Title: The age of smart cards: an exploratory investigation of the sociotechnical factors influencing smart card innovation (1974-1996)

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The Age of Smart Cards:

An exploratory investigation of the sociotechnical factors influencing smart card innovation (1974-1996)

A thesis submitted in fulfilment of the requirements for the award of the degree

Doctor of Philosophy

from

The University of Wollongong

by

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Declaration

This thesis is submitted in accordance with the regulations of the University of Wollongong in partial fulfilment of the requirements for the award of a Doctor of Philosophy. It does not incorporate any material previously published or written by another person except where due reference is made in the text. The work described in this thesis is original work and has not been previously submitted for a degree or diploma in any university.

Robyn A. Lindley

April, 1996

"As technologies become more complex and flexible in their application, so must people become more competent and empowered in their response."

(Taylor and Felton, 1993: 205)

Abstract

This thesis breaks new ground by providing the first detailed study of smart card innovation during its first twenty years (1974-1996). The overall aim is to apply sociotechnical principles to further our understanding of the innovation process as it relates to smart card technology. By using a sociotechnical framework, this study also seeks to illustrate the limitations of conventional innovation theory when applied to new information technologies such as smart card: The central thesis posited, is that to develop our understanding of the underlying innovation processes that have occurred during the development of this new information technology, it is necessary to study the interactions between three actors that have all appeared to play a role in the process of smart card innovation. These are smart card technology; the potential users and the organisations. However, in stating this, it is also important to realise that one tacit assumption underlying the work reported here is that new technologies are only adopted if the technological parameters (technology focus), the market needs (user focus) and the entrepreneurs (organisational focus) meet.

At a more abstract level, the work has also endeavoured to consider whether a sociotechnical approach applied as a framework for understanding the process of innovation for smart card is, in fact, a reasonable and useful paradigm for developing our understanding from both a theoretical and applied perspective. Thus the multidisciplinary process approach adopted is not intended to lead to a complete alternative theory: nor is it intended to be merely a synthesis.

What the current work has achieved, is to provide the very first insights into the understanding of smart card innovation. The sociotechnical framework adopted as a theoretical organiser and, which emphasises the role of the user, has also served to

highlight the need for a multidisciplinary approach to develop our understanding of smart card innovation. The view upheld is that the paradigm emerging from these analyses based on traditional innovation thought, both demands and empowers the view of smart card innovation as a sociotechnical process. One of the main outcomes has been to demonstrate that smart card innovation provides a case in point highlighting the benefits of adopting a broad and evolutionary approach to innovation and based on a sociotechnical framework. This is in agreement with recent paradigm shifts in technology innovation thought. For the practitioner, these findings also illuminate new possibilities for the development theoretically informed smart card systems, thus placing the smart card design team in a position to significantly and positively influence future smart card innovation patterns.

Acknowledgments

The time spent gathering the data and information presented in this thesis was a rewarding experience. This is in no small way due to the support and involvement of my supervisor, Professor Joan Cooper. I would like to thank Joan for her continued support and for giving me the opportunity to experience different facets of the academic process of inquiry. I would also like to thank my colleague Dr Leone Dunn for her support and encouragement during the final stages of the studies reported.

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Abbreviations

ADF	Application Data File
AES	Associated Electronic Services (Australia)
AFC	Automatic Fare Collection
AID	Alternate Identification File
AK	Authentication Key
AIM	Advanced Informatics in Medicine program of the Commission of European Communities.
ANSI	American National Standards Institute
ASS	Allterminal Security layer Specification (developed by the Swedish Agency for Administrative Development)
ATEA	Australian Telecommunications Employees Association (ATEA)
ATM	Automatic Teller Machine
AVI	Automatic Vehicle Identification
B-ISDN	Broadband ISDN
CAD	Card Acceptor Device
CASC	Comprehensive Analysis for Smart Card (basic design approach)
CCTV	Closed Circuit Television
CD	Compact Disc
CDF	Common Data File
CDK	Ciphering/Deciphering Key
CEN	*Comite Europeenne de Normalisation* (European Standards Organisation)
CEPT	*Conference Europeenne des Administrations des Postes et Telecommunications* (European Committee for Post and Telecommunictation Standards)
CK	Ciphering Key
CLI	Calling Line Identification
CMOS	Complementary MOS technology
Co-Co	Coordination of the primary care information network (an EU telematics project)
CPS	*Carte de Professionelle de Sante* (French Health Professional Card)
CPU	Central Processing Unit of a microprocessor
DEC	Digital Equipment Company
DES/DEA	Data Encryption Standard/Algorithm
DF	Data File
DIABCARE-Q-NET	Quality network for the care of diabetic patients (an EU telematic network project)
DK	Deciphering Key
DRAM	Dynamic RAM
DS	Digital Signature
DSA	Digital Signature Algorithm
EAA	Export Administration Act (US)
EC	(The) European Community
ECMA	European Community Manufacturers' Association
EDI	Electronic Data Interchange

Abbreviations

EDIFACT	European Committee for Information Technology & Telecommunications Testing and Certification (a program to achieve pan-European recognition of testing performed by certified laboratories)
EDL	Electronic Drivers Licence
EES	Electronic Exponential Signature
EEPROM	Electronically Erasable Programmable Read Only Memory (memory used for data storage or for volatile data storage)
EFT	Electronic Funds Transfer
EFTPOS	Electronic Funds Transfer at Point of Sale
EHTO	European Health Telematics Observatory
EK	Erase Key
EPROM	Erasable Programmable Memory. The memory is used to store application programs.
ES	Electronic Signature
ETSI	European Telecommunications Standard Institute
EU	European Union
FRAM	Ferro-electric Random Access Memory (enables smart cards to retain information without a battery)
GMPTE	Greater Manchester Passenger Transport Executive (public transport authority in Greater Manchester, UK)
GNP	Gross National Product
GP	General Practitioner
GSM	Global Standard for Mobile Communications
GVE	RA software tool developed by Daimler-Benz AG of Berlin
HCMOS	High Density, Low Power MOS technology
HIV	Human Immune deficiency Virus
IC	Integrated Circuit
ICC	IC Card
ICCP	Information Computer and Communications Policy (OECD Committee for security of information systems)
IK	Issuer Key
INFOSEC	Swedish Institute for Health Services R&D Program in the area of IT Systems Security and Information Security
IPR	Information Privacy Rights
IR	Infra Red
IS	Information Systems
ISDN	Integrated Services Digital Network
I/O	Input/Output lines
ISO	International Organisation for Standardisation
IT	Information Technology
ITSEC	The European Information Technology Security Evaluation Criteria
MAP	Modular Arithmetic Processor
MASK	Medium used to convert customers application software to a pattern in the silicon which can be read (ROM code).
MCU	A Single Chip Microcomputer is often referred to as an MCU.
ME	Mobile Equipment

Abbreviations

MFC	Multifunction Card
MFC/O	MFC operating in an Open systems environment
MOS	Metal Oxide Semiconductor technology
MS	Mobile Station
NMOS	N-channel Metal Oxide Semiconductor technology
NSA	National Security Agency (US)
NVM	Non-Volatile Memory (for permanent memory storage)
OCR	Optical Card Reader
OECD	Organisations for Economic Co-operative Development
PC	Personal Computer
PCMCIA	PC Memory Card Industry Association
PIN	Personal Identification Number
PKCS	Public-Key Cryptography Standards
PLANEC	Planning of the care of the elderly in the EU (telematics project)
PROM	Program Read Only Memory (data can be altered once the card is in use)
POS	Point of Sale
PTT	Post Telephone and Telegraph
PVC	Polyvinyl Chloride (used to manufacture smart cards)
QR	Qualitative Reasoning
RA	Risk Assessment
RAM	Random Access Memory (RAM used as temporary working memory. It is lost when the card loses power.)
R&D	Research and Development
REMEDES	*REseau Multimedia Europeens pour Doctuers et Etablissements de Sante*
RF	Radio Frequency
RISC	Reduced Instruction Set Computer
ROM	Read Only Memory (Installed by manufacturer of the microprocessor chip and the information it contains is the operating system - often called a template or *masque*. It cannot be altered.)
RSA	*Rivest - Shamir - Adleman* encryption algorithm
SIM	Subscriber Identity Module (used to identify the caller on a GSM network)
SC	Smart Card (ISO standard card embedded with a MCU)
SCT	SC Terminal (communications)
SMEG	Monetary Systems Engineering Group (research group at the University of Newcastle, Australia)
SPRI	Swedish Institute for Health Services Development
SRAM	Static RAM
SVC	Stored Value Card
TQM	Total Quality Management
VCR	Video Cassette Recorder
VME	Visa-Mastercard-Europay
WORM	Write Once, Read Many times optical disc

Chapter One
Introduction

The overall aim of this thesis has been to further our understanding of smart card innovation. Using a broad framework, the study has sought to identify the fundamental forces most relevant to the shaping and technological development of smart card during its first twenty-two years (1974-1996). By bringing into focus a range of otherwise disparate elements, the study has also served as an entry point for the characterisation of the smart card innovation process in the context of its own emerging technological paradigm. A central concern has been the role of the user in the process of smart card innovation.

