and both seek an underlying pattern to all physical and social phenomena. But the way to understanding complexity theory is *emergence.*

Chaos theory provides useful insights into the behaviour of complex systems but its contribution to organisations is rather limited. The main reason for this is that it treats systems as passive i.e. without the will or intelligence to intercept and reroute a set course of events. Human organisations consist of intelligent people who can individually and collectively learn and react to events.

7.4.1 What is meant by complexity?

Determining the degree of complexity of a given problem is the mission of mathematical complexity theory. It tells us whether the problem will be tractable - that is, whether it will be practical to attempt to solve it by systematic means.

> Within science, complexity is a watchword for a new way of thinking about the *collective* behaviour of many basic but interacting units, be they atoms, molecules, neurons, or bits within a computer. To be more precise, our definition is that *complexity is the study of the behaviour of macroscopic collections of such units that are endowed with the potential to evolve in time.* Their interactions lead to coherent collective phenomena, so-called emergent properties that can be described only at higher levels than those of individual units. (Coveney and Highfield, 1995).

The proponents of the new science of complexity claim that the conventional scientific approach has been seduced by simplicity, offering a reductionist approach as the universal route to understanding (Coveney and Highfield, 1995).

Ralph Stacey (1991), coming from a business management background, offers the following explanation :

> The natural scientists, particularly over the past three decades, have developed a new frame of reference within which they explain the workings of the world. It is a frame of reference which stresses uncertainty, unpredictability, irregularity, discontinuity and self-organisation, in direct opposition to the traditional view. It is a frame of reference which provides the tool for understanding turbulence and chaos - they are real phenomena generated by simple laws, not reflections of our ignorance. Chaos and turbulence are the essence of reality and there is often no cause when events change direction. And this has led to the realisation that the development of most of nature's system is a continuing process of creation which depends significantly on chance, so making it impossible for man ever to control outcomes. The focus has shifted from the machine view of order and pre-ordained paths of development, to the creative nature of disorder, irregularity and chance.

The Nobel laureate Murray Gell-Mann (1994) has argued that we must get away from the idea that serious work is restricted to "beating to death a well-defined problem in a narrow discipline, while broadly integrative thinking is relegated to cocktail parties. In academic life, in bureaucracies, and elsewhere, we encounter a lack of respect for the task of integration."

> Conventional science is frequently blind to connections that can be drawn between such apparently disparate things as frustration in antiferromagnets, the workings of the brain, the rise and fall of stock markets, and a host of other phenomena. Today most scientists restrict themselves to the detailed study of one aspect of a single sub discipline within one branch of the tree of science, be it the large scale structure of the universe or the molecular structure of a protein from the Human Immunodeficiency Virus. (Coveney and Highfield, 1995)

Alvin Toffler (1984) has remarked, "modern science is so good at splitting problems into pieces; that we often forget to put them back together again." There is a growing community of scientists endeavouring against this tide, and a large number of people all over the world have been working driven by a sense of inadequacy of the current state of affairs within their discipline and the need to find clearer understanding. "Since the 1960s a revolution in both mathematical and physical sciences has imposed a new attitude in the description of nature. Parallel developments in thermodynamic theory of irreversible phenomena, in the theory of dynamical systems, and in classical mechanics have converged to show a compelling way that the gap between "simple" and "complex", between "disorder" and "order", is much narrower than previously thought." (Nicolis and Prigogine, 1989).

A quiet scientific revolution in the form of a science of complexity has been gathering momentum over the last couple of decades. Complexity scientists (Kauffman, Langton, Holland, Goodwin, Prigogine, Dawkins) see connections across conventionally separate disciplines; they want to show that there is an economy of concepts necessary for understanding the way the world works. The results of research, not just from mathematics and physical sciences, but also from various branches of biology, computer science, economics and social sciences are 'converging' and consolidating to emerge in the form of a new science of complexity. The work represents a unification of the sciences.

However, the theory of complexity itself, at this point in time, does not lend itself to an easy explanation for it is "a subject that's still so new and so wide ranging that nobody knows quite how to define it or even where its boundaries lie. But then, that's the whole point. If the field seems poorly defined at the moment, it's because complexity research is trying to grapple with questions that defy all the conventional categories." (Waldrop, 1992). It is the synthesis of results and findings of a number of scientists working in different countries and in a number of different fields - in America, France, Santa Fe Institute in New Mexico, and Oxford University in the UK to name but a few. The common factor in the work of all these scientists is that they are developing new tools that solve many complex problems by copying the way living organisms handle the problems they face in the battle for survival. As such, complexity theory has developed from a number of scientific fields.

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7.4.2 Origins of complexity theory

The following is a list of the core disciplines where research on complexity is active:

- **Mathematics** Mathematical applications development in this field, which began 100 years ago by the French mathematician Henri Poincaré, is described very well in Gleick's (1988) book, *Chaos: Making a New Science.* In the 1960s and 1970s the study of mathematical description and analysis of non-linear and complex systems, including chaos and catastrophe theory, was developed further by Thom, Zeeman, Lorenz, Mandelbrot and other mathematicians. The use of strange attractors, fractals, cellular automata, and other nonlinear, graphical, mathematical models have given mathematicians tools for studying important data that was previously thought of as random and so ignored.

- **Biology** The work of evolutionary biologists such as Goodwin and Kauffman in evolution and genetics involving identification of new evolutionary processes leading to the study and understanding of how genes, species and ecosystems evolve.

  Computer models (notably from the work of Tom Ray, Chris Langton, Richard Dawkins, Stuart Kauffman and John Holland) simulating evolution have been the main tool in the study of evolutionary processes and for providing insights into how complex behaviour evolves i.e. the rate of change, adaptability, inheritance, emergence of structures and patterns of behaviour.

- **Physics and chemistry** Unexpected findings in nonequilibrium physics and nonlinear dynamics have dramatically contributed to the science of complexity, in particular, the second law of thermodynamics and its many facets; the study of turbulence leading to understanding of self-organising systems and system states (equilibrium, near equilibrium, the edge of chaos, and chaos). Ilya Prigogine (Nicolis and Prigogine, 1989) explains that the concept of entropy is the physicist's application of the concept of evolution to physical systems. The greater the entropy of a system, the more highly evolved it is.

- **Cognitive science, artificial intelligence and computer science** The study of the neurological, physiological and computational roots of intelligence, and approaches to simulate and create intelligence within a computer. Theory of computation, information and communications. Development of programming tools and computational techniques, including new software and hardware architecture, including highly parallel and neural computing.

- **Applied research** Complex systems theory is based not only on the above fields but also ideas from complexity theory are finding application areas in medicine, e.g. cardiology (Goldberger, 1996) and study of the human immune system.

> Application of concepts like positive feedback and increasing returns in economics by Brian Arthur (1989, 1990, 1994, 1996) not only provides a source of ideas, approaches and examples, but also a real world test of the relevance and appropriateness of complex systems theories.

7.4.3 Characteristics of complexity theory

As discussed in section 7.4.1, a 'unifying theory' of complexity does not yet exist. Even the Santa Fe Institute (SFI) in New Mexico, which can be described as one of the pioneering centres for research on complexity and acts as an *attractor*, to use the terminology of complexity, for leading investigators in the field, is discreetly silent on this subject. In spite of all this talent in one place "its researchers have yet to develop a unified theory of complex systems." (Horgan, 1995).

A necessary step in the direction of developing a unified theory is to identify the salient features of complex system behaviour; noting that "one of the essential features of complex behaviour is the ability to perform *transitions* between different states. Stated differently, complexity is concerned with systems in evolution, and hence history, plays or has played an important role in the observed behaviour." (Nicolis and Prigogine, 1989). The salient features of complex system behaviour are identified as follows:

(i) Evolution and complexity The biological theory of evolution itself has been evolving, as expressed in Lewin's (1993) argument: "The pure Spencerian view of the world, therefore, is that increased complexity is an inevitable manifestation of the system and is driven by the internal dynamics of complex systems: heterogeneity from homogeneity, order out of chaos. The pure Darwinian view is that complexity is built solely by natural selection, a blind, non-directional force; and there is no inevitable rise in complexity." The science of complexity takes the view that both internal and external forces apply, granting complex dynamical systems (natural and technological) an innate ability to evolve with following characteristics:

- **Creativity** Kauffman says that: "No complex entity that has evolved has done so on a random fitness landscape ... Things capable of evolving - metabolic webs of molecules, single cells, multicellular organisms, ecosystems, economic systems, people - all live and evolve on landscapes that themselves have a special property: they allow evolution to "work"."

  Evolution results in the creation of new structures, forms and types of behaviour. It is not limited to discovering pre-existing niches, rather it is the continual creation of new structures and the opportunity for further creativity and interaction (Trisoglio, 1995). "Computational ability increases as species become more complex. Consciousness then becomes a bottom-emergent phenomenon." (Inayatullah, 1994). "Deep, pluralistic evolution, like intelligence, is an emergent property of a community of dynamics." (Kelly, 1995).

- **Chance, not optimisation** Evolution is driven by chance, accident and historical coincidence. The species that survives or the design that wins is not necessarily the 'fittest' or best, whether in biological or technological systems (Trisoglio, 1995).

- **Punctuated equilibria** The concept of punctuated equilibrium was proposed by Stephen Jay Gould (of Harvard University) and Niles Eldredge in 1972. Physicists call this phenomenon phase transition. According to biologists, evolution does not occur gradually but intermittently. There are long periods of slow change and quasi stability followed by rapid periods of innovation and change. These periods of change may be triggered by internal processes reaching a critical state (edge of chaos or self-organised criticality), by changes in the external environment, or by emergence of new structures. In simple terms 'punctuated equilibrium' attempts to explain the phenomenon of long periods of inactivity (equilibria or statis), punctuated by short periods of evolutionary change.

- **Irreversibility and dissipation** "Evolution is irreversible, historical process. Structures may cease to exist or may become extinct, but a system does not evolve 'backwards' to a previous state." (Trisoglio, 1995). This fact was more readily acceptable in biological evolution studies than in other sciences. Nicolis and Prigogine (1989) write that among ancient philosophers "Plato was acutely aware that both permanence and change must be an integral part of reality. But in the nineteenth century a conflict appeared. In physics, irreversibility and dissipation were interpreted as degradation, while among natural scientists biological evolution, which is obviously an irreversible process, was associated with increasing complexity." Today scientists realise that dissipative systems that give rise to irreversible processes constitute a very large and important class of natural system.

Kauffman (1995) explains: "Nonequilibrium ordered systems like the Great Red Spot on Jupiter are sustained by the persistent dissipation of matter and energy, and so were named dissipative structures by the Nobel Laureate Ilya Prigogine some decades ago ..... In dissipative systems, the flux of matter and energy through the system is a driving force generating order."

(ii) Unpredictability Kauffman (1995) highlights three difficulties in support of the argument why it is not possible to establish general laws predicting the behaviour of all nonequilibrium systems. Firstly, quantum theory precludes detailed prediction of molecular phenomena. Secondly, the theory of chaos shows sensitive dependence on initial condition, where minute changes in initial conditions lead to profound changes in systems behaviour, a typical example being the weather. Lastly, the theory of computation also implies that nonequilibrium systems can be thought of as a universal computer executing an algorithm and behaving in a way that is its own shortest description.

(iii) Sensitive dependence on initial conditions James Gleick (1988) has traced the origin of this phrase to a paper Edward Lorenz delivered at the 1979 annual meeting of the American Association for the Advancement of Science. The paper was entitled, "*Predictability: Does the Flap of a Butterfly's Wings in Brazil Set off a Tornado in Texas?*" (Kellert, 1993).

In chaotic behaviour, a system operates to amplify tiny changes in conditions into major alterations of consequent behaviour. This is what lies behind the 'butterfly effect' first observed by Lorenz, who was attempting to predict weather patterns. It is not possible for anyone to trace the steps back from hurricane to the butterfly nor can one ever be sure what caused the hurricane. In such systems, tiny changes that could not possibly be detected, can lead the system to totally different states of behaviour and *synergy* becomes all-important.

> The standard theory of chaos deals with time evolution that comes back again and again close to where they were earlier. Systems that exhibit this 'eternal return' are in general only moderately complex. The historical evolution of very complex systems, by contrast, is typically one-way: history does not repeat itself. For these very complex systems with one-way evolution it is usually clear that sensitive dependence on initial condition is present. The question is then whether it is restricted by regulation mechanism, or whether it leads to long-term important consequences (Ruelle, 1993).

Parker and Stacey (1994) hold the view that: "Systems which demonstrate *sensitive dependence on initial conditions* will not be successfully engineered or planned. They cannot be controlled through monitoring their performance against some standard. They cannot be driven to realise anyone's prior intention. Instead such systems evolve through a process of self organisation from which their futures emerge."

(iv) Complexity affords a holistic perspective "Complexity affords a holistic perspective and with it insights into many difficult concepts, such as life, consciousness and intelligence, that have consistently eluded science and philosophy." (Coveney and Highfield, 1995).

As discussed in sections 7.2 of this chapter, until quite recently it was the norm to explain the behaviour of complex systems in linear terms in spite of authors being aware that relationships were non-linear. Coveney and Highfield, (1995) identify two necessary ingredients for complexity to arise, the first being the irreversible medium in which things can happen, namely time, flowing from the past to the present and towards a future that is open. The second essential ingredient is *nonlinearity* . Linear systems, as discussed earlier, have been the mainstay of science for more than three hundred years and follow the rule that 1 + 1 = 2. Non-linear systems do not obey this simple rule of addition.

(v) **Emergence and spontaneous self-organisation** In evolution, ordered structures and patterns of behaviour emerge spontaneously from within the system, rather than through some external ordering influence. Waldrop (1992) explains: "People trying to satisfy their material needs unconsciously organize themselves into an economy through myriad individual acts of buying and selling; it happens without anyone being in charge or consciously planning it. The genes in a developing embryo organize themselves in one way to make a liver cell and in another way to make a muscle cell. Flying birds adapt to the actions of their neighbours, unconsciously organizing themselves into a flock. Organisms constantly adapt to each other through evolution, thereby organising themselves into an exquisitely tuned ecosystem." As shown in Fig. 7.1 complex systems follow simple local rules but the resultant global order is the emergent property of dynamical systems. Prigogine confirms that such self-organising structures are ubiquitous in nature (Nicolis and Prigogine, 1977).

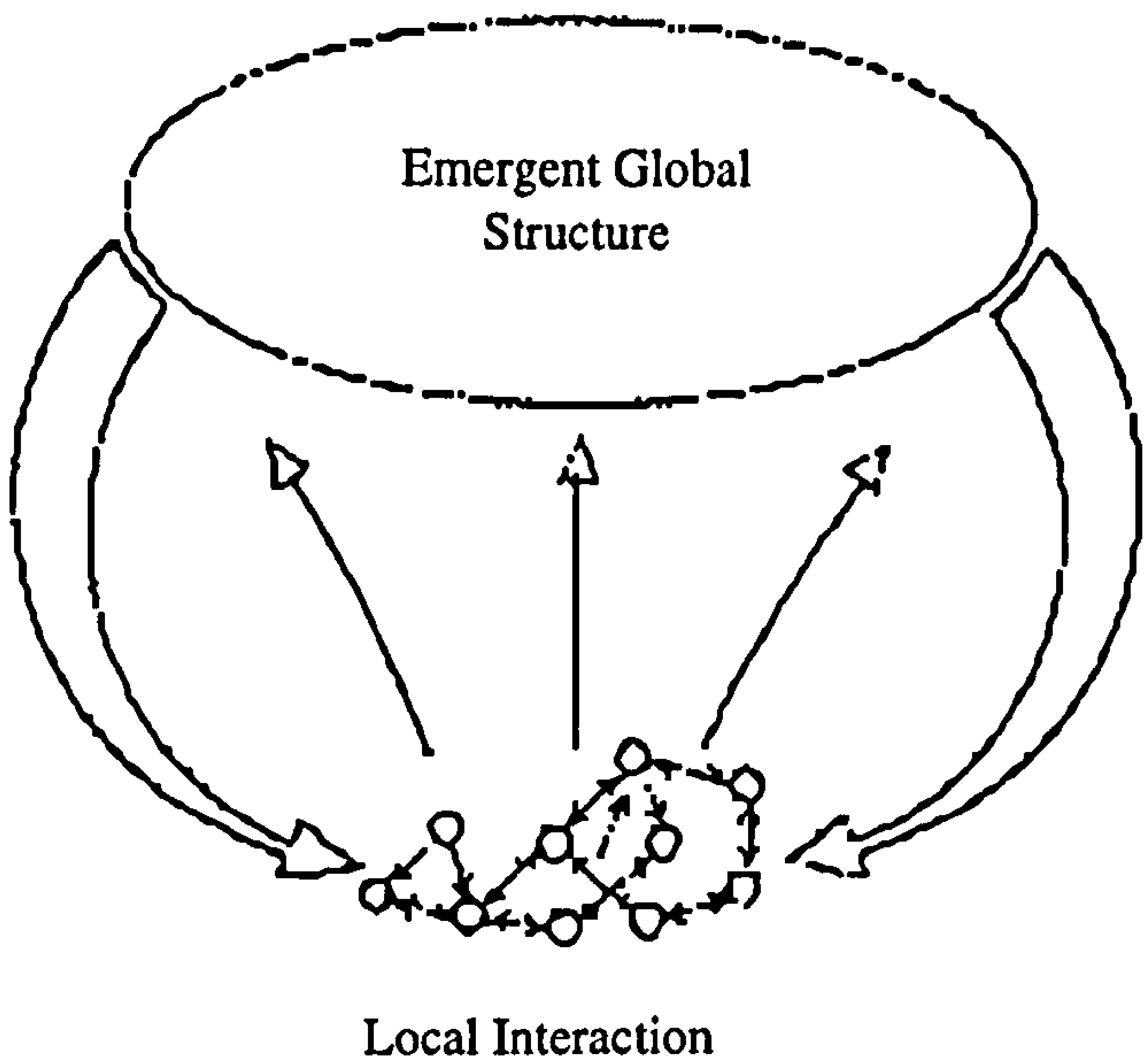

Fig 7.1 Chris Langton's view of emergence in complex systems.
Source: Lewin (1993)

(vi) Strange attractor Another important attribute of most complex systems can be expressed by borrowing the mathematical term 'attractor'. When disturbed, complex systems exhibit states to which the system eventually settles, depending on its properties. "In the language of dynamical systems, the state cycle is an attractor and the collection of trajectories that flow into it is called the basin of attraction. We can roughly think of an attractor as a lake and the basin of attraction as the water drainage flowing into the lake." Kauffman (1995).

However, there is not an infinite range of attractors. Brian Goodwin (1994, 1997), has shown that the mechanics of embryological development are constrained. In the language of complex dynamical systems, the space of morphological possibilities is thinly populated by attractors, (Lewin, 1993). Among the vast range of possible behaviours, the system settles into a few orderly states. A small number of attractors create order while with a large number the system remains in flux and never settles into an orderly state.

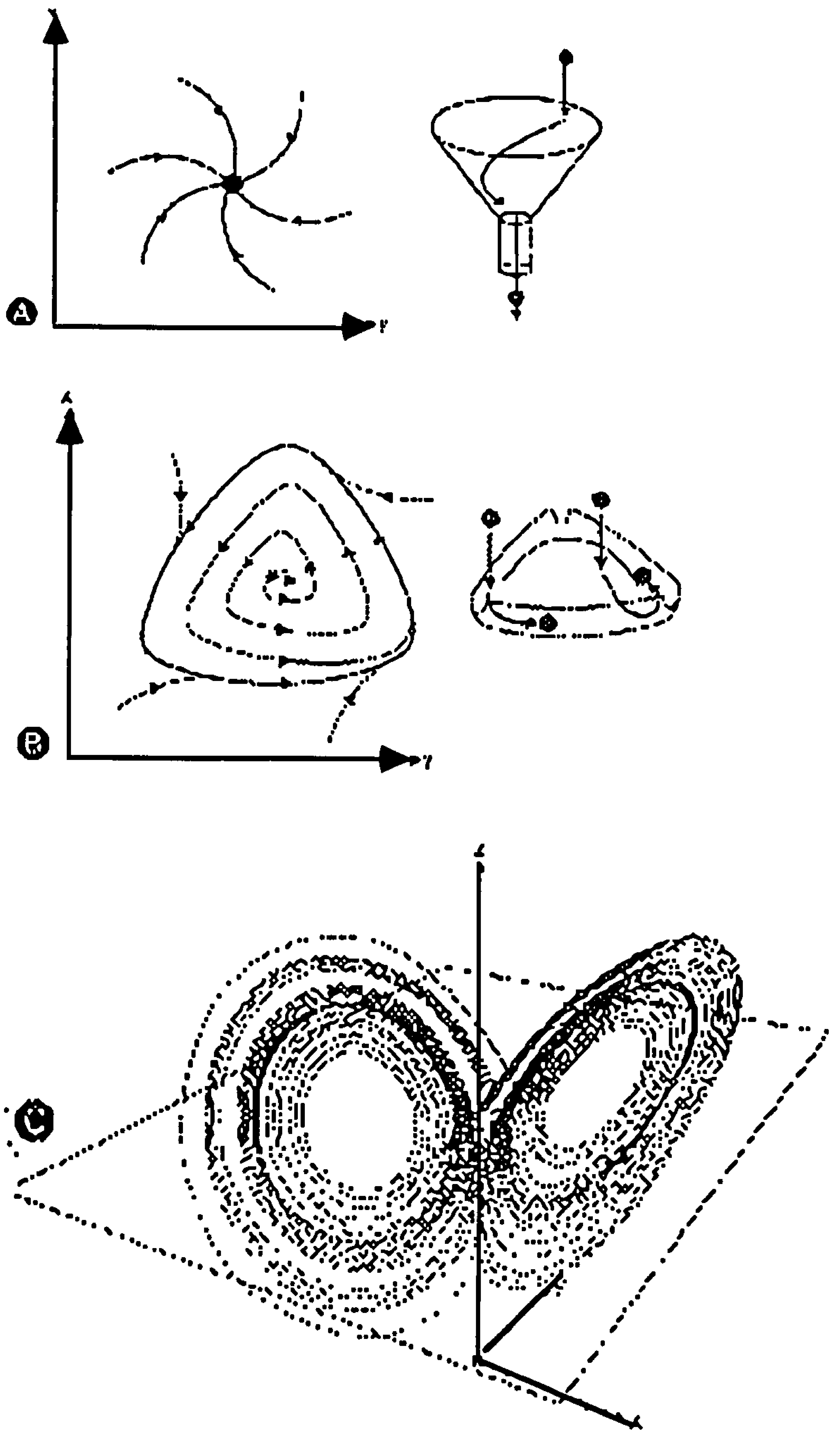

Fig. 7.2 Degrees of attraction. (a) A fixed-point attractor and its mechanical analogue. a ball bearing rolling into a funnel. (b) A limit-cycle attractor and its mechanical analogue, a ball bearing rolling around the rim of a tricorne hat.
(c) The Lorenz strange, or chaotic, attractor.
Source: Coveney and Highfield. 1995.

(vii) Nonlinearity "A striking difference between linear and non-linear laws is whether the property of superposition holds or breaks down. In a linear system the ultimate effect of the combined action of two different causes is merely the superposition of the effects of each cause taken individually. But in a nonlinear system adding a small cause to one that is already present can induce dramatic effects that have no common measure with the amplitude of the cause." (Nicolis and Prigogine, 1989).

Linear systems have a simple additive property, that is a linear system can be studied fully by breaking up its constituent parts and studying each part.

a study of all the parts of a system = study of the whole system.

Nonlinear systems do not have this additive property. The behaviour of a nonlinear dynamic system cannot be studied by reducing it to parts; nor can the results be presented in the form of deductive proofs. The only way to study and understand the behaviour of a nonlinear system is by detailed examination of the component parts and by understanding the interaction of all the components, thereby gaining the understanding of the behaviour of the entire system in a holistic manner.

(viii) Path dependence/lock-in Coveney and Highfield (1995) commenting on non-linearity say that: "A concomitant effect of the non-linearity is feedback - the outcome of an effect goes on to trigger more change .... Such feedback between elements of the overall process .... often leads to quite unexpected behaviour .... Feedback comes in two varieties. One is the reinforcing power of positive feedback - the loop of amplification from microphone to loudspeaker that turns a whisper into a deafening howl. There is also the damping effect of negative feedback ."

The present state of a complex biological or for that matter even a technological system is determined by its previous history. "Two features of complex systems combine to generate path dependence: variation and positive feedback. First, random events, capriciousness, and stochastic processes influence which of several choices is selected by the system at some relatively early point in its evolution. The initial choice is not the outcome of a flawed decision-making process; rather it is a random outcome, unpredictable and could appear insignificant at the time it occurs.

The second requirement is that self-reinforcing, positive feedback processes push the system along the selected path - even though it leads to an inefficient outcome." (Sastry and Coen, 1996).

Brian Arthur (1989) reminds us that some medieval clocks in Florence had 24-hour faces and hands that went anti-clockwise, illustrating that clocks could easily have proceeded down a different technological trajectory. But once the majority of clocks were built with 12-hour clockwise faces, the technology locked into that path. Other well known examples include the QWERTY keyboard and VHS versus Betamax video recorders.

Thus the approach needed to study nonlinear systems must be based on holism, experimentalism, and diachrony.

(ix) The edge of chaos Waldrop (1992) defines the edge of chaos as follows: "Complex systems have somehow acquired the ability to bring order and chaos into a special kind of balance. This balance point - often called *the edge of chaos* - is where the components of a system never quite lock into place, and yet never quite dissolve into turbulence, either." Kauffman discovered this behaviour very early in his research using the genetic network model. By varying the connectivity parameters in his generic networks he found that if the network had too few connections it would freeze. As Kauffman increased the number of links between nodes, the network produced a stable state cycle. It acquired resilience and 'bounced back' if perturbed. That is the system could maintain stability even if the environment changed. However, when the connections increased beyond a certain level of linking density, the network went into a chaotic state. Thus Kauffman (1995) arrived at the conclusion that "the reason complex systems exist on, or in the ordered regime near, the edge of chaos is because evolution takes them there."

Chris Langton while researching into artificial life involving cellular automata also made this remarkable discovery. He found that his system exhibited four different types of behaviour depending upon the tuning of an abstract quality which he referred to as the lambda parameter. The Cellular Automata Classes: I & II —> IV —> III are shown in Fig. 7.3. Each of these classes represent the following (Trisoglio, 1995):

Class 1: *Stable forms*, resulting from a frozen regime where structures exist but information cannot be transmitted.

Class 2: *Periodic form*, which can show periodic motion, but cannot change. The analogy is with a somewhat more flexible regime where behaviour such as crystal growth is seen.

Class 3: *Chaotic form*, where information moves so freely that its structure cannot be maintained; the regime is too chaotic to support life.

Class 4: *Complexity (and life?)*, where information is both stable enough to support a message structure and loose enough to transmit messages.

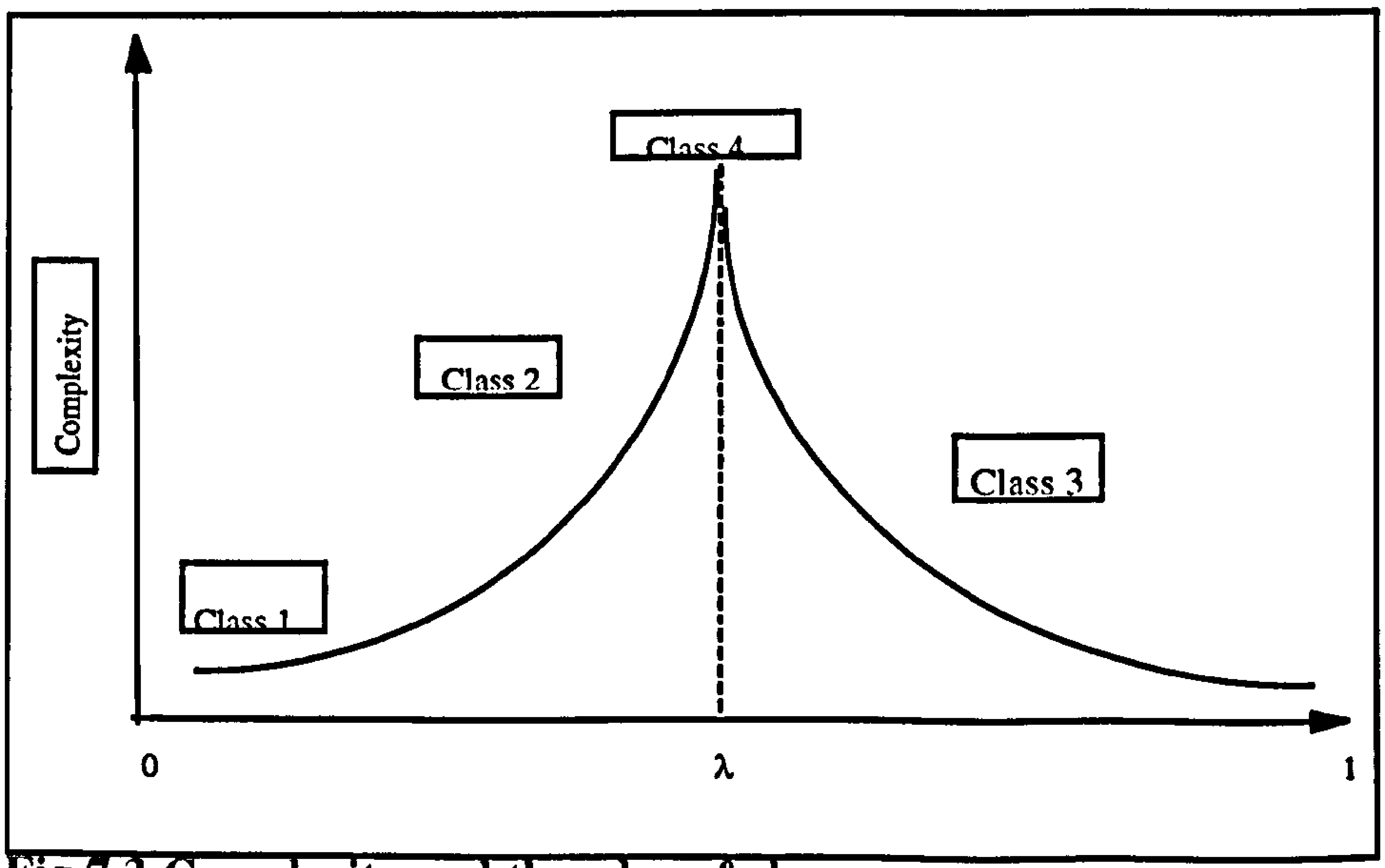

Fig 7.3 Complexity and the edge of chaos
Source: Trisoglio (1995)

The transitional region between order and chaos is where complex behaviour thrives. Langton has argued that evolution under natural selection would tend to favour systems at the 'edge of chaos' where the ability to process information is maximum (Trisoglio, 1995).

(x) Co-evolution Organisms in an ecosystem don't just evolve but coevolve. An organism does not evolve to fit a niche in the environment. Instead, an organism's 'environment' is largely determined by the other organisms around it, so predators and prey, organisms and niches co-evolve. "Real organisms constantly circle and chase one another in an infinitely complex dance of coevolution." (Waldrop, 1992). "The very struggle to survive, to adapt to the small and large changes of one's coevolutionary partners, may ultimately drive some species to extinction while creating novel niches for others. Life, then, unrolls in an unending procession of change, with small and large bursts of speciations, and small and large bursts of extinction, ringing out the old, ringing in the new." (Kauffman, 1995). According to Holland (1995) coevolution is the essential force behind emergence and self-organisation in any complex adaptive system.

The biologist Stuart Kauffman's primary coevolutionary tool is his NK model. In the words of McKelvey and Kiousis (1996) "Kauffman's *NK* model is an extension of the spin-glass modelling approach to 'landscapes' in which agents take 'adaptive walks' in the form of hill-climbing towards 'fitness peaks' (Stein, 1992). Landscapes vary in height, number, ruggedness, and steepness of fitness peaks, depending on the contribution of *N*, *K*, and *C*. Kauffman's basic argument is that complexity effects (measured by *N* and *C*) may stall adaptive agents at tops of less than optimal fitness peaks. In extending the *NK* model to coevolutionary contexts (the *C* part), Kauffman draws on Boolean networks and cellular automata." (Weisbuch, 1993).

Coevolution also gives rise to the edge-of-chaos image. This is so because in evolution as one system evolves, its competitors evolve with it too, each competing to remain at a fitness peak. Kauffman (1995) explains: "we must adapt to their adaptations. In coevolving systems, each partner clambers up its fitness landscape towards fitness peaks, even as that landscape is constantly deformed by the adaptive moves of coevolutionary partners. Strikingly, such coevolving systems also behave in an ordered regime, a chaotic regime, and a transition regime. "

7.5 Conclusions

Complexity theory underlies a new world-view. The earlier chapters of the thesis have gone to some length to establish that what the Western business organisational world is facing today is the unravelling of the dominant philosophies of the industrial era. Stacey (1991) defines the enigma when he says that the success of scientific knowledge, without doubt, has been phenomenal in controlling some aspects of the natural world, in fact so much so that many concepts and principles got imported lock, stock and barrel into the social sciences, and into understanding the managing and organising of businesses. The philosophies and principles of the industrial age, over a century, permeated the very fabric of our society to such a great extent that they have become highly institutionalised.

> The dominant metaphor for nature and society during 18th-20th centuries has been mechanical........Our contemporary concepts and practice in politics, organizational change, and development assistance are defined for the most part by an intellectual framework that began with the development of physical mechanics in the seventeenth century. We speak of machinery of government, re-engineering institutions, inputs, processes and outputs for instructional systems. (Hartwell, 1995)

With this as the frame of reference, the almost universal response to turbulence and chaos of the business world is to try to control the environment and impose consistency and harmony to create order. These prevalent beliefs are however, in contradiction with the revolutionary knowledge emerging from the science of complexity.

The science of complexity introduces a revolutionary way of thinking, even though it originates from highly abstract mathematics. It has potentially far-reaching implications in almost every area of human endeavour. Murray Gell-Mann (1994) calls it the science of the twenty-first century. It sheds light on how to come to grips not only with the complexity of any single phenomenon but also with the universal feature of complexity itself. It explains how order can emerge from a mass of evolving agents, whether atoms, cells or organisms. It shows how to find unity in diversity by pattern recognition

The key insight to be gained from the science of complexity is the endogeny of environment. "Every ecosystem is a dynamic web always in flux, always in the process of reshaping itself." (Kelly, 1995). The message is clear - survival does not stem from resisting change but from evolution and coevolution and therefore, "human institutions - those ecologies of human toil and dreams - must also be in a state of constant flux and reinvention...." (Kelly, 1995).

This means that at a fundamental level we are required to think of a business organisation as a combination of an information processing 'dynamic web' which must continuously adapt to its environment. Hierarchies and short-term planning may be needed to run day-to-day operations, but the long-term future must be allowed to emerge from self-organising activity of loose, informal, destabilising networks. These networks and organisation structures must coevolve.

Chapter 8 - The Theory of Complex Adaptive Systems: relevance to organisations

8.1 Introduction

The purpose of this chapter is to explore the potential connections between the science of complexity and the management of today's organisations. The aim is to assess if complexity theory has any insight to offer in dealing with the problems faced by organisations today. As discussed earlier there has been an awareness for sometime now about the 'anomaly' between contemporary organisational theories and management practices, and the 'emergence of new sorts of phenomena' in the form of organisational complexity. A paradigm shift in the field of organisation and management theories (identified and analysed in Chapters four, five, and six) is pervasive, and it is being increasingly realised that traditional theories and management practices are out of synchronisation with today's business environment. As yet (as discussed in the conclusion of chapter six) there is no framework to facilitate the study of organisations as complex systems and the search is on for a theory which can help explain things. In the words of Kuhn (1962):

> If awareness of anomaly plays a role in the emergence of new sorts of phenomena, it should surprise no one that a similar but more profound awareness is prerequisite to all acceptable changes of theory. On this point historical evidence is, I think, entirely unequivocal........Because it demands large-scale paradigm destruction and major shifts in the problems and techniques of normal science, the emergence of new theories is generally preceded by a period of pronounced professional insecurity. As one might expect, that insecurity is generated by the persistent failure of the puzzles of normal science to come out as they should. Failure of existing rules is the prelude to a search for the new ones.

Thus in keeping with Kuhn, the objective of this chapter is to evaluate the suitability of contributions the new theory of complexity can make to the field of business organisation theories and management practices. In other words the aim is to assess what the theory of complexity has to offer to facilitate:

- the understanding of the phenomenon of organisational change
- the study and understanding of organisations as complex adaptive systems
- coping with organisational instability under conditions of turbulence and rapid change.

8.2 The role of theory

A theory aims to provide both a description as well as an explanation of a phenomenon. As such, theories are founded on the principles that describe relationships observed in association with the phenomenon. Put simply, a theory explains the underpinning principles on which practice is based, and aims to improve it.

It is a well established fact that most theories, before they are accepted, go through a period of conjecture and refutation. Complexity theory too is going through such a period as far as the discipline of organisation and its management is concerned. There are a number of reasons for this. The science of complexity has arisen from an aggregation of knowledge from research into complex adaptive systems, referred to as CAS, in disparate fields. "The task of formulating theory for *cas* is more than usually difficult because the behaviour of a whole *cas* is more than a simple sum of the behaviours of its parts; *cas* abound in nonlinearities ..... Nonlinearities mean that our most useful tools for generalising observations into theory— trend analysis, determination of equilibria, sample means, and so on— are badly blunted. The best way to compensate for this loss is to make cross-disciplinary comparison of *cas*, in hopes of extracting common characteristics. With patience and insight we can shape those characteristics into building blocks for a general theory. Cross-comparisons provide another advantage: characteristics that are subtle and hard to extract from one system can be salient and easy to examine in another." (Holland, 1995).

8.3 Complexity theory's relevance to business organisation

This is not for the first time that attempts to import principles of scientific theories into social sciences are being made. It is widely claimed in current literature that the Newtonian scientific view gave rise to mechanistic models of the world characterised by repetition, predictability and reductionism. (Lewin, 1993; Horgan, 1996). Evolutionary theory was not only radical in its challenge to religious thought and history but also provided new metaphors for philosophy and social science. It was central to the thinking of Kant, Marx, Hegel, and Spencer. Complexity theory brings yet another new set of ideas based on the principles that complex adaptive systems 'evolve' and restore order through 'self-organisation'. Within the business world and in organisational development the shift to a new paradigm, consisting of the learning organisation whose foundation is based on networking well-organised teams of knowledge-workers, is already gaining momentum.

At present there is no 'unifying theory' of complexity. Nonetheless, it has introduced new metaphors and a host of concepts for enriching our understanding of organisations as complex systems. Metaphors are powerful change agents and the fervour with which they are being investigated by academics and practitioners cannot be ignored as another fad. There are a number of theories under the broad heading of complexity and their main characteristics are: self-organisation and autopoiesis, evolution and coevolution, creativity arising at the edge of chaos, NK networks and fitness landscapes, nonlinear probability, positive feedback, increasing returns leading to many possible equilibrium points and strange attractors.

Complexity refers to a state of affairs that covers a large area between the two extreme conditions namely complete order and utter chaos. We experience all three states, i.e. complexity, chaos and order, in all walks of life, and in all kinds of systems that interact with their environment. Systems that interact with their environment i.e. receive input, act upon the input, and produce output which goes back into its environment are referred to as 'open systems'. Business organisations and their management fall into the category of complex open systems.

The major concern of most organisations and senior management today is focused on how to handle complexity arising out of a turbulent business environment. "Changeability is a much-prized quality in business these days and is usually desired to enable the company to achieve a better 'fit' with its environment." (Lloyd, 1995). Management gurus are not very clear about what to do, or how to do it with any precision. Argyris (1998) points out that:

> Despite all the rhetoric surrounding transformation and major change programs, the reality is that today's managers have not yet encountered change programs that work.

Management consultants and academics advise Total Quality Management (TQM), reengineering or restructuring, team effort, more participation, more openness with information, and other procedural advice that has been empirically demonstrated to result in quicker genesis of solutions to equivocal circumstances. Albert et al. (1998) provides a description of the similarities and differences between employee empowerment, reengineering and TQM programs. The advice is generic and based on traditional organisational theories where emphasis is placed on seeking a stable or equilibrium state. Consequently the focus is on the function of pattern maintenance. Businesses facing unprecedented complexity and rapid change, demand specific guidance and solutions. If an organisation is in a state of chaos, that is in the language of complexity far from equilibrium, at or near the state of bifurcation, it needs a new set of principles to enable it to evolve to a dynamic new order (i.e. reach a new fitness peak). In more moderate circumstances, there is less equivocality and more room for separating the 'What' and the 'How', and controlling for specified outcomes (that is we know what needs to be done and have a good idea of how to do it). This is no longer the case.

When environments change, what changes is the paradigm i.e. the underlying framework that provided meaning. When a business's environment changes so dramatically that its old strategy of 'how we succeed in the business' no longer works, or is even actively dysfunctional, then the firm faces a chaotic, equivocal environment. A new underlying framework for making sense must be evolved and that means that both 'what needs to be done' and 'how to do it' are no longer clear. For example the ideas about work and organisation born under fundamental principles of management theories up until recently have been 'planning', 'command' and 'control'. In traditional, hierarchical bureaucracies, planning and control have been seen as the main tasks of business management. To put it simply, the task of management is to reduce uncertainty, enhance predictability, create equilibrium and order. Thus under ideal command and control conditions:

uncertainty = 0 and certainty = 1

In contrast to this is chaos where

certainty = 0 (or close to 0) and uncertainty = 1 (or close to 1)

According to conventional wisdom the growing complexity of business world should make strategic planning, monitoring and control even more important. Somehow, this no longer seems to be the case since command-and-control organisations are rigid and work best in a predictable and deterministic environment. They are effective under stable market conditions but are totally ineffective in a volatile environment. "Bureaucracy thrives in highly competitive, undifferentiated, and stable environments, such as the climate of its youth, the Industrial revolution. A pyramidal structure of authority, with power concentrated in the hands of few with knowledge and resources to control an entire enterprise was, and is, an eminently suitable social arrangement for routinized tasks." (Bennis, 1993).

The key problem with management under the command-and-control paradigm has been the belief that everything must be managed precisely or else the result will be chaos. In practice, while most forward-thinking managers have accepted the need to dispense with the 'command', few are ready to entirely abandon the 'control'. Most managers still believe in the conventional wisdom that planning is the main task of management. They share a common, tacit belief that they are trying to explain and secure order in the world of business. For them it stands to reason that the growing complexity of business warrants greater emphasis on corporate strategy. However, the world of our own making has changed in just those ways which make the command-and-control mechanisms not just problematic but totally inappropriate. The new economy needs new models urgently.

In our search for new models for today's dynamic and change-oriented new world of business the pointers direct to nature. The science of complexity puts forward a new way of developing organisations. It demolishes the view put forward by rational approaches that organisations can be engineered. Rather, it invokes a *biological* image of an organisation; that is, the image of an organism that tries to survive in a changing environment. To quote Morgan (1986):

> For the problem of mechanistic visions of organisation have led many organisation theorists away from mechanical science and towards biology as a way of thinking about organisations. In the process, organisation theory has become a kind of biology in which the distinctions and

relations among *molecules, cells, complex organisms, species,* and *ecology* are paralleled in those between *individuals, groups, organisations.*

The advice from scientists researching into chaos and complexity is to understand, appreciate and adopt the strengths of natural systems (Kauffman, 1995; Goodwin, 1994, 1997; Nicolis and Prigogine, 1989). Complexity theory suggests a new way of thinking. It points out that complexity lies in between the two extreme of complete order and utter chaos and its main characteristic is the inherent capability for coping with 'uncertainty' based on *self-organisation* and *emergent behaviour, creativity, and innovation.* Together these provide new insights for managing business organisations as 'complex adaptive systems' (CAS). "Biological systems are adaptable, resilient, and capable of generating perpetual novelty. That's not a bad list of attributes for the company of the future." (Taylor, 1994).

8.4 A critique of complexity theory

The main purpose of the discussion of the new scientific theories of complexity here is not to offer an exposition of the theory, rather to assess if they are applicable to organisations. The study of, and research into new theories for business organisation and management have preoccupied management practitioners and scholars for well over a century. The interest in complexity theory is a continuation of this search.

As discussed earlier research on complexity over the last three decade has mostly been confined to natural sciences. Over the last few years practitioners and researchers (Brian Arthur, John Holland, Stuart Kauffman, Ralph Stacey and many others) in the fields of economics, computer simulation, biology and other natural sciences, business organisations and management have started to take note of the findings from complexity theory. However, a systematic and scientific evaluation requires that serendipity must be replaced by understanding of the theoretical fundamentals involved.

> Theory is crucial. Serendipity may occasionally yield insight, but is unlikely to be a frequent visitor. Without theory, we make endless forays into uncharted badlands. With theory, we can separate fundamental characteristics from fascinating idiosyncrasies and incidental features. Theory supplies landmarks and guideposts, and we begin to know what to observe and where to act. (Holland, 1995)

The new scientific theories of chaos and complexity, and the theory of self-organisation are generating great interest amongst people who find dominant theories inadequate for explaining the phenomenon of change and the means for coping with complexity in the organisational context. In the search for useful guidelines for combating the problem there is a tendency to apply new findings to businesses in a wholesale fashion. This trend is alarming, for the process of distilling and synthesising the characteristics of complexity theory into general principles is far from complete. Scientists working on complexity themselves emphasise this point.

> We believe that there *are* general principles that will deepen our understanding of *all* complex adaptive systems. At present we can only see fragments of those principles, and the focus shifts from time to time; but we can see outlines, and we can make useful conjectures. (Holland, 1995)

With regard to the relevance of complexity theory in an organisational context it is important to take a more judicious approach. There are a number of reasons:

- the theory of evolution as it stands today is still far from complete. We are aware of the distinction between Lamarckian (theory of evolution based on the inheritance of acquired characteristics) and Darwinian (theory of evolution based on the action of natural selection) methods. Complexity theory offers a new perspective on evolution.

- One should not take the comparison between biological organisms and human culture/organisation systems too far. There have been many unfortunate and reprehensible consequences of attempts to link cultural and biological evolution in the past.

- Biological organisms and human systems are quite different in one important respect: components of biological systems have no free will and emotions. The similarities are nevertheless there - biological organisms exhibit emergent behaviour and self-organisation and are characterised by distributed control.

- Natural systems are indifferent to net outcomes. Species compete for existence but it does not matter to them who wins and who loses in the race for survival. This indifference cannot be imported into human systems.

- Natural systems lack the concept of values. Their study provides insight only into the 'how' questions. i.e. how organisms evolve and adapt to the environment but sheds no light on the 'why' question.

- We still need to clarify the semantic problems. What we mean by a certain term in natural systems may not apply to human social systems, and a lexicon defining the terms when applied to human systems is a prerequisite.

It is believed that, if we can get a better understanding of the workings of human organisations by comparing and evaluating them against the findings of the new science of complexity, we shall gain a lot.

Another important issue that we must not lose sight of is that the study of complexity is a new field and still evolving, and it is worth differentiating here between the main theories of non-linearity and explaining the extent of their relevance in the business organisational context. Catastrophe theory was developed in the 1960s by René unfortunate and reprehensible consequences of attempts to link cultural and biological evolution in the past.

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Thom (1975) and Christopher Zeeman (1977). Catastrophe theory provided invaluable insight into the phenomena of sudden and unpredictable changes, such as why the history of life is punctuated by mass extinction of species, how a bubble bursts or a bridge collapses. However, attempts to apply it to management and economics has not yielded any convincing result and its relevance is no longer seriously investigated.

The other key theory of non-linearity is chaos theory. Its significance lies in establishing that *linear and equilibrium seeking models of unpredictable systems are seriously misleading and inadequate descriptions of reality.* The word 'chaos' is used by chaos theorists as a metaphor to describe unpredictable and apparently random behaviour of the dynamic systems they investigate. Chaos theory demonstrates that non-linear dynamic systems exhibit order and disorder.

Since the early 1990s we have seen a burgeoning of interest of economists and management scientists in non-linearity, suggesting that chaos theory can show us how to cope with unpredictable business environments. However, according to Kellert (1993) the "new science such as chaos theory can reveal the limits of standard methodological approaches to understanding the world and impel a reconsideration of the metaphysical views that undergirded them. But any expectation that chaos theory will re-enchant the world will meet with disappointment". There are reasons why chaos theory too, on its own, is also not relevant as a model for human activity systems. Alex Trisoglio (1995) explains:

> Chaos theory can help us to understand the shape of a leaf or the unpredictability of the weather, but it cannot take us the next step forward to explaining or describing the processes of life or intelligence. We can write a set of equations to describe the physical and chemical processes behind the formation of a snowflake or the changes in the weather, although even here 'the map is not the territory', but we cannot reduce life or intelligence to the functioning of a machine that can be described by a set of equations. A set of equations is a mathematical system that is only capable of 'functioning', not evolving. It cannot restructure itself or

insert new relationships, yet this kind of innovation and evolutionary change is central to living systems.

The study of economics and management is the study of systems that are not only evolving, for example because of technological innovation, but that are also governed by the actions of intelligent, cognizing, strategy-forming individuals and organisations. In seeking a new model for economics and management theory, we should therefore look not to theories of chaos and non-linear systems but rather to *complexity theory* (which includes chaos theory and other non-linear dynamical systems theories as a subset).

Table 8.1 below (slightly adapted from Alex Trisoglio, 1995) highlights the major differences in types of behaviour between different theories. The theory of complexity itself covers three levels of behaviour (3, 4, 5)

Theory	Characteristic	Scientific Discipline	Examples	Behaviour Level
Classical	Linear, equilibrium	Classical science	Solar system, pendulum	1. Equilibrium
Chaos/Non-linearity	Non-linear, non-equilibrium	Chaos, catastrophe theory, non-equilibrium thermodynamics	Sand piles, weather, snowflakes, roulette	2. Unpredictable
Complexity	Non-linear, Non equilibrium + computation	Mathematics, computer science, information theory, linguistics	Languages, computer software, artificial intelligence, DNA	3. Computational and information processing
Complexity	Non-linear, non-equilibrium + Life	Biology, ecology, evolution, intelligent agents	Plants, viruses, ecosystem	4. Creative, adaptive, evolving
Complexity	Non-linear, non-equilibrium + life + intelligence	Cultural theory, game theory, economics, management theory	Humans, economies, companies, society, technology	5. Intelligent, strategic.

Table 8.1 The emergence of complex behaviour in 5 types of systems
Source: Alex Trisoglio (1995)

According to Ruelle (1993) quantitative studies of chaos in a system requires one to fully understand the dynamics of that system. For example, a good understanding of the dynamics of solar astronomy or hydrodynamics can be translated into basic equations of motion, implemented with precision in a computer and studied. This kind of study is not possible in social sciences and economics. This is because, "we do not know the basic equation of motion (models that agree qualitatively with the data are not good enough). It is hard to obtain long time series with good precision, and the dynamics is usually not simple. Furthermore, in many cases (ecology, economics, social sciences) the basic equations of evolution, whatever they are, slowly change with time (the system "learns")." (Ruelle, 1993)

The most relevant theory, from the organisational and management perspective, is the theory of complex adaptive systems (CAS). Major characteristics of CAS are as follows:

1. **CAS consists of intelligent agents** (or group of agents) that collaborate and compete with each other.

2. **Agents operate according to a set of simple local rules.** Out of multiplicity of local behaviours (guided by simple local rules) a global emergent behaviour is generated. This capability is known as *'self-organisation'*.

3. **There is no centralised control in CAS.** The control factor in CAS is dispersed, (e.g. there is no master neuron directing the brain, nor is there a master cell in charge of a developing embryo).

4. **CAS operate at the edge of chaos.** Emergent behaviour is the central feature of complexity. However, a small disturbance is capable of causing the system to switch into unpredictable behaviour. Thus the system is said to operate *'at the edge of chaos'*. Here 'chaos' means unpredictability.

5. **CAS are open and interact with their environment.** A CAS is capable of learning from its environment and evolving to accommodate environmental

changes. More importantly, a CAS is capable of changing its environment to accommodate its own goals.

6. **The process of change and development in CAS is nonlinear and irreversible.** Nonlinearity refers to the mathematical property of combining in more complicated ways than simple addition, as expressed by the whole is greater than the sum of its parts. Dissipative nonlinear systems are capable of exhibiting self-organisation and chaos. Evolution is an irreversible, historical process. Structures may cease to exist or may become extinct, but a system cannot evolve 'backwards' to a previous state.

7. **CAS evolve and co-evolve with other systems of the same kind.** Flora, fauna and other CAS, including humans and human systems, live in niches provided by other species. For example, flowers and insects coevolve; insects pollinate flowers while feeding on nectar. Species change as they interact with one another, jockeying for existence as mutualists, competitors, predators and prey, hosts and parasites.

The characteristics stated above can be best illustrated by looking at complex adaptive systems in nature, for example a colony of ants or a swarm of bees. It is important to make the distinction here that this comparison is not based on biological similarities but on the social interaction of the agents and global emergent behaviour. William Morton Wheeler (1911), an entomologist and founder of the field of social entomology claimed that an insect colony is not merely just like an organism but is indeed an organism in every scientific sense of the word. Referring to the insect colony he states: "Like a cell or a person, it behaves as a unitary whole, maintaining its identity in space, resisting dissolution ..... neither a thing nor a concept, but a continual flux or process".

Each worker ant has limited intelligence with little ability to learn. Its whole purpose in life is to find food. It does so by following a set of four simple local rules (BT Factfile 11, ES136 2/96) needed for establishing a trail from nest to the food supply and back. The rules can be defined as follows:

- If you find food, take it back to your nest, marking a trail by secreting an odorous substance to show your route between food and nest.
- If you cross a trail and have no food, follow the trail.
- If you return to the nest with food, leave the food in the nest and return along the same trail to get more food.
- If none of the above three rules apply, search around randomly for food or food trails.

The food brought into the nest stimulates the other ants into action too, but they do not disperse like solitary insects in search of food in all directions, rather they methodically follow the odour trail left by the first ant. Thus the limited intelligence of an individual ant is amplified by collaboration with other ants.

Successful colony establishment requires mutual interest and give-and-take. Trophallaxis, the mutual interchange of food and other materials among members of colony, acts as a stabilising factor.

Ants are flexible and adaptable. The simplicity and variability of their nests are remarkable too. If forced to move either when colonies become too large or due to some imminent danger, ants just pick up their brood and leave, establishing themselves in another nest. This is not as straightforward as it sounds because the initiative to move comes from a few members while the rest of the workers try to resist the change by carrying the eggs, larvae, and pupae back to the old nest. However the resistance is overcome gradually and the flow of ants towards the new nest is unified. In this way they exhibit collaboration and competition with each other. Disturbances are capable of switching the ants into unpredictable behaviour but the interaction among the ants gives rise to coherent behaviour. (Collier's Encyclopedia, 1978, Vol. 2)

Bees too, like ants, are members of the insect order Hymenoptera, but as CAS they belong to a higher order, based on their behaviour. Among the 20,000 or more known species of bees in the world, the bees who lack in social behaviour belong to the primitive stage in the evolution, while those living in complex colonial style are considered to belong to highly evolved state. We are concerned here with the behaviour of social bees such as the honey bee.

Honey bees live and work together in large communities in a highly organised society. They follow simple rules similar to ants as described above to perform their main task of foraging. There is no centralised control i.e. the queen bee performs her function of laying eggs but does not direct either the worker bees or the drones in their activities. From the time the bees are hatched, each individual adapts to the rigid class distinction and performs the complex functions of the class it belongs to without having to be taught. The behaviour is no doubt inherited.

Social bees show a higher level of intelligence than ants, because they interact with their environment and show evidence of controlling it. They can raise the temperature of their immediate environment in the cold and reduce the temperature when it is hot. Although honey bees cannot be credited with intelligence in the same way as humans, their communication skills definitely belong to a much higher level than other insects which belong to the hymenoptera category. Observations made in experimental hives with transparent (red) glass walls have clearly established that bees have an intricate means of communication by which they inform each other of the source of food, distance and direction to the supply, and the quantity available.

On finding a rich source of food, the successful forager covers the source with an odour which other bees of the same swarm can recognise. On returning to the hive from the food source it draws the attention of other bees by performing a dance and by feeding them bits of the food it has collected. The pattern of the dance communicates to the other bees the exact direction, distance and the quantity of food supply. For example, if the food supply is less than around a hundred metres away the bee performs a dance on the vertical surface of the comb by moving around in a circle about an inch in diameter. If the distance is over a hundred metres it moves to a figure of eight pattern of the same size as the round dance. The number of turns in a given time indicate further information about the distance, e.g. nine turns in fifteen seconds mean a distance of hundred metres or so, while two turns in the same time would indicate a distance of four thousand metres or more. The source direction is given in relation to the sun. Supply in the direction of the sun is indicated by making a straight upward run on the vertical surface while a similar downward run indicates away from the sun. A run at an angle from the centre indicates the direction at an angle towards or away from the sun. For example a 45° run right of straight up would mean that the source is located 45° right of the direction of the sun and so on. A brief or no dance is the signal of either poor quality or that the source is heavily exploited. (Collier's Encyclopedia, 1978, Vol. 3)

> One of the remarkable features of bee communication is that gravity-oriented dances on vertical surfaces are interpreted as directions for light-oriented flights. This relation evidently arose within the honeybee genus *Apis* , for the honeybee of southern Asia dances on the horizontal surface at the base of its exposed comb, and the direction of its tail-wagging run is directly towards the food source. The relationship itself is generally widespread. Various beetles and ants have been found to walk in a given direction in relation to a light in the laboratory; if the light is turned off and the surface on which they are walking is turned to a vertical, the force of gravity replaces the direction of light as an orienting stimulus.
>
> From these facts we can judge that the bees' language, like any other structural, or physiological feature, arose in the course of evolution as an inherited phenomenon from comparable antecedents. In contrast, man's language, as other aspects of his culture, is learned and can be

changed to a considerable extent in a generation or even within the life span of an individual. (Collier's Encyclopedia, 1978, Vol. 3).

Lewin (1993) quotes Edward Wilson of Harvard, an authority on ants and insect sociality -" An individual social insect processes less information than an individual solitary insect, but as part of an aggregate activity, the social insect contributes to more complex computation. The colony works as a single organism."

We see that in CAS evolution, ordered structures and patterns of behaviour emerge spontaneously from within the system, rather than through an external ordering influence. To judge if CAS theory could be useful for designing human activity systems such as business organisations, it is necessary to check if business organisations behave anything like a colony of ants or a swarm of bees and we therefore ask ourselves the following questions:

1. Do business organisations consist of agents and group of agents that collaborate and compete?
2. Do groups of agents work according to local rules?
3. Is there any evidence of emergent behaviour? If so, is the behaviour stable?
4. Are there examples of companies sliding into chaos caused by small disturbances?
5. Are there organisations capable of learning, evolving and affecting their environment?

Do business organisations consist of agents and group of agents that collaborate and compete?

Yes. All human social systems are composed of interdependent individuals, whom we refer to as 'agents' in the terminology of complexity. In an organisational context agents are its employees, customers, suppliers, as well as competitors. Of course, *human agents cannot and should not be compared to ants or bees.* Human agents are different because they are more intelligent and capable of more complex and variable behaviour. Human agents may pursue similar or differing, even contradicting goals. This is where human agents begin to part company with agents in CAS in natural systems.

Human behaviour has been much studied and researched but, and not surprisingly, there is no consensus of opinions. One school of thought states that an individual's behaviour is determined by the structure of the system with which the individual interacts. While the other school of thought asserts that it is the behaviour of the individuals that influences how an organisation is structured.

Individual agents as well as groups of agents compete with each other at all levels. For example in a football or rugby team, players within the team collaborate but compete against other teams. In the organisational context, individual salesmen compete with each others. Groups and business units within organisations collaborate and compete with each other, and we are familiar with corporations competing with each other all the time at local, national and global levels.

In order to survive relentless competition, novel ways of competing are being advised. Michael Porter (1985, 1987), who has written a series of books on the subject, provides a set of tools and techniques. His 'five forces framework' is aimed at enabling a firm to see through the complexity and identify the critical factors involved. The firm can then devise innovative strategies that shift the rules of competition in their favour. For example, one such way is to identify the value chain and reconfigure it in a way that is significantly different from the competitors to gain competitive advantage. British Airways (Hampden-Turner, (1994) and Federal Express are two examples of firms that have prospered by this. Another method for creating competitive advantage is based on harnessing interrelationships among business units within a diversified industry (Lane and Maxfield, 1995). Using games and industry scenarios to identify the range of possible futures are also being used increasingly (Porter, 1985; Arie P. De Geus, 1988).

Competition from Japan and the countries of the Pacific rim have also forced Western businesses to look at new ways for gaining competitive advantage. The ability to exploit linkages that affect cost underlies the success of many Japanese firms like Matsushita and Cannon. Collaborative relationships with manufacturers of parts, and just-in-time deliveries are further examples of cost-cutting principles learned from Japan.

Many of the principles on which the Japanese based their manufacturing and gained spectacular competitive advantages originated in the West. Frederick Taylor, (1911), even in those early days of organisation history, understood the power of co-operative and collaborative effort in business. Up to his death he maintained that his aim was "the creation of a society in which owners and workers, capitalists and proletarians had a common interest in productivity and could build a relationship of harmony on the application of knowledge to work. The ones who have come closest to understanding this so far are Japan's post-World War II employees and Japan's post-World War II unions." (Drucker, 1993).

Do groups of agents work according to local rules?

A business organisation is regarded as a purposeful social unit and "it consists of a number of people who perform differentiated tasks while filling differentiated roles, offices, or positions and whose actions are co-ordinated so that their individual outputs are integrated." (Litterer, 1969).

In human organisations the process of devising tasks and assigning individuals to them necessitates that a description of how to carry out the task be specified. To accomplish organisational objectives, the work to be done is broken into a series of jobs that individuals can perform. Even when jobs are well defined there is the need for further specifications such as when to start work, when to finish work, how to work, what materials and resources to use, how many units to produce, what to do with the completed units of work and so on.

All business processes like product introduction, order processing, stock reordering, even concurrent engineering, are based on a set of simple instructions and rules. Each process has a team of workers who carry out the process according to a set of local rules and guidelines. It is these small and basic business processes on which the foundations of complex organisations have been laid.

This organisation of productive activity in nearly all Western industrial organisations are based on Adam Smith's idea of division of labour. The division of work permits efficient completion of a job, or component or service but, in order to assemble components into a finished product, the means of integrating and co-ordinating the efforts of individual is also needed, thus not just creating and necessitating hierarchical organisational structures but also the highly articulated functional divisions of the corporate structure, based on the division of responsibility. (Chandler, 1977)

However, all this is different to the way in which natural organisms follow simple local rules. In summary the important point is that in comparing human complex adaptive systems like business organisations with complex adaptive systems in nature we find some similarities but there are significant differences also. The local rules obeyed by CAS in nature are *inherent* while the rules in human systems are *developed, adapted and changed* by human agents.

Is there any evidence of emergent behaviour? If so, is the behaviour stable?

To the best of my knowledge there is no comprehensive study on the 'emergent' behaviour of workers in business organisations. What exists is the empirical study of human behaviour in the work place. The Hawthorne research (Mayo, 1933) marked a turning point in the study of man at work. It demonstrated the importance of social factors to employees such as friendship, the good esteem of colleagues, recognition and attention. It was the start of a search into identifying fundamental factors that influence human behaviour and motivation, and it picked up great momentum in the years after the second World War.

We know that there is a natural tendency of people to 'self-organise' in teams or groups to achieve their common goal. There is also evidence of emergent behaviour among interacting individuals or agents in an organisational context. Emergent behaviour arises largely from the relationships individuals establish between themselves and not the formal hierarchy of the organisation. In command-and-control styles of bureaucratic environment one cannot and does not build or specify these relationships; they emerge naturally. These relationship are formed when agents interact with their environment and when relationships include other agents such as other employees, customers, suppliers and even competitors. In their effort to achieve their goals agents interact with their environment and adapt to it. They establish the necessary connections needed to fulfil their objectives. Even in the most authoritarian set-up informal relationships and leaders emerge. In a rigid hierarchical set-up authoritarian managers may to a certain extent thwart such behaviour locally but cannot control it on a wider basis. This is because the command-and-control model fails to fulfil the societal needs of humans to belong. The fact that most organisations have a dual system, i.e. the formal and the informal, has been sufficiently researched and documented in the literature. (Litterer, 1969; Woodward,

1965) The informal system evolves naturally to get around the bureaucracy and red tape and can be classified as exhibiting emergent behaviour.

Examples of emergent behaviour in human organisation can be generally found in *empowered teams of knowledge workers*. Bill Gates of Microsoft understands the importance of such relationships among his staff. He knows that effective network needs something more than smart nodes. It is how the nodes are connected that makes the difference. A major reason why Microsoft is so successful is because the company hires intelligent people and then provides an environment where their creativity can be unleashed. Bill Gate sums it up: "we hire the smartest people, and then let them do their thing."

Example of emergent behaviour can also be found in a football or rugby team, or in a team of doctors, surgeons and nursing staff in an operation theatre, or in a team of firemen. Members of teams abide by rules and set procedures but each match, operation, or fire presents a unique situation for those involved.

During an operation the team of doctors, surgeons and nursing staff continually monitor a patient's condition and prioritise problems as they arise, taking the most critical and life threatening first and dealing with it. If sudden complications arise and there are a number of simultaneous, life threatening problems, all members of the team collaborate, with each specialist tackling the problem pertaining to his/her domain. They do this by drawing on their own individual knowledge and past experience as well as by interacting and communicating with each other, receiving and providing instant feedback, as well as reacting to feedback from others on the spot.

One effort to capture self-organising emergent behaviour in a mob of 5,000 people is described by Kevin Kelly (1995). In his book he describes an experiment carried out by Loren Carpenter. The experiment demonstrates how a mob of 5,000 people sitting in a darkened auditorium can learn to respond quickly in unison to something as simple as playing a video game of Pong to something as complex as collectively flying and landing an aeroplane using a flight simulator.

We however need to find answers to the following question which arises from the discussions above:

Do people need a framework or guidelines for organising into communities that achieve organisational objectives or can they achieve them on their own?

There has been a great deal written recently about attempts to restructure organisations using some of the latest techniques, such as TQM and BPR; the latest being the 'team empowerment process'. There are reports of some successes but failures out-number the success stories by far. (Davenport, 1993; Hammer,1990; Hammer and Champy, 1993; Grant et al., 1994; Bartlett and Ghoshal, 1995; Rothstein, 1995). Failures largely occur when these have been applied as an add on to the top-down approach within a command-and-control organisation. This is because, in most cases, the segregated and rigid hierarchical structure of the command-and-control model of organisation blocks communication. In addition the decision making authority, the design of work, accountability and responsibility are either superficially modified or remain unaltered. The case study of Sportsgear by Rothstein illustrates these points (Rothstein, 1995). The failures seem largely the result of myopic vision.

Senge (1990) too has illustrated this by the Beer game example and other examples of company failure due to the myopic view of leaders whose concerns are focused on their own department or area. Where more participatory approaches have been used, fostering an environment underpinned by a learning culture, and in which employees are given the authority and information needed for emergent creative responses, the results have been success stories.

Senior management is also slowly learning the 'counter-intuitive' lesson that they need to involve others in decision-making. Most good organisations fall between dictatorial and consensus decision making in which the management invites lots of input, makes a decision and explains clearly why and also acknowledges the choices rejected and why. This approach builds credibility with people but does not achieve either shared meaning or shared goals.

Senior managers of organisations operating in dynamic and highly competitive markets are increasingly faced with the following dilemma, Simon (1995):

- How to protect their companies from control failures when empowered employees are encouraged to redefine how they go about doing their jobs.
- How to ensure that subordinates with an entrepreneurial flair do not put the well-being of the business at risk.

Simon suggests that managers need to combine traditional 'diagnostic control systems' with additional three control levers to reconcile the conflict between creativity and control, namely - 'belief systems', 'boundary systems', and 'interactive control systems'.

Unguided and unsupported teams on their own cannot produce the emergent innovative and creative responses needed in the current business environment. When members of teams are working on a problem for conflicting or even wrong reasons they are thereby pursuing different outcomes. This leads to the charge of hidden agendas, but is in reality the old problem of different blind people touching different parts of the elephant. Most problems require some resources to resolve them, even if only people's time. In a world of scarce resources, teams need support from experienced people. Management needs to move away from the command-and-control style imbedded in bureaucracy and take on the role of leader and facilitator, but creating a new order always faces intense opposition and an uphill battle for acceptance

Mere understanding and commitment from senior management is not enough. The entire organisation needs to understand and be committed, to generate the environment which encourages spontaneous creative responses. Empowerment radically changes working patterns and the use of human resources in the organisation. This means a fundamental departure from the past as the old principles no longer apply.

Collective responsibility is an attitude based on shared values and concerns. It is the result of a culture change. Empowering teams does not mean that all responsibility is handed over to the teams. Teams collaborate but at the same time they compete with each other. Limited competition is not bad but uncoordinated team behaviour can lead to chaos. When people whose job is to complete a project are brought together, they naturally organise themselves. The problem occurs in many organisations when the tendency to self-organise into informal results-oriented structures runs into conflict with formal organisational structures and the chain of command. The formal structures and the people who occupy the hierarchy may feel threatened by such self-organisation. Bureaucracy adds little value to the processes by which the work gets done.

Too many teams self-destruct due to personality conflicts, hidden agendas, bad processes and lack of resources. Some of these problems were encountered in the empirical study A & P Fund holding (Appendix 1). There remain many unanswered questions relating to 'self-organised' human structures. For example, if we eliminate hierarchical structures, identify business processes and divide people in teams to carry out these processes, the problem arises of how much freedom the teams should be given so that they remain productive and not fall into chaotic behaviour. There are problems if teams are fully empowered and there are problems if they have too little freedom.

Self-destruct behaviours do not contradict the points made above, They just exemplify the nature of self-organising, which is a function of the larger system in which it is taking place. There must be a payoff to the participants to behave in such ways, or we run into the risk of participants not taking the goal or project they are working on seriously. We need to look at such behaviours as symptoms of how the system they are part of operates. It is likely that parts of the system itself contain hidden agendas, and inefficient (though staunchly defended) processes. In other words, people will self-organise to the best of their ability, given their experience, information, resources, awareness and the environment in which they are operating. Recognising this, we should work at dealing with organisational symptoms that would foment such dysfunctional behaviour of the team members.

Given some of the negative consequences of naturally self-organising teams, the causes are more than just hidden agendas and personality conflicts. These are factors, but the bigger issue is that the localised, self-organising team does not, and cannot have, perfect information about happenings beyond its own boundaries. It does not know what is happening 'out there' that is going to cause it to self-destruct. This is the reason most organisms in nature become extinct. They are not able to prepare themselves for an environment that is coming upon them, but which they cannot yet see.

It is therefore essential that teams are given structure, particularly at an early stage. This means establishing boundaries by setting limits to what teams can and cannot do, as well as setting the extent of team accountability and responsibility. The main aim of setting limits should not be seen as controlling the teams but as nurturing them at the early stages and allowing them to evolve.

What CAS theory provides is a new insight for expanding and exploring the *possibility space* of human endeavour and creativity in organisations, which has so far remained stunted under the command-and-control model of management. It suggests that there is a need to create and nurture an environment with appropriate conditions and rewards for self-organisation and the emergence of human behaviour which is productive and rewarding for all concerned.

Are there examples of companies sliding into chaos caused by small disturbances?

Organisational history is witness to the fact that the intensity of competition increases as the environment in which most organisations operate becomes more and more complex. New technology has always added new dimensions to environmental complexity. Competition has been and still remains at the core of business success or failure. This is evident by the fact that more than one third of the companies on the original list of Fortune 500 no longer exist and the average age of the world's largest corporations is around forty years.(Kets De Vries, 1995)

Organisational history is also driven by chance, accident and historical coincidence. The design that wins (or survives) is not necessarily the best, whether in biological or technological systems. Some examples are:

- Dominance of VHS over BETA video recorders
- US Motor companies in general and GM and Ford in particular
- Decline and rise of IBM.

The question - what crucial factor determine the success or failure of a business in a dynamic environment? - is the subject of extensive research. Widely quoted research by Hamel and Prahlad (1989) studied a number of global companies in America, Europe and Japan. Their study compared successful companies like Honda, Komatsu and Canon in Japan with their respectively less successful counterparts in the West, namely General Motors, Caterpillar, and Xerox. The conclusion Hamel and Prahlad arrived at was that the key differentiating factor was the difference in the mental models guiding their respective strategies. They found that the less-successful companies followed conventional prescriptions and were guided by conventional wisdom and traditional practices. Such companies spend much of their effort maintaining strategic fit whereas more successful firms are flexible and adaptable to changing environments and continuously seek innovative ways to achieve competitive advantage.

Are there organisations capable of learning, evolving and affecting their environment?

Chapter six of the thesis addressed the concept of Learning Organisations in some detail. Organisations that are capable of learning, evolving and affecting their environment can be characterised by three factors: adaptability to changing environment, ability to learn about and from the environment, and ability to build shared vision and mental models. Such organisations learn to adapt to their changing environment. There are organisations capable of learning about (and from) their environment and adapting to it. A prime example of one such company is British Petroleum (BP) which has transformed itself in a decade from being an unfocused mediocre performer to a highly advanced learning organisation capable of changing its environments with a view to achieving desired goals, (Prokesch, 1997). A competently designed organisation can exhibit more intelligent behaviour than the sum of intelligence of its employees.

8.5 Conclusions

The science of complexity offers a new perspective for managing change. (Parker and Stacey, 1994; Stacey 1995; Lane and Maxfield, 1995). This insight into complex adaptive systems is valuable for organisational management today. It dissuades us from the conventional wisdom of forcefully seeking equilibrium, encouraging flexible and adaptable behaviour. In an ordered state of affairs when things are comfortable there is neither the incentive nor need for flexibility, adaptability and creativity, equally when systems fall into chaos then it is not possible to generate these abilities. Kauffman (1993) says that "systems deep in either the ordered regime or in the chaotic regime are probably neither capable of complex behaviour nor highly evolvable". Thus we learn from nature that it is at the edge of chaos that evolution results, creating new structures, forms and types of behaviour that did not exist before and out of which self-organisation emerges.

One may argue that the emergence of the "learning organisation" as a subject of study and discussion in management literature is a testament to the limitation of people's natural ability to self-organise. Such an argument results if the principles of CAS are applied too literally to human systems and there is great danger in doing so. However, as a metaphor the edge of chaos has great significance, for this means that success is not dependent on discovering pre-existing niches, but on continual efforts to create new structures and opportunities for further creativity and interaction.

Another challenge for organisations in this information age seems to be how to develop the ability to acquire and use information/knowledge more effectively than their competitors. The key to achieving this lies in designing and developing organisational information systems which exploit the advances in information technology. The next chapter reviews advances in IT.

Chapter 9 - New Information Systems

9.1 Introduction

This chapter provides an outline of a set of technologies that are now emerging and have heralded a paradigm shift in the domain of information systems. The transition from host-centric computing with centralised information processing paradigm to the distributed processing paradigm has been slow and cautious but there is clear evidence that client/server based distributed networked information systems are replacing rigid centralised and hierarchical systems. The two fields critically important for the design of information systems, namely, organisation theory and information technology are both experiencing similar changes. Chapters four - six of this thesis were devoted to discussing this paradigm shift in organisation theory from the *command-and-control paradigm* to the new *learning organisation paradigm* (LOP). A fundamental and somewhat similar change is also taking place in the field of information system design which appears to be following parallel developments and discontinuities. In contrast to the mainframes, corporate databases and application programs that dominated information systems since the 1960s, the new information systems are exemplified by the Internet, World Wide Web, multimedia, browsers, search engines and intelligent agents.

The full implications of these new information systems on business organisations is as yet difficult to fathom as Kelly (1997) puts it "...turning slowly beneath the fast-forward turbulence, steadily driving the gyrating cycles of cool technogadgets and gotta-haves, is a much more profound revolution - the Network Economy". The old cliché that only the tip of the iceberg is visible, and a lot of what is yet to come is under the surface seem to fit the situation. However, even at this early stage it is clear that the new information technology is going to revolutionise business organisations. Internet technology, when applied and used within an organisation, or between two or more organisations is referred to as *intranets* and *extranets* respectively. The intranet and extranet embody the shift to *virtual information*. They provide organisations with a collaborative computing environment, enhanced internal and external communication, and new sources for competitive advantages, the like of which has never been experienced before.

9.2 Conventional perspective

Before proceeding to discuss the new IT and its implication for both the LOP and the new information systems paradigm, we retrace our steps to understand the conceptual framework on which conventional computerised information system design is based and the hold it has had for well over 30 years.

> Close historical investigation of a given speciality at a given time discloses a set of recurrent and quasi-standard illustrations of various theories in their conceptual, observational, and instrumental applications. These are the community's paradigms, revealed in its textbooks, lectures, and laboratory exercises. By studying them and by practising with them, the members of the community learn their trade. (Kuhn, 1962).

9.2.1 Computing paradigms This section briefly outlines the shifts in computing paradigms within the short history of computer applications in business.

9.2.1.1 The host-centric computing paradigm When standalone mainframe computers entered business application from the late 1950s and early 1960s, they created the batch processing mode and centralised computing environment where most or all computing was done in a discrete data centre, housing the central mainframe computer. This host-centric computing model supported the prevailing command-and-control model of organisations. This fact held little or no significance at the time but with hindsight it is clear that *the centralised computing paradigm was in line with the principles of the hierarchical model of the organisations.*

By the 1970s with the advent of databases and advances in telecommunication technology, the concepts of networking, data sharing and real-time processing slowly gained acceptance. But the architecture of early systems, now often referred to as "legacy" systems, still followed the host-centric computing paradigm where the software and data for the applications continued to be housed in a single centralised mainframe computer. All computing tasks were done on the mainframe and timesharing techniques were developed to allow access by several users through remote "dumb" terminals.