1.1 Background to the study

1.1.1 A brief chronological history of smart card development

Although initially conceived by Jurgen Dethloff, smart card was first invented by a Japanese academic, Professor Kunitaka Arimura in 1970. However, Professor Kunitaka Arimura only patented his invention in Japan. In the early 1970s, a Frenchman, Roland Moreno first promoted his vision of the *Electronic Bank Manager*. His goal was to patent and develop a secure electronic payment card with an embedded chip designed to provide a secure means of authentication and authorisation. The first smart card prototype was developed by Roland Moreno in 1974 when he placed an electronic memory chip in a plastic card and conducted transactions. Roland Moreno patented his Electronic Bank

Manager in 1974 and subsequently obtained worldwide patenting rights for his ideas through his company Innovatron. Innovatron licensed patent rights to over 200 separate organisations until the original patent rights expired in 1994.

Later, in 1977, Michael Ugon, an Engineer from Bull, added a processor as well as memory. It was also soon realised that smart card microchip technology could incorporate the latest advances in cryptography. Transactions employing cryptographic techniques can avoid the possibility of fraud, while maintaining the privacy of the individual using the card. The starting point had been the development of the digital signature first proposed by Whitfield Diffie in 1976 (Chaum, 1992).

By the early 1980s, the world's first smart card trials were being conducted by a the French Bank Group, *Cartes Bancaires*. By 1982, smart cards containing both a microprocessor and memory were available from Bull, Philips and Flonic-Schlumberger for trial. By 1983, the first electronically programmable read only memory (EPROM) based cards were being produced by SGS-Thomson for distribution by the French Post Telegraph and Telephone (PTT). After these initial trials, the first commercial orders for smart cards commenced in 1985 and mass production of smart card integrated circuits (ICs) began for large scale distribution in 1986.

Visions of smart card have since hailed it as the answer to bank security questions. The technology has also been described as the ultimate hand held technology - giving users the opportunity to store, retrieve and access information and services from a number of locations. These technologies have also since been acclaimed as offering organisations such as bankers a new secure weapon to fight financial fraud.

1.1.2 Defining a smart card

Since the first trials began, *smart card* has generally become the accepted term to describe a range of portable token cards with integrated circuit (IC) chip technology on board. As a result of developments in the semiconductor and computing industries, smart cards, or Integrated Circuit Cards (ICCs), can now incorporate a range of tools and offers the potential to build extremely secure systems. In particular, the technology provides a platform that can be used to tailor a security system to meet the specific requirements of each application. In Chapter Two, some of the more advanced technological features of smart card technology and worldwide industry development trends will be examined. However, as a result of the wide choice of technical options now available, several definitions of what constitutes a smart card are now in use. So what do we mean by the term *smart card*?

In 1994, Roland Moreno has described a smart card as, "A card with a self-protected integrated memory" (Roland Moreno, 1994). In comparison, a number of other industry analysts have adopted a more limiting definition based on the International Standards Organisation's (ISO) definition. An ISO smart card is defined as:

> *A credit-card sized piece of plastic with a single IC (integrated circuit) chip on board and conforms to ISO 7816.* (Atkinson, 1994)

The ISO itself also defines a smart card as any card that conforms to ISO standards and has a semiconductor chip on board. An alternate definition, and one adopted by Denise Lathom-Sharp, Managing Director of Cardinal (UK) Ltd. is:

> *A card of ISO dimensions which has in-built logical ability.*
> *(Lathom-Sharp, 1995)*

Both of the above definitions recognise that for a device to be a *smart* device, it must have some inbuilt intelligence in the form of a semiconductor chip. Both also incorporate the ISO standards that have been in place for magnetic stripe cards for many years. However, these definitions preclude the possibility of adopting other card standards in the future. As a consequence, others have defined smart card in less restrictive terms as simply an Integrated Circuit (IC) card. Yet in adopting this broad definition, this overlooks the fact that some IC cards only store and retrieve data by limited command sets sent from an external device. In effect, these are simple memory only cards, yet they meet ISO standards by definition. Thus, in practice it could be argued that these should not be termed *smart*. Many existing memory only cards are disposable prepaid debit cards for use in applications such as pay phone cards or transit cards. Each card is preloaded with a small allocated number of data bits that are effectively destroyed - or decremented - after each use.

Also of concern is a general misconception, largely due to the popular press, that the smart card is primarily a sophisticated bank or credit card. In fact, there is very little overlap between a smart card and a magnetic stripe bank - or a credit card. A smart card has the capacity to provide self contained computer processing capabilities. It can store, manipulate, code, decode and access data. In this respect it can be regarded as a combined hardware and software, whereas magnetic stripe cards can only be regarded as software media. This means that smart cards can manage a significant amount of processing and access authorisation on stand-alone terminals - without the need to use computer network services. This difference is important because it can save the cost of the installation and management of extensive network services for many applications. Furthermore, because the service is localised, transaction times will be faster.

Because of the lack of a generally agreed definition for smart card, and for the purposes of this study, a *smart card* will be defined here in simple terms as *a hand-held information-based storage device in the form of a plastic card with one or more integrated circuit (IC) chips mounted on it.*

In adopting this broad definition, it is therefore conceded that the present standards affecting smart card's shape, could conceivably become more flexible and permitting a range of accepted physical designs for the technology. It also recognises that, as a result of further technological convergence in the form of information technology (IT) devices, additional features might be incorporated into the design of the card. For example, a microphone and speaker, a rechargeable power supply, or a keyboard, display could all become additional features as the technology advances.

At present, most smart cards now in use look like an ISO (International Standards Organisation) standard credit card with an implanted microchip holding a processor and a memory located on the left hand side of the card. For the early trials the French had adopted a card standard with the microchip located in the *Amphor* position (upper right section of the card). This standard was abandoned largely because of the physical problems associated with combining a standard magnetic stripe and chip technology on the one card. If a card with a microchip located in the Amphor position such as the Bull CP-8 card, was inadvertently placed into a magnetic stripe reader upside down, physical damage to the chip could occur. Figure 1-1 provides a diagram illustrating the dimensions of an ISO smart card.