9.2.1.2 The distributed processing paradigm A decade or so later, in the early 1980s, the microcomputer revolution began. In 1981 IBM introduced its first personal computer (PC) and in 1984 Apple introduced the Macintosh. The PCs and workstations were endowed with processing capabilities which in a short time began to match, and even excel, mainframes.

Most organisations quickly recognised the potentials of PCs, particularly of networked PCs, in their overall computing structure and a considerable evolution in computer-networking took place as the host-centric paradigm was gradually replaced by the "distributed processing" paradigm. Today, it is evident that apart from some very large companies, most organisations have abandoned mainframes.

In the distributed processing paradigm, communication was no longer restricted to to/from a central computer, but could take place between any two computers on the network. The most important characteristic of distributed processing was the interconnectivity which enabled PCs, workstations, minicomputers and mainframes to coexist in a seamless system, and allowed users to share files and applications.

Early versions of networks supporting distributed processing were 'peer-to-peer networks' where a collection of computers share information equally, and no one machine is the controller of the network. Every machine attached to the network has the same access rights as every other machine on the network and no centralised location exists for application storage. The main advantages of such a network are that it is inexpensive, easy to set up and maintain, and enables the sharing of data and processing. While such networks can be beneficial for small, non-critical collections of computers they however, had some significant disadvantages such as: limited data capacity; unable to support more than ten users; no central control, so that administration must be performed at each machine; no overall security; difficult to connect to variant platforms and operating systems (OS), and difficult to perform effective backups.

The real point of departure from centralised computing arrived only after the development of the client/server architecture. As PCs evolved and their users became more sophisticated the need to exchange more and more data/information, easily and efficiently from variant platforms became a prime concern. The client/server technology and applications created the much needed flexible platform and provided the essential tools which gave a new meaning to computer networking and distributed processing. The client/server based network and its components, are discussed next.

9.2.1.3 Client/server paradigm A client/server network is a combination of two sets of computers - one that holds shareable resources and the other that accesses these resources. Computers designated to store, process, and distribute data and resources are called *servers*. Other, more numerous computers, designated to access and use the data and resources managed by the server, are known as *clients*. This type of network uses a rigid authority structure to manage and maintain resources. The network is designed around the convention that application and data are stored on one or more servers that *users can access from any of the clients*. Each client has a specific level of access that enables it to use, view, or manipulate data on the server. The network in a client/server architecture contains only 3 basic building blocks: servers, clients and communication hardware and software devices, as described below:

9.2.1.3.1 Servers Servers provide services. They are the computers on a client/server network at which applications, data and resources are managed. Early in the client/server networking history, servers were mainly used to share the office printer or to store common files. Now servers are employed for innumerable other services, such as total network management, information service manipulation, security-based access control, and office workflow control.

A server can be centralised or dedicated. A centralised server is a single server on a network that handles all server-specific networking tasks, whilst a dedicated server is a single server on a multi-server network that handles one or more server-specific tasks. In order to perform these tasks, servers, like any other computers, require an operating system (OS). The first servers were UNIX-based workstations. Today the trend is for Windows NT to replace UNIX. Other popular network OS include Netware, Vines, OS/2 LAN Server and LANtastic.

9.2.1.3.2 Clients Clients are window-based PCs or workstations on a network that lets users access the servers' data and resources. They range from diskless workstations with monochrome screens to multimedia enhanced complete desktop systems. Today it is not uncommon for a network to have multi-platforms clients e.g. some Macintosh, some Windows and some UNIX. Multi-platform clients are able to exploit the capabilities of various platform-specific hardware and software while avoiding their deficiencies.

9.2.1.3.3 Communication devices These consist of the remaining hardware devices on a network that cannot be categorised as either servers or clients. Communication components include network interface cards (NICs), network conduction paths, modems, hubs, bridges, routers and gateways. Many other devices can be attached to a network to improve productivity, speed of access to data, applications and special resources. This includes network-enabled printers, CD ROM readers, faxes, modems and scanners. The network versions of these products are equipped with NICs built in or as add-on modules.

9.2.2 The information system design paradigm

The process of paradigm articulation for computer-based information systems design can be best achieved by identifying their conceptual roots and landmarks, as well as their analytical framework. All of these are summarised below.

9.2.2.1 Conceptual roots and landmarks

The basic principles of computation: *sequence, selection and iteration* proposed by the mathematician Alan Turing in 1940/50 initiated the development of electronic computing that led to commercial computing. However, in the 1950s and after, computers were considered to lie within the discipline of mathematics and be governed by its concepts. The application of computers was for numerical computation and the major quality problem was their computational *efficiency*. This was considered to be largely a mathematical problem and solutions were sought by developing efficient algorithms and data structures.

During the 1960s, in addition to numerical computation, computers were widely used for commercial transaction processing, and as their application increased in scope, size and importance, a new major quality problem emerged: *system unreliability.* This was attributed primarily to unstructured and to a large extent unplanned programming. As a result, the new discipline of *software engineering* was created. Mathematicians reasserted Turing's principles, and provided mathematical proofs in support. It was suggested that a programming language need only contain Turing's basic concepts to be complete. Edsger Dijkstra, in 1962 presented his famous paper in support of eliminating GOTO statements, during a conference on structured programming. Further inspiration for systematic design and implementation of software was drawn from conceptual principles of the already well established disciplines of mathematics and engineering.

In the 1970s, with software unreliability reasonably under control, an unprecedented surge occurred in the spread of applications of computer system in all walks of life and particularly among inexperienced business users. Inevitably, new quality problems emerged. One was the *lack of user friendliness* of information systems. Stewart (1974 a, b), Shackel & Shipley (1970), Martin, (1973) are amongst many who contributed to this analysis. Their research involved disciplines like anthropometry, physiology, intelligence and cognitive structures of Man. The problem was alleviated to a considerable extent, by a plethora of hardware and software solutions which soon appeared on the market, including devices like raster-scan displays, touch-sensitive screens, pull-down menus with icons, and object-oriented languages.

As the number of data processing applications increased, the emphasis switched from developing simple transaction processing applications, e.g. order processing, stock control and accounting, to applications characterised by considerable *fuzziness* or excessive *complexity* of information system requirements. It became very difficult and time-consuming to identify and precisely specify user requirements for such systems, particularly since in some cases the users themselves were not clear and/or the requirements changed so rapidly, (e.g. with markets and consequent organisational changes) that it was considered not practical to spend resources on specifying a moving target.

As a consequence, many systems were designed and implemented without the benefit of properly defined requirements. Not surprisingly, such systems did not add value to business processes. They only increased operational costs.

The other problem with information system quality that emerged as critical from late 1970s onwards was more serious yet little recognised. Many information systems, although designed using state-of-the-art structured methods, when commissioned, could not meet user requirements and expectations. In spite of all the best structuring and modular design, systems *lacked relevance.* This lack of relevance, with hindsight, is easy to explain if not to justify.

By the 1980s many organisations had well established data processing departments which were developing business applications using *structured methods* (discussed in the next section). Soon it became common for many 'user departments' to develop their own computing systems. Rapidly, as the number of computers of different make and specification increased in each organisation, many 'islands of automation', unable to communicate with each other, were created. This critical quality factor became the *lack of system integration.* The consequent lack of common purpose substantially reduced the capabilities of systems to provide low-cost, high-quality information for decision makers.

The second important and rather unexpected failure of the 1980s was the *inadequate performance* of information systems. As a rule, designers overestimated the capability of real-time systems to process voluminous business transactions within the tight time constraints imposed by the information systems environment. It was therefore not uncommon to find that a transaction processing system, when implemented, failed to process the required load and then at best, went into the expensive cycle of modification and/or enhancement, or at worst was scrapped (Rzevski, 1989).

9.2.2.2 The analytical framework

Beneath the traditional perspective of the information systems design discipline lies an analytical framework that:

- captures the allegiance of a community dedicated to its articulation

  and

- governs the specification of design tools to define the world from the perspective it supports.

Analytical frameworks with these properties are paradigm. The conventional perspective of computer-based information systems is based on Anthony's (1965) schema for planning and control systems (which over the years achieved a paradigm status). In 1970 Zani (1970) borrowed Anthony's conceptual framework to apply it to the field of Management Information Systems (MIS). The adoption of Anthony's paradigm contributed significantly to the development of an information management discipline (Wiseman, 1985). Researchers, consultants and practitioners refined and expanded the paradigm to cover new cases.

9.2.2.2.1 Structured methodologies Structured methodologies were developed for the analysis and design of information systems and some of the best known early ones are described in Yourdon & Constantine (1979), Gane & Sarson (1979) and Jackson (1983). A more recent example is the Structured System Analysis and Design Method (SSADM), which was made mandatory for all UK Government projects in January 1983.

Attempts to formalise the Information System (IS) design process as a sequence of well defined activities, drew heavily both on 'scientific management' and Anthony's conceptual framework as possible sources of guiding principles for a new paradigm. These, together with the mathematical treatment and notion of optimality, resulted in a prescriptive approach to IS design. The phases of programming, optimisation, testing and implementation have their roots in the engineering discipline, and include:

- The prescriptive sequence of stages/phases of the so called *Waterfall model* of the system development life-cycle, begins with the system developer conducting a detailed analysis of the problem situation by employing a number of (subjective) techniques of data collection pertaining to the system under investigation, e.g. interviews, observation, record/data analysis.

- The finding are then systematically documented using various graphical techniques such as Data Flow Diagrams, Entity-Relationship Models, Entity Life Histories, which together constitute the requirement specification of the proposed system. Design progresses systematically, top-down, each step well documented and reviewed.

- Coding is modular and allowed to begin only after the design, documentation and test schedules have been approved.

9.2.2.2.2 Limitation of structured methods Centralised, business-driven information systems, developed using structured methodologies, are fully compatible with hierarchical command-and-control organisational structures and work well under stable external conditions, but the question is: *can structured methodologies cope with the problems that are likely to face information systems and software communities in the 1990s?* That is, can we develop information systems to meet business requirements in a world characterised by rapid change?

Structured methodologies that were developed as an answer to the problems of the 1960s have been unable to cope with the conditions prevailing in late 1970s and 1980s and are totally unsuited for designing IS today. It is contended that this approach is now out of date and should be abandoned, except in situations in which the command-and-control organisational model is preserved. Several new factors have conspired since their advent, and the major limitations of structured methodologies, brought to surface by recent developments, are as follows:

- Structured methodologies, as already discussed, are based on 'scientific methods'. They employ conceptual principles that are well tried and tested and give good results when applied under stable conditions like mass production, long product development cycles and when applied to well defined problems, but are not suitable when frequent changes in demand and requirements is the dominant factor.

- The thoroughness of top-down decomposition and the emphasis on comprehensive documentation, that helped to improve system reliability, causes long development times; long in relation to the current rate of change of user requirements.

- The requirements specification expressed in numerous pages of text and voluminous diagrams, even if organised in a systematic manner, does not give users of the new, complex system an adequate opportunity to check whether they have articulated their needs and expectations correctly.

- Conventional IS developments are being seriously questioned because of their limitations of handling only structured data and text.

The trajectory of the development outlined above, from past to present and into the immediate future is very eloquently summarised by Schwartz and Leyden (1997) as follows:

> From a historical vantage point, two developments start around 1980 that will have profound consequences for the US economy, the Western economy, then the global economy at large. One is the introduction of personal computers. The other is the breakup of the Bell System. These events trigger two of the five great waves of technological change that will eventually help fuel the long boom.
>
> The full impact can be seen in the sweep of decades. In the first 10 years, personal computers are steadily adopted by businesses. By 1990, they begin to enter the home, and the microprocessor is being embedded in many other tools and products, such as cars. By the turn of the century, with the power of computer chips still roughly doubling every eighteen months, everything comes with a small, cheap silicon brain. Tasks like handwriting recognition become a breeze. Around 2010, Intel builds a chip with a billion transistors - 100 times the complexity of the most advanced integrated circuits being designed in the late 1990s. By 2015, reliable simultaneous language translation has been cracked - with immediate consequences for the multilingual world.
>
> The trajectory for the telecommunications wave follows much the same arc. The breakup of Ma Bell, initiated in 1982, triggers a frenzy of entrepreneurial activity as nascent companies like MCI and Sprint race to build fiber-optic networks across the country. By the early 1990s these companies shift from moving voice to moving data as a new phenomenon seems to come out of nowhere: the Internet. Computers and communications become inextricably linked, each feeding the phenomenal growth of the other. By late 1990s, telecom goes wireless. Mobile phone systems and all-purpose personal communications services arrive first with vast antennae networks on the ground. Soon after, the big satellite projects come online. By 1998, the Iridium global phone network is complete. By 2002, Teledesic's global Internet network is operational. These projects, among others, allow seamless

connection to the information infrastructure anywhere on the planet by early in the century. By about 2005, high-bandwidth connections that can easily move video have become common in developed countries, and video phones finally catch on (Schwartz and Leyden, 1997).

9.3 New information technology

The idea of an interconnected computer network capable of supporting multiple users with simultaneous access to the same information, had long been proposed by scientists who recognised its potential before technology made it possible. The roots of the term 'Internet' can be traced back to the technology of *Internetworking*. Since the early 1970s there has been a concern regarding *lack of system integration* (see section 9.2.2.1). Internetworking, developed in response to this concern, refers to the technology that enables interconnection of many disparate physical networks enabling them to work as a transparent, co-ordinated unit. The major contributions to the concept of internetworking came from ISO (International Standards Organisation), CCITT (Comité Consultatif International de Téléphonie et Télégraphe, and the USA Department of Defence (DoD). The Internet has emerged spontaneously, as computers and telecommunication became inextricably linked, heralding a new paradigm, one that affects not just computing but the whole world of communications, information, learning and knowledge.

9.3.1 The Internet

Evolution of the Internet as discussed above dates from the 1960s. The Internet is an OSI (Open Systems Interconnection) 'network of networks' based on client/server technology designed to allow access to application ports in hosts. Open Systems network specifications, as opposed to proprietary networks, are publicly available.

The Internet is also referred to as the 'Information Superhighway' and is based on packet-switched networks, that is data/messages fragmented. The subparts, or packets, are discrete data units routed and reassembled at the other end of a transmission, permitting several users to share the same connection. This mode of data transmission is different from other kinds of transmission. For example, a telephone network is a circuit switched network where a connection between two nodes, once initiated, remains a dedicated unbroken connection, whether data is being transmitted or not, until disconnected. Packet-switched networks enable the most efficient means of data delivery by utilising unused network resources, thereby making the best use of network resources.

In 1969 an early packet-switched network was implemented at the US Department of Defence's Advanced Research Project Agency (DARPA). In the early 1980s, a meeting of DARPA, the National Science Foundation, and scientists from various universities resulted in the development of the Computer Science Research Network (CSNET). In 1982, ARPANET (the ground-breaking network first launched in 1969 for DARPA) replaced its original Network Control Protocol (NCP) with the Transmission Control Protocol (TCP) and Internet Protocol (IP). TCP/IP was developed in the 1970s, when experiments in internetworking were being carried out. It was not owned by any company and was published as an *open standard.* CSNET and ARPANET were later connected through a gateway called Value Added Network (VAN). The VAN, coupled with free access to TCP/IP, heralded the beginnings of what is now known as *the Internet* (Garrett et al., 1996). Having spawned the Internet, ARPANET finally ceased to exist in 1990.

TCP/IP TCP/IP refers to a collection of protocols which supports a wide variety of underlying computer platforms and technologies. Its robustness has been demonstrated on a large scale since it forms the base technology for the global network 'The Internet'. The main objective of TCP/IP was to connect a number of different client and server based networks, designed by different vendors, and deliver the basic services that everyone needs such as: file transfer, electronic mail, remote logon. The initial philosophy guiding the design of this suite of protocols was to develop a communications web that could survive nuclear attack. That is, if the communication network sustained damage the protocol will be robust enough to automatically recover from any node or telephone line failure. A further characteristic of TCP/IP is that it allows the construction of large networks with minimal central management. In common with other communication protocols, TCP/IP is based on the Open Systems Interconnect (OSI) and has a layered architecture. The two fundamental protocols in TCP/IP and their functions are:

- **TCP (Transmission Control Protocol)** TCP provides the dedicated connection (*virtual circuit*) between computers. It is a connection-based protocol that provides reliable, full duplex data transmission between a pair of applications.

  TCP performs the work of separating data into packets at the sending end and reassembling the packets in their original form at the receiving end. It is responsible for verifying the correct delivery sequence of data from client to server. Data can be lost and retrieved in the intermediate network and TCP was designed to recover from node and line failure. TCP detects errors or lost data and triggers retransmission until all the data is correctly received.

- **IP (Internet Protocol)** The set of conventions used to pass packets from one host to another is known as Internet Protocol. IP is responsible for sending datagrams across the Internet and ensuring that all packets reach the right destination. It forwards each packet based on a four byte destination address (the IP number). The Internet authorities assign a range of numbers to different organisations. The organisation can assign groups of numbers to departments. IP operates on gateway computers that move data from department to organisation to region and then around the world.

- **Sockets** are the software packages (of subroutines) that provide access to TCP/IP on most systems.

In addition to TCP/IP there are two further layers of packet-switched network - the Application Protocol Layer and the Physical Network Layer. The former consists of e-mail, File Transfer Protocol (FTP), Telnet (a remote access protocol) etc., the latter supporting specific network media such as Ethernet, FDDI (Fiber-Distributed Data Interface) etc. Combinations of hardware and software known as Bridges and Routers are also essential to a packet-switched network. Whilst both perform the function of routing packets their difference lies in their capability. Bridges work only on identical physical networks whereas routers are more 'intelligent' as they can identify and adapt to different networks.

The Internet Protocol was developed to create a *Network of Networks*. TCP/IP ensures that all types of vendor systems can communicate. Individual machines are first connected to a LAN. Popular LANs in use include: Ethernet, Token Ring, ARCnet and FDDI LANs. Data can be sent across LANs using 'phone lines, cable TV services, or by using existing internal networks of an organisation e.g. IBM's SNA. Newer high speed options include: ISDN (Integrated Services Digital Network), frame relay, FDDI, ATM (Asynchronous Transfer Mode). TCP/IP shares the LAN with other users such as a Novell file server, Windows for workgroup peer systems. One device provides the TCP/IP connection between the LAN and the rest of the world. Cable TV and telephone companies are competing to build Information Superhighways.

During the 1970s and early 1980s, the Internet was very small in terms of the number of users. In those early years, the only way one could get access to the Internet was through a university or government agency and a few research organisations. Dial-up users would dial into the universities or government network to access a computer that was connected to the Internet. Businesses certainly had no access to the Internet. When companies like UUNet and PSI began building Internet network systems that could be connected to the existing Net, the first commercial access began. Even a few years ago, in the early 1990s, the applications and types of connections used to access the Internet were very limited. A user with dial-in access, for instance, would be accessing the Internet through a Shell account[5], which is text based; no graphical access existed for Internet services (Garrett, 1996).

In the 1990s Internet software improved in usability and within this period the Internet has grown exponentially, with millions of users worldwide. The main characteristics of the Internet are as follows:

- Internet is a working system which has emerged spontaneously as a result of the union between computers and telecommunications, and which continues to evolve.
- It is robust and has cross platform capabilities.
- Internet uses packet-switching to send messages/data. This allows various packets of the same message the flexibility to take any route

[5]A text-based account on UNIX machine that allows the user to remotely access files, compile binaries and run programs etc.

through the network to be reassembled at their destination, thus enabling messages to get through even if part of the network is down.

- There is no central control or authority for managing the network. All computers on the network are equal in status. There are, however, some agencies which take the role of overseeing standards in terms of protocols e.g. CERN, and W3 Consortium. The latter was set up in 1994 at the MIT and is responsible for co-ordinating Web development worldwide and for introducing standards for a whole range of issues.

- The principles on which the Internet is based provide a sound foundation for intranets and extranets for business applications.

The most important development in network interconnectivity over the last couple of years has been the Internet's World Wide Web. The Web has enabled exponential growth of the Internet and has produced profound changes in the Internet's population, generating a great deal of media interest.

9.3.2 World Wide Web (also known as **WWW, W3,** or just the **Web**)

The Web is a distributed browsing and searching system initially developed at CERN (Conseil Européan pour la Recherche Nucléaire, which is a collective of European high-energy physics researchers) by Tim Berners-Lee to enable him and fellow researchers at CERN to share information. He created the first Web software in October 1990. World Wide Web was first made available outside CERN on the Internet in summer 1991.

9.3.2.1 Characteristics of the Web The Web is fertile with hypertext activity consisting of a collection of linked documents that reside within the Internet. A hypertext document contains *links* that lead readers quickly to other parts of the document or to other related documents, and thus enables the readers to chart a personal trail through information. Vannevar Bush, (President Roosevelt's science advisor), first proposed such an interactive cross-referenced system in 1945, and computer pioneers like Doug Engelbart and Ted Nelson pushed the technology towards that vision. Early efforts were called *hypertext* because they allowed textual information to be linked in *nonsequential* ways (Beekman, 1997).

9.3.2.1.1 Hypertext This is a term created by Ted Nelson to mean non-sequential text. Conventional text media like books are linear, or sequential; they are designed to be read from beginning to end. Even on the computer, most applications commonly in use today, such as word processors and drawing programs, have WYSIWYG editors - that is what you see (on the screen) is what you get (on the printed page). But if a document doesn't need to be printed, then it does not need to be structured like a paper document. When the objective is to focus on the relationship of ideas rather than the layout of the page, then we may be better off with a dynamic, cross-referenced super document that takes full advantage of the computer's interactive capabilities. A hypertext document is equipped with all the basic features of regular text i.e. it can be read, edited, searched and stored, but it has one additional feature, that it contains links to other documents embedded within the text. Web is based on hypertext as its means of responding to the needs of users.

There are millions of hypertext documents on the Web, and each document has a unique name called URL (Uniform Resource Locator) or simply the Web address. By linking related documents, the Web makes it very easy for users to locate information anywhere in the world. Hypertext links are called 'Hyperlinks'.

9.3.2.1.2 Hyperlink Hypertext documents can have links to other documents. Continually selecting links takes users on a free associative tour of information. Hyperlinks create a virtual web of connection. It is this ease of access that has captured the interest of the general public and has popularised the Web on the Internet.

One of the major reasons for the Web's proliferation is its simplicity. Despite intense media interest "the Web is profoundly primitive technology. It treats today's powerful computers as if they were the rudimentary machines of the 1970s. On one side is the Web server, an idiot savant that responds to every request by sending out a hypertext document. On the other side is the Web client, a dumb terminal that simply displays documents and waits for mouse clicks." (Steinberg, 1996).

While what Steinberg says is technically accurate but fundamentally untrue, it is Kevin Kelly who really captures the real value and power of the Web as an evolving organism when he writes:

> Dumb power is what you get when you network dumb nodes into a smart web. It's what our brains do with dumb neurons and what the Internet did with dumb personal computers. A PC is the conceptual equivalent of a single neuron housed in a plastic case. When linked by the telecosm into a neural network, these dumb PC nodes created that fabulous intelligence called the World Wide Web. It works in other domains: dumb parts, properly connected, yield smart results (Kelly, 1997).

9.3.2.1.3 Hypermedia A Hypermedia document contains links not only to other hypertext documents but also to other media. In addition to hypertext the WWW offers *hypermedia information* environments that deliver text, graphics, video and sound while providing universal access to documents. The ideas underlying the Web's hypermedia technology originated in HyperCard, a software package for the Macintosh, which can combine text, numbers, graphics, animation, sound effects and music in hyperlinked documents.

9.3.2.2 The Web and electronic commerce From the perspective of business organisations, their main interest in the World Wide Web, in its present form, is that it can be used to publish information such as product catalogues for other users to view, transforming the WWW into a selling tool, thus enabling existing and potential customers to make purchasing decisions without having to request information or brochures.

However, in the long term it is envisaged that the WWW will develop into one of the world's major electronic trading environments and the possibility of conducting business over the Internet is an area which has received a great deal of recent attention. (Cronin, 1994, 1996; Verity, 1994; Eng, 1995; Moroney & Matthews, 1995). Tim Berners-Lee sees the development of the Web in four main areas:

> The first is Web publishing - still dominated by few write, many read paradigm.
>
> Next come intranets, which still tend to be mainly internal publishing, although tools are there to make intranet a really collaborative medium.
>
> The third area is electronic commerce, which requires trust.
>
> And the fourth is education and training. The technology industry is not as excited about training as it deserves. (Riley, 1998)

In an interview by Gary Wolf (Wolf, 1996) Steve Jobs predicts that designing, building and deploying object-oriented Web interface applications will be the key to keeping-up with the exponential growth of the World Wide Web, and it is commerce, he says, that will fuel the next phase of the Web explosion.

> Almost every major player in the computer industry is looking at ways to breathe life into the Web. These efforts, many of them still rough, seem to fall into three stages. The first stage involves making the client and servers smarter. On the server side, this means linking Web sites to information stored in local databases and spread sheets. On the client side, it requires making every application you use - not just your specialised Web browser - able to access the Web.
>
> Things start to get much more interesting in the second stage. The client and server will begin to exchange not just data, but programs. These little applications, or applets, will allow for new, powerful kinds of interaction. A stockbroker's Web site might send out an applet that acts as a front end for displaying a ticker

> tape at the top of your screen. An architect's site might provide a front end that lets you experience a 3-D walk through a planned building. You'll no longer have to worry about whether you have the capability to display a new kind of data type because the "capability" will be sent to you with the file.
>
> In the final stage, the distinction between clients and servers will begin to blur. Code will flow in both directions. A client might send a small program to the server to perform a specialised database search. Applets will begin to resemble agents. (Steinberg, 1996)

9.3.2.3 World Wide Web Consortium The World Wide Web Consortium, made up of academics and user organisations and based at Massachusetts Institute of Technology, was set up in 1994 with Tim Berners-Lee as its director. Its main aims are: to safeguard the Web from becoming fragmented, to provide the technical know-how and direction to enable it to evolve, and to improve the Web access and facilities for users. In an article, which is partly based on a symposium organised by the Rutherford Appleton Laboratory and *Computer Weekly* for the World Wide Web Consortium, John Riley (1998) reports on the work that is already going on at the W3 Consortium to improve the Web for users as follows:

> CSS (Cascading Style Sheets) is a new style sheet language for specifying the layout of documents on the Web and giving content providers more control over colour, text indentation, positioning and other aspects of style.
>
> New 'Web collections' technology aims to provide more ways of providing relationships between Web documents.
>
> The new Computer Graphics Metafile (CGM) standard aims to open the possibility of searching graphics on the Web.
>
> Performance problems, caused by the very success of the Web, are being looked at, through new versions of HTTP and automated distribution of copies of sites across the Net.
>
> The personal censoring of unsuitable material can be managed by the PICS (Platform for Internet Content Selection) rating and filtering method.
>
> There is also work on ways of dealing with the limitations of imprecise addressing information, which HTTP currently ignores.

The Internet in general and the interactive multimedia environment of the WWW in particular are indicative that the new IT is set to bridge the chasm between the separate and relatively isolated cultures of the past. The culture of film, television, and professional video is merging with the culture of data processing, computers, and programming, and in doing so presents a radically new perspective for the design of interactive multimedia information systems.

> This culture isolation cannot last. The desktop revolution that shook the mainframe world, and then the print world, is spreading into film, television, and industrial video. Meanwhile, the new visual and sound possibilities of computers are changing the way professional programmers think about computing. They are learning new ways to use sound, colour, motion and drama to interact with users.
>
> From the perspective of computing, what is occurring is a shift away from a strict definition of the computer as a "data processing engine" to include the computer as a delivery platform for *content.* In the new paradigm, users do more than crunch numbers and retrieve data; they acquire *knowledge* from desktop computers using all their senses. (Shaddock, 1992).

The Web has led the Internet's transformation from a text-only environment into an interactive multimedia landscape.

9.3.2.4 Interactive multimedia

Interactive multimedia is the driving force behind the phenomenal popularity of WWW. Web publishers are discovering the advantages of cleverly designed interactive multimedia pages on their Web site. By incorporating directly supported graphics, sound effects, digitised video/voice, animation and Java-applets, multimedia authoring software helps in creating visually impressive, highly interactive, and dynamic pages that entice users to visit a page repeatedly. Multimedia authoring software serves also as a glue that combines documents, created and captured, with other applications. The most widely used interface for authoring tools is the card-and-stack interface originally introduced with Apple's HyperCard.

The combination of text, numbers, graphics, animation, sound effects, music, and other media in a hyperlinked document, is often described not as a hypertext system, but as a hypermedia system. "Hypermedia tools focus on the interactive capabilities of computers. Unlike books, videos, and other linear media, which are designed to be experienced from beginning to end, hypermedia allows users to explore a variety of paths through information sources. The combination of multimedia and hypermedia has an almost unimaginable potential for transforming the way we see and work with information". (Beekman, 1997). Depending on how we choose to use it, the term *hypermedia* might be synonymous with *interactive multimedia.*

Multimedia has depended much on the growth of high-performance computer and high speed digital transmission technologies. According to Baynes (1997) until few years ago most multimedia programs were of little use to anyone outside a computer research lab. The main reason for this was the low bandwidth of early modems. Before the Web most users encountered multimedia applications on CD-ROM. In the contest for multimedia delivery the web has the interactivity, but CD ROM has the capability to deliver material in a timely manner. The World Wide Web, using human computer interfaces which are more friendly than the majority of business systems, suddenly made multimedia very attractive. The low transmission rate of modems poses a problem in accessing large data files from the Web. Viewing a good quality video is far from satisfactory and this is also the main reason for the limitation on Web file size.

This however, is about to change with the Cable modem, capable of providing bandwidth of up to 30 million bits per second, compared to the 28.8 thousand bits per second of an average modem, and which will initiate a multimedia computing revolution. "At its simplest a cable modem combines the new telecommunications infrastructure installed by cable TV operators such as Nynex, Mercury, and Cable and Wireless with modem techniques to provide bandwidth of up to 30 million bits per second.....initially a single cable modem will be shared between several houses or offices, even so Internet access will be hundreds of times faster than is currently the norm. And when this happens multimedia will spark a computing revolution..... the boundaries between TV and PC hardware, Internet, Web and commercial TV services will blur and rapidly disappear. Mass multimedia delivery content to home via cable services will not follow the passive model of pushing sound and pictures towards a viewer but delivering rich interactive content at the command and control of the user." (Baynes, 1997).

Interactive multimedia software is delivered to consumers on a variety of platforms: multimedia computers - Macintosh and Window based PCs with high quality colour displays, fast processors, large memories, CD-ROM drivers, speakers, sound cards. The only requirement on the user's side is to have a browser that supports interactive multimedia features. Client pull/server push can be used with most popular browsers such as: Netscape Navigator, the Internet Explorer, and various versions of MOSAIC.

9.3.3 Browsers A browser is a software application that translates HTML and enables the user to view a series of connected information of which the best known example is the World Wide Web. Web browsers are client programs essential for anyone who wants to explore the Web. Web browsers allow different computer systems to view the information on the WWW. As mentioned earlier, the WWW was first conceived in 1980 at the European Laboratory for Particles Physics by Tim Berners-Lee of CERN. It was nearly a decade later that he submitted a formal proposal to CERN for an Information Management system which later acquired the name World Wide Web. By December 1990, the first browser had been written, using the NeXTStep platform.

Some of the best known commercial browsers today are Netscape Navigator, Internet Explorer and Oracle PowerBrowser. Marc Andreessen, while working at the University of Illinois, created the browser Mosaic which is still being developed at the university. However, he left the University in 1994 to form Mosaic Communication Corporation. By the end of the year the company had changed its name to Netscape Communication Corporation and released the browser known as Netscape Navigator. Although Netscape was the first commercial browser it is by no means the last. Other companies released similar products. Microsoft included a rudimentary browser - Internet Explorer 1.0 with Windows 95; soon after, Internet Explorer 2.0 was released with proprietary enhancements.

A browser provides the means of accessing information and communicating on Internet. Its most basic function is to access the information stored on remote servers using HyperText Markup Language (HTML). HTML, a subset of Standard Generalised Markup Language (SGML), tells the browser what type of information to display (list, heading, link) and then lets the browser determine the best way to display the information.

Many features of browsers are so pervasive that they are considered standard. The most basic level of compatibility is HTML compliance. HTML is a constantly evolving standard that controls the appearance of documents viewed on the Web. All current browsers support HTML 3.0. A typical Web browser has the following characteristics: it has a mouse-driven point and click graphical interface; displays hypertext and hypermedia documents in a variety of font, colour, and format; supports sound, video, images and animation; makes hypertext and hypermedia links to other documents and keeps a history of travelled hyperlinks; stores a list of URLs in a 'bookmark' and retrieves them for later use on request; maintains a window history of all documents viewed during any session, offering a quick way to return to a document viewed many hyperlinks earlier.

Whilst HTML provides a variety of text formatting capabilities, images too play an important part in conveying ideas and are an integral part of the capabilities of any browser. Images come in many different formats, but most browsers support all of them. GIF87 and GIF89 (Graphic Interchange Format, versions 1987 and 1989) are the formats used for storing images with few colours.

The three key Web-related standards that control the movements of data and information between user, browser and Web server are as follows:

- HTML defines the formatting of pages of information and how the Web Browser will display the information to the user. It is a scripting language that does not contain any branching or looping functions. A browser such as Navigator or Mosaic simply loads an HTML file (designated by .HTML or .HTM) and interprets the information in it.

- HTTP (HyperText Transport Protocols) define how the Web browser and Web server exchange pages of information and other data objects. It is the simple request/response protocol which utilises the TCP/IP and enables the transfer of data from plain text, hypertext and images to any other form or combination.

- CGI (Common Gateway Interface) is a method of defining how dynamic information is exchanged between external applications (outside the Web site) such as information stored in legacy databases, and the Web server.

With advanced programming, the browser can let users manipulate data or run applications.

9.3.4 Search Engine Searching and cataloguing tools, known as search engines, are utilities that enable the user to find any word, concept, or file on a network using a variety of criteria, including date, size, and physical location. One of the earliest search engines was Yahoo!. Today a number of search engines and directories exist; these include Excite, Lycos, Infoseek, Magellan, Open Text, Alta Vista, HotBot and more than a hundred specialised search engines. The search engine Netscape's phenomenal rise has spurred other Internet companies to offer their products widely.

Search engines are programs that search Web pages, extract the hypertext links on those pages, and automatically index the information they find, to build a database. Electronic searches can be accomplished in a number of ways, but all start the same way. A user requests some information i.e. makes a query. A search engine is activated by a query and begins by searching the files. Increasingly most documents are HTML pages, but search engines can access a variety of file formats.

Each search engine has its own set of rules guiding how documents are gathered. Some follow every link on every page that they find, and then in turn examine every link on each of those new home pages, and so on. Some ignore links that lead to graphics files, sound files, and animation files; some ignore links to certain resources such as databases; and some are instructed to look primarily for the most popular home pages. Companies such as AltaVista and Verity, known for their sophisticated search engines, have developed advanced search mechanisms.

9.3.5 Intelligent agents

The study of situated systems that are capable of reactive and goal directed behaviour has generated much interest and attention over the last decade. One approach to the design of such systems is based upon agent oriented architecture. Nicholas Negroponte (1970), Alan Kay (1984) and Marvin Minsky (1985) pioneered the concept of agents. In the last few years there has been an explosion of interest in the issues concerning the design and implementation of agents that can make rational decisions and act autonomously in time-constrained, multi-platform and multi-agent environment. The research is being carried out in such diverse fields as software engineering, robotics, knowledge representation, knowledge-based systems, database designs, problem solving, machine learning, cognitive science, psychology, computer graphics, human-computer interaction, as well as art, music and film. The intersection of research interests from so many diverse areas presents unique opportunities for the integration of ideas (Riecken, 1994).

The idea that mind is a society of agents that collectively generates our behaviour without the need for centralised control is immensely powerful yet simple and plausible (Minsky, 1985). It triggered the development of a new paradigm in Artificial Intelligence (AI). Each agent is designed using current AI technology, including knowledge-based systems, neural networks, genetic algorithms and fuzzy logic. Some agents can communicate with each other, work in parallel on complex tasks, and even clone themselves.

An agent is a computer program that is given a specific task that can be completed without user assistance. Agent technology is increasingly available on the Internet. "The agent view provides a level of abstraction at which we envisage computational systems that are able to interoperate globally on "the Net". It abstracts from aspects like the hardware or software platforms of various components or the internal structure, methods or processing of these components, focusing attention on how complex, heterogeneous, distributed and evolving systems can be built from interoperable and reusable building blocks." (Barbuceanu and Fox, 1996). Programs that automatically search the Internet and download specialised information are an example. There is a rapidly growing population of software robots known as *bots* on the Internet that exhibit many of the characteristics of agents. The information on the Web is growing at an exponential rate and we are being given access to billions of items of information. It is already becoming impossible to search through all the available information. Instead of having to sift through it, users can depend on agents to roam the networks 24 hours a day, identifying and retrieving the needed information (Beekman , 1997).

9.3.5.1 Definition of intelligent agents Wooldridge and Jenning (1995) distinguish and propose two usages of the term 'agents', the first *"most general usage is to mean an AUTONOMOUS, self-contained, REACTIVE, PROACTIVE Computer system, typically with a central locus of control, that is able to communicate with other AGENTS via some ACL (Agent Communication Language)"*. ACL is a programming language which could be either proprietary or some standard means such as KQML (Knowledge Query and Manipulation Language). The second a *"more specific usage is to mean a computer system that is either conceptualised or implemented in terms of concepts more usually applied to humans (such as beliefs, desires, and intentions)."*

Norman and Long (1996) further extended this definition by adding that: "Autonomous agents in the real world must be capable of asynchronous goal generation..... The state of the environment may change at any time such that pursuing a goal may no longer be realistic, required or even possible. A single goal may need to be satisfied more than once, or periodically, depending on how the environment, the agent and the relationship between them (i.e. the domain) change over time. So, for an agent to be effective in such a domain, it must be goal autonomous. In other words it must be capable of: (1) generating goals on the fly; and (2) altering its focus of attention, i.e. the goal it is presently acting on, as its goals and the priorities of those goals change."

A more detailed discussion on the definition and taxonomy of an agent is covered in Müller et al (1997).

9.3.5.2 Characteristics of intelligent agents An intelligent agent, as stated earlier, is a piece of software, but there are a number of characteristics that makes intelligent agent software different from other computer software. The first four characteristics of those listed below are essential features of intelligent agents, while the next four characteristics are also useful and more often than not present in software classified as an agent (Gilbert, 1997).

- Agents are autonomous.
- Agents are goal driven.
- Agents are reactive.
- Agents could be driven by scripts or rules. They could also be programs which are driven by goals.
- Some agents interact and communicate with other agents.
- Some agents are adaptive i.e. they learn from past experience and modify their behaviour.
- Some agents can be mobile i.e. they move from one machine to another in order to carry out their task.
- Agents can strive to be believable. In order to do this they take a visible form and interact by expression of emotion or personality.

9.3.5.3 Intelligent agent applications The agent-based approach to software interoperation is now a practical technology. Agents are finding applications in many traditional business areas too. As Singh (1996) observes: "Like many previous artificial intelligence (AI) ideas, as agent technology matures, it is moving into more traditional computing applications. These include old chestnuts such as information management, enterprise integration over heterogeneous databases, concurrent engineering and so on. The rapidly advancing infrastructure for computing and communications has also opened up several new applications, for which also agents are a natural technology. These include accessing and using open information systems, agile manufacturing, electronic commerce, and so on. Lastly, certain applications that have been known for several years are picking up steam and are again natural targets for agent technology. These include robotics, space and aeronautics systems, and control systems in general." What makes agents applicable in such varied applications is that they are natural loci of autonomous activity. Some typical agent-enhanced application already in use are:

- **User Interface** Alan Kay who pioneered and revolutionised PCs by developing the icon based user interface also developed one of the first agent, NewsPeek, at MIT's Media Lab in the early 1980s. He now predicts that Internet and Web will drive the switch to agents and the future of user interfaces will be based on agents.

  An interface agent behaves like an intelligent assistant for the user by simplifying the use of the computer. Icons allow users to move away from the complexity of command languages. Software agents allow guided interaction offering transparent friendly assistance. Intelligent agents mask the complexity of today's feature-rich desktop applications, and perform actions users could not or would not do.

IBM's Web Browser Intelligence (WBI, or "Webby") is an example of an interface agent . WBI assists users in a number of ways: it finds information for them on the Web; automates Web browsing by notifying users when sites of interest are updated; customises users' views of the Web (a) by automatically keeping a bookmark list ordered by how frequently and how recently users have visited a site and (b) by memorising the users' fixed pattern of browsing and taking them directly to the required site (Gilbert, 1997). Apple's hypothetical "Knowledge Navigator" (Apple, 1989), programming by demonstration system (Cypher, 1993), mail and news filtering agents (Maes and Kozierok, 1993) are other examples.

- **Agile manufacturing** Short manufacturing runs, short lead times and demand for highly customised goods and services, favour flexible, responsive manufacturing systems, concurrent engineering teams and global supply-chain partnerships. Distributed factories, virtual design studios, autonomous machines and global intelligent systems are likely to dominate the industrial scene in the next century. Such situations require agile manufacturing systems consisting of intelligent machines negotiating with each other how best to achieve specified goals. Each intelligent machine, in turn, is controlled by a team of intelligent agents. (Rzevski, 1997)

- **Electronic Commerce** As the Internet becomes increasingly commercialised it is not difficult to envisage a world where personal agents act on behalf of their users in locating the best deal for a customer, close the deal and pay the supplier. A shopping agent can customise both store and merchandise, remember and correlate buying patterns, as well as remind users when they need to shop e.g. birthdays, anniversaries (Gilbert, 1997). These applications are at the intersection of economics and distributed AI. Although many problems need to be solved it is believed that agent technology will play an important role in commerce at Internet, intranet and extranet levels. Pattie Maes, an Associate Professor at the MIT and the founder of Firefly, a $100 million business, "has created a stir by making agents a household word." (Holloway, 1997).

Multiple-Agent To behave intelligently, agents need to reason about other agents while interacting with them. "In a multi-agent environment, intelligent agents often need to interact with other individuals or group of agents, either collaboratively or non-collaboratively, to achieve their goals. Many of these multiagent domains are real-time and dynamic, requiring the interaction to be highly flexible and reactive, as well as real-time." (Tambe, 1995). A long-term goal in AI research is to understand how this reasoning is done, and to replicate it in computational systems.

The novelty of the agent-based approach lies in replacing centralised hierarchical control architectures, which are difficult to modify, with network configurations in which nodes are capable of negotiating how to achieve specified goals without centralised control. Even more important is the *collective intelligence* of the society of agents, which represents an *emergent* property. A team of agents, like a human team, exhibits certain features that are not attributable to individual members. These features *emerge* from interaction between agents and depend on the nature of the protocols governing mutual relationships. Liberal protocols enable unexpected modes of interaction, which may result in original emergent behaviours. Perhaps the most important feature of a multi-agent system is that no element in the system sees the big picture. The overall behaviour emerges from elementary agent interaction.

Agent technology is still new and there are a number of obvious areas where much research efforts is needed e.g. issues such as computational complexity and expressiveness of the specification language must be addressed. Another "obvious area of work is the extension of logic to more general multi-agent cases. While principles remain the same, a key difficulty in extending the logic in this way will be dealing with concurrency." (Wooldridge & Jennings,1995).

9.4 New IT and its business applications

In today's changing and competitive commercial world the benefits of e-commerce (electronic commerce) cannot be understated. Electronic Data Interchange (EDI) was implemented in some industries as early as the late 1970s and early 1980s. As the enabling and supporting technologies for EDI have evolved and matured e.g. Technical Data Interchange (TDI), Electronic Fund Transfer (EFT), electronic mail (e-mail), electronic catalogues, fax, voice messaging, and video conferencing, it is considered that the term EDI is too restrictive and has now been substituted by the term e-commerce.

Technological and business trends together play a dominant role in defining the shape, style and structure of the information systems that serve business organisations' needs. Today the synergy between business and technological trends has again stimulated new ways of communication within an organisation, in the form of Intranets, and between trading partners in the form of Extranets.

> The grand irony of our times is that the era of computers is over. All the major consequences of standalone computers have already taken place. Computers have speeded up our lives a bit, and that's it.
>
> In contrast, all the most promising technologies making their debut now are chiefly due to communication between computers - that is, to connections rather than to computations. And since

> communication is the basis of culture, fiddling at this level is indeed momentous. (Kelly, 1997).

9.4.1 Intranets When Internet technology is applied within an organisational network to deliver information to a closed group of users, it is referred to as an *intranet.* The only significant difference between Internet and an intranet is that organisational intranets require a security system, usually referred to as a *firewall*, to keep intruders out.

Intranet is a network of computers within an organisation, that allows a company's employees to send e-mail, share and exchange information, even confidential company data and documents. It connects employees regardless of where they reside geographically. The distinguishing feature of an intranet (or an extranet) from traditional LANs or WANS is that intranets are based on TCP/IP protocols i.e. the collection of software rules that controls the Internet.

The term intranets was coined in late 1995; until then these networks were called 'enterprise internets' - private or corporate miniature versions of the Internet. Intranets are self-contained intraorganisational networks that link multiple users within an organisation. An intranet "offers the potential to integrate core business processes across the enterprise through a single interface .... Those companies that can harness this opportunity, with strategic intent, will be able to create a corporate knowledge base, integrate training, their sales presentation, business application and communications in one consistent environment". (Garvey, 1997).

One of the world's first corporate intranets was designed by Sherman Woo in 1993. Woo, a 51-years-old programmer at US West Communications developed a 'Global Village'. "I knew from the start it was going to be counterculture," said Woo. Global Village began in response to reengineer the billing system at the Denver headquarters.

It required information to be distributed to geographically dispersed employees across 14 states. Woo figured that the TCP/IP technology that formed the backbone of the nascent World Wide Web could also be used to create a proprietary online network *within* US West. Woo set up his first intranet using off-the-shelf software and the then primitive Mosaic browser. Today, roughly half of US West's 60,000 employees are linked to the Global Village. (Lappin, 1997)

9.4.1.1 Intranets verses groupware Workgroup software has been used in conjunction with Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) software for some time. The first major workgroup software for personal computers, which allowed end-users to share information, was Lotus Notes. It combined electronic mail, discussion software, workflow software and database technology. These tools were not designed for Intranets, though, in more recent times intranet based features have been added.

The future of groupware is under debate with the advent of intranets. Groupware has advantages over Intranets e.g. enhanced security, ability to support replication and thereby remote users, and a powerful development environment. However, major investment is going into Intranet technology, and with reduced set-up costs, intuitive user interfaces provided by hypertext and multimedia, and cross platform facilities, Intranet is a serious contender as a solution to corporate information sharing.

Table 9.1 compares the current state of the art between Lotus Notes, GroupWare and Intranets against six main properties of an efficient groupware.

Property	Lotus Notes Groupware	Intranet
Standards	Proprietary Standards: Does not offer the source code to public domain Licence required to access the application program interfaces	Open Standard Framework: Promotes vision of purchasing components as required. Freedom to form an integrated groupware platform as needed.
Security	Uses public-encryption standards Allows users to assign access level to information	Security remains challenged: Firewalls provide security from outside world but internal security risks remain
Replication	Supports: synchronised & consistent information across users; multiple copies of documents & databases on more than one server.	Data repositories are collections of URL pointers: do not offer replication; documents and files do not move hence need for replication functionality questioned.
Application Development	Relatively robust application development environment.	Intranet tool market still immature in comparison
Information Repository	Ability to: store all types of information; integrate with other data sources; retrieve and organise information using full text searches, version control etc.	Traditionally Web repository consists of files on HTTP servers. Only just coming to terms with information repository; integration of object stores and search engines with Web servers only recent
Database Integration	Object repositories are not relational, a shortcoming for transaction data processing. Reliance on commercial data pumps to move data from a relational DBMS to the GroupWare server	Using CGI for relational DBMS provides efficient method of database integration.
Workflow	Provides a powerful combination of a data repository/notification system, which is at the heart of workflow applications.	Not nearly as advanced but developments in progress.

Table 9.1 A Comparison of Lotus Notes GroupWare and Intranets
Source: (Hausenloy, 1998)

Intranet is proving to be an inexpensive, powerful alternative to other forms of internal communication and it is contended that Intranet-based interactive applications will shortly provide both what Notes and CAD/CAM can do, and more.

9.4.2 Extranets The Extranet is similar to intranet but with one main difference. While intranets facilitate communication and information accessing and processing within organisational boundaries, extranets address the interorganisational communication needs of collaborating business partners. "Extranets (a hybrid term for "extended intranets") deliver two key ingredients companies have been clamoring for to make electronic commerce real: tight security and the ability to reach out to remote employees, business partners, and customers. Intranets offer the security; the Internet offers the reach. Extranets promise to bring the two together." (Bushaus, 1997).

The key feature of Extranets is that they open internal servers to specified outsiders by allowing the company to control the data available to both parties. A classic example of an Extranet application is the FedEx website (www.fedex.com) which allows its customers to track a package based upon its air tracking number. Extranets facilitate:

- **Information retrieval** Extranets enable customers and suppliers to retrieve information from each other such as order-status, project tracking, scheduling and account information.
- **Information deposition** Extranets enable customers and suppliers to communicate directly with each other. Order-placement applications, electronic-filing for compliance and warrantees are typical examples.

9.4.3 Benefits of intranets and extranets Intranets and extranets both provide organisations with advantages. They are far more than a hybrid of network and Internet technologies for they improve on the capabilities of both, and offer the ability to deliver information quickly, are easy to learn to use, are scalable, allow unlimited simultaneous users and provide secure private communication. The benefits may be classified as follows:

- **Universal communication** Employees can communicate with other employees throughout the organisation and people in client, supplier, and partner organisations. The inclusion of video and audio chips enable videoconferencing, and whiteboard technology increases the effectiveness of communication. Multimedia can be used to communicate the message effectively.

- **Easier accessing of company data** Intranets and extranets allow easy incorporation of legacy databases. "With Web-to-database query tools using Common Gateway Interface (CGI) and a variety of intermediate software Intranet users need only type in requests in a Web page, and this technology goes out, searches the database, and sends back the result in HTML format on Web page." (Gralla, 1996).

  Numerous search tools are available for easy accessing of information such as Agents, Spiders, or software robots that traverse the intranet indexing information. People can search for information within and outside the organisation (using the Internet).

- **Reduction of paper work** Intranets and extranets deliver information to customers without using paper forms.

- **Low-cost proven technologies** Internet technologies are inexpensive when compared with proprietary networking environments Most organisations have already established TCP/IP networks. HTTP, TCP/IP, Telnet FTP and SMTP are the proven, highly robust and reliable Internet technologies.

- **Communication and adaptation** The use of standard protocols and programming interfaces such as TCP/IP, FTP, HTML and MIME can deliver tools that enable internal infrastructures to adapt to changing business needs as well as permit communication with the systems of external partners, clients and suppliers.

- **Standard based delivery** supported, for the most part, by the technology features of the Web, information containing a variety of data formats, from text to graphics, audio to video, can be transferred across any TCP/IP network. Navigation from one data-object to another, or from page to page, is done by selecting, or by clicking a hypertext link embedded within a document.

- **Interoperability** is a problem in organisations when information from diverse systems needs to be brought together with a single user interface. With a given number of information systems to make "interoperable", the number of translation algorithms (TA) required are as follows: .5(n(n-1)). This means for five systems to become interoperable 10 translation algorithms are required, and with 10 systems, 45 TA are required.

  By selecting a standard, or a set of standards, through which all information sources must be made available, a company can reduce the number of TA e.g. a classic example of an extranet application is the FedEx website (www.fedex.com) which allows its customers to track a package based upon its air tracking number.

- **Better use of resources** Most companies pursuing extranets hope to reduce unproductive and wasteful telephone time servicing routine questions. The benefits are twofold: (a) they can lead to large savings

Chapter 10 - Matching Information Systems to Learning Organisations

10.1 Introduction

Over the last few decades it has become increasingly clear that information is not merely a by-product of business activity but the key resource, a guiding force and the connecting medium that regulates and binds all business processes and activities. This understanding leads to the realisation that information systems have always been an integral part of an organisation's structure. Information Systems (IS) existed well before the advent of computers (Buckingham et al 1987). Information and communication systems, both formal and informal, within organisations, evolve to suit their needs.

The host-centric computing paradigm supporting centralised information systems with batch processing mode, discussed in the previous chapter, was developed in the 1960s to align with the then prevalent command-and-control model of deep hierarchical organisational structures. Today, as discussed in earlier chapters, the Learning Organisation Paradigm (LOP) is replacing the hierarchical structures of organisations and this switch is now widely accepted.

The prolific literature on the shift to LOP is almost universal in its emphasis that change in the organisational structure will not on its own produce desired effects. Changes in organisational management, with particular emphasis on mental models and culture, are some of the necessary prerequisites (Senge, 1990; Argyris, 1990, 1995). Hampden-Turner (1994) explains that "the modern knowledge-intensive world economy is a "learning race" in which only corporate cultures with a thirst for discovery can survive." However, it is not yet fully appreciated that this thirst cannot be effectively quenched if learning organisations continue to be supported by structured, centralised information systems.

If it is crucial that business organisations must make the transition from command-and-control to LOP in order to survive, then, the issue of matching information system to learning organisation is no longer a question of desirability, but rather of imminent and compelling need.

It must be recognised that today every business is an information business with information and knowledge as its prime resource. Examples of the severe consequence of ignoring this fact are not hard to find e.g. the recent near-demise of Encyclopaedia Britannica. Even in those organisations which do not consider themselves to be in the information business, the cost of capturing, storing, and processing information actually represents a large percentage of their cost structure. An important fact quite often ignored in management literature, for example even Porter (1985) who is the author of a number of widely quoted books on competitive strategy and competitive advantage completely ignored the information aspect in his definition of a company's value chain. His description of a value chain consists only of a linear flow of physical activities, though the value chain also includes all the information accompanying each activity, that needs to be captured, stored and processed (Evans and Wurster, 1997).

In order to match information systems and satisfy the needs of learning organisations it is necessary to revisit the ways in which information is supplied in an organisation to its employees, partners, suppliers and customers. The old paradigm for mission-critical application development has reached the end of its usefulness and it is contended that such an approach to developing information systems is now out of date and should be abandoned, except in situations in which the command-and-control organisational model is to be preserved. Consequently, conventional information system design strategies and development methods become subject to close scrutiny because of their limitations in handling only structured data and text.

A new paradigm for the design of information systems, which supports the LOP, has not as yet been articulated. It is important that a theoretical framework for future information system design must be considered bearing in mind the paradigm switches both in the domain of organisational theory and of information technology. A deeper understanding of the *synergy* that exists between organisational structures and the information systems that evolve to support them, is a key prerequisite for developing a new framework.

10.2 The synergy between organisation structure and IS

Information Systems are an integral part of an organisational structure. Information and communication systems, both formal and informal, have always evolved to suit the needs of organisations.

Organisational structure specifies the distribution of authority among managers; sanctions the segmentation of functions and establishes patterns of relationships among functional units. It prescribes corporate governance, individual responsibilities, reporting relationships, measurement and reward systems, as well as planning and control systems (Galbraith, 1977; Nadler et al., 1979). "Organisational structure must perform the major functions of facilitating the collection of information from external areas as well as permitting effective processing of information within and between subunits which make up the organisation." (Tushman and Nadler, 1978).

Based on the above axiom, it is postulated that the role of information systems in an organisation is to provide an effective collection, storage, processing, distribution and utilisation of information with a view to increasing the effectiveness and satisfaction of users. Consequently, frameworks for future information systems theories must be considered in the context of organisational and management theories.

A careful re-examination of constituent elements of an organisation and its information systems leads one to the conclusion that information is woven into the fabric of organisational structure itself. Constituent elements of organisational structures, e.g. constitutions, regulations, organisational charts, procedures, job specifications, contracts of employment, are interrelated pieces of information whose purpose is to reduce the uncertainty associated with questions such as: what is to be done, by whom, how and when? Elaborate structures (those containing a large quantity of information) leave little uncertainty and therefore give employees little freedom to either exercise judgement or take other than prescribed actions. Such organisations are rigid. They guarantee predictability and repeatability. They enable the employment of an unskilled and semiskilled workforce. In that sense a production line too is an information system (in addition to being a material handling system) from which each worker receives signals when to begin and when to finish a well-defined operation.

Like all social groups (nations, communities, families) so it is with organisations: what is not defined by the structure is constrained by the culture. Shared values expressed through symbols (such as uniforms), rituals (e.g. collective outings), slogans ("every morning kill a complexity" is proclaimed in Beneton offices), heroes, mascots and habits, are in place with a view to directing the behaviour of members of the organisation. Some cultures may demand respect for authorities, others encourage team work, but all are information systems with elaborate ways of coding the message.

Based on the above discussion it is clear that the importance of the close link between the domain of organisational theory and the domain of information systems cannot be overemphasised (Rzevski & Prasad, 1998). However, this has often been overlooked in the development of information system strategies.

10.3 Information needs of the learning organisational model

The generally accepted notion, under the old paradigm, that information systems should be designed to meet business requirements is now overdue for re-examination.

Each of the two models of organisation requires different kinds of information system, which in their turn must be, supported by different information technology. The conventional information technology of databases, tailor-made programs, mission critical applications, while well suited to the command-and-control model of organisations, cannot provide adequate support for learning organisations and, because of inherent rigidity, often represent serious obstacle to change. Such systems are not capable of exercising judgement.

Table 10.1 provides a comparison between the major characteristics of the command-and-control and learning organisation paradigms. These characteristics play a direct role in designing information system strategies.

COMMAND & CONTROL ORGANISATION	LEARNING ORGANISATION
Economy of scale Top-down design Deep hierarchies Vertical integration Individual specialists Function-oriented units Functional organisation	Flexibility, agility Evolution Networking Partnerships Multidisciplinary teams Process-oriented units Virtual organisations
Avoidance of uncertainty Precisely specified tasks procedures Predictability	Designed-in uncertainty Empowerment of employees Performance not completely predictable
Hierarchical power structure Unskilled and semiskilled workforce Detailed job specification	Caring culture Skilled, well-educated workforce Learning Intellectual capital Organisational memory Emergent intelligence

Table 10.1 Major differences between command-&-control and LOP

Under currently prevailing market conditions, business requirements appear to change so rapidly that we now often face a paradoxical situation in which information systems, designed to meet a particular set of business requirements, become obsolete before they are delivered and installed. Business requirements tend to change too rapidly to be a valid starting point for the development of expensive technological systems. Furthermore, our experiences from the past have shown that technology-driven solutions are more likely than not to be irrelevant to business needs and we are now discovering that business-driven solutions are likely to have a short useful life.

New flexible, distributed and virtual organisations, built on the learning organisation model, require flexible, distributed information systems. In particular:

- The devolution of decision making dictates a need for distributed decision support systems.
- The learning organisational model encourages team-work and working in teams cannot be effective without appropriate workgroup support software.

- Volatile markets and rapidly changing business requirements demand fast information systems development methods and tools, such as rapid prototyping, application generators and visual programming (rather than top-down, structured methodologies).

- Ever changing company boundaries (due to acquisitions, de-investments and reorganisations) require networks of systems (rather than a corporate system).

- The switch from functional to process-oriented organisational units implies a switch from functional systems (e.g., marketing, manufacturing) to systems supporting new organisational units centred on business processes (such as new product development).

- Close but temporary partnerships between geographically distributed companies, often located around the globe, demand multimedia networks (to compensate for lack of regular face-to-face meetings) which must be flexible (changes to routing) rather than dedicated.

- Unprecedented competition focuses attention on the importance of rapidly delivered and effectively presented information via general (Internet) or specialised networks (Intranets and/or Extranets) with the help of colour screens, windows, digital personal assistants, mobile e-mail workstations and NoteBooks.

- Large networks are complex and therefore to locate and retrieve information one needs 'intelligent agents', programs capable of exchanging messages with other programs and reasoning about the content of these messages with a view to achieving their tasks by *negotiation.*

In order to achieve learning, organisations must develop the ability to cope with unpredictable events and this, in turn, requires systems capable of exercising intelligent judgement. Conventional information system do not possess this capability.

10.4 The evolutionary information system design paradigm

The sum total of the changes listed above, from the perspective of information system design, amount to no less than a new information system paradigm - the evolutionary paradigm. The shift from the structured to evolutionary paradigm in the domain of information systems is summarised in Table 10.2.

PRE-PARADIGM OLD CONCEPTS	***STRUCTURED INFORMATION SYSTEMS PARADIGM*** Well ESTABLISHED CONCEPTS AT THE END OF THEIR USEFUL LIFE	***EVOLUTIONARY INFORMATION SYSTEMS PARADIGM*** EMERGING CONCEPTS LIKELY TO DOMINATE THE FUTURE
	guiding ideas: *1 economy of scale* *2 structured design*	guiding ideas: *1 flexibility, evolution* *2 pattern recognition, intelligence*
	large systems, production line, automation.	systems capable of adapting to changing requirements, self-organising systems.
independent programs	centralised information systems, corporate databases, large application programs.	networks of PCs or NCs, distributed systems, client-server architecture, the internet, Intranet data warehousing, data mining.
data	data	objects, multimedia, hypertext, www, virtual reality, video conferencing, whiteboarding.
data + algorithm = program.	databases + application programs = systems.	communicating objects = agents, collection of intelligent agents = multi-agent systems, emergent intelligence.
	large schedulers and control systems, large information retrieval systems.	scheduling, control and information retrieval by negotiation among intelligent agents.
	local area and wide area networks.	global networks, information superhighways, "nomadic" personal systems, personal digital assistants.
	independent workstations, telephones, faxes and leisure equipment.	integration of PC, video-phone, TV, HF and video-e-mail into a single personal work/leisure station.
technology-driven IT strategy.	business-driven IT strategy.	concurrent & coevolving development of business and IT strategies, concurrent design of organisational structure and supporting IS.
technology driven solutions.	business-driven IT solution.	generic packages & systems, human centred intelligent information systems.
ad-hoc programming.	top-down structured analysis & design.	incremental development rapid prototyping, visual programming.
vendors sell 'boxes'.	vendors sell 'IT solutions'.	vendors sell 'IT tools'.

Table 10.2 Paradigm shifts in the domain of information systems

The new paradigm is characterised by the concepts of networks, workgroup support, human-centred technology, distribution of decision support, incremental development, capability to evolve with changing business requirements, support for teleworking, multimedia and multi-agent systems. It contrasts with the traditional structured paradigm, characterised by centralised computer-based information systems, corporate databases, tailor-made large COBOL application programs and data-driven structured methodologies.

10.5 Conclusions

The discussion above leads us to the inevitable conclusion that we *are at the start of a new era in which organisational theory and information systems theory converge.* It emphasises that the only effective way of ensuring a close match between an organisation's information needs and the information systems that support it is to ensure that the organisation structure, its management and information systems continually evolve and coevolve.

To achieve the desired synergy between organisational structures and organisational information technology it is necessary to design them concurrently. Any mismatch is known to cause a loss in effectiveness (Rzevski and Prasad, 1997). The only way to develop such information systems is by creating a network of networks by exploiting the technology of Internet, WWW and above all agents. The main features of the new information systems paradigm are as follows: the integrated multimedia representation of information e.g. text, data, sound, colour, images, animation, video and virtual reality; the rich interconnection of multimedia elements based on hypertext e.g. the WWW format; the world-wide, broadband communication between users and remote/local information sources e.g. the internet/intranet/extranet;

support for teams of specialists working in virtual office/organisation i.e. videoconferencing combined with white boarding and shared virtual reality software; intelligent support for information retrieval e.g. browsers and search engines, multiagent systems and push-technology; complete transparency of operation; and user-centred design.

Margaret Wheatley's (1994) comments regarding new principles of organisation theory seem to apply equally to the new information systems theory:

> In our past explorations, the tradition was to discover something and then formulate it into answers and solutions that could be widely transferred. But now we are on a journey of mutual and simultaneous exploration. We can not expect answers. Solutions, as quantum reality teaches, are a temporary event, specific to a context, developed through the relationship of persons and circumstances. In this new world, you and I make it up as we go along, not because we lack expertise or planning skills, but because that is the nature of reality. Reality changes shape and meaning because of our activity. And it is constantly new. We are required to be there, as active participants.

It is therefore essential to develop *concurrently* with organisational change, a concept of *Intelligent Information Systems*, which include multimedia-based client/servers, broadband networks, Web technology, browsers, learning algorithms, fuzzy logic, neural networks and above all intelligent agents.

Chapter 11 - New Theoretical Insights into Design of IS

11.1 Introduction

The aim of this chapter is to address some of the IS community's concerns, which are focused on finding philosophical foundations and guiding principles to deal with the demands of the new realities in which the discipline of Information Systems finds itself. The aim of any theory is to provide explanations of phenomena which are outside the experience and knowledge of a particular discipline. From the perspective of organisations these phenomena are *'complexity'* and *'continuously changing environments'*, and from the perspective of information systems the problem is how to develop *'information systems which adopt and adapt to changing business requirements and yet remain relevant and useful'*.

The latest technological developments, discussed in Chapter nine, have opened up a host of opportunities for designing concurrent IS. However, technology in itself cannot provide the solution. "Technological devices make a fundamental contribution to the dissemination of information but these devices in themselves are not information." (Mingers and Stowell, 1997). In the absence of standards and universally accepted guiding principles there is a risk of creating Towers of Babel.

Successful computer application to business problems has largely been confined to automating large volumes of repetitive and mundane tasks e.g. transaction processing, and for holding and processing large volumes of data, electronically in files or databases. There is another application of computers to business, which may be classed as 'decision support tools', which have the aim of assisting management in making effective decisions by providing *what if* scenarios. Management Information Systems (MIS), Decision Support Systems (DSS) and Executive Support Systems (EIS) are examples of efforts in this direction. These systems unfortunately have not lived up to their expectations. The main reason for this, as made evident from the Science of Complexity, is that equilibrium models representing a complex system are incapable of taking into account the diverse trajectories arising out of interdependent, interrelated, interconnected interaction of all the element (agents) of such systems, and as such they fail to represent reality.

The repeated failings of long-term business strategies and the futility of strict adherence to planning and control philosophies of no longer effective management theories are proof enough of the fact that most business decisions are based on a combination of experience and intuition of the decision maker. The conceptual framework for modelling non-linear dynamics and co-evolutionary landscapes of real life business scenarios has not been available to information system designers until now.

All research in Complex Adaptive Systems (CAS) is based on the less-familiar use of computer simulation and computer modelling of non-linear complex problems such as biological evolution. A brief outline of some of the main techniques of computer simulation used in CAS research is provided below, before we discuss the relevance of CAS principles for computer-based IS (CBIS) since the "use of computers as devices for imitating other devices is central to the concept of computer-based thought experiments, so it is important to distinguish this use from "number crunching"." (Holland, 1995).

11.2 Computer simulation: the key to intractable problems

Computer simulation is widely used for seeking optimum solution to all kinds of engineering problems such as design of an aeroplane, a car or a bridge. Simulation is a technique which is also widely used in creating an environment for experiencing real-life phenomena, particularly where real-life experience is either infeasible or prohibitive e.g. training of astronauts and airforce pilots. The concept of computer simulation was originated by Turing (1937) when he showed how to construct a *universal computer*, that could imitate any other computing machine or computation. Alan Turing and John von Neumann both independently laid the logical and physical foundations of modern digital computers. Their interest in simulating the complexity of the human brain with computers spawned the theoretical study of complex systems. Complex problems capable of being represented by computers today range from non-linear dynamics of fluids to thinking machines. These capabilities are enhancements of the vision shared by Turing and von Neumann.

Cellular automata By emulating Nature in computers, the concept of simulation took great steps forward in the finding of optimum solutions for complex problems. One of the earliest concepts in modelling complexity in digital computers was cellular automata. Stanislaw Ulam the mathematician, inspired partly by observing the growth of crystals and partly by his desire to understand biological self replication, advised John von Neumann on the development of the cellular automaton. Tommaso Toffoli and Norman Margolus (1987) of MIT neatly sum up the attraction of cellular automata for studying complex emergent phenomena, as follows: "Cellular automata are stylized, synthetic universes defined by simple rules, much like a board game. They have their own kind of matter which whirls around in a space and a time of their own. One can think of an astounding variety of them. One can actually construct them, and watch them evolve". Coveney and Highfield (1995) report that "from using cellular automata as models of living systems in all their complexity, some researchers have claimed in recent years that there is a suggestive relationship between biological life and artificial systems capable of performing universal computation". Later Sherrington and Kirkpatrick's (1975) work on simulated annealing provided further powerful techniques to deal with some tough optimisation problems.

Genetic algorithm and adaptive agents In recent years there has been a surge of interest in John Holland's work. He has introduced two radical concepts in dealing with complex problems. The first is *genetic algorithms* (GA). Holland has exploited the ingredients of biological evolution - mutation, crossover, inversion - to locate the minima and maxima in the fitness landscape representing optimal solutions. The effectiveness of genetic algorithms has already been proved in cases such as the search for optimal design of jet engine turbines; and the control of gas flow in pipelines, adjusting the flow to meet daily and seasonal fluctuations. It is being increasingly recognised that genetic algorithms provide improved results for intractable (NP) problems (Coveney and Highfield, 1995). The second concept Holland introduced is *adaptive agents.* Holland uses the fact that nature controls complexity by the co-operative and conflicting interaction between the elements (agents) in nature - be they atoms, swarms of bees or colonies of ants (covered in Chapter seven). The elements of a complex system are referred to as agents. The collaborative and conflicting interaction of individual agents, and then groups of agents create the building blocks of complexity.

Genetic programming is an extension of genetic algorithm pioneered by John Koza (1992) of Stanford University, the main difference being that in GA there is only one type of solution algorithm, whereas in genetic programming, programs of varying size (software agents) themselves undergo adaptation. This provides the software agents with the ability to explore the search space in parallel and combine their best findings through adaptation (mutation, crossover, inversion). In this way agents not only *learn* but also produce a behaviour which simulates *intelligence.*

11.3 The relevance of CAS theory for design of intelligent IS

In this section we consider the implications of CAS theory for IS strategy. In doing so we draw attention to the earlier discussion in Chapter eight concerning *organisations as complex adaptive systems* and the major characteristics of CAS. To facilitate the discussion here the major characteristics of CAS are listed again as follows:

1. **CAS consists of intelligent agents** (or groups of agents) that collaborate and compete with each other.

2. **Agents operate according to a set of simple local rules.** Out of multiplicity of local behaviours (guided by simple local rules) a global emergent behaviour is generated. This capability is known as *'self-organisation '*.

3. **There is no centralised control in CAS.** The control factor in CAS is dispersed, (e.g. there is no master neuron directing the brain, nor is there a master cell in charge of a developing embryo).

4. **CAS operate at the edge of chaos.** Emergent behaviour is the central feature of complexity. However, a small disturbance is capable of causing the system to switch into unpredictable behaviour. Thus the system is said to operate *'at the edge of chaos '*. Here 'chaos' means unpredictability.

5. **CAS are open and interact with their environment.** A CAS is capable of learning from its environment and evolving to accommodate environmental changes. More importantly, a CAS is capable of changing its environment to accommodate its own goals.

6. **The process of change and development in CAS is nonlinear and irreversible.** Nonlinearity refers to the mathematical property of combining in more complicated ways than simple addition, as expressed by the whole is greater than the sum of its parts. Dissipative nonlinear systems are capable of exhibiting self-organisation and chaos. Evolution is an irreversible, historical process. Structures may cease to exist or become extinct, but a system cannot evolve 'backwards' to a previous state.

7. **CAS evolve and co-evolve with other systems of the same kind.** Flora, fauna and other CAS, including humans and human systems, live in niches provided by other species. For example, flowers and insects coevolve; insects pollinate flowers while feeding on nectar. Species change as they interact with one another, jockeying for existence as mutualists, competitors, predators and prey, hosts and parasites.

11.4 Application of CAS principles to design of IS

To judge if CAS theory could be applied to the design of distributed, networked CBIS to learning organisations, the following key questions need to be answered:

1. *Can we design information systems that consist of agents and group/s of agents that collaborate and compete to fulfil their stated goals?*

2. *Can we design IS consisting of group/s of agents working according to simple local rules?*

3. *Is it possible to design distributed CBIS with no central control yet capable of self-organisation and self-maintenance?*

4. *Is it possible to design information systems capable of interacting with their environment and learning from the interaction?*

5. *Is it possible to design information systems capable of emergent knowledge/intelligence?*

6. *Is it possible to design information systems capable of evolving and coevolving, with changing organisation structure and changing management information needs, in an uncertain and unpredictable environment?*

The theory of CAS has its origins in biology and is frequently articulated stressing the importance of concepts that have direct relevance to biological systems. In an effort to answer the questions listed above we need to draw on the works of several researchers in this field, the reason being, as stated earlier in Chapter eight section 8.4, there is as yet no unified theory of complexity. Evolution and co-evolution; self-organisation which emerges from the multiplicity of local behaviour of collaborating and competing agents; patterns of behaviour which emerge spontaneously from within the system rather than through an external ordering influence, are some of the generic characteristics of CAS amongst several examined in Chapter eight. We next consider the extent of their relevance as guiding principles for the new paradigm of CBIS.

In applying the principles of CAS to human systems, we need a cautious approach as we know that all attempts so far to use either physics or biology to explain the behaviour of organisational systems have failed. What we are attempting to do here is to distil the relevance of the principals. What we are certainly avoiding is the direct mapping of CAS principles onto human organisations.

1. Can we design information systems that consist of agents and group of agents that collaborate and compete to fulfil their stated goals?

John Holland's (1995) book 'Hidden Order: How Adaptation Builds Complexity' is a coherent synthesis of an emerging discipline of complex adaptive systems. It reveals how various CAS (such as the kaleidoscopic nature of large cities, economics, ecologies, the mammalian central nervous system) emerge, adapt, evolve, compete and co-operate to survive.

In the seminal work of Holland (1995), the theory is expressed in a manner which shows the potential of CAS theory as a powerful tool for designing CBIS capable of assisting teams of workers to take informed decisions. He states that fundamental elements of a complex adaptive systems are autonomous agents, capable of freely co-operating or competing with each other within certain limits imposed by the design of the system, which may itself evolve with time.

It is contended that future information systems will be designed as swarms of intelligent agents, where an 'intelligent agent' is a software object capable of exchanging messages with other agents and exhibiting characteristics of intelligent behaviour such as reasoning, learning and making decisions under conditions of uncertainty. A swarm is a group of agents with a goal, which operates through the interaction of member agents.

2. *Can we design IS consisting of group/s of agents working according to simple local rules?*

In Holland (1995) the theory is expressed in a manner which shows its potential as a tool for explaining, and possibly predicting, behaviours of human organisations and artefacts. Holland presents a speculative scenario that suggest how single free agents can evolve into multi-agents and then into aggregates of multi-agents referred to as a *swarm* of agents. The term swarm is the metaphor used to refer to any loosely structured collection of interacting agents, the classic examples being a bee-hive, or a colony of ants.

According to Holland, an agent's behaviour is guided by local rules that reflect locally available knowledge, and the global behaviour of the system *emerges* from the sum total of all local behaviours and is, as a rule, unpredictable. The system is said to be at the edge of chaos, the implication being that if disturbed it may disintegrate. This is an excellent model for the learning organisation. A learning organisation is characterised by devolution of decision making and teamwork, and is subject to the risk inherent in any system lacking centralised control, namely the risk associated with a possibility that different teams may single-mindedly pursue incompatible objectives.

This same principle holds promise for the design of IS based on the swarm model. The overall behaviour of a swarm is complex (and not predictable in detail) although the behaviour of each agent is simple. Consider an example, a swarm of agents supporting a marketing team. Typically, the swarm would be based on a server allocated to the team and connected by a broadband network to the organisational intranet, an extranet connecting all companies belonging to a particular partnership and to the Internet. The members of the marketing swarm would be an:

- agent responsible for collecting up-to-date information on activities of major competitors, one for each competitor;
- agent responsible for keeping the marketing team informed about the changing requirements of customers, one for each major account;
- agent responsible for monitoring technology trends;
- agent statistician, calculating sales performance figures;
- agent advisor, offering advise on, say, advertising;
- agent responsible for maintaining the organisational memory of the marketing team;
- agent monitoring the accumulation of the intellectual capital of the marketing group.

All information collected is stored as objects (which may be text, image, voice, or video) in the appropriate team object base and presented to users in multimedia format with hyperlinks.

Such an information system would have all the characteristics of a complex adaptive system and its global behaviour could be assessed by means of swarm simulation software.

This scenario was inspired by the work of many researchers, in particular Minsky (1985), Negroponte (1970) and the research team from the Santa Fe Institute.

Further development of the theory is needed to enhance its predictive powers and thus increase its usefulness to designers of CBIS. In particular, it would be useful to understand how much uncertainty should be left in the system, and where this uncertainty should be placed, to provide requisite freedom of action for agents without running an unreasonable risk of sliding into chaos; also, how to partition a network of agents into reasonably self-contained zones with a view to optimising their interaction. If too many agents attempt to send messages to each other the likely result will be deadlock. It may well be that answers to these questions will be obtained by simulating alternative designs and then comparing simulation results, using for example, the swarm simulation software developed at the Santa Fe Institute.

3. *Is it possible to design distributed CBIS with no central control yet capable of self-organisation and self-maintenance?*

The key tenet of CAS theory is the processes of self-organisation and the spontaneous emergence of ordered structures. The principle refers to the spontaneous organisation of a system's elements into coherent new patterns, structures and behaviours. In the last two chapters of his book *At Home in the Universe* Stuart Kauffman (1995) presents thought provoking and tantalising arguments that the advances in our understanding of the evolution of complex adaptive systems in biology may shed light on, and even lay rigorous theoretical foundations for studying the behaviour of human organisations and artefacts.

Kauffman (1995) developed the 'Kauffman models', which are random networks exhibiting a kind of self-organisation which he refers to as "order for free". His research into the foundation of a social architecture of networks sheds light on what happens when networks come together.