The memory can contain either a read only memory (ROM), electronically programmable read only memory (EPROM), erasable electronically programmable read

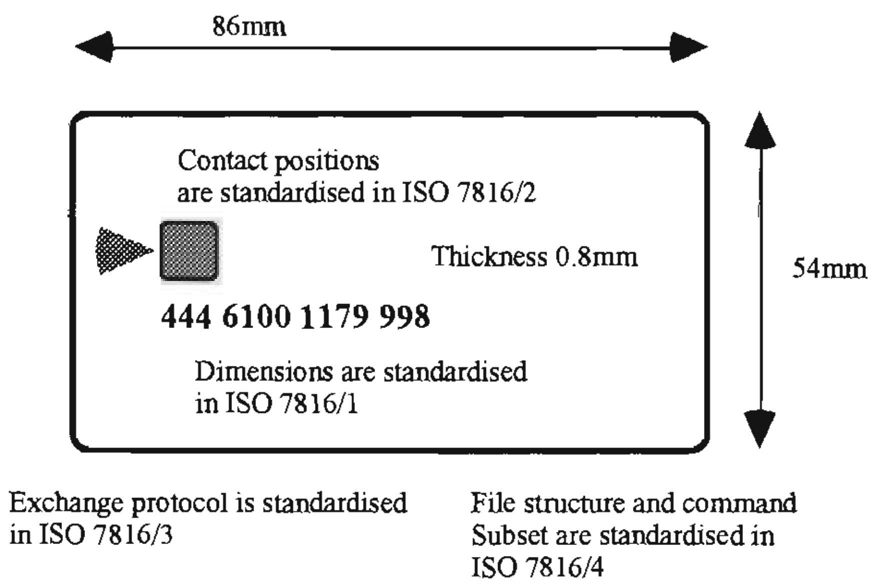

Figure 1-1 Diagram of an ISO smart card: Standardisation exists on the essential.

only memory (EEPROM), or a combination of these. A maths coprocessor can also be installed to speed up cryptographic functions. The intelligence of the card is located at the ROM in the form of programs to calculate, encrypt and record data. The smart card chip(s) can store, retrieve and process information through read/write terminals or self-contained power supply, keyboard and display arrangements. It can also provide self-contained or interactive computer processing capabilities, and a highly compact and secure computerised management capacity. Its unique features provide capacity for high level security data storage and retrieval and offers both flexibility and multi-functionality. Smart cards have a variety of applications in the areas of security, telecommunications, banking, health, and transportation.

1.1.3 Smart card development in context

Smart cards are therefore the result of combining the plastic card technology with semiconductor IC technology. In practical terms, this means that smart card is able to satisfy two key needs: To satisfy consumer demand for an intelligent card product that can be trusted; and, to prevent fraud associated with magnetic stripe technologies. The most important feature of smart card technology, is the potential it offers for providing a secure hand held device capable of incorporating multiple functions and applications. This means that it provides the opportunity to combine historically incompatible services on the one card. For example, a user can be permitted physical access to a building, provide payment for transport and fast food services, as well as use it for access to healthcare services. In addition, the technology also has the potential to provide a high level of security as well as unconditional anonymity using public key encryption techniques.

There is also now little doubt among leaders in the banking industry that smart card will take over from magnetic stripe card technology because of its ability to reduce fraud. The main advantage of smart card compared to other technologies is that it does provide a large range of design and service options with a high degree of security which is required when monetary or secret information exchanges are to occur. The old card technologies are rapidly being made obsolescent as the rate and level of sophistication of fraudulent use are rapidly approaching unacceptable levels. It is therefore now seen by many as only a matter of when, and how the services will be differentiated. The trend in the technology is towards larger memory capacity and programmable functions both for security and customisation of the applications. It is also technically feasible to deliver secure multiapplication cards offering several services and operable over public network infrastructure on the one card.

Yet, despite the many promises of the technology, the use of smart card did not become widespread until the late 1980s. Until this time, smart card was heavily pushed by the French government. However, in recent years, and after a long gestation period, smart card has begun to gain a more general worldwide acceptance. Since the early 1990s, worldwide smart card shipments have increased dramatically. In 1993 it has been estimated that around 260 million were sold worldwide. By 1995 this number had increased to around 580 million.

1.1.4 The research problem

Why the paradox? Why has a technology that has promised so much not been widely accepted? Why too, were most of the 580 million smart cards issued in 1995 based on technology developed over 15 years ago? Is this evidence that the technology has been viewed too narrowly? Do we need to adopt a broader framework for understanding smart card innovation? Alternatively, might these observations tell us something else about the smart card innovation process itself? These are the questions to be addressed by this study. However, in attempting to address the central research problem, it is necessary to bring together the field of innovation thought and the various aspects of smart card development that might further our understanding of the underlying innovation processes shaping the technology.

1.2 Towards a theoretical framework

1.2.1 Understanding the relationship between invention, innovation and diffusion

Invention

Invention is the act of creating a new or novel process or product. Thus, it can be considered to be, 'the first reduction to practice in a physical form' (Johnson, 1975:18). In the case of smart card, the first physical prototype that was patented and later trialed can be considered to be the invention. This is the definition adopted here. However, by accepting Johnson's broad definition, it should also be noted that it is rather abstract in that it does not allow for the distinction of its potential utility which is a pre-requisite for the gaining of a patent. To gain a patent for an invention, a new product or process must be new or show a significant degree of novelty and have a prospective utility as suggested by Schmookler (1966). Yet, even this does not adequately describe all allowable inventions as many have never been developed to a stage where the practical utility was realised. Thus, it follows by deduction that an invention does not necessarily have to be patentable; nor does it need to be commercially viable. In the case of smart card, the original concept patented by both Kinitaka Anmura and Roland Moreno was patentable and has evolved to become commercially viable. Here, the act of invention can be considered to be only a part of the product development process.

Innovation

If we accept the above definition of invention, then the process of developing an invention to a point where is becomes commercial - or has improved utility for its inventor - then additional acts of creativity, resources and skills are required. It is this set of additional product development acts that can loosely be termed the process of *innovation*. That is, the concept of innovation can be expressed in terms of improved utility or commercial terms. Here, the process of innovation is limited to the development of the invention. The process of innovation may also result in the need for further inventions. In this sense, innovation and invention are closely allied, yet also fundamentally different concepts. This distinction is essentially maintained in the literature.

Thus, it is generally agreed that the development of any new technologies requires a degree of innovation. It requires the recognition and discovery of new and improved ways to design a new technological system; and, bringing it to market. Innovation theorists such as Deideren *et al* (1990), therefore contend that the concept of innovation involves a broad range of activities. It can be understood as,

> *... a process or a product, a technical or an organisational change, an incremental improvement or a radical breakthrough.*
> (Deideren *et al*, 1990: 123)

Diffusion

If we accept Deideren's view of innovation, the question then arises as to how the process of innovation is related to the diffusion of the technology. To clarify the relationship between innovation and diffusion, diffusion can be viewed as involving the transfer of the product to the market. That is, the process of diffusion is only one aspect of innovation: It implies reproduction and transfer of an innovation.

The study of innovation diffusion is therefore mostly concerned with the economic dynamics associated with new innovations. However, it is important to note that the vast body of knowledge that now exists in the broad field of innovation thought, traverses three fundamental concepts: invention, innovation and diffusion.

1.2.2 The development of innovation thought

Within the wide ranging literature that now exists on innovation, many philosophical perspectives have been observed and described. Last century, Marx and Schumpeter wrote about the interactions between innovation and economic growth (Brewer, 1984). Cook and Morrison (1961) observed that innovations only occur when 'a need for the innovation is actually felt'. As our ideas on innovation have developed to keep pace with industrial change, researchers like Nelson and Winter (1977) have broadened the scope of innovation thought by introducing the twin concepts of *natural trajectories* and *selection environments* as a useful theoretical organiser to describe the environmental influences on the path of innovation. More recently, the multidisciplinary studies reported by Sharp and Holmes (1989) have considered the role of the State as an agent for innovation, and as a regulator.

Given the large number of inquiries in the field of innovation thought, the literature can be generally categorised according to the main focus adopted for analysis. Using this criterion, the literature may be broadly classified as either belonging to the *product* or *process* school of thoughts. The first group is characterised by a market orientation. That is the main focus is the product and how to get it to market. Many of the product views adopted therefore involve the use of stochastic models and quantitative methods for analyses. In adopting a process focus, the second group is more descriptive.

1.2.3 Product - process dichotomy

One of the major differences between the two groups is that of product and process in innovation. The product approach, as used here, refers to how innovation should be directed (ie. a normative orientation is adopted). The origin of the product, is not a consideration in most product schools of thought. In many cases, the product is assumed to have arrived in its final form at some time in the past. In comparison, the process school of thought deals with what should be done (ie. a more descriptive orientation is adopted). In much of the literature which can be classified as belonging to the process school of thought, the development of the product itself is treated as endogenous to the innovation process. The development of each of these schools of thought will be considered.

1.2.4 Product

A predominant proportion of the literature on innovation, deals with product. Important among the product approaches are the many theoretical innovation diffusion models. Most innovation diffusion research is used in marketing and is based on behavioural theory to forecast sales and market penetration (Silverberg 1990:177-192). Much of this literature deals with the development, selection and application of new product forecasting models. Collectively, they also provide a rich literature relating to consumer choice associated with a particular situation. In this sense, innovation is viewed as involving a series of activities that transforms a new idea or process into profitable products.