Kauffman introduces the concept of an "optimal patch" which allows a complex system to adapt successfully on a rugged landscape. "Small patches lead to chaos; large patches freeze into poor compromise." (Kauffman, 1995). So what, if anything, characterises the optimum patch-size distribution? With reference to organisations Kauffman (1995) explains that:

> Real cells, organisms, ecosystems, and, I suspect real complex artefacts and real organizations never find the global optima of their fixed or deforming landscapes. The real task is to search out the excellent peaks

> and track them as the landscape deforms. Our "patches" logic appears to be one way complex systems and organizations can accomplish this.

Referring to his recent work where he has applied the logic of patches to organisations Kauffman writes:

> The results hint at something deep and simple about why flatter, decentralised organizations may function well - and that contrary to intuition breaking an organization into "patches" where each patch attempts to optimize for its own selfish benefit, even if that is harmful to the whole, can lead, as if by an invisible hand to the welfare of the whole organization.

The concept of 'patches' in such networks makes visible the conflict of establishing the patch size which enables overall 'low-energy minima', encouraging the system towards a phase transition that exists between order and chaos. Thus when an intermediate optimum patch-size exists, it is typically very close to a transition between the ordered and the chaotic regimes. Properly chosen patches, each acting selfishly, achieve the co-ordination. What does this principle offer for the development of IS design?

This principle has great relevance for the design of IS in general, and IS networks in particular, for it suggests that effective information systems supporting continuously changing business needs cannot be designed in great details anticipating all contingencies. Under these conditions, a 'bottom-up' approach to design and evolution of the system becomes important. Each patch (in this instance a local network) learns from local feedback and optimises its performance according to local needs. The sequence of such behaviour, i.e. each patch optimising its local functionality but in the process influencing its neighbouring patch in a coevolutionary manner, triggers mutual adaptation and evolution. Theoreticians of complexity address the issue of how order emerges from the interaction between the competing constituents. The interaction influences their behaviour. It provides an insight into how distributed and networked information systems could become capable of self-structuring, self-organising and emerging in a co-evolutionary way. The science of complexity supports indirect intervention, which results in adaptation, rather than top-down or direct intervention. It allows for coexistence of opposing interests.

Networks designed using structured methods are rigid in the sense that the degree of dependency on each node functioning properly is far greater than desirable. The self-organising principle offers a more flexible and adaptive approach. Its consequence is that networks should have a built-in capacity to reconfigure themselves, that is, if one or more nodes go out of action, the system can recognise the failure and restore alternative paths, keeping all this hidden from the user.

4. *Is it possible to design information systems capable of interacting with their environment and learning from the interaction?*

The combination of freedoms given to, and constraints imposed upon agents, together with the cognitive capabilities of each agent, will determine the ability of the system to respond to changes in its environment and shape the environment to suit its own purposes.

5. *Is it possible to design information systems capable of emergent knowledge/intelligence?*

Emergent behaviour is a global property of all Complex Adaptive Systems. Commonly this idea is expressed as - the whole is greater than the sum of its parts. How does this principle hold for IS design?

Information systems holding text and data under the structured IS paradigm are not capable of emergence. Text based screens are unattractive because they are difficult to read, navigate, or interact with. The information remains static, waiting to be used. However, information systems development with integrated multimedia representation of information i.e. text, data, image, animation, video, virtual reality, colour and sound, and the rich interaction between all these forms generates an effect which is far greater than is possible otherwise. The information thus created acquires a vibrant quality hitherto lacking, and thus emergent information is generated through the interaction of the media.

6. *Is it possible to design information systems capable of evolving and coevolving, in an uncertain and unpredictable environment?*

Uncertainty in information systems is an important issue and both academics and practitioners are interested in addressing the issue.

> It would be impossible for an organisation to survive if it only made decisions with information that was certain. Constantly, members of an organization have to handle a wide variety of kinds of uncertain information in order to fulfil their role in the organization .... via learning, humans, and more generally, organizations can become highly adept at using uncertain information. (Hunter, 1996).

The ubiquitous usage of uncertain information by organizations contrast sharply with the low level of computer-based handling of uncertain information.

From the perspective of information system design it is impossible to design the "best" information system *a priori*; there are simply too many variables and issues to be considered. Information is *composable.* Under conditions of uncertainty, a "bottom-up" approach to design and evolution of the system becomes important. Complexity suggests managing through bottom-up evolutionary development rather than through top-down structured design. What this means is that design principles should preserve a compromise between contradictory demands (specific/general; summarised/detailed; etc.).

As the user learns by doing and by using, characteristics of these bottom-up processes allow those associated with the technological field to create a process comprising local feedback. Local feedback consists of a series of trial and error experiments, based on using and doing, that creates the base for learning by simulation of the parameters required to fine hone the design of a technological system. The knowledge that is generated through use and practical experimentation is retained within individuals and other institutional bodies. Consequently, local feedback results in global adaptation.

11.5 Conclusions

Complex Adaptive Systems share a fundamental underlying architecture: interacting and collaborating group of agents create complex and holistic emergent behaviour. This offers fresh insight for developing a new framework for the design of information systems to support the new learning organisation paradigm. Information system design based on swarms of agents can support effective concurrent and parallel execution of processes.

The developments in computer simulation discussed in this chapter enable a radical way for developing CBIS. A good solution results from a combination of features in the possibility space or 'fitness landscape' where various combinations can produce the fitness landscape comprising a host of peaks and valleys. The merging of two major waves, one comprising advancements in the field of computing which offer a natural and powerful way for modelling nonlinear and intractable problems using techniques such as cellular automata, simulated annealing, genetic algorithms and genetic programming, neural networks, and the other comprising technological advancement responsible for the information superhighway (Internet, World Wide Web) has provided a new paradigm for IS design.

There is enough evidence to suggest that once again a mismatch between theory and practice in organisations has occurred. From the perspective of adopting the principles of learning organisations, practice often lags behind theory. However from the perspective of IS needed to serve the LOP, evidence suggests that the practice of implementing new technology is not supported by adequate theory.

Chapter 12 - Conclusions and Further Research

12.1 Introduction

In each chapter of this thesis, with the exception of chapters one and two, conclusions have been drawn within the context of the topic presented in that chapter. This final chapter presents conclusions drawn from the totality of this research, and in the context of the research hypotheses stated in chapter two. Conclusions are in the form of either acceptance or refutation of the research hypotheses. They are then followed by proposals for future research. Before presenting the conclusions of this research a few words clarifying the research alignment are necessary.

One of the principle area of agreement (amongst numerous differences) between Sir Karl Popper and Thomas Kuhn, the two great contemporary philosophers of scientific research, is that scientists conditioned by their education and training, develop their ideas within a definitive theoretical framework (Kuhn, 1970; Popper, 1970). The discipline of Information Systems has proved to be no exception. The intellectual foundations of information systems come mainly from computer science and management science. Both have their intellectual roots in engineering. As such most research related to the design and development methods of Computer-Based Information Systems (CBIS) has been confined to these traditions. Research within an established paradigm is what Kuhn calls 'normal science'.

The findings of the research presented in this thesis and the conclusions drawn from it cannot be classed as 'normal science' rather they identify more closely with what Kuhn refers to as 'scientific revolutions' i.e. those 'non-cumulative development episodes in which an older paradigm is replaced in whole or in part by an incompatible new one'.

This research takes a holistic view of the design process and the product of CBIS which are required to serve the needs of new organisational structures that are emerging under the Learning Organisational Paradigm. It is therefore concerned with the interrelationship between the organisational structure, prevailing management style and work culture of organisations, developments in information technology, and the design of a computer based IS in its totality. It makes the following contributions to knowledge:

- It uncovers the intricate, and entwined relationship between the discipline of organisation and management, and the discipline of information systems design, a relationship largely ignored by both disciplines.

- It establishes the need to optimise the synergy arising from the interplay of the two disciplines as a crucial factor in designing flexible and evolving IS.

- It explores the potential of Complex Adaptive Systems theory for providing the theoretical underpinning for a new IS design paradigm.

- It uncovers a flaw in the theory of Complex Adaptive Systems as currently professed, namely the lack of precision in defining *uncertainty* and in providing quantitative/qualitative measures which would help designers of complex adaptive systems to achieve a desired behaviour.

12.2 Conclusions

Hypothesis (i)

Centralised database oriented information systems are suited to the traditional hierarchical structure of organisations and 'command-and-control' style of management.

The analysis and synthesis of the principles and characteristics of the command-and-control paradigm, in Chapters 4, 5, and 6, clearly establish the alliance of scientific management and the design of structured, centralised CBIS. From its earliest beginnings command-and-control management recognised the power of efficiency management and centrality of control. This understanding makes it clear that centralised CBIS *did* conform to the needs of such organisations and were in keeping with the requirements of management in supporting its most fundamental task of planning and control.

The command-and-control model of organisation is built on the foundation of a stable environment where management effort is channelled into reducing uncertainty, enhancing predictability and maintaining equilibrium. Linear, sequential business functions provide repeatability, stability, and predictability. Planning and control of these functions are key management responsibilities, and the centrality of control of these operation under such conditions provides better results. Such organisation of work is ideally supported by centralised database information systems.

The complaints about and, dissatisfaction with, the centralised database information systems were only felt as the organisation's ability to survive shifted from maintaining stability and equilibrium, to quickly perceiving and understanding the shifts before competitors did, and adapting to the change effectively and profitably in a business environment marked with *uncertainty* and *unpredictability*.

Hypothesis (ii)

A Learning Organisation (LO) cannot be supported by centralised, database oriented information systems. Learning organisations require radically new types of information system, characterised in particular by flexibility, and capable of evolving and adapting to meet the constantly changing set of requirements.

One of the most fundamental principles on which the concept of LOs is based, is to develop an inherent ability within the organisation to exercise intelligent judgement under conditions of uncertainty, and when faced with unpredictable events. In Chapter six, section 6.4, it is argued that in order to operate autonomously and intelligently, under a turbulent environment and changing conditions, an organisation requires advanced capabilities for monitoring, acquiring and interpreting information relating to any part of its universe, be it local, national or global, where changes that might affect it are taking place. Section 10.3 in Chapter ten identifies the radically different information requirements of a LO from those of a command-and-control organisational structure.

The many facets of LOP create new and different demands and expectations from CBIS. The new flexible, distributed and virtual organisational structure requires flexible, distributed networked information systems. The increasing complexity, uncertainty, and unpredictability of business environments, and unprecedented competition, not just at local or national level, but at global level, demand teamwork. Shallow hierarchies with small power distances incorporate the concept of individual and team empowerment, promoting devolution of decision making.

The ever changing company boundaries (due to acquisitions, de-investments and reorganisations) represent a business environment directly in contrast to that in which command-and-control organisations operate. The new environment requires networks of systems rather than a corporate system. Unprecedented competition focuses attention on the importance of rapidly delivered and effectively presented information via general (Internet) or specialised (Intranets and/or Extranets) networks, with the help of colour screens, windows, digital personal assistants, mobile e-mail workstations and NoteBooks. Such an organisation requires information to be supplied directly and quickly to those who are empowered to make decisions. This results in the need for small local databases, connected in a network.

Web and Internet technologies, discussed in Chapter 9, provide the necessary open architecture for creating scalable, flexible, distributed information systems networks needed to support the LOP. The technology supporting the Web and the Internet can be applied at all levels within the organisation and in all locations. Intranets and Extranets are examples of such networks.

The recent development of Intelligent Software Agents represent an active technology, as described in Chapter 9, and provides potential for transforming the way of searching for relevant information. Powerful software agents are capable of continually searching for specified information on behalf of their users. In this way agents greatly reduce the information overload for the users and at the same time provide a means, which is humanly impossible, of continual scanning for relevant information within and outside the organisation. It is emphasised that the flexible, distributed and networked systems, using the new IT, *can only be developed in an evolutionary manner.* This point is elaborated further in the argument presented under hypothesis (iii).

A LO cannot be supported by traditional centralised databases as they do not possess these capabilities. In centralised databases all the information for decision making is concentrated in company headquarters for reasons stated earlier under hypothesis (i).

Furthermore, centralised corporate databases are very difficult to update in the operational environment of LO where there are frequent changes.

That most organisations are trying to restructure themselves on a LO model is a trend that is clearly discernible. Analysis of the data obtained from the 'Organisational Complexity and Learning Questionnaire', (referred to as Questionnaire 1 in Chapter 3: Research Methods) is presented in Appendix 3a. With reference to Appendix 3a 94% of the respondents claimed to have undergone structural change. Achieving the desired organisational structure is however slow, and most organisations seem to be in the transition phase. This situation is understandable in the light of the knowledge that:

(a) LOP is based on radically new concepts, which have not as yet taken the form of a universally accepted theory. A variety of frameworks exist some of which were discussed in Chapter 6. In their present form these concepts are neither easy to grasp nor implement. This is clearly evident from the analysis of the responses received to the question concerning the restructuring approaches adopted by the organisation. Nearly 26% of the respondent did not reply to this question. The other 74% stated that more than one popular approach was adopted. The picture concerning the results achieved is unclear.

This clearly indicates that a transition from the existing to a new paradigm in the organisational and management discipline is in process.

(b) breaking away from the ingrained patterns of traditional work organisation, and deep-rooted mind-sets are equally difficult. Nonetheless, the result from analysis on this issue indicates the move in the direction of flat (53.33%) and decentralised (60%) organisational structures. A clear move in the direction of the LOP was indicated.

Analysis of the responses from the questionnaire again provides a clear evidence in support of the trends mentioned in (b) above. Although 26% of respondents did not reply to the question concerning 'which work pattern was adopted following organisational change?', the other 74% clearly stated some form of teamwork as standard after restructuring.

The trend towards employee empowerment is also discernible. Only 15% of respondents did not identify any new patterns of behaviour. But amongst those that did, the responses were as follows: 27% identified group empowerment, 38% individual empowerment and 35% cross-functional interaction.

It is clear from the arguments presented here that organisations who are restructuring themselves under the LOP require radically different information systems. It is inconceivable that a flexible and distributed organisational structure, with new patterns of working under the LOP could be supported effectively by traditional centralised database oriented CBIS.

The sum total of the changes listed above, from the perspective of information system design, amount to no less than a new information systems paradigm.

Hypothesis (iii)

Top-down structured methodologies that were designed to develop centralised database information systems are not suitable for the design of flexible, evolving information systems.

It is apparent from the LO's information needs outlined above, that the kind of information systems needed for the new generation of organisations are extremely complex and cannot be understood by applying a reductionist approach, that is breaking up the business system into its constituent parts to understand, design and implement, the approach pervasive in all top-down Structured Information System Design Methodologies (ISDM). The conceptual roots and limitations of structured ISDMs were discussed in Chapter 9, Section 9.2.2.

Organisations restructuring themselves under the LOP, are moving away from typical functional units and a linear dynamic approach to problem solving in the face of complex, turbulent environments. Process-oriented work environments eliminate functional boundaries, and technology eliminates geographical boundaries, giving rise to not just in concept but in reality to 'virtual teams' of experts working from a 'virtual office', or a 'virtual design studio', who come together in cyberspace to carry out a project and then disperse. In such a work environment it becomes essential to develop, *concurrently* with organisational need, a concept of *Intelligent Information Systems*, which includes multimedia-based client/servers, broadband networks, Web technology, browsers, learning algorithms, fuzzy logic, neural networks and above all intelligent agents.

The IS that are needed, in the form of Intranets and Extranets, are so complex that it is impossible for anyone to comprehend the entire system let alone design and implement one in the traditional way. In addition, rapidly changing business requirements demand fast information systems development methods and tools, such as rapid prototyping, application generators and visual programming (rather than top-down, structured methodologies).

With LOP the aims of, and expectations from, an IS design methodology are no longer limited to identifying some problem within the structured or semi-structured business function, analysing it and then computerising, or automating it. The situation is further exacerbated by the complexity, unpredictability, and perpetual change associated with today's business environment.

Information systems comprising interactive workstations and/or laptops, based on groupware and graphical interfaces, interconnected to other workstations via LANs and/or WANs, and more recently via Intranets and Extranets, provide not just local or national, but global access to databases and other multimedia forms of stored information. Virtual reality of electronic text, and other new forms of text, (based on hypertext) will also play a crucial role in future design of CBIS.

Such CBIS are different in their size, scope and complexity to the traditional IS developed by means of top-down structured methodologies that were designed to develop centralised database information for the command-and-control model of organisations. Distributed multimedia-based information systems have special development requirements, which cannot be met by any IS development methodologies conceived prior to the existence of these distributed networked systems.

Structured ISDMs are based on the philosophy that user requirements must be specified before any design can commence. The work environment in a LO makes it impossible for users to articulate their information systems requirements in advance. This raises a big question on the validity of systematic development methodologies where user requirements must be identified and signed-off before design and development can commence.

Most conventional IS design methods follow a project-based, linear, phased approach, where designers aim to meet a static set of user requirements. The weakness of this paradigm becomes increasingly apparent when it fails to capture, store, distribute, access and present the dynamic, multimedia information concurrently needed to support the LOP. The attention that has been paid to prototying and other rapid application development (RAD) methods provides further evidence that structured ISDM are becoming increasing inadequate for the design of flexible, distributed and network IS. However, just as scientific management continues to suffuse much current organisational and management thinking and human relation theories are used just as an overlay, in the same way, structured ISDMs continue to dominate the design of CBIS. Rapid application development methods and protoyting are used only as overlays.

Hypothesis (iv)

The theory of Complex Adaptive Systems (CAS), as expounded by John Holland, is a suitable theoretical basis for both LO and the IS that support them.

The theory of complex adaptive systems (CAS) and its relevance to human organisations has been covered in Chapter 8. The extent to which the principles of CAS can be applied to human behaviour in an organisational context is discussed in Section 8.4 of Chapter 8.

There is no unified theory of CAS, however, the concept of autonomous agents, as the fundamental elements of CAS, shows potential as a powerful tool for explaining, and possibly predicting, behaviours of organisations. In natural CAS, an agent's behaviour is controlled by local rules that reflect locally available knowledge, and the global behaviour of the system *emerges* from the sum total of these local behaviours and is normally unpredictable. The system is said to be at the edge of chaos, the implication being that if disturbed in a certain manner it may disintegrate. This was illustrated by describing the behaviour of insects such as a colony of ants, and a swarm of bees, in Chapter 8. This is an excellent model of a Learning Organisation since such organisations are characterised by their devolution of decision making and their teamwork, and are subject to the risk inherent in any system lacking centralised control, namely the risk associated with a possibility that different teams may single-mindedly pursue incompatible objectives.

The combination of freedoms given to, and constraints imposed upon agents, together with the cognitive capabilities of each agent, determine the ability of a system to respond to changes in its environment and to shape the environment to suit its own purposes. If we now replace the term agent with the word employee, the above statement gives us an almost perfect description of key mechanisms that make a company rigid or flexible, namely, the amount of freedom given to employees to learn and participate in decision making.

The principles of the swarm model when applied to the design of CBIS, based on Intelligent Software Agents, also holds promise for the kind of flexible, distributed, intelligent IS needed to support LOP.

Hypothesis (v)

The academic community continues to teach conventional IS design and IS design methodologies whilst at the same time industry is forced to introduce new information technologies such as Intranets and Extranets without any theoretical underpinning.

With particular reference to the analysis of Questionnaires 2 and 3 (See appendix 3) there is evidence to suggest that again there is a mismatch between theory and practice. According to results of the analysis questionnaire 1 (appendix 3) most organisations are attempting to transform themselves into a learning organisation. The speed of change varies, based on changing the mind-set of its workers, which is largely dependent on the responsiveness of the workforce and the preparation that has gone towards achieving it.

From the perspective of the CBIS that serve organisational needs, the evidence from the analysis of questionnaires 1, 2, and 3 (appendix 3) suggests a very different picture; this research indicates that there is as yet no discernible change in the ways academics teach ISDM. The research also indicates that the practice of implementing new technology is far ahead of the theory that supports its development. This lack of academic contribution is a cause for concern.

The need to match IS to Learning Organisation is dependent on the need for concurrent alignment of organisational and management theory and practice with information systems theory and practice.

12.3 Future research

The practice of research, in the process of finding answers also uncovers problems that need further research. This research does not go as far as expounding a theory, but it prepares the ground work for doing so.

Further development of the CAS theory is needed to enhance its predictive powers and thus increase its usefulness to designers of organisations. In particular, it would be useful to understand how much uncertainty should be left in the system, and where this uncertainty should be placed to provide requisite freedom of action for agents without running an unreasonable risk of sliding into chaos.

Another area where further research is needed, is to gain knowledge of how to partition a network of agents into reasonably self-contained zones with a view to optimising their interaction. If too many agents attempt to send messages to each other the likely result will be a deadlock. It may be that answers to these questions will be obtained by simulating alternative designs and then comparing results, using for example, the Swarm Simulation Software developed at the Santa Fe Institute.

Application of CAS theory to organisation and management science, and to IS design holds promise, but serendipity must be replaced by cautious and rigorous testing of the principles. Much research is required before it can be established whether the complex adaptive systems approach will generate durable theoretical insight into the design of adaptive, evolving concurrently IS and other stubbornly difficult problems of organisational dynamics.

Research is also needed to assess the effect of multimedia communication on IS design and the response of humans to this new mode of interaction.

The science of complexity has introduced a whole host of concepts and new metaphors. Attempts by both organisational theorists, information systems theorists and practitioners to conceptualise contemporary management issues are hindered by the lack of common language to describe emerging organisational phenomena.

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Appendices

Appendix 1

Empirical Case Studies

Empirical case study 1
World-wide Information System (WIS)

Background

This study was based in one of the UK branches of a large multinational computer firm WIS (a pseudonym). The study lasted four months full-time. The project involved the development of a proprietary IS development methodology.

During this period I participated by researching and documenting the proposals for the 'testing and validation'. The methodology developed was based on the principles of a top-down structured system development method. It was adopted in October 1992 and superseded all previous system development methods and procedures used within the organisation in the UK, USA, and elsewhere.

Aim of the study

This study was undertaken to assess the extent to which IS designers adhere to prescriptive structured IS Development Methodologies (ISDMs) in practice.

The research approach

Five days a week full-time, over four months were spent working at the company.

In order to study the development process of a proprietary ISDM, the research approach adopted was dualistic. One aspect consisted of action research, since during the period of study I also participated by researching into and documenting the proposals for the 'testing and validation' phase of the system development. The other aspect was participative observation, employing ethnographic techniques which enabled me to directly observe features of the work environment e.g. management style and structure of the managerial hierarchy. These observations were compared and contrasted with the data collected from some interviews with staff.

The first meeting at the organisation was with my primary contact and it was through her that I arranged all the interviews. 17 staff from a range of levels in the company were interviewed. All participants were homogenous in being actively involved in IS development either in-house or at client sites. Clients included both large and small organisations, in the private and public sectors. Interviews ranged from one to two hours and took place over one to three meetings. At the interviews I explained my role and involvement.

Study results

The underlying model of the information system development process for many structured ISDMs is the information systems development life cycle (SDLC) model. At the time when this study was undertaken it was being widely acknowledged in the press, both by academics and practitioners, that the IS development process is an iterative rather than a sequential process, yet the underlying model of the new methodology developed at WIS took no account of this new understanding and retained the linear SDLC approach.

The in-house development methods at WIS, prior to the new methodology, were based on structured methodology and linear top-down approaches. Most staff involved in developing IS either in-house or at client site, when interviewed, stated either implicitly or explicitly that they did not fully adhere to these prescribed methods, at least not in the way that they were intended to be used.

Analysis of the material gathered from the interview revealed a number of important results:

Nearly 75% of the people that were interviewed said they did use a structured approach (either in-house, or other e.g. SSADM). However, an interesting and revealing fact was that approximately 85% of those who did use a structured approach did not use the method in its entirety but combined intuitive/ad hoc procedures based on personal experience.

Those system designers who were involved in developing a project where the client insisted on using and producing documentation based on a certain methodology (most commonly mentioned was SSADM[6]), admitted to using the methodology only as a front-end to *keep the customer satisfied.* They admitted to using certain techniques such as data flow diagrams, logical data structuring, normalisation from SSADM, but overall found it too 'time consuming' and 'long winded' and requiring too much documentation. They used other methods such as prototyping to get results more quickly. Case tools supporting SSADM were not easy to use[7].

Nearly all those who claimed they used prototyping, said they did not use prototyping as the sole method but combined it with the structured ISDMs.

Findings confirmed the suspicion that structured methodologies represent what Kuhn would call a 'paradigm in crisis' i.e. they represent the existing paradigm of CBIS

[6] Structured System Analysis & Design Methodology. Mandatory for UK Government projects.
[7] This comment is only relevant in the context of the time of study. Case tools have improved much since.

which is well established and has a stronghold, but is no longer relevant or effective for the design of IS that are different from traditional, centralised databases.

It was evident from the interviews that there was a mismatch between the theory guiding the design of the new in-house ISDM. It was based on the same structured, linear and top-down approach that system designers and developers found impractical and the rigid adherence to the system development life cycle approach was found to be restrictive.

Empirical case study 2

A centralised organisational database

Background

This study was part-time, three days a week, lasting three months. The project involved a large UK Government database project. During the period of observation I also took part in documenting the design of the database, in particular developing the 'Entity Life History' part of the database using a CASE tool.

This project was a second attempt to design the database. Initially the project was developed in-house but could not be implemented successfully due to technical problems.

The same database was being redesigned but this time involving outside consultants called in to assist the original team of designers. SSADM was the methodology used both times.

Aim of the study

The primary aim of the study was to see in action, and experience the development of a large centralised database information system in a real life situation using top-down Structured System Analysis and Design (SSADM) which is the UK Government's mandatory methodology for all public sector projects.

The research approach

As with case study 1 a participatory/observation approach was adopted to evaluate the process of developing a centralised database information system. The main difference was that no formal interviews were carried out. The project was based at the Headquarters of a Government organisation and the manager was extremely sensitive about breaches of confidentiality and did not agree to an interview.

Study results

The study lasted only three months and the following observations were made:

SSADM support in the logical design of the database was prescriptive. Documentation was excessive and the CASE tool supporting SSADM not user friendly. I was not involved with the logical design of the database but only with its documentation.

The project, in spite of earlier difficulties, was again being developed in a linear manner, adhering to the system development life cycle approach, leaving physical design and implementation for later consideration.

I was given to understand that the consultants involved at the time would design and document the logical design only but the coding, testing and implementation would not be their responsibility. Another private consulting firm would be engaged for physical design and implementation.

Adherence to every step of SSADM was almost religious.

Empirical case study 3

A & P fund-holding consortium

Background

In order to make primary care more cost-effective HM Government devised a scheme in 1992/3 whereby General Practitioners (GPs) could become voluntary fund/budget holders. Under the regulations at the time, to be eligible the practice needed seven thousand or more registered patients. Since none of the practices participating in this scheme had an individual list size of 7000 or more, the participating practices decided, under the provisions of the regulations, to merge and form a consortium for the purpose of fund holding. The funding was intended to support four elements :

- hospital services
- community services
- drugs and appliances
- payments to practice staff.

The project

The project was concerned with a team of doctors assessing the feasibility of becoming fund/budget holders. It was undergoing a one year preparatory stage before going live and involved a consortium of six General Medical Practices (3 group practices of 3 doctors each, and 3 single-handed practices) serving a patient population of around 25, 000.

During this period all 12 doctor were engaged in a series of meetings with all concerned with the project throughout the preparatory year. During this one year, doctors and other staff invested considerable time, energy, thinking and money spent on buying computers (hardware and software) and office equipment. Just before the scheme was due to go live, all except one practice in the consortium pulled out.

Aims of the study

1) To observe how a group of general medical practitioners (i.e. knowledge-workers) organised their team and progressed in the venture of fund-holding.

2) To analyse the interactions in a team of knowledge-workers.

The research approach

To evaluate the process of team-working, a participatory/observation approach was adopted.

Initially some apprehension was expressed by members of the consortium concerning a potential breach of confidentiality, but after signing a written assurance to maintain confidentiality and anonymity I was accepted. I eased into the project gradually, taking time for me to become acquainted with them and vice versa.

No formal interviews were carried out in this study. I did officially meet the representative of the Family Health Services Authority (FHSA) under whose supervision the fund-holding consortium was working, to explain my involvement and get her consent .

The documents concerning fund-holding schemes in general, and the formal and informal records of meetings, were used as sources of data. The documents were studied with two main objectives, firstly to keep informed about development of the fund-holding project, secondly, and more important from the perspective of my research, to study and interpret the beliefs, behaviours, and interactions of the participants. Specific areas of interest were:

- interaction amongst the consortium members
- interaction of the members individually with other parties involved with the project
- interaction of the members as a group with other parties involved with the project
- the conflicting issues from individual members' perspectives.

The data was derived from observations made of the following activities of the practices during the preparatory year:

- The process of appointing a fund-holding manager and other staff.
- The purchase of hardware and accredited software for efficient handling of clinical data and financial accounts generated by the fund-holding process.
- The daily collection of clinical data for each practice on the utilisation of services offered by the providers i.e. hospital admissions, X-ray and laboratory facilities and services offered by Community and Social Services. These were to form the basis on which a tentative budget would be based.
- Negotiations on contractual arrangements with providers of services.
- Analysis of the cost of drug prescription.

Study results

This project, although a failure on the part of the group of general practitioners in their endeavour to become fund-holders, did provide for this research, an interesting opportunity to observe the interaction of a group of knowledge/expert workers i.e. doctors. These doctors, though highly educated professionals, lacked team building spirit, organisational and financial planning skills, and seemed to lack mutual trust and the ability to resolve differences of opinion. All these resulted in a failure to appoint a trusted and effective team leader.

Under the terms of fund-holding, savings made by under-spending could only be utilised for improving the premises and services of the practice. The lack of personal reward as incentive, and for the time and effort expended, and the potential of penalties for over-spending the budget, were for some doctors the reasons behind their poor motivation.

Conclusions

This case study shows that for any team effort to succeed, having just professional expertise and financial backing alone can never be enough. A high degree of motivation, efficient team building, mutual trust amongst those involved and adequate reward or other incentive for the time and effort made can be key issues for success.

The benefit of using the participative approach was immense. I was able to observe and experience the factors that emerged when a team of experts came together from necessity but did not have a clear and common goal or a shared vision. Each expert had a different level of motivation about the fund-holding scheme, ranging from enthusiastic, to indifferent or antagonistic. This was true not only amongst the practices but also among partners in the same practice.

Appendix 2

Action Research Case Studies

Introduction to action research

Introduction

In Chapter 3, section 3.3.3.3 it was mentioned that the Design Workshops provided the opportunity for action research. Before describing some of the case studies undertaken in action research a brief introduction to the Design Workshops is provided.

As part of their first year studies on the BSc (Hons) Computer Information Systems Design course at Kingston University, students develop a design for an information system. I teach at Kingston University and have been involved in organising and running the Design Workshops over the last ten years. As mentioned in Chapter 3 Section 3.3.3.3, the workshop project always involves a "real" client. The following is a brief description of how the workshop is organised, the role of the client, the project activities and the final product.

Working in small teams, students elicit the requirements of the client as the starting point to plan and execute a project. From start to completion the elapsed time is about twelve weeks. The final products include analysis of the existing information system used by the organisation, a complete design specification for a proposed information system, a documented working prototype which gives the "look-and-feel" of a potential implementation, and a report on the state of relevant technologies.

Participating as a client is of interest to an organisation which does not yet use computer-based information systems extensively. Just as likely, it is of value to an organisation with some experience in IS and which would like to reappraise its current and impending information requirements, and its existing provision. The scope for integrating these in an architecture to support the business and information strategies is explored. It allows for an opportunity to assess the potential for more detailed gathering, sharing and presentation of information.

The project is *not* intended to deliver a fully implemented production system (though it might form the basis of a final year project which could come closer to that goal). Rather, it provides the client, free of any commitment, with a framework within which his or her information requirements can be identified and discussed. A solution is defined which matches business objectives. The design features, including interface considerations, are illustrated in a prototype, with which the client and developers together review quality of the proposed solution and requirements .

The client is exposed to some of the techniques employed, and the decisions which need to be made, when designing an information system. The state of the art survey alerts the client to the technologies which are currently available, or imminent, to implement such a system and to plan future developments. Evaluation of alternative solutions may lead to a clear recommendation, but its real value probably is in airing the criteria and preferences employed when making such choices.

Stages of the project

1. Proposal and planning
2. Analysing and specifying requirements; State-of-the-art investigation
3. Designing the system
4. Constructing a prototype
5. Demonstrating the prototype
6. Presentation and review

Involvement of the client

It is recognised that an organisation, although interested in co-operating as a client on a project, may find that the person nominated as "user" can spare only a small amount of time. The most crucial points of contact with the development team are probably at the beginning and at the end of the project. Feedback in the middle of the project is also important, but in this project was usually provided, as and when necessary, by me acting as the representative of the client. Typical involvement of the client in the formal stages of the project is outlined below, but further time is expended if ideas of particular interest have arisen and the client wishes to discuss these with the tutors or individual teams.

0. **Initial discussion**
   with the Workshop Tutors, to set up the project brief,
   1-2 hours, at the client's place of work.

1. **Proposal and planning**
   Client presentation: to introduce the organisation and outline its information needs, - 1 hour, at the University
   Team representatives visit client's place of work, (where appropriate and convenient), to gain an overview; 2 hours (2 groups, 1 hour each).

2. **Analysing and specifying the requirements**
   State-of-the-art investigation;
   a panel of student team representatives interviews the client, 2 hours, place to suit the client.

3. **Designing the system**
   Client (usually represented by lecturers), meets the project team to select options and to discuss possible design solutions.

4. **Constructing the prototype**
   Client/User, (usually represented by lecturers), meets the project team for quality reviews and to discuss prototypes.

5. **Demonstration of the prototype**
   demonstration of the prototype system to the client and/or user,
   1 hour, at the University (selected teams, 15 min each).

6. **Presentation and review**
   Project team makes a formal presentation of the system to the client for acceptance, 2-3 hours, at the University (selected teams, 20 min each).

Project activities and products

1. Proposal and planning

Students study the information system brief, considering its feasibility and the business implications of alternative strategies. They construct an overall plan for the project, estimating the cost of resources to meet the requirements within the time constraints imposed. The results are presented as a project proposal.

2. State-of-the-art; analysing and specifying the requirements

Students explore existing work in the area of computer applications to discover:
- what approaches and techniques have been developed and applied successfully.
- what appropriate resources have been developed recently.
- what level of skills would be needed to exploit these technologies.
- to what extent are the technologies and skills available.

By liaising with the client and examining current documents, the project teams determine the detailed requirements of the proposed system and the problems which it must address. These include:
- identifying the information which should be output by the new system.
- determining how the information input and output should be designed.
- estimating the volume of data to be stored, the rate of transaction throughput, acceptable response times, and so on.

The analysis considers the overall business strategy of the organisation and the financial, social and management implications of the type of system to be introduced.

Several alternative solutions are developed, in the form of outline models. Then, in collaboration with the client, the choice is narrowed down by refinement and selection to one business system option (BSO), a model of the required system.

A number of different techniques are applied to the problem; by cross-checking the results of one technique against those of another the risk of omissions or discrepancies is greatly reduced.

3. Designing the system

Having specified the requirements, the way in which business functions are to be fulfilled must then be agreed; the data structures to be used and the processing steps are defined at this stage. Cost/benefit analysis is applied to proposed alternatives, physical resources (hardware and software), operational support and data communications provision. Estimates of the rates at which transactions must be processed, and of the volumes of data which must be stored, are compared with the capabilities of the equipment under consideration.

Particular attention is paid to the interface between the computer and the user; it must be as supportive and efficient as possible. The team plans the development, implementation and testing of the final system.

At this stage "throwaway" prototypes are developed to allow the client to assess the "look and feel" which the system might have in operation.

4. Constructing the prototype

Part of the agreed design specification is realised as a prototype of a part of the system. There is time only to implement this minimal functionality. The teams' activities at this stage include:

- selecting available resources
- creating a database (where applicable), populating it with test data
- writing testing and debugging procedures
- exercising quality control.

These are achieved with the help of rapid development tools - such as a client/server database and retrieval interface tools (e.g. Access and Visual Basic), a hypertext language, an integrated word-processing and spreadsheet package (e.g. MsOffice) or an expert system shell.

The necessary software components (and possibly hardware) may be integrated to form a working prototype, or run separately. Platforms available include Unix, VAX VMS, PC and Macintosh networks.

5. Demonstration of the prototype

The application prototype is tested and modified. An introductory user manual is prepared containing screen reproductions of the prototype and proposals for further development.

Each team gives a 15-minute demonstration of their prototype system to a panel of staff.

Some teams are selected to demonstrate their prototype to the client and/or user at a later date.

6. Presentation and review

The teams make formal board-room presentations of their proposed solutions to a panel of staff, and if possible a representative of the client. The product and project will also be evaluated by the team and reported in the end-of-project report. This report will also include a review of aspects of team organisation and effectiveness of group work.

A typical timetable:	**Duration in weeks**
Team organisation & briefing	1 week
Interviewing	1 week
Feasibility study	1 week
Project planning	1 week
Requirements analysis	2 weeks
Requirements specification	1 week
Design & development	4 weeks
Presentations to tutors	1 week

Client presentations and prototype demonstrations are outside the timetable and are usually arranged at a later date.

Examples of recent clients and application systems

Examples are listed below chronologically. Only the first three of these case study are elaborated in some detail (due to the thesis size restrictions) to illustrate the varying nature of Information Systems requirements of the client.

- The London Tourist Touch-Guide
- National Housing and Town Planning Council
- Local Dispensing Optician
- Student Financial Advisory Service (SFAS)
- The North Surrey Group Spastic Society.

Action research case study 1

The Touch Screen System

Organisation: Interactive Media (Europe) Ltd
Linden House
379 London Road, Mitcham
Surrey CR4 4BF

Note: The client does not wish to be contacted.

Company's aims

The company aims to provide a comprehensive quality interactive tourist information guide using modern information technology.

Background

The company, located in South London, has been in operation for just under 3 years. The main reason for this is that the technology being used has become available as a cost effective medium only in the last few years.

The client's Customers are advertisers. These advertisers consist mainly of businesses that cater for tourists and wish to advertise their business on a Touch Screen network. The nature of the businesses being advertised is very varied and a few examples are :

- Restaurants
- Shopping
- Entertainment
- Sightseeing

The client has a contract with each company to advertise their business, commercials and service/product on the Touch Screen System.

Organisational Roles

- Managing Director
- Director
- Technical Manager
- Technical Assistant
- Production Manager
- Graphic Designer
- Two Salesmen
- One secretary
- P/T Accountant

The Tourist Information Guide

There are two systems in operation. One is the 'Touch Screen kiosk based system' which is rich in graphical content but restricted in functionality. The other is the 'concierge system' used by the reception staff within hotels which has limited graphical content but is richer in functionality e.g. possessing the ability to search on categories or shop name.

The commercial difference between the two systems is that the Concierge System with limited graphical facilities carries extensive information, but only about the paying advertiser (about 700 advertisers) which have contracts with Interactive Media. The Touch Screen System has far more establishment entries (approximately 3,000, and is likely to double shortly) most of which are free adverts e.g. London Transport System. Ideally, a higher percentage of non-paying customers need to be converted to paying customers to make the system profitable.