However, in responding to the challenges issued here to develop an understanding of smart card innovation, this body of literature is limited by its market orientation. It is focused on producing and predicting market outcomes based on behavioural characteristics and the calibration of associated variables, rather than offering a way forward in understanding the innovation process for new and more complex information technologies like smart card.

In comparison to the market focus adopted by innovation theorists, other product approaches have attempted to develop a broader framework. Nevertheless, in recognising the complexity of social and technical forces shaping technology in the innovation process, this body of literature has continued to rely on arguments in support of the view of innovation as an essentially economic activity (Rosegger, 1980). An underlying assumption is that innovation requires the commitment of resources and ultimately the promise of profit. In this sense, the organisational emphasis or view of innovation could be described as the decision to produce or design a new product for the market to test. This approach is the primary role of organisations in the process of innovation. In fact, it can be argued that all of the concerns raised by organisations when considering new innovations relate to profit.

A third body of literature which can also be considered as belonging to the product school of thought, deals with contributions prescribing an economically focused framework for sociologists. Almost all attention is focused on social systems' analysis and is limited to the social setting. The product focused social analysis thinking has been useful in fields such as industrial sociology and in directing attention to relational determination and social subordination issues. However, they have tended to focus on the statics of social structure and to neglect the structural and social change issues associated with the innovation and diffusion of new technologies. In fact, researchers such as Peter Drucker (1970) have observed that the *human relations* school of thought assumes that the requirements of the technology are relatively unimportant compared to the social and psychological requirements of the users.

Over the last decade, the role of innovation has also been viewed as an integral part of a company's strategic armoury in the face of global competition and rapid technological change. According to industrial economists such as Michael Porter (1990: 585-587), the success of a company now depends on both the rate and direction of innovation. Some of the ways he advises this can be done include (among others): sell new products to the most sophisticated and demanding buyers; and, strive to exceed the toughest regulatory requirements or product standards. Yet, it could be argued that again, such approaches are bound to the organisational setting and the focus remains fixed on economic performance.

In recent years, other industrial economists have also broadened the focus of innovation studies and provided new analytical tools for economists conducting empirical research on technological development. Contributions made by Nelson and Winter (1982), Dosi (1988), Freeman and Soete (1990), among others, have increasingly contributed to the now rapidly growing awareness of the interrelatedness of the process of technological innovation and economic development. Implicit in the arguments supporting broader frameworks for analyses, is a convergence between the product-process schools of innovation thought. This is important here, as many of the more recent multidisciplinary contributions that could be considered as belonging to the product school of thought, have also helped to provide a broader understanding of the evolutionary or process nature of innovation and innovation thought discussed in the preceding section. However collectively, the newly recognised importance of social considerations and the different aspects of technological innovation have added little to our understanding of the innovation process itself.

In summarising, it should be noted that the product focused approaches to innovation are predicated upon certain assumptions, which, for the most part are not explicitly stated in the literature. These can be stated with brevity as follows:

(i) The focus is restricted to a *product* or market orientation and is contained within clearly defined boundaries for analyses;

(ii) The origin of the *product* or technology itself is viewed as exogenous;

and,

(ii) The approaches adopted are directed towards achieving predetermined goals.

In stating these assumptions, two additional points should also be noted. First, certain economic assumptions which have underpinned much of the economic theory of innovation are not common to all approaches. For example, profit maximisation may not be a goal common to all of them. Second, in noting the restricted focus of the product schools of thought, this body of literature is now evolving to incorporate inherently multidisciplinary approaches. This has been particularly notable over the past decade as theorists have attempted to recognise the increasing complexity of the underlying industrial processes themselves.

Second, and related to the first point, the broadening scope of product focused innovation theory has also resulted in a convergence between the product and process schools of thought in recent years: Product and process theorists are now recognising the more expansive and pervasive role of new information technology innovations. The bargaining and negotiation potential of the users of a new system, the possibility for the development of new market segments, and the importance of the role of changes in the regulatory and legal environments which form a part of the macro-environment, are all now becoming recognised as important factors influencing innovation. This point will be discussed further in the proceeding sections.

1.2.5 Process

While many of the product studies reviewed above have taken technology as exogenous, the success or not of innovation is judged according to whether technological change was successfully introduced. In comparison, the process based approaches, while not directly questioning the need for a more normative approach, suggest the realities of innovation as a process with causes due to various environmental influences. This section will therefore provide a summary overview of the antecedents that have shaped our ideas about contemporary process approaches. Only key contributions that relate to this study will be highlighted.

The roots of classical technology innovation theory can be traced back to as early as the last century. Among the earliest contributions to the process school of innovation thought, the work of Marx and Schumpeter have had the most significant influence.

Schumpeter's contribution stands out with the focus of attention being placed on technological innovation and its impact on a capitalist economy. However, much of his work focuses on innovation theory in relation to the role of the entrepreneur and the innovative performance of companies. In spite of this, he does provide a basis for a more broadly based view of the innovation process than many of his contemporaries. In particular, Schumpeter's recognition of the need to create new industrial structures that involve analysis and understanding of company behaviour appears to be a productive early start for any effort to analyse industrial change and innovation from a broader, more process oriented framework.

Unlike Schumpeter, Marx's theories gained him much more acceptance in the orthodox economic schools of thought. In fact, Marx's theory is still frequently cited as one of the first major contributions to the evolutionary theory of economic change in which technological innovation as a process, plays a key role. A central tenet of his theory is the assumption that technological development acts as a force to periodically create economic disequilibrium and therefore being at least partially responsible for economic crises at various stages in our economic history.

Nevertheless, and although both Schumpeter and Marx adopted a more descriptive - or process - view of innovation, they have each cited the generation of profits as being the key stimulus producing technological innovation. Several authors, notably Rosenberg (1986), have since emphasised this similarity in their respective visions of the importance of innovation in economic progress. According to Rosenberg, both have also addressed the relationships between innovation, company growth as well as industry concentration. Yet, when viewed from this perspective, neo-Marxist and some neo-Schumpeterian theories are limited in scope to the role of the individual organisation. However, in reality today technological innovation often requires a number of organisations acting in a cooperative manner to produce a major innovation such as in providing a global satellite system for communications. These earlier approaches have also ignored the interactions between the regulatory and cultural factors in adopting a process oriented approach to innovation.

Notwithstanding these similarities, they were also quite different in a number of respects. Not only do their works refer to different industrial periods, but Marx's work was characterised by his socialist political praxis in that he condemned materialism as a social evil and was more concerned about income distribution and social class structures. Marx did not appreciate the work of an earlier classical economist Adam Smith, as Smith was not at all concerned with issues relating to the division of labour. While

Schumpeter's work emphasised the role of the entrepreneur, economists like Marx and Smith did not pay much attention to the entrepreneur as a distinct factor in their analysis.

Despite these quite significant differences, both Marx and Schumpeter reached similar conclusions on the causality between technological innovation and economic development. However, it is their process approach to innovation studies that is most relevant to the studies reported here. It should also be said that within the technological paradigm adopted by Marx in particular, it was clear that he was aware of the broader social and economic consequences of technological innovation. It was this awareness that led him to emphasise the need to gain a greater understanding of the technological innovation process itself (Brewer, 1984). In contrast, Schumpeter was less ambitious. To understand the role of innovation, he focused on closed systems while still adopting a process oriented framework for analyses.

Since the path breaking work of Schumpeter and Marx, much subsequent innovation research has tried to establish the relationships between economic performance and innovation effects. Collectively, these classical process approaches have also added to our present understanding of innovation. However, the most important point to note is that like the product focused research efforts, the process approaches adopted have also become contextually broader over the past decade. The challenge has been to develop theoretical frameworks for analysis that are able to incorporate the increasingly complex social forces that interact with more sophisticated technological systems and help to transform the cultural, economic and regulatory frameworks within which the new technology exists.