Touch Screen kiosks developed by Interactive Media (Europe) Ltd are currently located in big hotels in London. The project is concerned with improving the Touch Screen System using the Internet and Web technologies.

The main reason for selecting hotels as an ideal location is because business people and tourists who stay there have spending powers large in comparison to the local community, but are often unfamiliar with the surroundings. The Touch Screen system provides an electronic tourist information guide that connects potential customers to the businesses who advertise on it. The system is flexible in the sense that it allows advertisers to adapt their advertising according to seasonal and specific market needs. Advertisers can change their commercial to suit their requirements as often as they wish (but see the technology constraint below). The intention is that every sales message is always up to date.

Each kiosk at present is a stand alone system and advertisers' information is updated weekly by going to each location and physically changing the hard disks.

A typical Touch Screen kiosk comprises a console which measures 1525mm x 508mm x 600mm and consists of the following components:

- a touch screen colour TV monitor
- a telephone
- a thermal printer.

The touch screen The screen is a 14" full colour monitor, depicting fascinating graphics and text. A potential customer can gain information about an advertiser's business in any of the five languages: English, French, German, Spanish and Italian, just by touching coloured icons on the screen.

The telephone The telephone provides a direct line from the hotel to the advertiser's business. By touching the dial icon on the screen the potential customer is able to communicate with the business whilst looking at their commercial. The customer can also make reservations and receive confirmation from the system in a few minutes.

The printer There is no need for a customer to carry a pen or write any information received from this system. The customer can get a printout of the business address and directions as to how to get there etc., plus any other relevant information just by touching the printer icon on the screen. This service is also available in a choice of five languages stated above.

Existing technologies

- The systems in the field (20 in all) comprise:

17	pentiums 133s and
3	486s.

All the field machines include a touch screen, telephone, and thermal printer encased within a kiosk.

- The office contains:

6	pentiums and
3	486s

There are two colour ink jet printers for testing adverts before being transmitted.

Information held in database

A system called 'Act' holds information on existing and potential advertisers.

Information produced

- Log files are read from each machine in the field once a month. These files show all the accesses made to each advert over the month and when they were accessed. This information is ported to MS Word and translated into a report for each advertiser.
- Contracts for each advertising agreement.
- Letters exchanged between company and advertisers.

- Invoices sent to advertisers requesting payments for advertisements currently on the system.
- Marketing material produced to promote the product/service.
- Accounts kept by the part-time accountant.

Project objectives

- To analyse the existing Touch Screen (kiosk-based) System.
- Produce the requirement specification.
- Design, develop, and demonstrate a prototype for a Web based replacement system.

Action research case study 2

Organisation: National Housing and Town Planning Council
14-18, Old Street, London EC1V 9AB

Contact: Kelvin McDonald, Director

Note: The client must *not* be contacted *directly* without express permission

Organisation's aims

The NHTPC works to achieve better standards and conditions in housing, promote more effective town and country planning, and improve the built and natural environments.

History

The NHTPC is a charitable organisation, which started life as the National Housing Reform Council in 1900, demanding stronger action in rehousing families from slums to healthy houses. Regular deputations to Prime Ministers and Housing Ministers in the first 50 years contributed to the passage of the major housing and planing acts of 1909, 1930.

Main activities

The NHTPC has the following key roles:

1. to provide a discussion forum, both nationally and regionally, to bring together people across institutional and professional boundaries that all too often divide those involved in housing, planning and environmental issues.

2. campaigning for higher standards, increased resources and appropriate legislation in housing, planning and environmental matters.

3. conducting and commissioning research into key areas. Drafting position papers, responding to Government White Papers etc.

4. publishing *Housing and Planning Review* (a bimonthly journal), books and reports, drawing on its particular expertise to publish material of value to individual householders, and to people working in the housing and planning fields.

5. arranging seminars and conferences, in particular the major annual conference, in London and the regions, focusing on issues which cross traditional boundaries.

6. making partnership awards to promote cooperation for innovative housing schemes and environmental developments involving joint ventures from different sectors of housing and planning.

Membership and organisation

The NHTPC has about 600 institutional members, including about 220 local authorities, plus major building companies, housing associations and about 120 independent members. The members elect a National Executive Committee at the annual conference, at which policy decisions are made. The organisation has a paid core central staff, equivalent to 5 full-time employees, who are responsible for organising most activities. There are also volunteer (unpaid) regional contacts who organise local meetings.

Organisational roles

The client is the Director of the NHTPC. He has the responsibility for the overall management of the organisation. His main work is based at the central office in London, but his role also requires him to travel throughout the country, attending regional meetings etc..

In addition to the Director, other roles in the office are:
- Assistant Director/Company Secretary
- Finance Officer
- Publications Officer
- Director's Personal Assistant
- General Administrator

Some of these staff work on part-time only.

Sources of funding

The NHTPC is a limited company, and a registered charity under the Charities Act. It is a non-profit making organisation funded entirely by membership fees and money made on conferences, publications and seminars. A major source of income is the annual conference (see below). The organisation currently has a significant *deficit* and needs to save or raise money.

Existing technology

The office staff have 3 relatively new Macintosh LC3 and 1 Performa 475 workstations, and 2 old MacPlus machines. These are networked via System 7 and AppleTalk to enable users to share a Laser printer. Backup is via 44Mb optical discs. Staff use PageMaker 5 for desktop publishing, but the final printing is sent via floppy disc to the printer. Articles from external sources can be received on disc, but those written on a PC must be sent out to a local company for data conversion. Otherwise, hard copy is received and scanned in by optical scanner (with OCR). Other software used are Microsoft Word and ClarisWorks. The office has a small membership database system, running on 4th Dimension. Roles and experience in the office are relatively specialised, so only two people know how to use the database, which was set up by a member of staff who has now left, and only 2 use PageMaker. There are currently no email facilities or access to the Internet.

Information held (computer-based)

- Members
- Research clients (manual)
- Delegates
- Advertisers (manual)
- Service providers (manual)

Information held (paper-based)

- Other organisations
- Other Events
- Government documents

Information Produced

- Newsletters
- Invoices
- Statements
- Mailshots (part manual)
- Marketing literature
- Diagrams and charts
- Internal memos (manual)
- Accounts (manual

Known information problems

Much of the existing hardware is obsolete and requires replacement.

Related information is held on several different incompatible systems, or on paper, so that access is limited, and much has to be re-keyed.

Not many people in the office understand all the software being used.

Contact with the outside world is either paper-based or restricted to discs sent through the post. Some of these are incompatible with existing technology and require third party translation.

Opportunities for improving information provision

Membership database system needs to be improved.

The office would like to undertake more DTP within house.

No proper accounts system is in use.

The Director would like to be able to keep in closer contact with the office when visiting the regions.

Budget for IT Approximately £12K over 2 years

Action research case study 3

Organization EUROPA OPTICIANS (Pseudonym)
South East London

Contact Mr. P. Pankhania - Proprietor

Organisation's aims

The practice attends to the needs of a wide range of customers: children of all ages, young and old patients. Most of the time patients come to Europa Opticians, but, there are occasions when old patients are unable to come to the practice. In such cases, eye examination and dispensing are arranged through home visits. As such, today's opticians play an increasing role in the preventive health care of the general public.

History

'Europa opticians' is a private business, established in 1948 in South London. In the opinion of the proprietor small private businesses are often preferred by customers due to the personal service provided.

Business scope

A distinction needs to be drawn between a dispensing and prescribing optician. Europa Opticians are both, since they employ the services of a qualified and registered ophthalmologist.

Most people use the services of an optician to test their eyes, usually when they experience problems in seeing clearly. Regular eye examination is essential. It is not only necessary for testing a person's eye-sight and to determine whether s/he requires spectacles, but also as part of preventive health care. It can help detect illness like diabetes, high blood pressure, glaucoma etc.. Glaucoma can lead to partial or total blindness if left undetected for too long. Today's optician plays a significant role in the preventive health care and well being of the general public.

Staffing

This is a small private and family business and apart from the visiting ophthalmologist, all members of staff possess basic business knowledge and assist each other in their jobs if and when required. Europa opticians have the following staff:

Ophthalmologist An ophthalmologist is a qualified, registered medical doctor who specialises in eye diseases. The ophthalmologist at the Europa Opticians is based at Moorfield Eye Hospital, and holds three sessions (Wednesday, Thursday and Saturday) at the premises of Europa Opticians. Extra sessions may be held during very busy periods. He tests the eye-sight of patients on the day's 'appointment list'.

Contact lens practitioner Once a patient's eye-sight has been tested and the patient wishes to have contact lenses, then his or her particular contact lens specific needs are dealt with by the contact lens practitioner.

Dispensing optician Deals with post eye-test needs of the patient e.g. assisting in selection, from a wide range of spectacle frames and lenses. The practice usually has a wide selection of frames on display.

General Administrator Duties include ordering the lenses, maintaining practice accounts, both accounts payable and accounts receivable.

Dispensing optician's assistant helps the dispensing optician, maintains patient record card file, files etc.

Receptionist main duties involve dealing with customers who come in person to Europa Opticians, or who telephone. The receptionist books appointments and assists with a variety of enquiries.

Main activities

The Europa Opticians' business activities may be classified under the following headings:

Patient-record system Patients' records are maintained manually on a card filing system. A record card is raised when a new patient makes an appointment for an eye-test. It records the patient's personal details such as name, address, DOB, occupation, GP's name and address, telephone number. It also contains a history of all eye-tests carried out at the opticians, test results and dispensing details.

Appointment system A patient can book an appointment by telephone or by attending Europa Opticians. The receptionist checks if the patient is booking the appointment as a new patient, in which case the patient-record card is filled out, as described above. Otherwise the receptionist finds the patient's-record card from the filing cabinet and verifies details to make sure that she has the right record card. Patients who come in personally are given an appointment card stating the date and time of the appointment. Appointment date and time is confirmed over the telephone for telephone enquiries.

The appointment diary kept at the reception, is updated with the patient's name and other relevant details.

Eye-testing system The patient reports to the reception for the eye-test at the appointed time. The receptionist verifies the appointment diary entry and the patient-record card.

It is also necessary to ascertain whether the patient falls into the category of 'private patient' or 'NHS patient'. The former is required to pay the fee for the eye-test while the latter is exempted. Patients who are covered by the NHS are:

- people on income support or family credit
- children under the age of 16
- full-time students under the age of 19
- diabetics, or persons suffering from glaucoma
- registered blind or partially-sighted patients
- patients in need of certain type of very strong lenses.

With reference to the above two categories separate forms need to be filled out. For example a NHS form (GOS (ST)A) is filled-in and signed by a patient covered by the NHS.

The ophthalmologist carries out the eye-test and records the findings on the appropriate form.

A private patient's eye-test fee is collected by the receptionist and paid to the ophthalmologist as his fee. The NHS form mentioned above is sent to the NHS for re-reimbursement.

After an eye test, if the patient chooses to buy spectacles or contact lens from Europa Opticians, then the dispensing system is activated.

Dispensing system The Dispensing Opticians finds out if the patient wants contact lenses or spectacles. If the patient wants contact lenses then a further appointment is made with the contact lens practitioner. In all other cases the dispensing optician will advise and guide the patients with regard to the variety of frames and lenses that are available in their shop.

Once the patient has seen the contact lens practitioner s/he too is also advised about the various options and variety of contact-lenses available. The dispensing optician also deals with the sale of sun glasses and other accessories (as described in the stock control system).

Recall system At present the recall system is based around physically searching the entire patients-record cards in order to send the following reminders:

- general annual reminders to all patients
- 3-6 monthly reminders for all children
- two yearly reminders to patients using contact-lenses.

Stock control system Stocks are held of the following items:

- frames
- contact-lenses
- accessories e.g. sun glasses, contact-lens care solutions etc., some top of the range eye cosmetics, cases, cleaning cloths stationery.

Stock control involves maintaining records of items in stock and ordering supplies when needed.

Accounts system Comprises a manual accounts system maintaining all records of accounts payable and receivable.

Known problem

All information held, and processed is paper-based. This is error prone and time consuming and leaves little scope for finding new ways of generating income e.g. e.g. by using an efficient recall system.

Information system opportunities

The opticians would like to develop within house a computerised

- patient record and recall system
- stock control system
- accounts system

Budget for project Initial investment in the region of £5,000

Appendix 3

Questionnaire analysis

ANAYLSIS OF QUESTIONNAIRE 1

ANALYSIS OF DATA

A TOTAL OF 425 QUESTIONNAIRES WERE SENT OUT. A TOTAL OF 78 WERE RETURNED, OF WHICH 65 WERE USABLE, GIVING A RESPONSE RATE OF 15.29%.

SECTION A **Identifies the organisation**

QUESTION 1 *Nature of Industry*

Please tick one which represents major activity

1. **Agriculture**
2. **Mining**
3. **Manufacturing**
4. **Utilities**
5. **Construction**
6. **Whole/Retail**
7. **Transport**
8. **Business Services**
9. **Education**

Responses were as follows

55% - Business Sector
17% - Manufacturing Sector
11% - Education Sector
7.5% - Wholesale Sector
5% - Utilities Sector
3% - Transport Sector
1.5% - Construction Sector

Analysis

The majority of responses were from the Business Sector followed by the Manufacturing Sector etc.

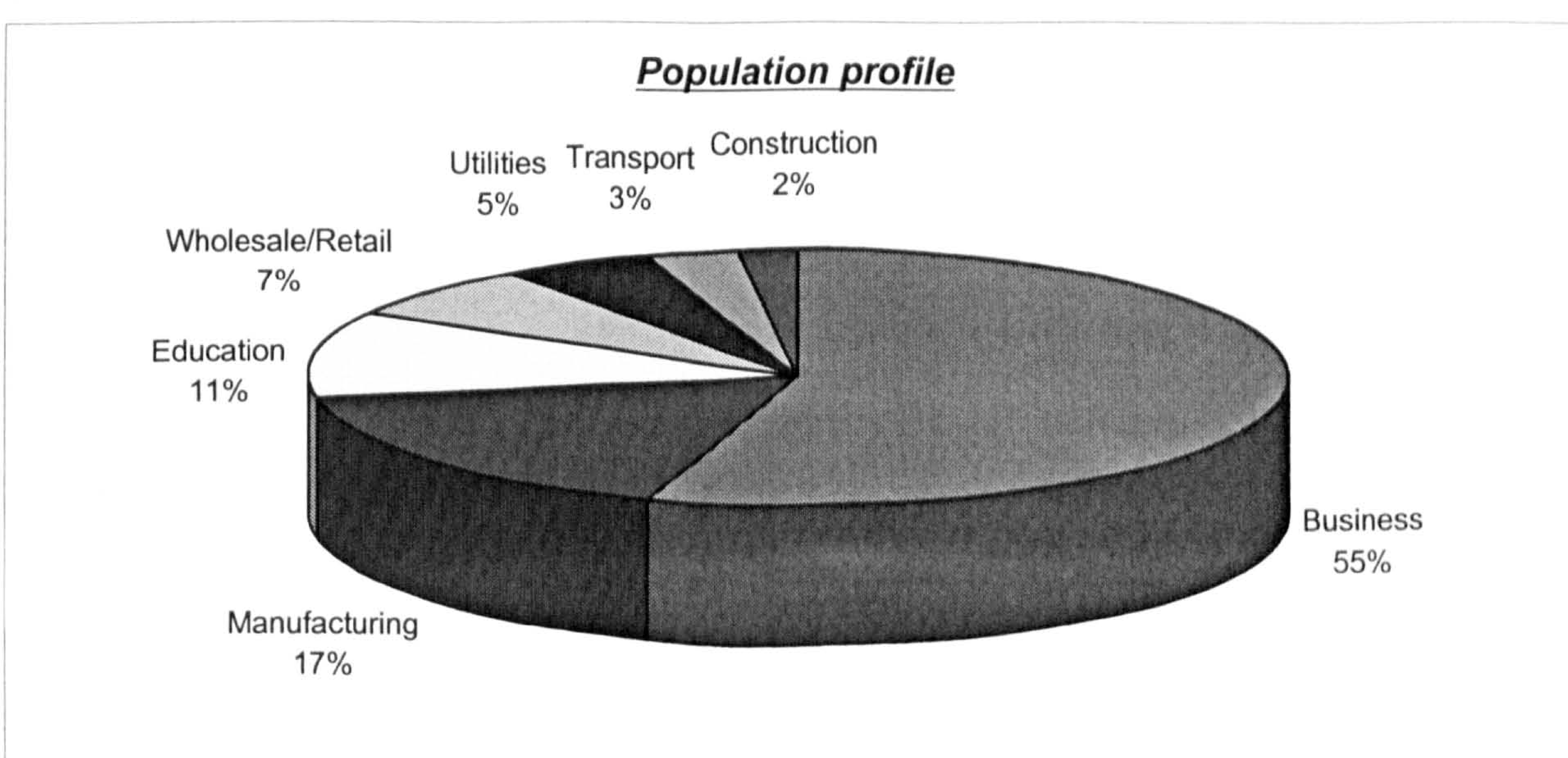

Table Q1.1

QUESTION 2 *Location of Organisation.*

Is your organisation's entire operation

1. **National**
2. **Global?**

Responses were as follows

46.15% - Were Nationally based Organisations
53.85% - Were Globally based Organisations

Analysis

The majority of organisations were globally based.

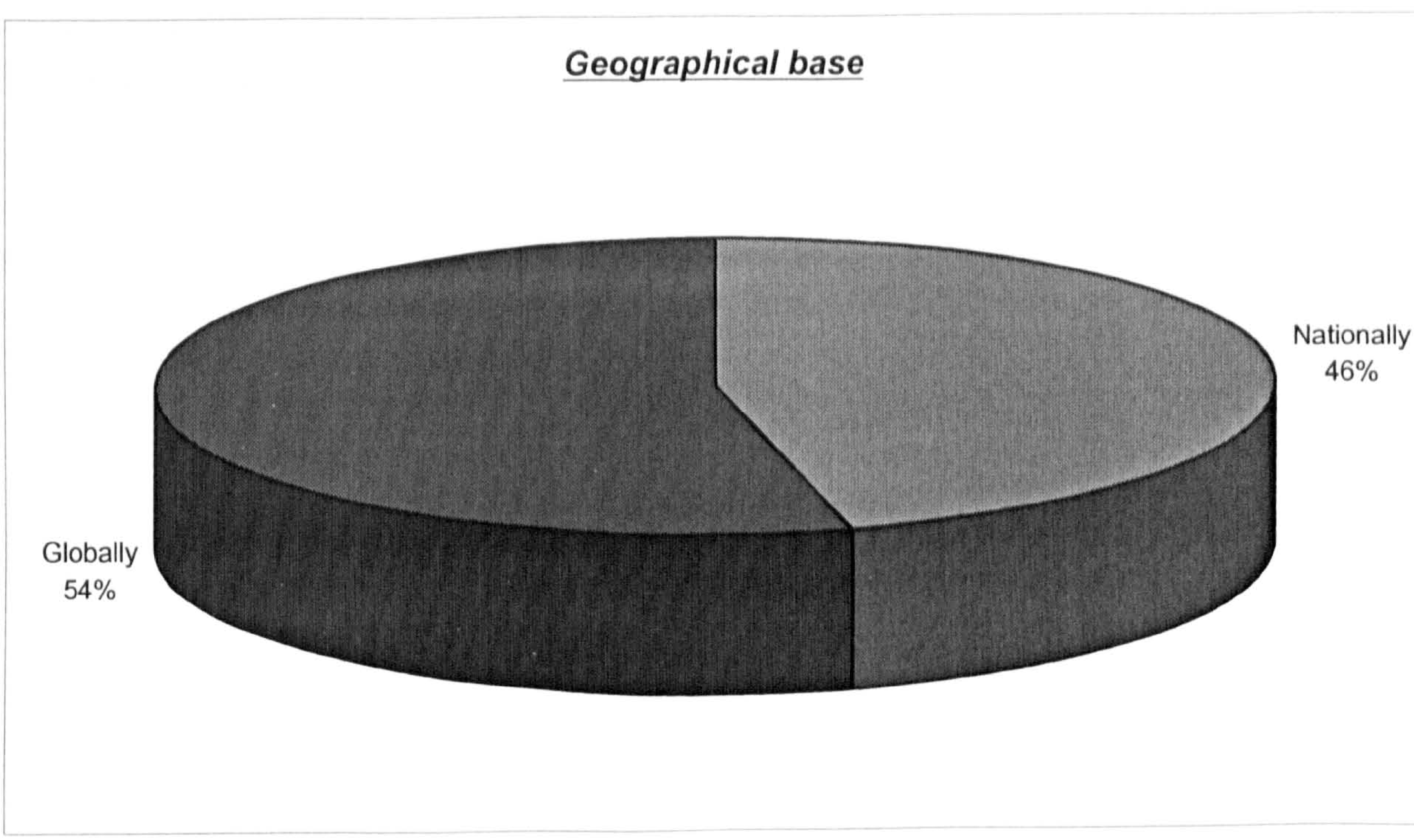

Table Q1.2

QUESTION 3 *Predominant Management Style.*[8]

Which would general describe the predominant management style of your organisation?

1. **Formal procedures & rules**
2. **Few rules, responsible autonomy**
3. **Co-operative & group oriented**

Responses were as follows

47% - Predominantly have formal procedures & rules
27% - Predominantly few rules, responsible autonomy
26% - Predominantly have co-operative & group oriented

Analysis

Approximately a quarter of responses claim to have made the transition to a participative management style.

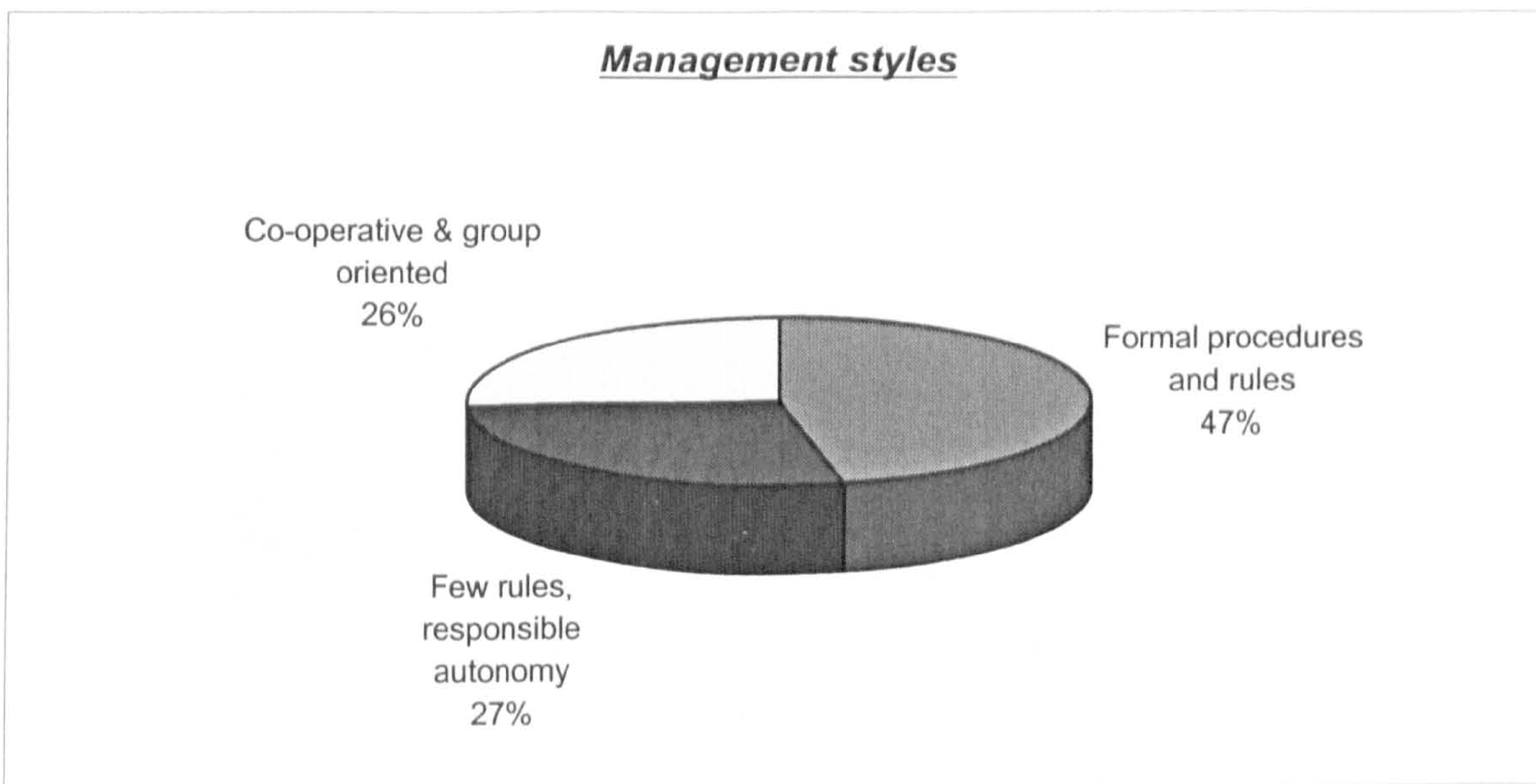

Table Q1.3

Overall analysis in SECTION A of perceived trends

- Response rate equally split between nationally and globally based organisations.
- Change from formal procedures and rules to a co-operative style is slow.
- Mainly still working to formal procedures and rules.

[8] Of a 65 potential responses 63 answered

SECTION B **Ascertains organisational adaptation to change**

QUESTION 4 *Has organisation gone through structural change in the past 10 years?*

Has your organisation gone through structural change in the past ten years in order to adapt to the changing business environment?

1. **Yes**
2. **No**

Responses were as follows

93.85% - Have gone through structural changes in the last 10 years
6.15% - Claim there has been no change

Analysis

Clear indication that nearly 94% of those who replied underwent change

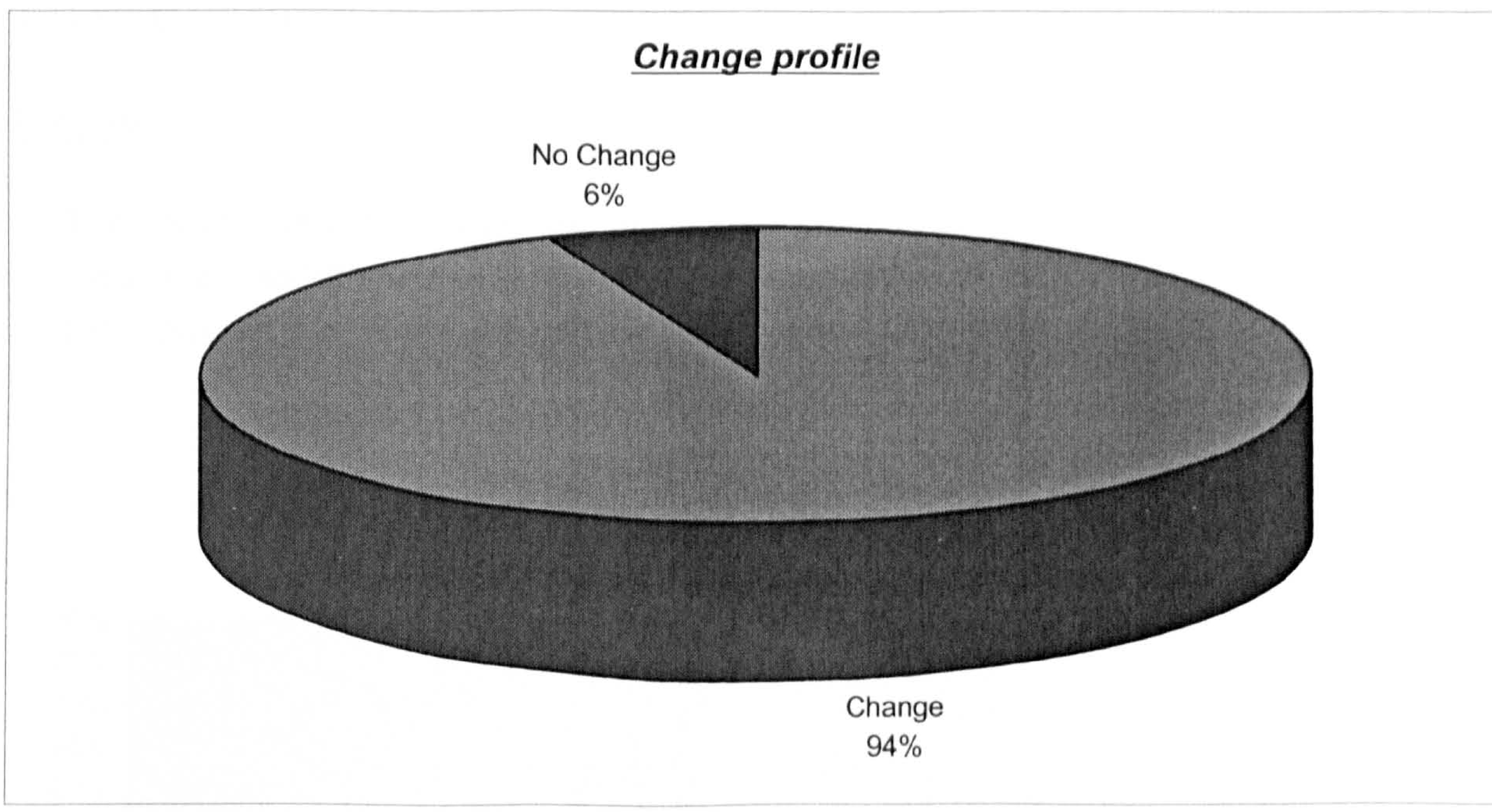

Table Q1.4

<u>*QUESTION 5*</u> <u>*Predominant Management Style after change.*</u>[9]

Which of the following would most closely describe the predominant control style, subsequent to structural change? (Please tick one in each pair)

1. **Hierarchical or Flat**
2. **Centralised or Decentralised**
3. **Cross-functional or Divisional/Functional**
4. **Fully Networked or Partially Networked**

Responses were as follows

46.67% - Have Hierarchical Control Style
53.33% - Have Flat Control Style

40.00% - Have Centralised Control Style
60.00% - Have Decentralised Style

46.37% - Have Cross-Functional Control Style
53.33% - Have Divisional/Functional Control Style

28.89% - Have Fully Networked Control Style
71.11% - Have Partially Networked Control Style

Analysis

- The results indicate that hierarchical style is still predominant.
- This is in line with the results of centralised/decentralised style of management.
- Only one third of the organisations claim to be fully networked.

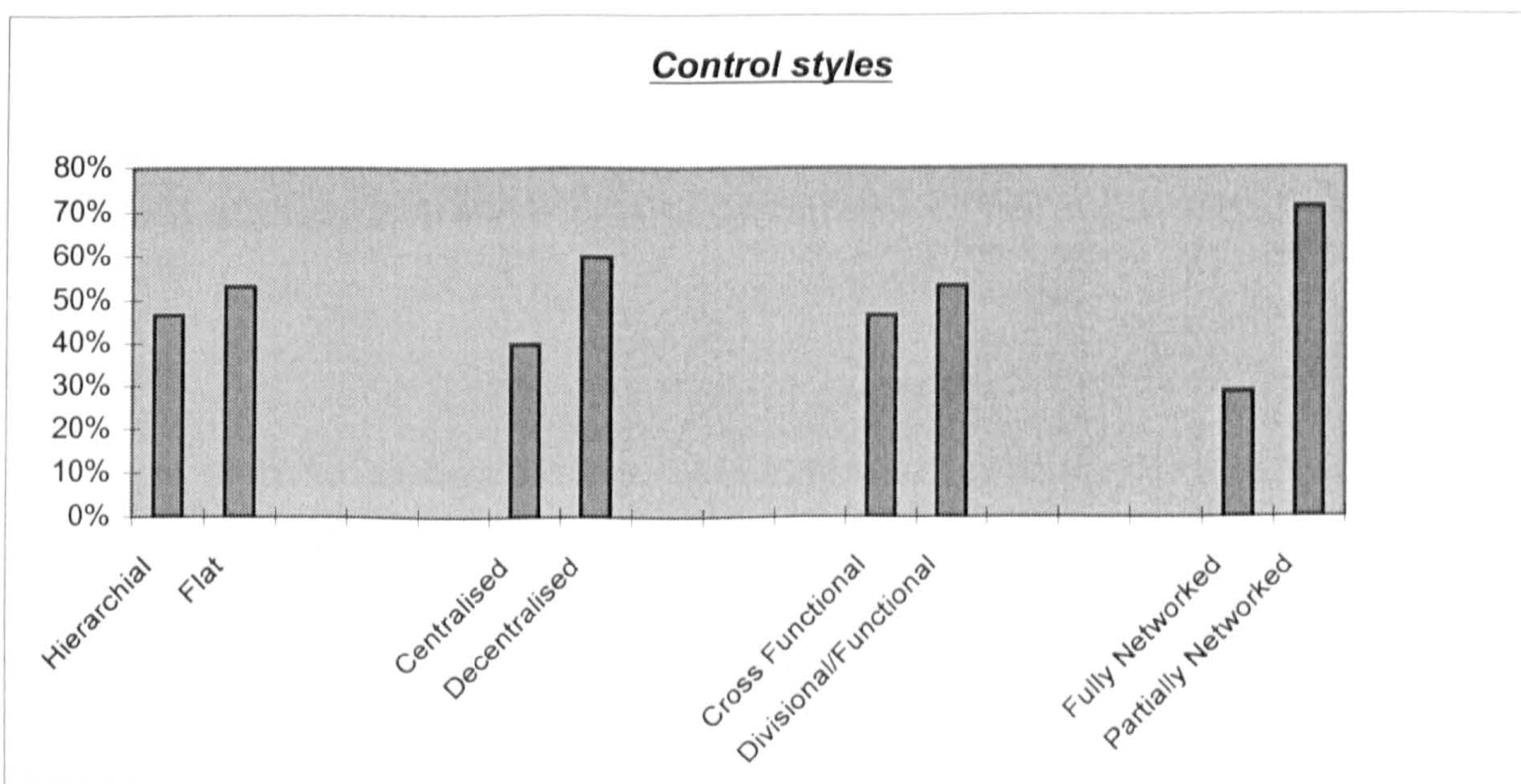

Table Q1.5

[9] Of a 65 potential responses 45 answered

QUESTION 6 *Ascertains which re-structuring approach was adopted.*[10]

Which of the following re-structuring approaches has your organisation adopted over the past ten years?

1. **Total Quality Management (TQM)**
2. **Business Process Re-engineering (BPR)**
3. **Lean Production**
4. **Concurrent Engineering**
5. **Organisational Development (OD)**

Responses were as follows (overlap allowed, also see footnote 10)

27% - Business Process Reengineering (BPR)
23% - Total Quality Management (TQM)
22% - Organisational Development (OD)
6% - Lean Production
3% - Concurrent Engineering

Analysis

Although 94% of the population (see analysis of question 4) claim to have gone through structural change in the past 10 years, 26% (17/65, see footnote 10) did not adopt any of the popular methodologies for restructuring the organisation.

Of those who did adopt a methodology (i.e. answered something) the most popular was BPR, followed by TQM.

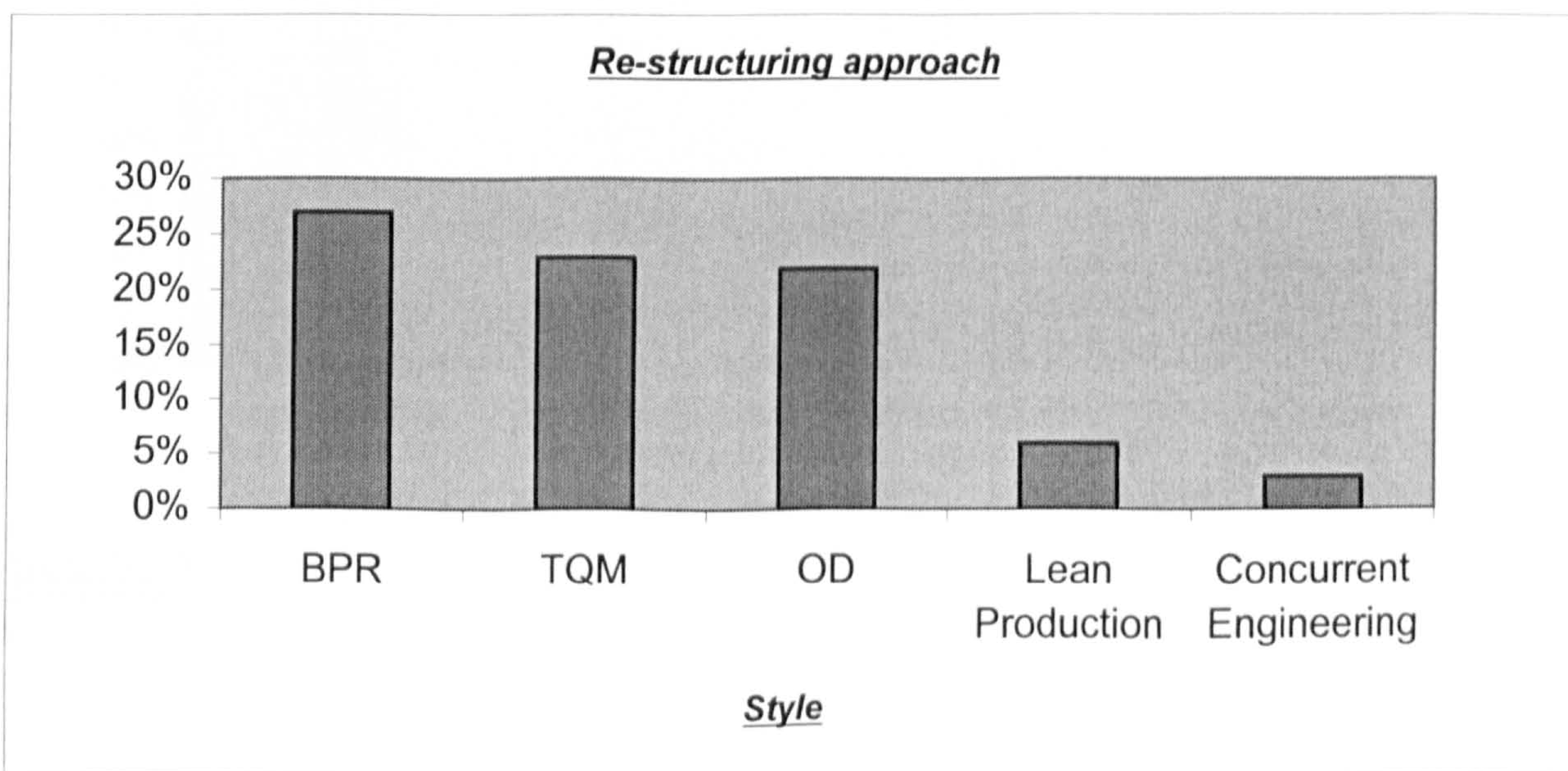

Table Q1.6

[10] Of a potential 65 responses, 48 answered, hence, 26% of the respondents failed to reply to this question. Respondents were given the choice to tick as many as applied.

QUESTION 7 *Ascertains what patterns were adopted following organisational change.*[11]

Which of the following best describes the work patterns you follow now?

1. **Cross functional teams**
2. **Project teams within functions**
3. **Teams of experts**
4. **Business process teams**

Responses were as follows (overlap allowed, also see footnote 11)

77.08% - Cross-functional teams
56.25% - Project teams within functions
33.33% - Business process teams
27.08% - Teams of experts

Analysis

73.85% use some form of teamwork as a regular work pattern after restructuring. However, 26.15% do not seem to use any form of teamwork pattern.

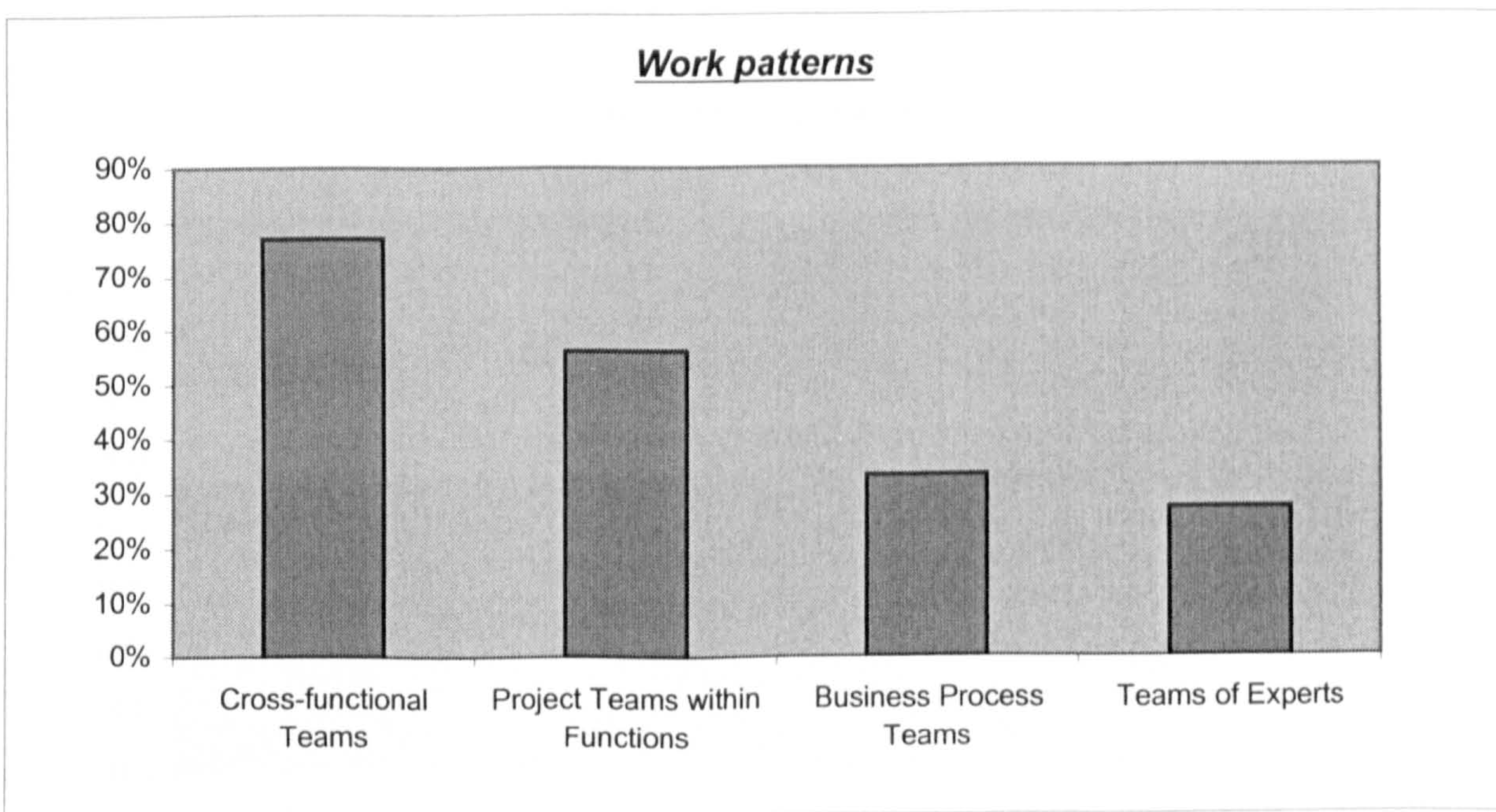

Table Q1.7

[11] Of a potential 65 responses, 48 answered, hence, 26% of the respondents failed to reply on this question. Respondents were given the choice to tick as many aspects as applied.

QUESTION 8 *Ascertains emergent pattern of behaviour following restructuring.*[12]

Can you identify any new patterns or behaviours emerging from structural changes?

1. **Individual Empowerment**
2. **Group Empowerment**
3. **Cross-functional interaction**

Responses were as follows (overlap allowed, also see footnote 12)

78.18% - Individual Empowerment
72.73% - Cross-functional Interaction
56.36% - Group Empowerment

Analysis

10 of the 65 (15.38%) did not identify any new patterns of behaviour emerging from structural change. The trend is towards individual and group empowerment. This implies that tailoring and reactivity to change in business requirements is no longer concentrated in the hands of senior management but is being delegated.

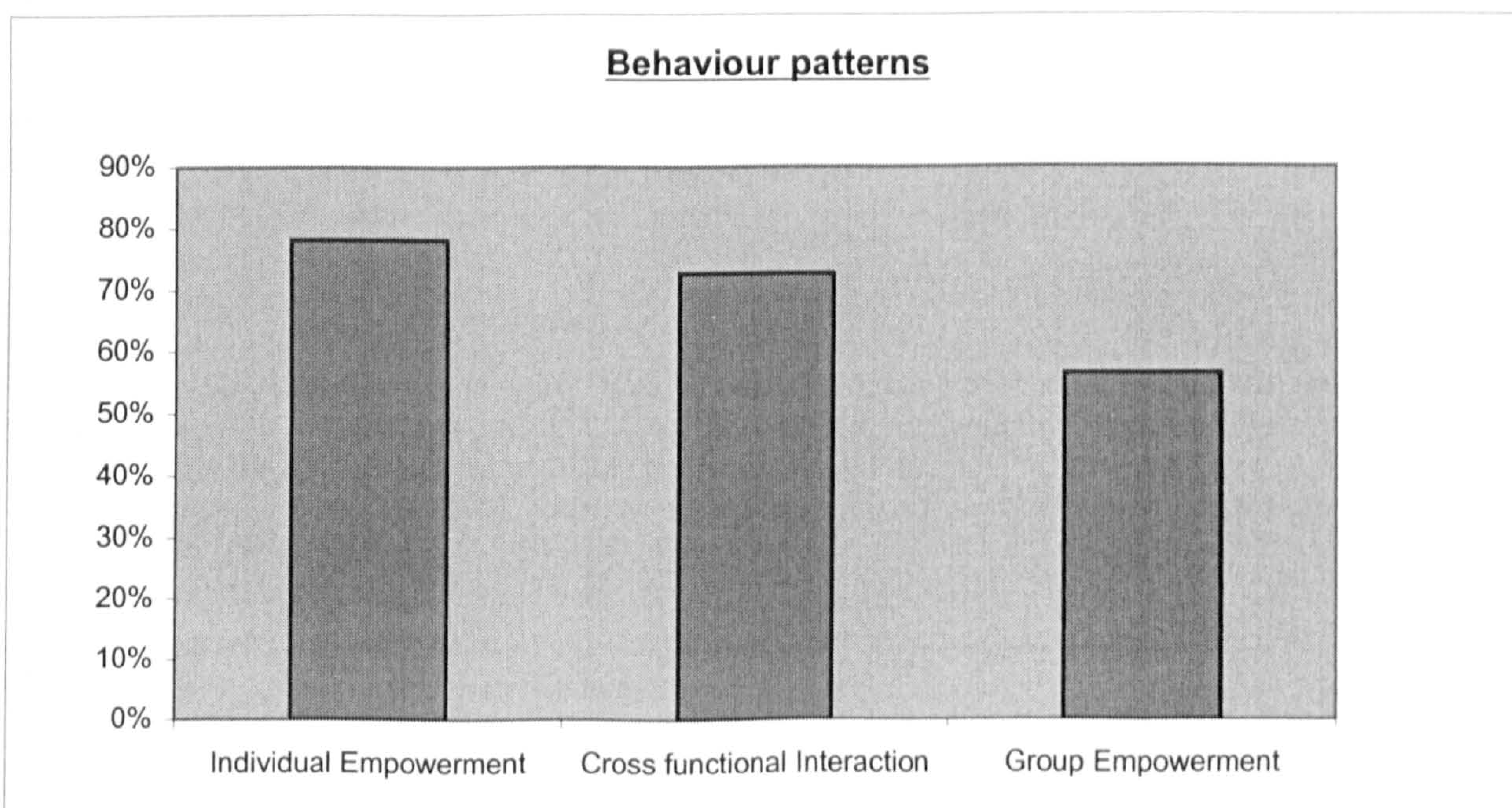

Table Q1.8

[12] Of a potential 65 responses, 55 answered, hence 15% of the total respondents did not answer.

QUESTION 9 *What in your view are the most important elements in implementing the concept of organisational learning?*

Analysis Quite a few people evaded answering this question; of those that did respond, their views of Organisation Learning initiatives were seen as either academic or educational advancements.

Overall Analysis in SECTION B of perceived tends

- Approximately 47% of organisations moved from one hierarchical structure to another hierarchical style i.e. no apparent change.
- Those, (nearly 53%) who did change to a flat control style retained a divisional/functional style of management.
- However, what is also clear is that a considerable number (65%) have introduced group/individual empowerment as well as teamwork.

SECTION C **Ascertains how IT/IS supports the new organisational structure**

QUESTION 10 *Identifies if IT/IS also been restructured.*

If the organisation has been restructured in recent years, has the IT/IS functions also been restructured to support the new organisation structure?

1. **Yes**
2. **No**
3. **Don't know**

Responses were as follows

75.38% -Yes
15.38% - No
9.23% - Don't Know

Analysis

A high proportion (i.e. 75.38%) claimed IT/IS has also been restructured to support organisational restructuring. This is clear evidence that a change from hierarchical organisational structure to flat structure necessitates re-structuring of IS.

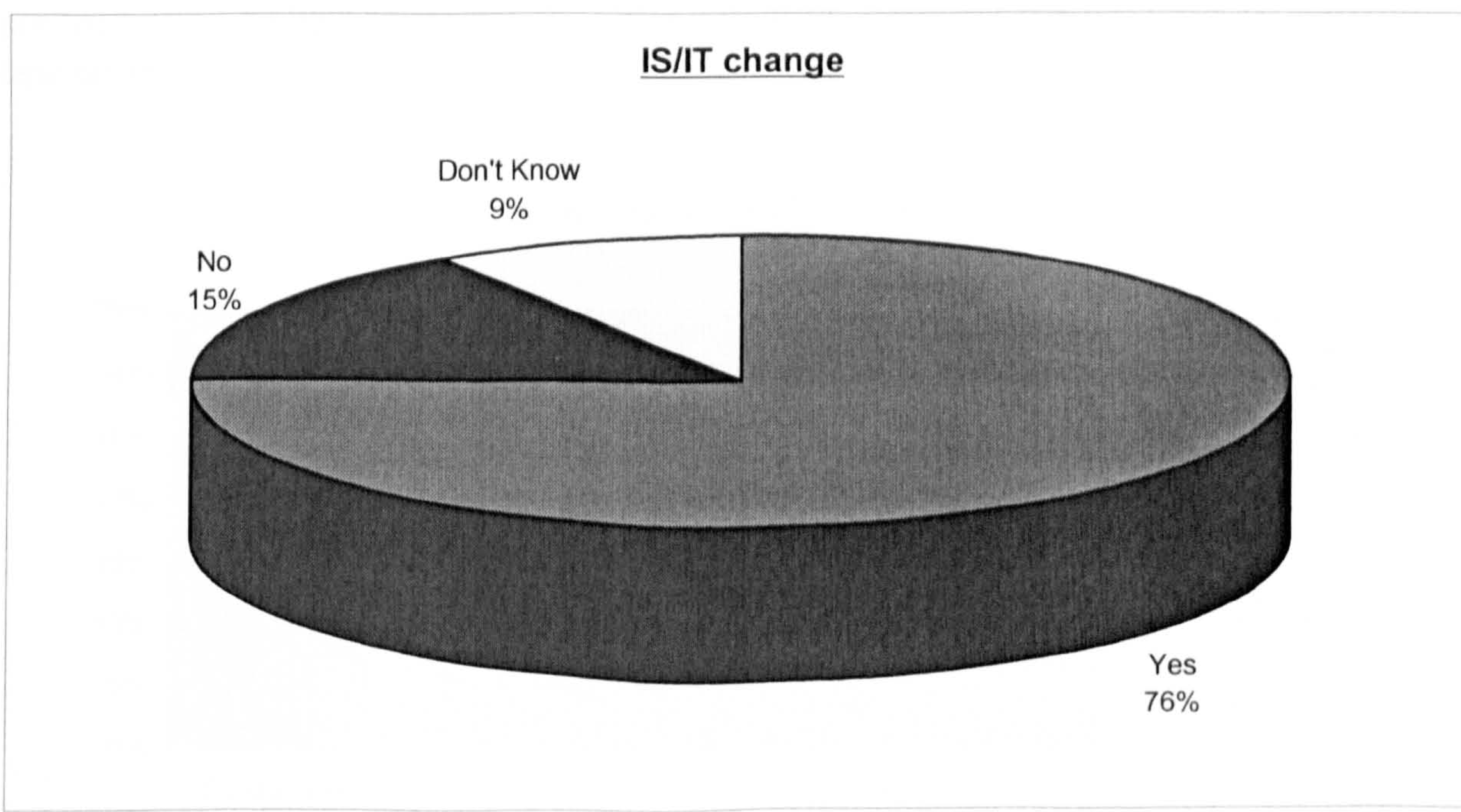

Table Q1.10

QUESTION 11 *To describe the structure of IT/IS functions.*

Which of the following would most closely describe the structure of the IS/IT function?

1. **Centralised and controlled fully by HQ**
2. **Centralised federal, guidelines from Centre, some input from other units**
3. **De-centralised federal, guidelines from centre, primary input from other units**
4. **De-centralised, controlled fully by individual units**
5. **Ambiguous**
6. **Not answered**

Responses were as follows

29.23% - Centralised federal, guidelines from Centre, some input from other units
26.15% - Centralised and controlled fully by HQ
24.62% - De-centralised federal, guidelines from centre, primary input from other units
7.69% - Ambiguous
6.15% - De-centralised, controlled fully by individual units
6.15% - Not answered

Analysis

Although 75.38% of respondents (with reference to question 10) perceived IT functions to have restructured with organisational change, only 6.15% claim to be fully decentralised. Another 24.62% claim to be moving towards decentralisation i.e. are still in a transitionary stage. The other 55.38% are either fully or partially centralised.

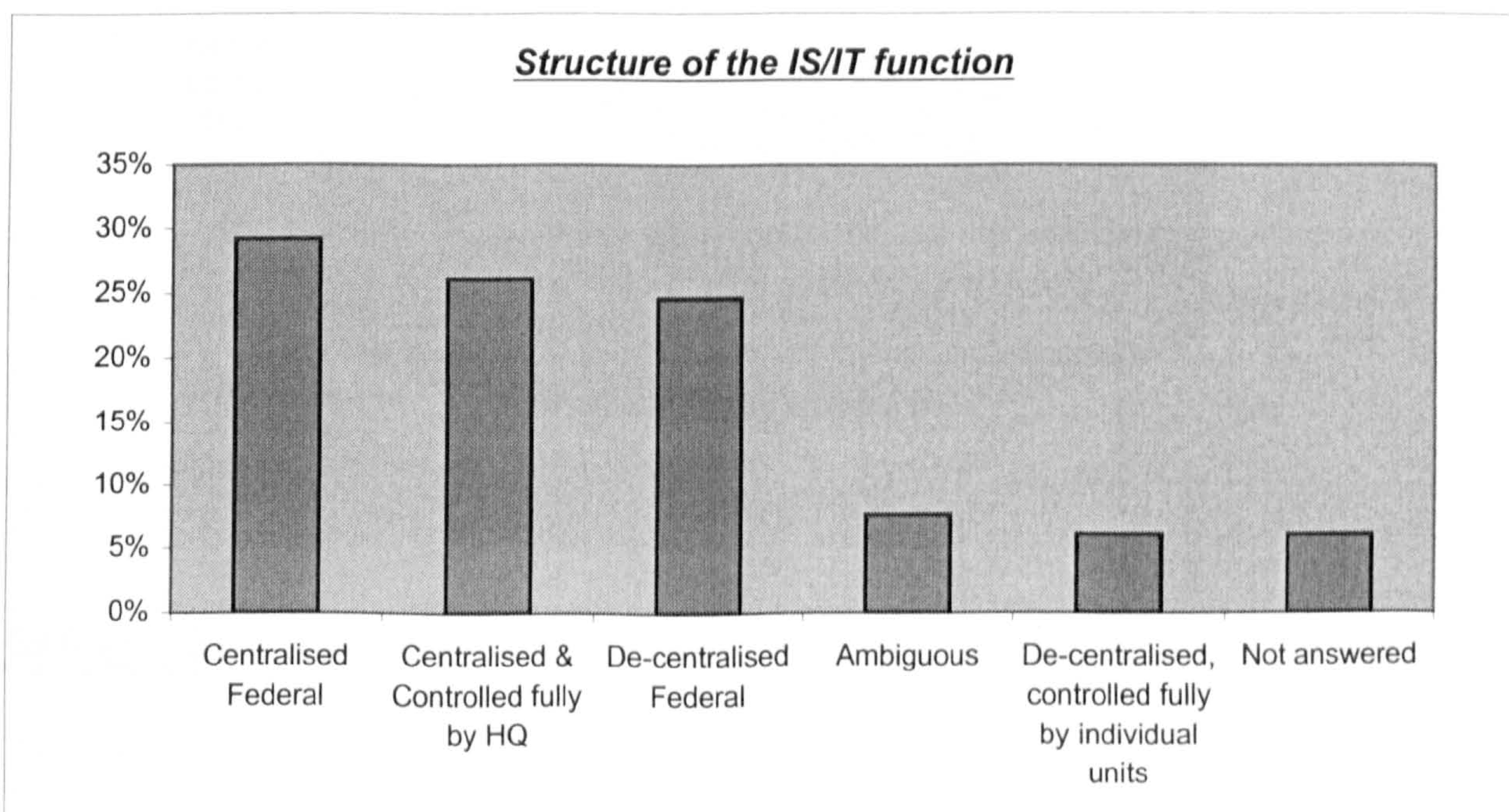

Table Q1.11

QUESTION 12 *Prevalence of IT/IS strategy.*

Does your organisation have an IT/IS strategy?

1. **No**
2. **Yes, corporate wide**
3. **Yes, business unit based**

Responses were as follows

53.85% - Yes, corporate wide
20.00% - No/Not answered
16.92% - Yes, business unit based
9.23% - Both corporate and business unit

Analysis

20% have no strategy, and the remainder have both corporate and business unit strategies. A very high percentage of respondents have a IS/IT strategy. A considerable number have moved from purely centralised to a combination of business unit and corporate strategy – a surprising result.

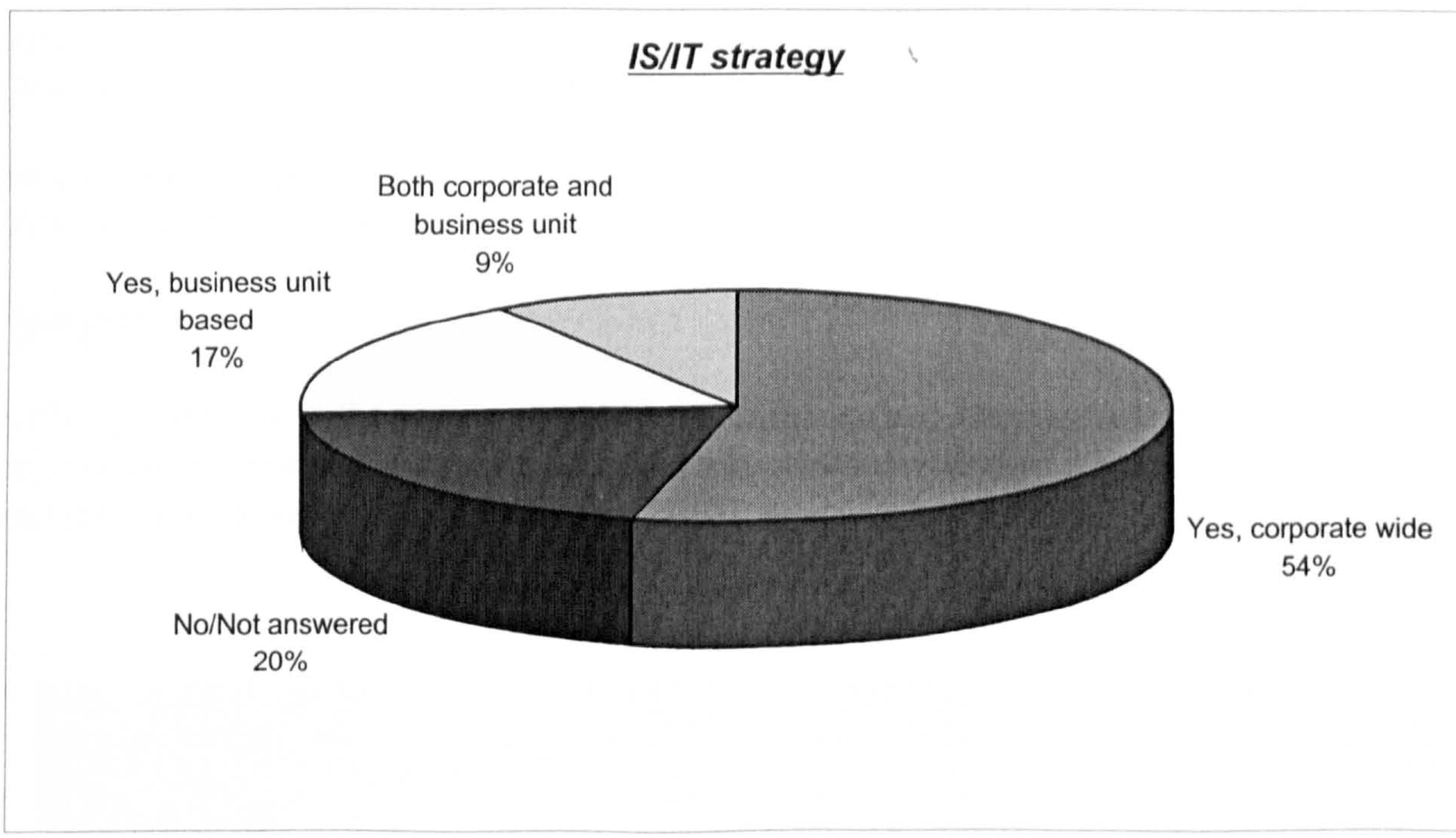

Table Q1.12

QUESTION 13 *Focus of IT/IS strategy.*

What is the focus of your IT/IS strategy?

1a Corporate hardware/software acquisition
1b Business-unit hardware/software acquisition

2a Corporate business strategy
2b Business-unit business strategy

3a Corporate competitive advantage
3b Business-unit competitive advantage

4a Corporate strategic alliance
4b Business-unit strategic alliance

Responses were as follows (overlap allowed)

46% - Corporate hardware/software acquisition
24% - Business-unit hardware/software acquisition

60% - Corporate business strategy
48% - Business-unit business strategy

30% - Corporate competitive advantage
18% - Business-unit competitive advantage

24% - Corporate strategic alliance
16% - Business-unit strategic alliance

Analysis

Although there is still a strong emphasis on software and hardware, there is a healthy orientation to base IT strategy on corporate business level, competitive advantage and strategic alliances.

Focus of IT/IS strategy

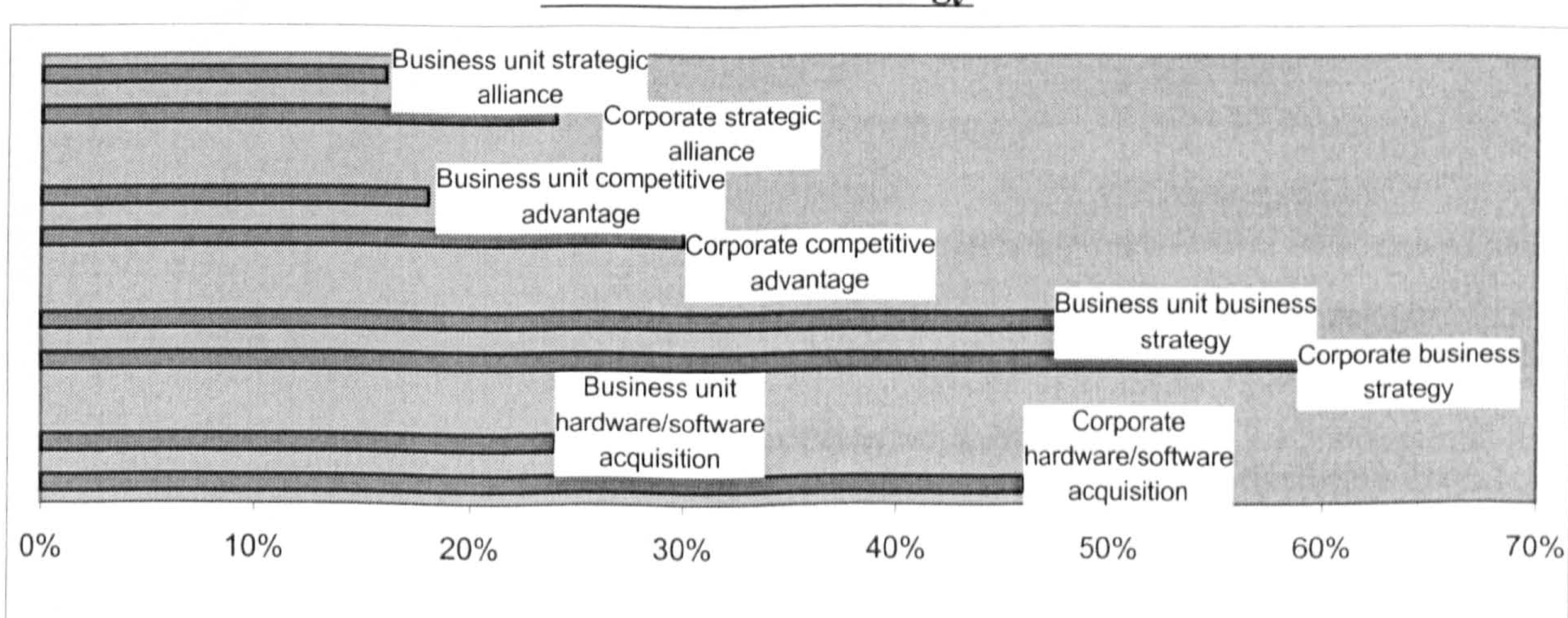

Table Q1.13

QUESTION 14 *Ascertain the extent to which new IT developments have been incorporated.*[13]

Which supporting IS and IT multimedia building blocks do you use?

1. **Groupware**
2. **Internet/Intranet/WWW**
3. **Expert systems**
4. **Neural networks**
5. **Virtual reality**

Responses were as follows (overlap allowed, also see footnote 13)

53.85% - Groupware
78.46% - Internet/Intranet/WWW
26.15% - Expert Systems
10.77% - Neural networks
4.62% - Virtual reality

Analysis

Industry is actively incorporating new IT particularly Internet/WWW technology

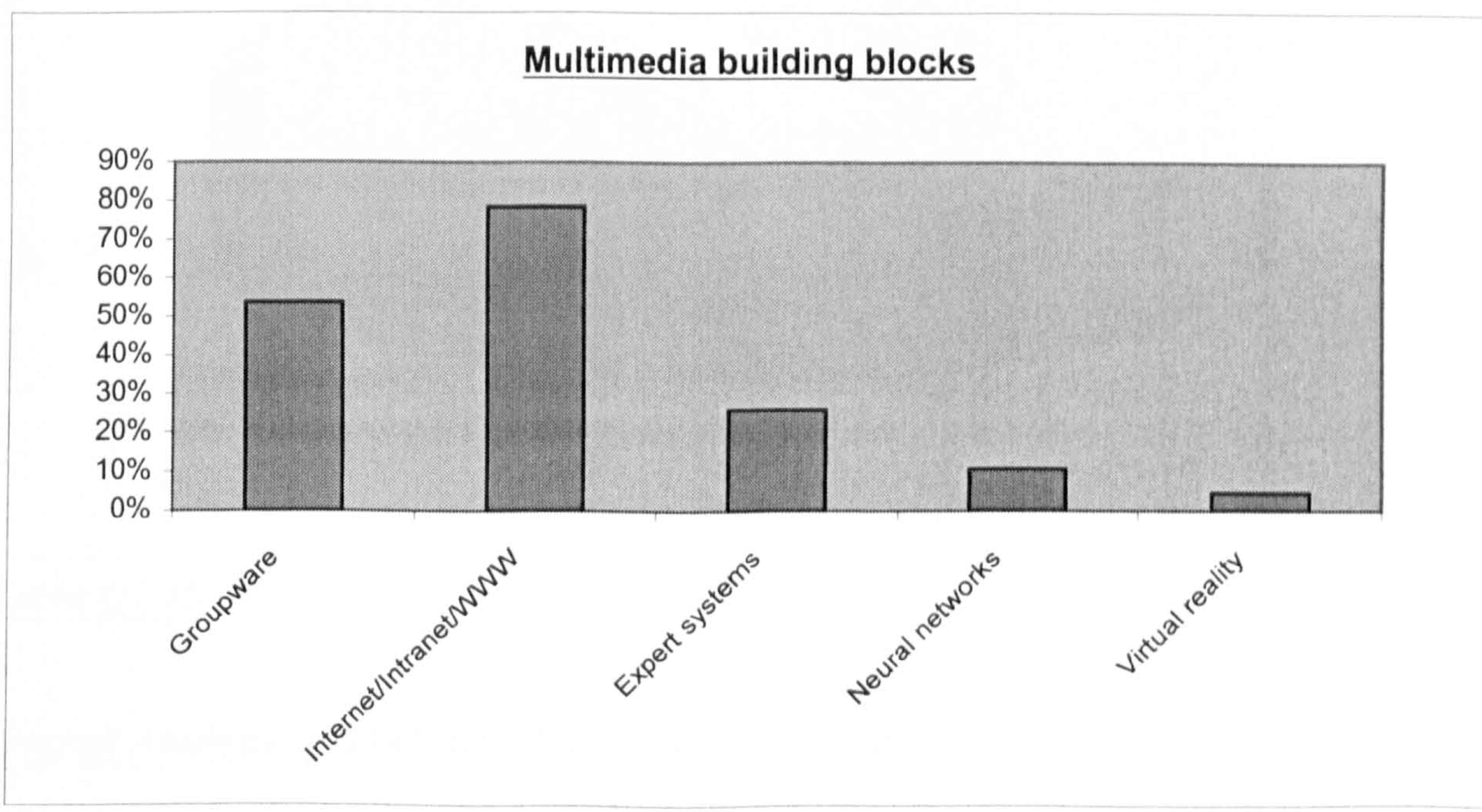

Table Q1.14

[13] Respondents were given the choice to tick as many as applied.

QUESTION 15 *Use of Networks.*

Do you use networks for active multimedia video/tele-conferencing?

1. **Yes**
2. **No**
3. **No answer**

Responses were as follows

50.77% - No
40% - Yes
9.23% - No response

Analysis

60% of the respondents do not claim to use active multi-media technology.

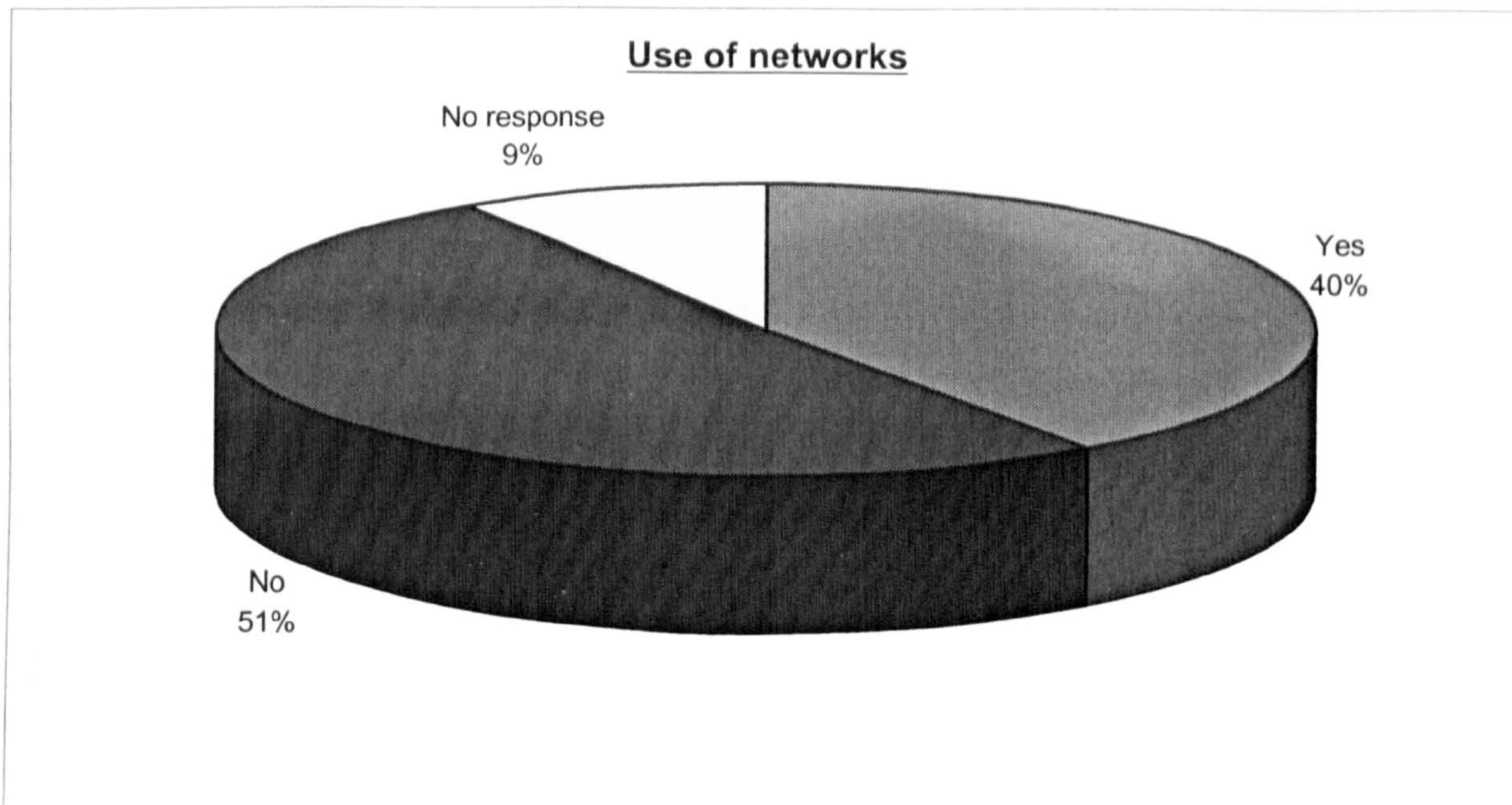

Table Q1.15

Overall Analysis in SECTION C of perceived trends

- It seems that there is a lack of any integrated theoretical framework for implementing new IT-based IS.
- This requires further investigation.

ANAYLSIS OF QUESTIONNAIRE 2

ANALYSIS OF DATA

A TOTAL OF 60 QUESTIONNAIRES WERE SENT OUT. A TOTAL OF 30 WERE RETURNED, OF WHICH 29 WERE USABLE, GIVING A RESPONSE RATE OF 48%.[14]

QUESTION 1 *Use of ISDM together with Learning Organisations & new IT.*

Is your University developing/teaching an Information Systems design Methodology (ISDM) which combines Learning Organisations and new Information Technology (e.g. Internet, WWW)?

1. **Yes**
2. **No**

Responses were as follows

62% - Yes
38% - No

Of those that said 'Yes'
83% - Not at an integrated level
17% - At integrated level

Analysis

Only 17% who answered 'yes' combine aspects/characteristics of learning organisations and new IT in an integrated manner in the IS development method being taught.

[14] This was an exceptionally high response rate. A number of reasons are attributed to this
(a) The survey was targeted at IS academics who could identify with the issues raised.
(b) A very high proportion of the academics targeted were delegates from the recent UKAIS annual conference on 'New Information Technology for Learning Organisations' – April 1998.
(c) The survey was sent out within four weeks of the conference.