Significant among the more recent contributions to innovation thought, is the work of Nelson and Winter. In a seminal paper entitled, "Towards a Useful Theory of Innovation" (1977), the twin concepts *natural trajectories* and *selection environments* were developed. A technological trajectory can be defined as the pattern of innovation resulting from the process of technological and economic trade-offs over time. The idea of a selection environment which acts to encourage or inhibit new innovations is implicit in this definition. In other words, it is contended that both the rate and direction of technology innovation and diffusion pathways might be determined through demand conditions by forcing technologies to meet new technological imperatives. For example, in the semiconductor industry, technical and market forces have acted in concert to produce smaller, lower cost and more reliable microchips that also consumed less energy. Nelson and Winter also proposed the concept of a *selection environment*. They have argued that the selection environment acts to influence the path of innovation and the rate of diffusion generated by any given innovation, and at the same time generate feedback to strongly influence the direction and type of R&D programs that firms might invest in.

These contributions are of particular relevance to this thesis as such approaches have helped to support the central supposition that innovation can be viewed as a process that involves the interactions between the product and the environment within which it exists. This means that innovations might be viewed as being developed selectively as a result of their interactions with the environment over time.

More recently, writers such as Sharp and Holmes (1989) have also endeavoured to provide more broadly based frameworks for understanding the process of innovation compared to the purely economically focused content explanations of technological change that have dominated the literature in the past. In their work, they emphasise the role of public policy in innovation support and in influencing social acceptance factors. In addition, these concerns have contributed to the ongoing debates surrounding industrial policy development and the role of government as innovator from a national perspective.

Other significant contributors to the process school of thought have also attempted to provide alternative frameworks for innovation theory by emphasising the human-centred information management practices that are now emerging for a range of new information technology studies. In particular researchers like Davenport have noted that "information managers must begin by thinking about how people use information, not how people use machines" (Davenport, 1994: 121). The works of researchers such as Von Hippel (1988), have also contributed to this body of literature by recognising the role of the users in innovation.

Thus it can be argued that in migrating from a content based view of innovation, to a more process focused approach, the focus of the researcher is shifted away from the organisation or the technology itself, to place a greater importance on how people using the system relate to particular design aspects of the new technological system.

1.2.6 Recent changes in innovation thought

As can also be seen from the discussion in the preceding section, our idea of innovation from the product point of view has developed in recent years to involve responding to pressures for change and forcing it to occur faster. This means that it has evolved to become more process oriented: The underlying assumptions from a product perspective have therefore been expanded to the extent that there is a convergence with the process school of thought. A crucial implication is that much innovation is therefore now viewed as incremental - or evolutionary. It depends more on the accumulation of understanding the systems within which the technology itself forms only a part, rather than on fundamental breakthroughs or discoveries. This means it is the result of a growth in our technological developments, organisational learning and social understanding.

However, it always involves investment in developing all three key areas and assumes the existence of physical infrastructure and marketing effort.

This observation of the changing view of the role of innovation is important as it would also explain the appeals for more multidisciplinary approaches by some contemporary product theorists. N. Clark (1986) for example, has called for the need to widen the scope of innovation theory to further develop our understanding of new and more complex technologies which are now impacting both our professional and private lives. At the same time, these efforts are also helping to provide the justification for researchers to adopt a more process based innovation paradigm to further develop our understanding of the process of innovation.

These changing perceptions are also important because they highlight our altered understanding of what is meant by the term *innovation*. It is agreed that innovation involves the recognition and discovery of new and improved ways to design a new technological system and bringing it to market. However, in the context of the newer innovation paradigms now emerging, innovation now also needs to be more broadly defined, to encompass both technological improvements and better ways of defining the systems within which the technology exists. In this sense, innovation can be apparent in product design changes, technological process changes, systems design changes, systems use changes and, in our understanding of the role of environmental factors in shaping new technologies.

1.2.7 Implications for smart card technology

In reviewing contrasting approaches to innovation (exemplifying the product-process dichotomies), some important themes relevant to this thesis emerge.

The first is the need for the adoption of more broadly based theoretical innovation frameworks for analyses. In the last decade, attempts to analyse company behaviour in relation to environmental influences and the role of industry structures, as for example advocated by Arnold (1985) have demonstrated that it is not only possible, but now necessary to abstract from the whole macrocosm of a technological system to be able to understand the increasingly complex nature of innovation. This of course, involves a number of strategies. The framework adopted must also be sufficiently broad so as not to lose the dynamic perspective.

The second central theme of the many contributions to the advancement of evolutionary theories of technological development is the notion of technological innovation as a process of what Sahal (1981: 37) refers to as *accretion*. That is, the continued accrual of technological *know how* that results in further innovations in a series of incremental changes. This cumulative aspect of innovation can also be viewed as a historical process. This view of technological innovation as an evolutionary process forms a useful technological paradigm and also requires the introduction of the concept of technological trajectories. Such concepts can be readily applied to enhance our understanding of innovation. They share the Marxist notion of the role of the *forces of production* in the innovation process.

The more recent paradigm shifts highlighted in the preceding analysis have also served to foreshadow the need to expand our thinking on the interactions between the many environmental influences impacting technological innovation in the face of the growing complexity of information technologies and their changing role in today's society. This will require the development of broader process-based frameworks that can be used by researchers for analyses to further our theoretical understanding of innovation as it relates to these new information technologies. To use Keith Harding's terminology, it is now becoming necessary for the sociotechnical or user-interface technologies to advance hand-in-hand (Harding, 1993: 25). This point is also of importance to this thesis, as we are only just beginning to appreciate the potential impact of new information technologies like smart card and we have developed little understanding of the innovation processes that have underpinned the diffusion of these new technologies to now. The current study is a contribution towards this end.

By going one step further with this perspective, it becomes evident that the distinction between innovation and diffusion cannot easily be made. To ignore the tangency of each process is to ignore the possibility of improvements being made in the product, or the processes involved in producing it, during diffusion. That is, innovation here is viewed as an evolutionary process that occurs during diffusion. Much of the product focused literature however, has ignored this point. By embracing a perspective which has an innovation arriving at time zero, the process of diffusion is then analysed. The main problem with this view is that it does not help to explain why new information technologies like smart card have taken so long to be adopted by the potential users. If such an assumption formed the underlying part for this thesis, then the non-adoption period would be self-evidently irrational. By deduction, the only questions remaining unanswered would relate to the factors determining the rate of diffusion, the potential time and levels of saturation forecast and to determine the characteristics that distinguish the late adaptors from the early adaptors (a *priori* clearly defined).

Another lacuna in the body of literature reviewed above, is the observation that the role of the user has been largely neglected. In part, this neglect has been justified by the argument that innovation is inherently an economic activity and as such, is of vital importance to the firm. The reasons for such apparent oversights are in themselves also observations that have rarely been explicitly stated. The purpose of highlighting them here, however, is that they may serve as an entry point into the framework used for this study. In adopting this broader perspective the analyses are able to bring into focus a range of otherwise disparate factors. Further, by adopting such a stance, it can be argued that one of the reasons that the technology is able to advance is precisely due to the many human factors that form a part of this process itself: In the case of smart card systems, it is not only the technologist, but also the organisational and social stakeholders that have learnt by doing. The importance of the interactive role between the producers and the users during this process, has not escaped the attention of a some contemporary innovation researchers such as Lundvall (1988) and Von Hippel (1988).

At a more general and abstract level, the preceding analyses also reveal how technology innovation paradigms can best be understood as a changing collection of rules directing the research efforts within the available plethora of technologically mediated insights provided in a wide literature. As is the case for scientific paradigms, most technology innovation research has been conducted within the safe frameworks provided by mature paradigms and are aimed at solving problems with existing tools. However, as the reality confronted begins to challenge the limits of existing product-process schools of thought, and when research questions can no longer be answered within the existing theoretical frameworks, then new paradigms have to be considered. If the more broadly based paradigms now emerging from both the product and process focused schools of thought, can provide a better framework for furthering our understanding of technological innovation, then it becomes a part of a new paradigm. The main purpose of this thesis is to provide the very first insights into the understanding of the smart card innovation process from within the new and more broadly based innovation paradigm now emerging.

Collectively, these implications therefore call forth the need to adopt a theoretical framework with the following characteristics:

(i) open systems approach incorporating social, organisational and technological factors, and;

(ii) evolutionary.