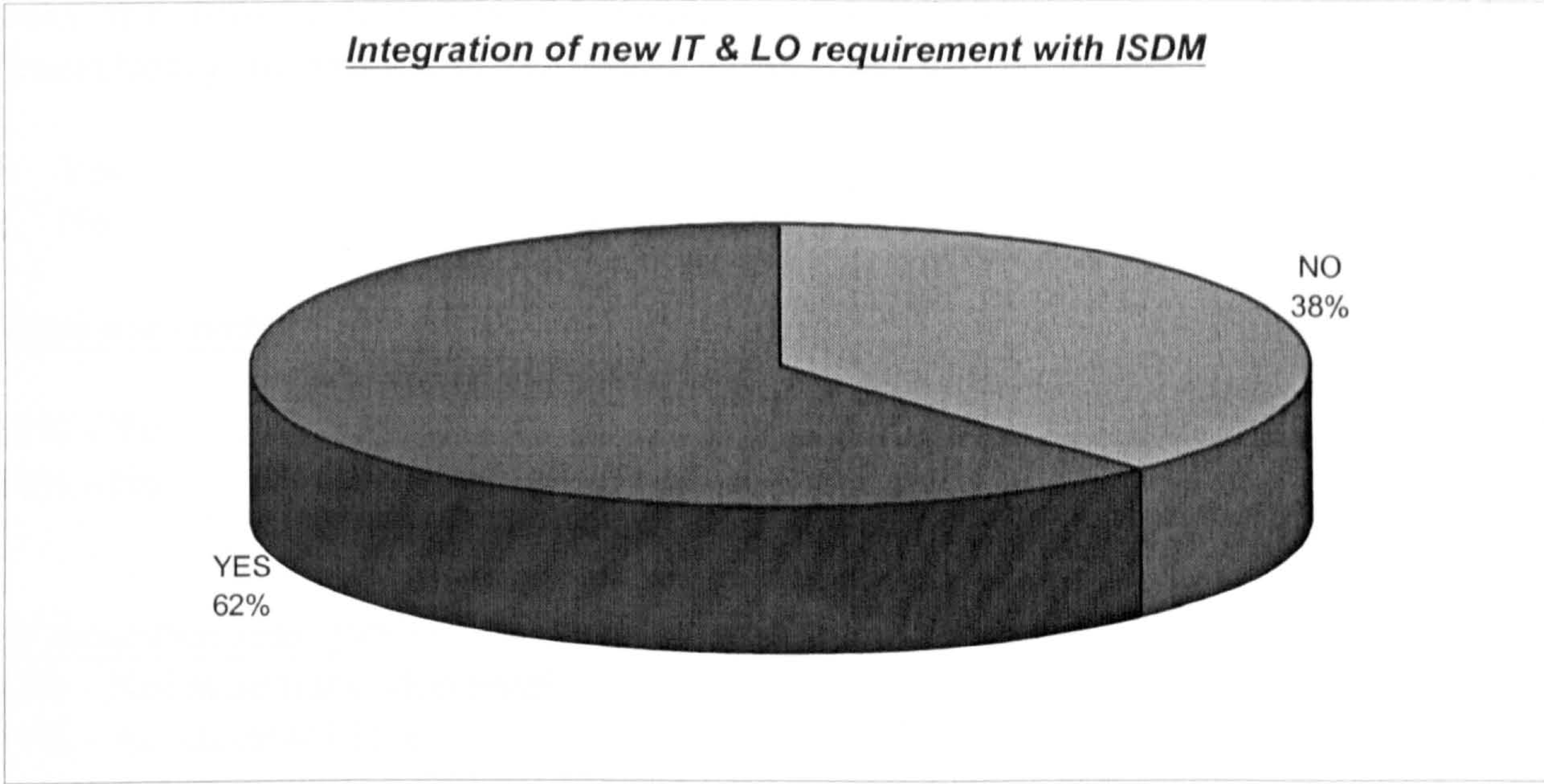

Table Q2.1

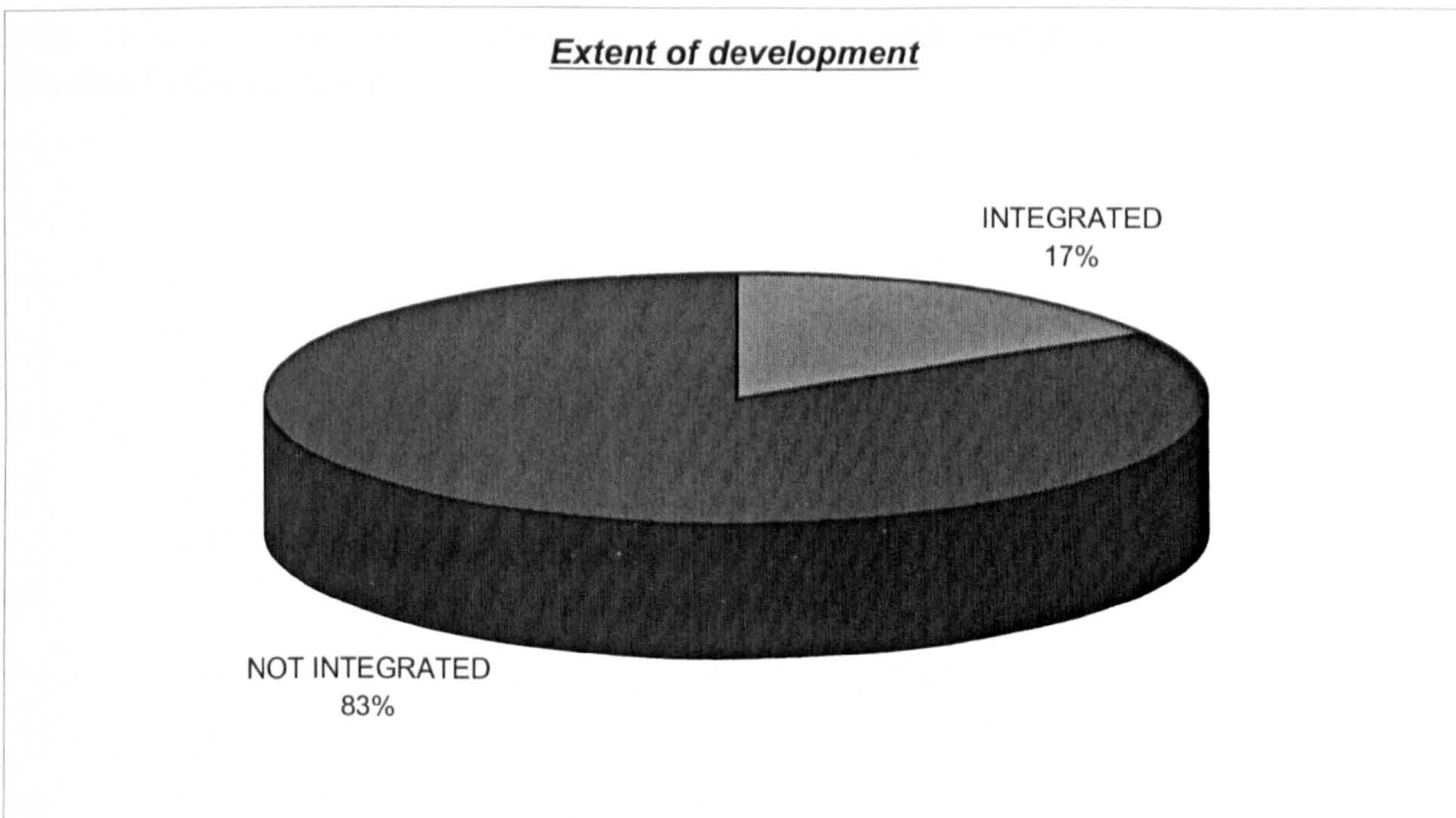

Table Q2.2

QUESTION 2 *Course cover of complexity and uncertainty.*

Does the Information Systems course cover the topics of 'complexity' and 'uncertainty' in relation to the design of Information Systems?

1. **Yes**
2. **No**

Responses were as follows

59% - Yes
41% - No

Of those that said 'Yes'
71% - Not at an integrated level
29% - At integrated level

Analysis

Only 29% of those who replied understood the term complexity/uncertainty as intended in the question.

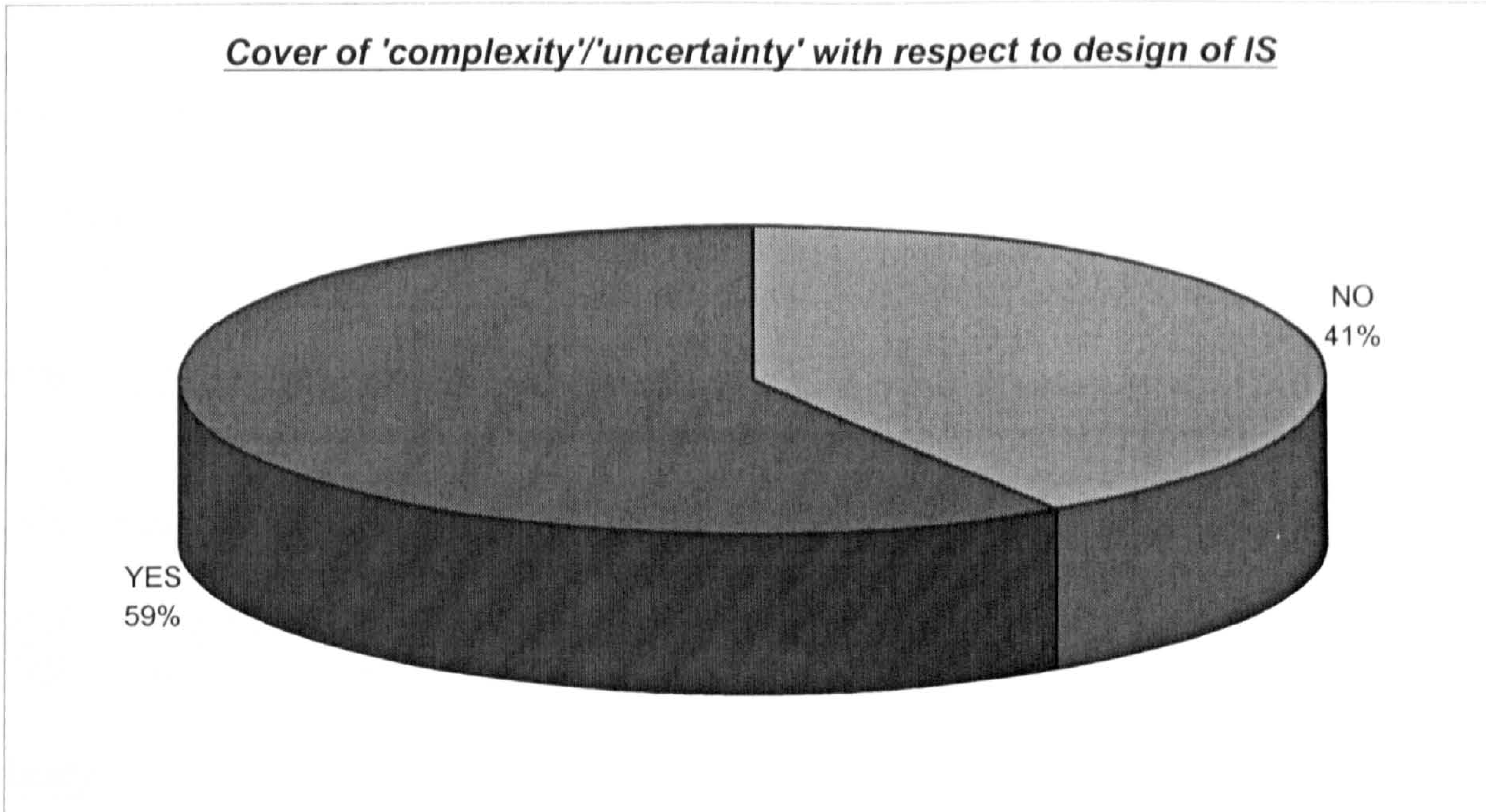

Table Q2.3

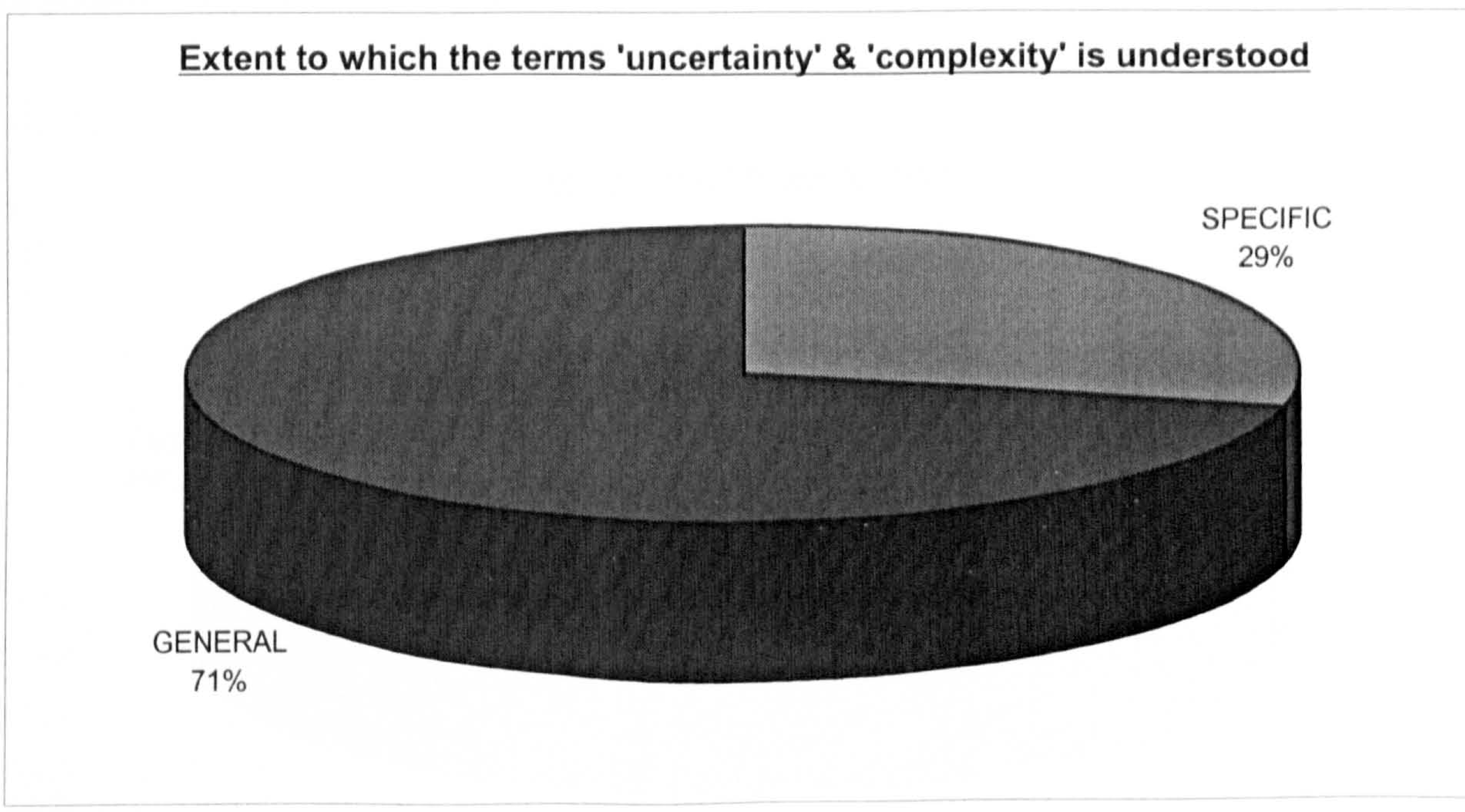

Table Q2.4

QUESTION 3 *Involvement in research on LO & theory of complexity.*

Are you or any of your colleagues, who teach on the Information Systems course, involved in conducting research on Learning Organisations and theory of complexity?

1. **Yes**
2. **No**

Responses were as follows

55% - No
45% - Yes

Of those that said 'Yes'
100% were in very general terms

Analysis

Those who responded positively 'yes' are involved with research in Learning Organisations not Complexity Theory.

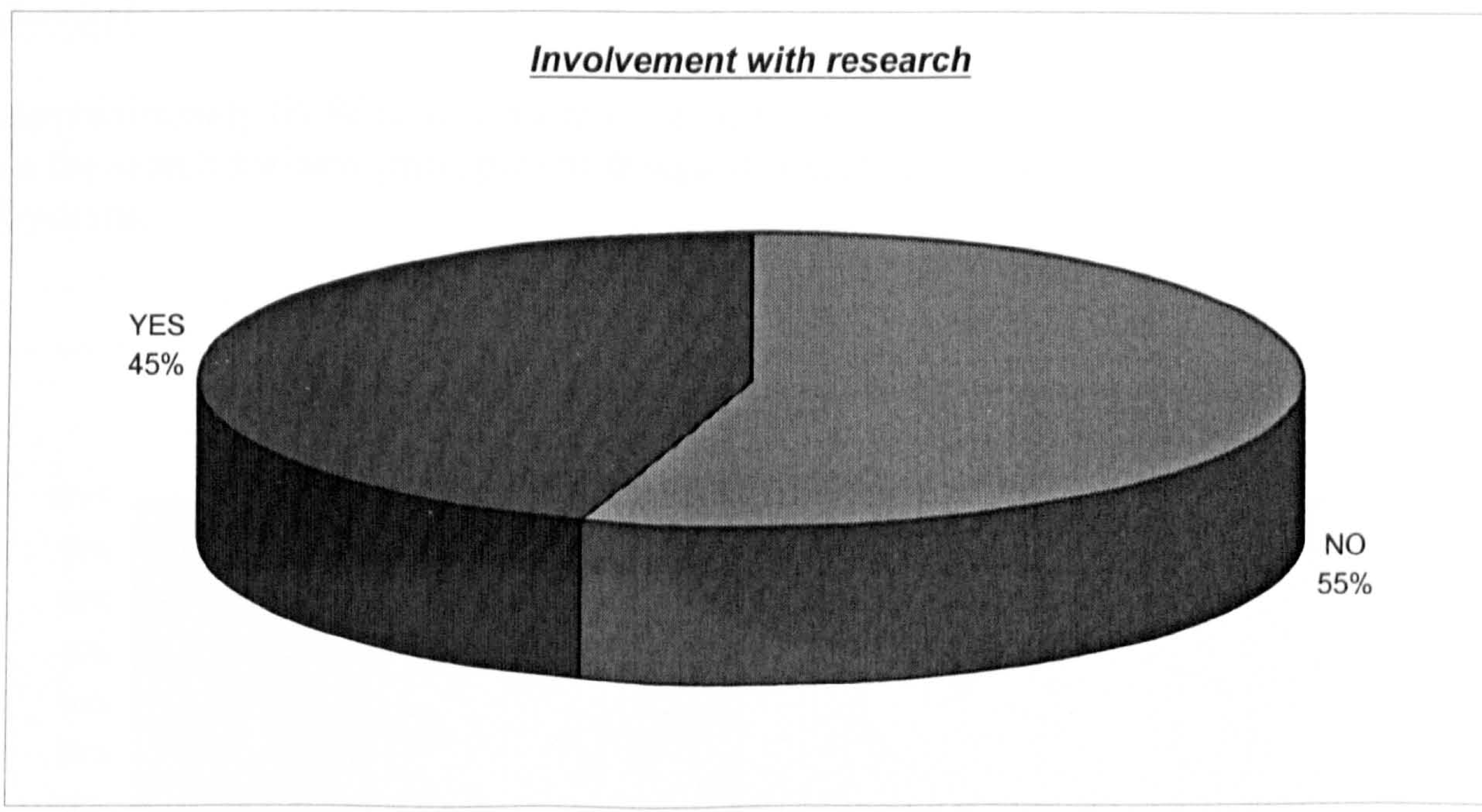

Table Q2.5

QUESTION 4 *Published Papers.*

Have you, or any one of your colleagues, published papers on the relevance of the following theories to Information Systems design?

1. **Complex Adaptive Systems Theory (CAS)**
2. **Self Organisation Theory (SOT)**
3. **Multi-Agent Systems Theory (MAST)**
4. **Emergent Behaviour Theory (EBT)**

Responses were as follows

21% - CAS – YES
79% - CAS – NO

14% - SOT – YES
86% - SOT – NO

17% - MAST – YES
83% - MAST – NO

34% - EBT – YES
66% - EBT – NO

Analysis

Approximately 66-88% of academics are not looking at the 'Science of Complexity' in the search for new principles of design of Learning Organisation and Information Systems.

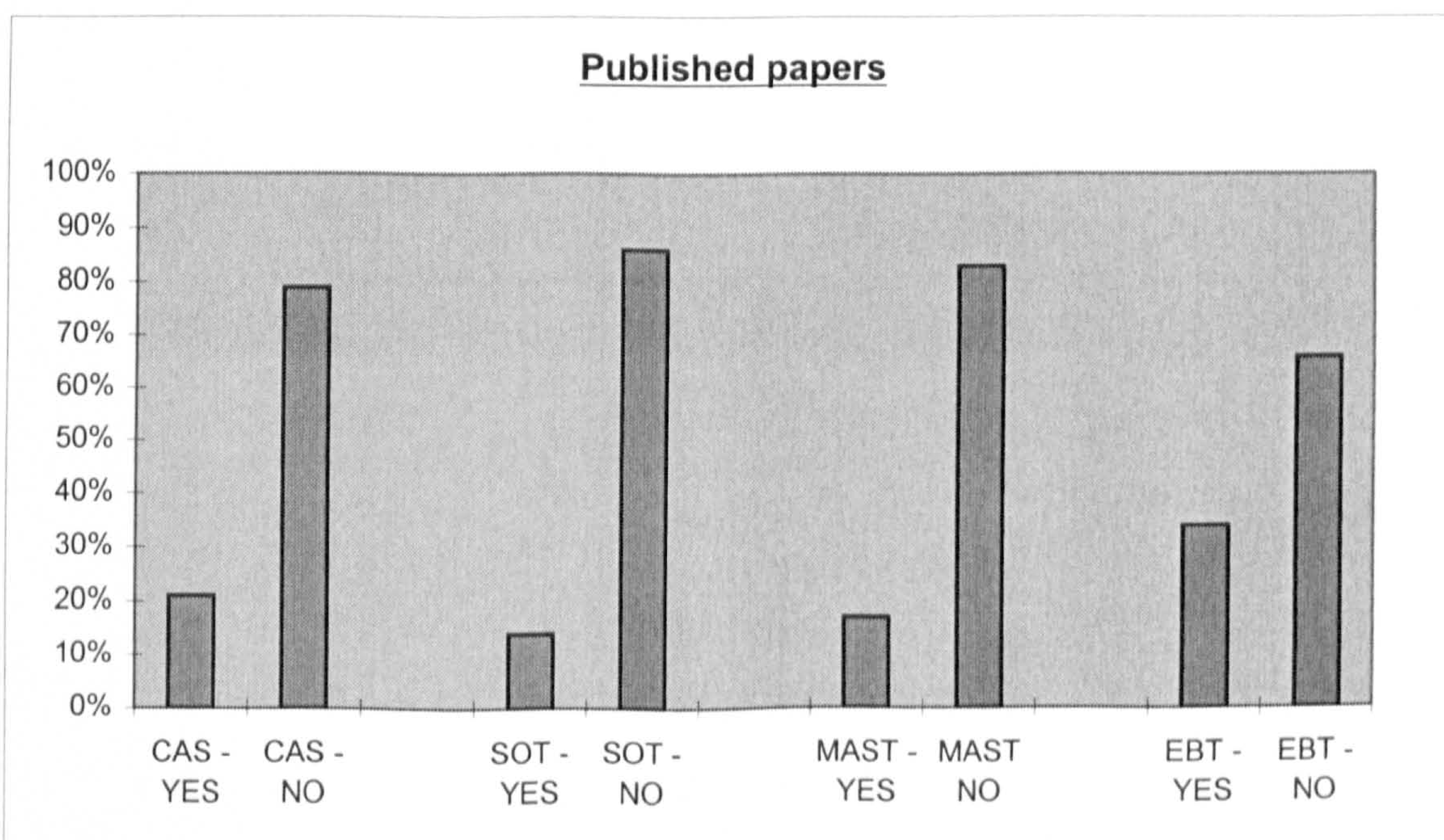

Table Q2.6

ANAYLSIS OF QUESTIONNAIRE 3

ANALYSIS OF DATA

A TOTAL OF 60 QUESTIONNAIRES WERE SENT OUT. A TOTAL OF 23 WERE RETURNED, GIVING A RESPONSE RATE OF 38%.[15]

QUESTION 1 *Tools to design organisational IS.*[16]

Are you using any of the following to design organisational IS?

1. **Internet**
2. **Intranet**
3. **Extranet**

Responses were as follows

83% - Intranet
78% - Internet
26% - Extranet

Analysis

The greatest use is that of the Intranet followed by Internet. Extranets are also increasing but the rate is comparatively slower – possibly since it involves inter organisational networking.

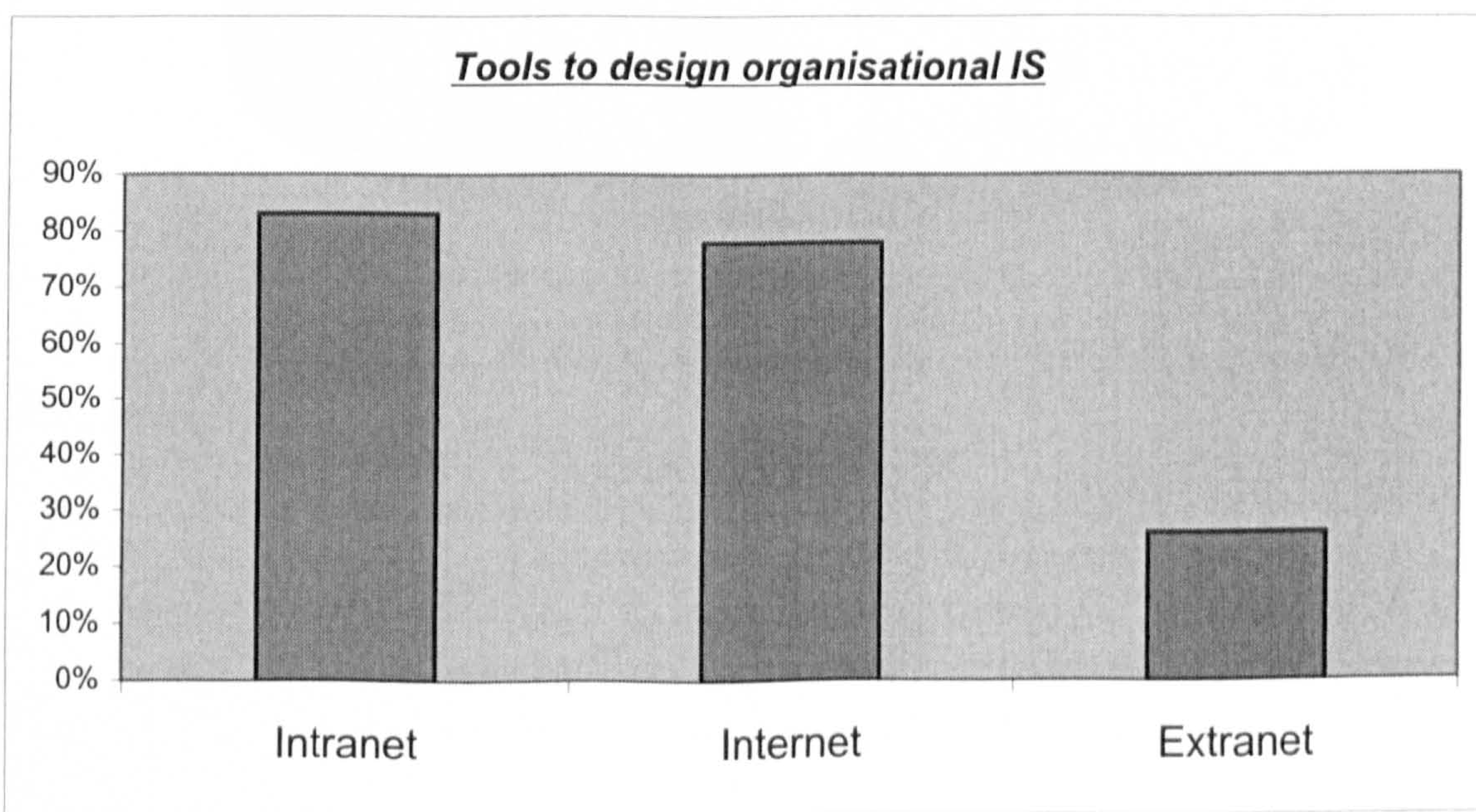

Table Q3.1

[15] This is a high response rate due to the fact that the survey was sent mainly to those organisations where our students are in industrial placements.
[16] Respondents were given the choice to tick as many as applied.

QUESTION 2 *Use of neural networks in the design of organisational IS.*

Do you use neural networks in the design of organisational IS (e.g. for data-mining or knowledge management)?

1. **Yes**
2. **No**

Responses were as follows

4% - Yes
96% - No

Analysis

The results show that there is very little use of neural network technology in the design of organisational IS. This is attributed to the fact that it is a relatively new concept which has not yet penetrated.

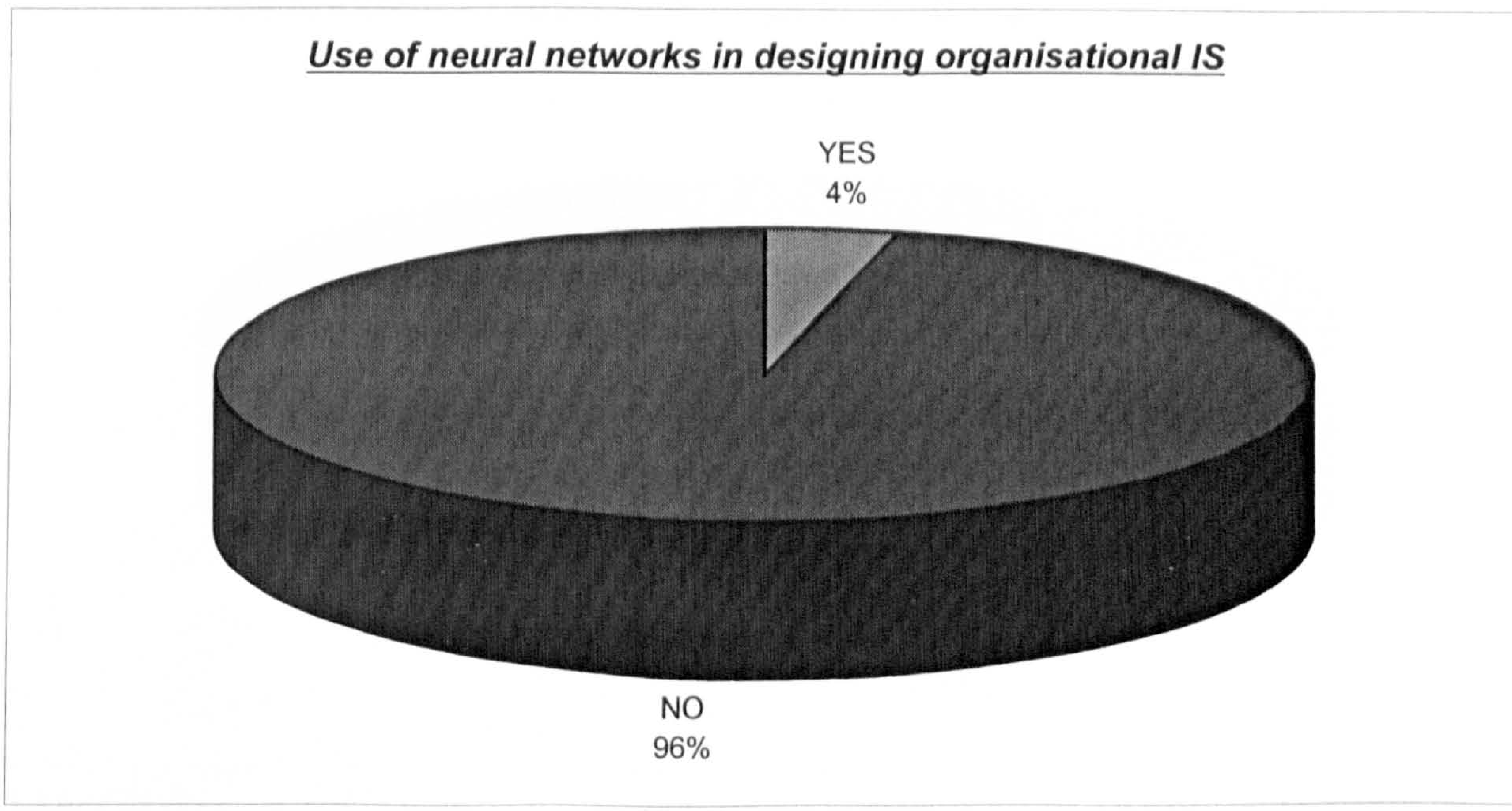

Table Q3.2

QUESTION 3 *Use of 'intelligent agents' in the design of organisational IS.*

Do you employ "intelligent agent" technology in the design of organisational IS?

1. **Yes**
2. **No**

Responses were as follows

4% - Yes
96% - No

Analysis

The results indicate that there is little use of intelligent agent technology in the design of organisational IS. This is attributed to the fact that it is a relatively new concept, which has not yet penetrated.

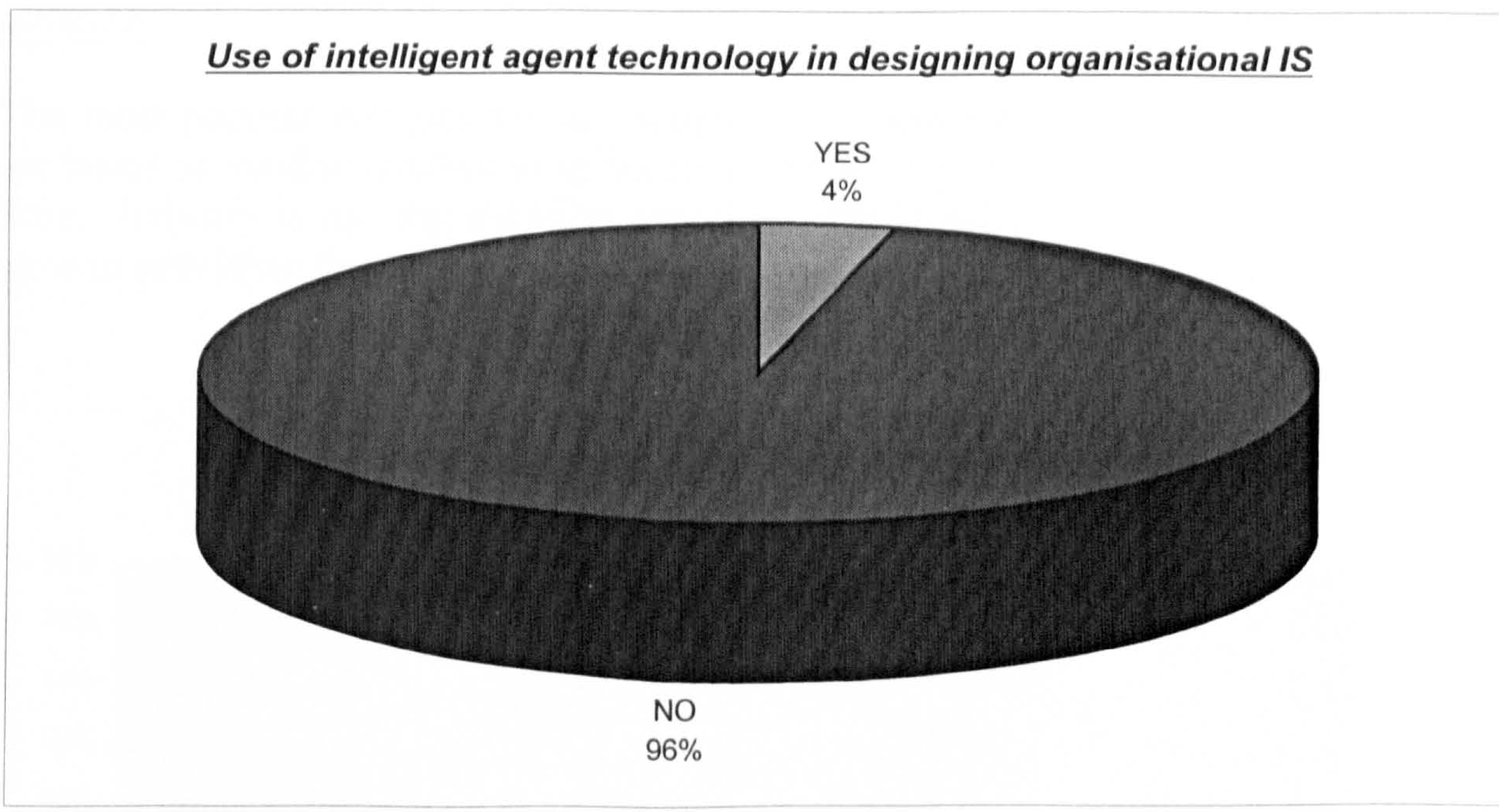

Table Q3.3

QUESTION 4 *Methods of design & implementation of organisational IS for the above.*

Which of the following methods do you use to design and implement organisational IS based on any or all of the above three technologies?

1. **Developed in academic institutions**
2. **Vendor supplied**
3. **Home grown**
4. **Ad hoc**

Responses were as follows (overlap allowed)

70% - Home grown
61% - Vendor supplied
48% - Ad hoc
22% - Developed in academic institutions
4% - Not Answered

Analysis

The most popular methods for the design and implementation of organisational IS are based on vendor supplied or in-house methods. Academics have contributed very little. Industry is moving ahead in employing the new IT, however, academics are slow in providing the under-pinning theory.

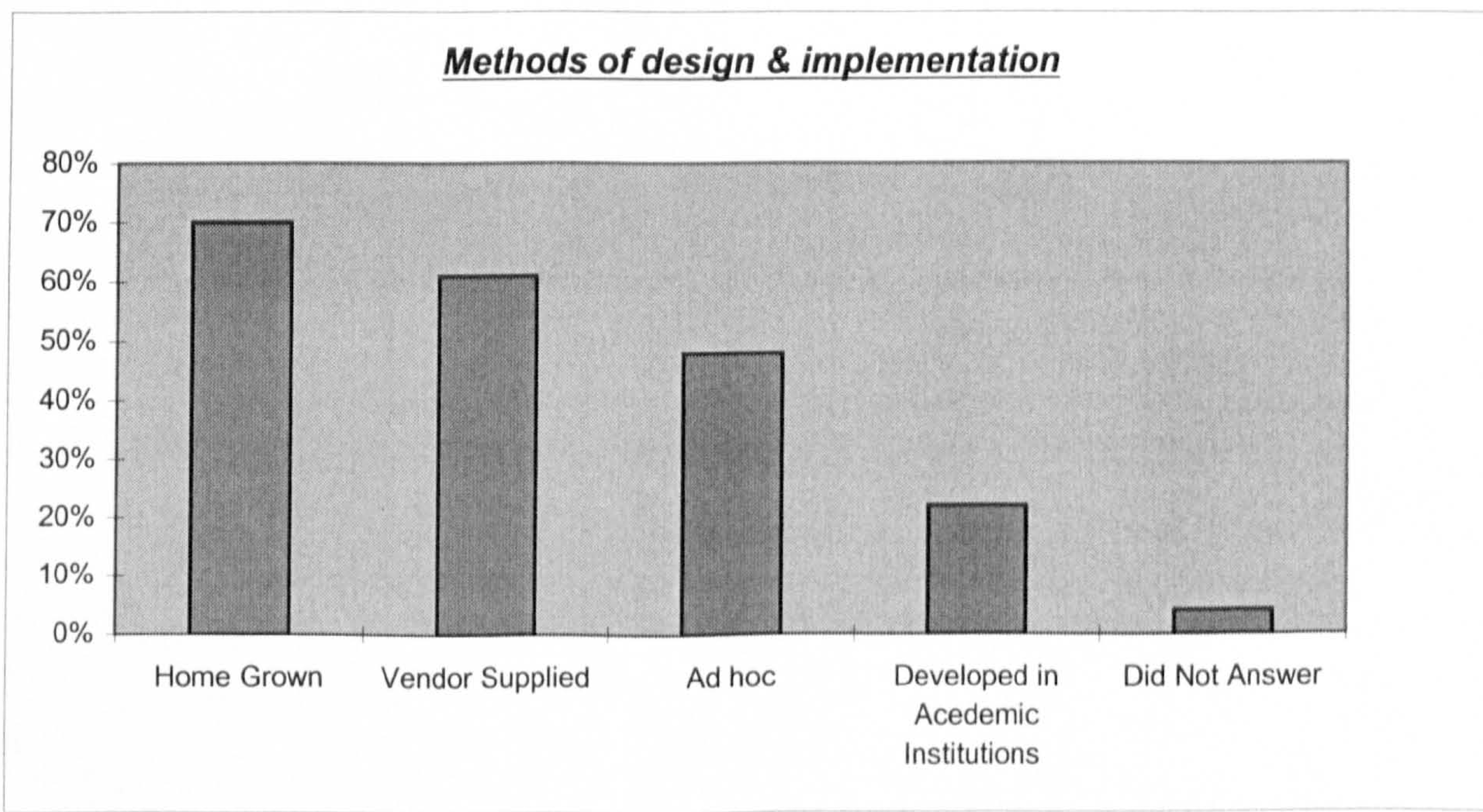

Table Q3.4