However, it is also important to note that if one attempts to address an innovation problem using such an approach, eventually, implicitly or explicitly, one ends up conducting what has been traditionally called a *sociotechnical* analysis. That is, one involving social, technical and organisational considerations. By conducting an exploration of the more dialectical relationships between technology, social structures and organisational needs this study represents a first attempt to contribute to an alternative analysis of smart card innovation based on sociotechnical theory. According to researchers such as Law and Bijker (1992: 306), '...the academic time is right for work on the sociotechnical'. The study reported here, applies the same sociotechnical principles adopted in the recently published work of Bijker (1995). Bijker's work represents one of only a few innovation studies using a sociotechnical framework to present a broadly based view of innovation for a number of technologies such as the bicycle. The result is a view of innovation that integrates economic, technical and social considerations to explain innovation as an implicitly sociotechnical process. In such a framework, it is possible to incorporate both the gradual evolutionary characteristics, the dynamic social and cultural considerations as well as the needs of the organisations involved in the development of a complex new technology.

1.3 Study aims and objectives

In so far that it is agreed that technological innovation is an important subject, the literature explored, bears witness to the fact that there have been few departures from both the theoretical and empirical research of the past. While it is also observed that contemporary studies of innovation have become more broadly based, previous approaches can only take us so far when they are applied to major new information technologies like smart card. This thesis represents a first attempt to develop our understanding of the fundamental forces most relevant to the shaping and technological development of smart card.

For this reason, the primary aim is to analyse the characteristics of smart card innovation patterns between 1974 and 1996 within a sociotechnical framework to discover the contrapuntal characteristics in the context of its own innovation paradigm.

The research objectives of the study are:

(i) To conduct an exploratory investigation of the sociotechnical factors influencing the development of smart card technology for the period 1974 to 1996 in order to discover the main factors characterising the smart card innovation process to now.

(ii) To analyse and interpret the current smart card design practices used by Australian firms known to be adopting smart card technology from a sociotechnical perspective.

(iii) To determine how implementation and execution capabilities of the design team can influence smart card innovation in the context of the many large scale multifunction smart card projects now emerging.

(iv) To assess whether the sociotechnical approach applied as a theoretical framework for developing our understanding of smart card innovation, is in fact, a reasonable and useful paradigm.

The intent is to start by considering the historical and social aspects of the technology and to work towards an interdisciplinary result. A schematic representation of the main investigative stages is shown in Figure 1-2. The results have yielded the conclusion that what commenced as a series of quite separate inquiries, has turned out to be a main pathway toward an emerging sociotechnical view of smart card innovation. In this sense, the sociotechnical framework used as a starting point, is also developed as a heuristic device, representing a set of interrelated concepts that allow analysis of the key factors influencing smart card innovation.

The central thesis posited is that to begin to develop our understanding of the underlying innovation processes shaping smart card technology, it is necessary to examine the interactions among three key factors: smart card technology; the potential users; and, the organisations. In the context of the theoretical analysis provided in the preceding section, there are four key assumptions underlying this central idea:

(i) Firstly, it is assumed that innovation is best understood as a process of accretion where product improvements are made as a result of a number of factors that may be external to the technology itself and which interact over time.

(ii) The second, and a corollary to the first, is that new technologies are only adopted if the technological parameters (technology focus), the market needs (user focus) and the entrepreneurs (organisational focus) meet. This paradigm - based upon our traditional views of what constitutes a sociotechnical systems analysis - provides the foundation upon which the entire research structure rests.

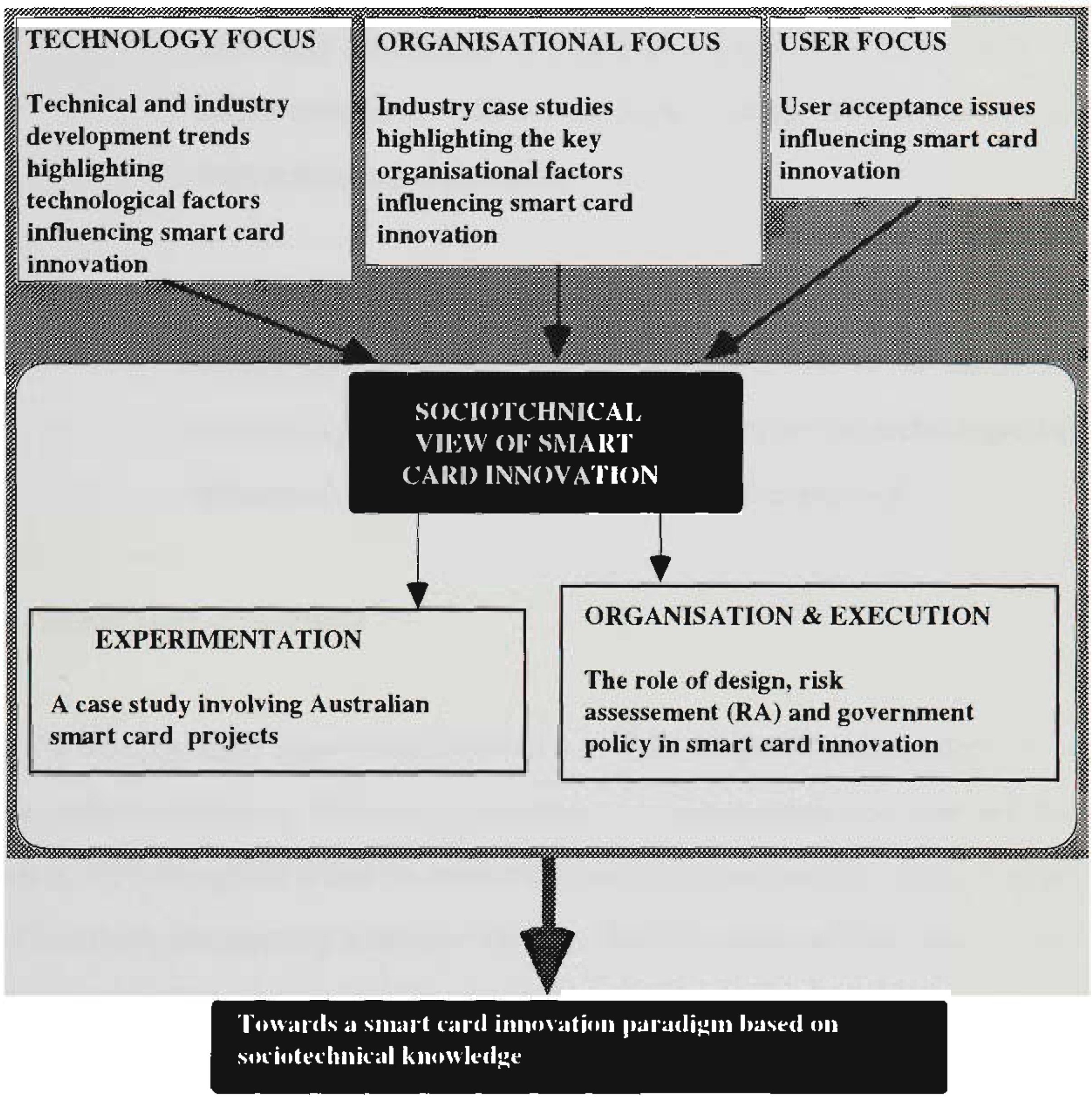

Figure 1-2 A schematic representation of the various stages of investigation undertaken in this study.

(iii) At a more abstract level, it is assumed that the conceptual framework should adopt the view that the utility and design of smart card technology are the result of sociotechnical processes; not its cause. The aim is therefore to address the topic of smart card innovation as a subject requiring explanation.

(iv) A final assumption is that no *a priori* distinctions should be made among the factors identified as playing a role in the smart card innovation process. The social, the regulatory and the technological are all parts of a whole and cannot be considered in isolation.

1.4 Furthering knowledge

It has also been argued that the interests of the identified stakeholders are not independent and that one view alone is insufficient to understand the processes involved. That is, the view upheld is that the smart card paradigm emerging from these analyses - and based on contemporary innovation thought - both demands and empowers the view of smart card innovation as a sociotechnical process.

Besides the contribution envisaged to furthering our theoretical understanding of smart card innovation, possibilities for serving the ends of the practitioner have also emerged during the study. For example, smart card systems designers can apply the theoretically informed smart card innovation concepts to improve systems design and risk assessment tasks as suggested in Chapter Seven and, hence also influence the innovation process itself. Moreover, it is argued that by being theoretically informed, the smart card design team would be in a position to significantly and positively influence the rate of diffusion of new innovations: Overall, the design team could attempt to use some of the more traditional product based approaches combined with the theoretically informed process design tools, to exercise a greater degree of control over the smart card innovation diffusion process.

The present work differs in two important respects from earlier studies of technological innovation. First, not only has smart card innovation not been studied before, but this work has shown that smart card technology requires an understanding of social, organisational and technical issues before we can begin to develop our understanding of the factors influencing smart card innovation. Second, no hypothesis is proposed. It was initially proposed to include a large range of perspectives from many sources and incorporating several methodologies, not merely to explore a broad range of issues to further our understanding smart card innovation, but also to develop our practical knowledge of the underlying processes at play.

1.5 Methods used

To investigate the factors influencing smart card innovation diffusion for the period 1974-1996, a three year study was conducted from July 1992 to March 1996. In the preceding sections, a conceptual and theoretical framework that enables the analysis of smart card innovation at different levels of abstraction has been introduced. These concepts will be applied from within a traditional sociotechnical framework in order to develop our understanding of the core technology of this study, and the process of innovation which has resulted in its transformation. Thus, smart card innovation is analysed within existing paradigms.

This investigation has been conducted in the belief that if studies of technological innovation are process based, and treating the technological system in endogenous terms, it becomes possible to use a range of strategies to develop our understanding of the many facets and effects of technological change in an evolutionary and richer contextual way. This is necessary if one is not to assume that the smart card innovation process has followed a peremptory course. This approach, has been adopted for the following reasons.

(i) First, this is the first study of its type.

(ii) Second, the strategy to use a broader framework for analysis has made it possible to both assume and predict a wider range of observations without first establishing premises at the outset of every observation noted.

(iii) The third reason is that the time at present is ripe with opportunity. Historically, smart card has undergone a number of technical innovations. We are now in a position to accommodate a new understanding of the technology and to be able to provide valuable insights into the smart card innovation process so that future researchers and practitioners may benefit from the previous experience.

These basic tenets have also influenced the choices made about the methods used for this study. In particular, it was thought necessary to employ a wide range of research methods. Some involving rigorous and systematic approaches, and some involving industry observations, secondary data collection and informal interview techniques.

In the past, and from an information systems' research perspective, a number of research methodologies have been proposed and used since the early 1970s (Galliers, 1992). Since then, researchers are also becoming increasingly aware of the limitations of adopting a more scientific approach given the growing complexity and sociotechnical nature of the information systems environment (Fitzgerald *et al,* 1985). It is therefore not surprising that during the last decade, qualitative methods based on a descriptive and interpretive approach have been considered and used widely in information systems research. However, it is also recognised that as the degree of methodological rigour of evaluation decreases, the possibility of unconscious bias by the researcher is increased (Rosenthal, 1966; Terpstra, 1981).

It is against this backdrop that the methods chosen for this research rely mainly on qualitative methods as well as quantitative methods where possible, to investigate a contemporary phenomenon of smart card innovation within its real-life context; especially when the boundaries between the phenomenon being investigated and its context are blurred. According to Yin (1984), other characteristics of the study should include the need for the methodology to be able to handle many variables of interest and as one result. This means that multiple sources of data will be required to converge in a triangulating fashion. As the study progressed, it was also necessary to use a combination of literature review and feedback from industry representatives to informally test the validity and reliability of the findings as well as to evaluate the applicability of the findings. In addition, this means that the prior development of theoretical propositions which can be used as a theoretical framework to guide the data collection and analysis will also need to be developed. In this sense, qualitative research used in information systems research is not a 'soft' option, and it is often more difficult to conduct in reality. An added difficulty is that, the researcher becomes a part of the research.

Literature search

The projects reported in this study began with a literature review covering the development of smart card technology since the initial patents were taken out in 1974 to 1996. Academic journals, industry newsletters and reports as well as conference proceedings relating to smart card have also been regularly reviewed by the author for the duration of the study. Newspaper, periodicals and television coverage of smart card technologies were also reviewed to keep abreast of contemporary attitudes and issues. As this thesis represents the first comprehensive analysis of the development of the smart card, much of the historical content reported here has been gained through media sources. The information included has been validated by follow-up personal contact with key industry personnel and industry reports.

For the more theoretical level of investigation in the areas of technology innovation and sociotechnical systems analysis, the author used libraries at the University of Wollongong and the Australian National University, as well as online library information services.

Conferences

A network of research contacts involving both Australian and overseas researchers has been established through attendance at academic and industry conferences during the course of the work reported. The most important set of resources for this thesis were the many industry contacts and reports provided both formally and informally. Many of the resources for keeping abreast of a rapidly changing and developing technology - and the contemporary issues which the technology raises - have been gained from personal interaction and participation in industry conferences relating to smart card.

The author has also been invited to chair industry panels, present academic papers at national and international conferences, as well as deliver private industry presentations for senior smart card project staff. These opportunities have provided the author with access to much research material that has not previously been available to academic researchers. While it has not been possible to include details of all information revealed as a result of these activities on the request of various industry contacts, there have been no consequential omissions. However, the close contact with industry has enabled the author to gain a first hand working knowledge of current developments and attitudes towards smart card development.

During the interviews and discussions arising out of conference activities, the author practiced a non-assuming form of receiving the information presented using two distinct methodologies. In the first instance, the basis for people's reasoning about the problems and issues they believed they were confronting was the focal point. Here the interviews used were designed to explore the outer bounds of each individual's paradigmatic framework that they used to solve their problems or to provide alternate explanations. The second method sought to examine and explore the more implicit aspects of people's experiences and attitudes. Information regarding attitudes and perceptions of the technology that developed as a result of their experience or perceptions about how the technology has been or will be accepted by users was sought by the author.

Data analysis

The analytical methods adopted for this study, could be described as inductive or rationalised exploration, rather than empiricism. The author sought information from observation, interview and literature searches without imposing any pre-conceived framework. However, after spending time considering the type and range of information received, it seemed to not fit into any one of the traditional theoretical innovation frameworks reviewed in the previous section. In each of the innovation frameworks adopted in the literature, there was evidence of additional dimensions being excluded in the various options considered. Thus, an analysis of the scholarly literature in the areas of innovation thought and sociotechnical systems theory is brought together in a way that provides the broad theoretical substructures required.

With the themes that emerged, it was subsequently deemed to be necessary to extend the existing theoretical frameworks to be able to include all the factors that appeared to play a role in the smart card innovation process. Only after some time did it became evident that a sociotechnical framework would be required to provide a sufficiently broad basis for analysis purposes. The task then became one of interpreting the many conjunctive and interdisciplinary themes emanating from the analyses, and to triangulate these as a way to build our theoretical and practical understanding of the processes involved.

Industry involvement

By necessity, the kind of research process adopted was field intensive and broad because of the lack of any previous studies in the field of smart card innovation. In most cases this involved discussions and meetings with smart card project managers to determine if the framework adopted was appropriate, and whether they themselves stood to learn something from the new knowledge that might be generated by conducting such a study.

As research progressed, and as the conceptual map became more detailed and comprehensive, a clearer understanding of the issues began to emerge. For each issue, several field-tested ways of asking questions that would tease out the level of information sought, and provide additional understanding of the associated nuances were also used. As the author became more involved as an invited presenter at key smart card industry meetings, there was a genuine commitment to producing new knowledge that could both enhance our understanding of smart card innovation and improve the smart card innovation diffusion process in practice. It was evident that if the author was going to learn anything about the overall innovation process that was occurring, it would depend on the capacity of industry personnel to understand the nature of their interior - or individual project - experiences with smart card.

As a result of this direct involvement with the smart card industry, the author was not reporting as a completely independent observer. This point is important and has been recognised as a factor in the outcomes of the research efforts reported. This has been justified in the belief that it would foster the mutual collaboration needed to help the author search for information or insight that might only be forthcoming from frank and open discussion.

Surveys

Survey data was used as the primary source of data for the case study reported in Chapter Six. To improve the validity and reliability of the data collected, interviews were also conducted immediately after completion of the questionnaire. Full details of the survey methodology is provided in Chapter Six.

Interviews

In addition to the discussions and interviews arising out of the author's involvement in conferences, industry activities and the case study referred to above, another major source of information came from planned field, laboratory and telephone interviews with key industry representatives and academic researchers in the field. There were many opportunities among systems designers, engineers, software developers, industry consultants, users, academics working in smart card laboratories and members of the public. On several occasions, people also provided follow-up information in the form of newspaper articles or telephone discussions about certain developments that might be of interest.

These interviews were generally open-ended and focused on four groups: managers of smart card technology manufacturing and distribution firms; smart card project managers and operations staff; researchers from smart card laboratories; and, civil liberties group representatives. On some occasions, depth interview techniques were employed as being "conversations in which the informant is encouraged 'to relate', in their own terms, experiences and attitudes" that appear to be of relevance to the central research problem being addressed (Walker, 1985: 4).The aim was to uncover new clues or dimensions.

Because of the range of information sources available to the author, it was possible to compare and validate information received from different sources. However, it is also important to note that most of the source evidence used for the study was of a documentary nature. To reiterate, industry activities, planned interviews and conference participation were used to validate, augment or clarify the information supplied.

1.6 A look ahead

In discussing the origins of smart card in a broad historical context, Chapter Two has sought to describe and analyse the problems confronting smart card technology development to set the background for understanding how these factors have influenced smart card innovation. It traces the origins of smart card from when Roland Moreno first promoted his vision of the Electronic Bank Manager in the early 1970s to 1996 in a broad historical context. It also examines the state of the global smart card industry. In Chapter Three, a wide range of applications for smart card are considered to highlight the interplay of social, organisational and technological factors as smart card technology develops. Against the backdrop of the key findings of the preceding chapters, Chapter Four takes a closer look at the key social factors influencing smart card innovation. The role of the user and the regulatory and legal frameworks are also examined. The point is made that smart card innovation needs to be viewed from a multidisciplinary perspective.

In the context of the findings of Chapter Two, Three and Four, Chapter Five analyses the foundations of sociotechnical theory and its application in providing a broad theoretical framework to examine the process of developing new information technologies such as smart card. A working model for understanding and adopting the objectives of sociotechnical knowledge for smart card systems innovation is proposed as a framework for designing and redesigning new technological systems during the innovation stages. The findings in Chapter Five have also highlighted the need to consider the user as a major player in the innovation process. Consequently, it was decided to conduct a case study based on the collective design practices of Australian firms known to be using smart cards to determine at a practical level, if the design team considered the needs of the users in determining the design of the system. This study is reviewed in Chapter Six and highlights the blurring of boundaries between the theoretical and applied aspects of smart card innovation at the operational and systems design level. The case study that was conducted in 1993, sought to analyse the smart card design practices by Australian smart card project leaders. The outcomes showed for the first time how theoretically informed systems design is now being used to help break down the barriers that arise as a result of user concerns. It has also showed that there are some additional reasons - other than social - that smart card uptake has been inhibited in Australia. Second, and at a more general level, the case study reported illustrates in a practical way how the use of sociotechnical knowledge can further our understanding of the innovation process and the interaction between the many identified forces at play.

In Chapter Seven, the link between the smart card innovation process and basic design practices highlighted in Chapter Six are extended. In the context of this analysis, together with the collective findings of the previous chapters, the criteria for formal design techniques for the translation of sociotechnical principles to smart card systems design as a key part of the innovation process are considered. The risk assessment challenges now emerging as a result of the growing need to consider the users as a major part of any new information technologies like smart cards, are also highlighted.

In Chapter Eight, the collective findings of this study are examined in the context of the new age in informatics now emerging. The future of smart card is also discussed. It is argued that this understanding both demands and empowers the innovators to design future smart card systems that are flexible and can simultaneously satisfy the needs and concerns of the users and organisations. By adopting such an approach, it is assumed that designers of new smart card systems must pursue the interests and concerns of the organisations, and the users - thus becoming humanised and defining the relationship of the technology within its larger societal context. The insights gained have been useful in characterising the emerging smart card innovation paradigm for the first time. This extended view of innovation is necessary if we are not to take the arrival of smart card technologies for granted and assume that the emerging systems have followed an autonomous or technologically determined course.

In Chapter Nine, a summary of the main contributions arising from this thesis is provided and the limitations of the study are noted. In the light of the implications revealed in Chapter Eight, some directions for future research in the area are also suggested. Finally some conclusions which have emerged for the development of our understanding of smart card innovation are drawn.

Chapter Two
Origins of Smart Card: A history and interpretation

In the preceding Chapter, a brief introduction to smart card technology and some definitions were provided. The relationships between several technological innovation schools of thought were also dissected.

It is against this backdrop that this chapter has sought to describe many of the historical and technological factors influencing smart card development and to consider how these factors might have played a role in smart card innovation. The primary objective is to provide a broad technological and industry development overview from within a historical framework as a basis for the interpretations of the following chapters. While only the more important innovation factors have been highlighted here, it is recognised that many others might also have been included. The information has been drawn from a variety of sources and some of the dates provided must remain somewhat arbitrary.

2.1 An introduction to smart card technology

If we accept the definition of an ISO smart card considered in Chapter One, then the essential technology for nearly all smart cards now in circulation, consists of an integrated circuit (IC) chip, always less than 25 mm^2, embedded into a plastic card of

Please see print copy for image

Table 2-1 **A brief smart card chronology (1970-1996).** (Lindley 1996a) standard credit card size (85 mm x 54 mm x 0.76 mm). These *smart cards*, or *IC cards* as they are sometimes called, can be designed to perform different functions depending on the type of chip(s) mounted. A brief chronological history of smart card and some definitions have also been provided in Chapter One. The key historical events affecting smart card development are summarised in Table 2-1.

In comparison to alternate card technologies, smart cards provide a faster and more secure service. They also offer greater flexibility and are more robust. The simplest smart cards are merely simple memory cards that may have some write protection features added to the memory area. The majority of the 1 billion (*ie.* 1×10^9) smart cards produced to date are of this type and most are used as prepaid telecom debit cards. Other smart cards can perform functional operations in addition to providing memory storage capacity. Some higher level smart cards now also contain more than one microprocessor and may include a coprocessor to speed up complex cryptographic calculations. The smart card chips might also contain circuitry for interfacing with other equipment and they can incorporate some additional circuitry to distinguish the different types of interface technology and to render them tamper resistant. A comparison of the different card technologies available at present is shown in Table 2-2.

The core technology to access smart card with read and write functions is smart card terminals, or readers as they are sometimes referred to. However, they too can be designed and programmed to perform a range of functions. Using mechanical guides to align the card with the electrical interface circuits, the read/write devices used in many applications targeting the general public are now more simple and cheaper to build than comparative technologies. In many cases, a separate card acceptor device (CAD) is used and it may contain a separate numeric key pad for a personal identification number (PIN) entry. This is also an important security feature since it enables tamper resistance to be built in, to reduce the risk of somebody unlawfully accessing the code or information on its way to the smart card chip. Some devices are also able to detect altered wiring on smart cards inserted, or to detect a range of other abuses of the system.

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Table 2-2 A comparison of different card technologies available at the present time. (*Source:* Gemplus)

2.2 Types of memory

Memory in smart card is made up of an array of electrical cells in the semiconductor material. Each cell has two states that correspond to the absence or presence of an electron. The two possible states can be represented by the binary numbers 0 or 1 respectively. In addition, there are two different types of smart card memory in use: *volatile* or *non-volatile.*

Volatile

Random Access Memory (RAM) is an example of volatile memory that can be quickly written to or read. However, RAM loses its memory when power is disconnected. In smart cards, RAM is used for data transfer and manipulation. Two different types of RAM are used. These are Static RAM (SRAM) and Dynamic RAM (DRAM).

Non-volatile

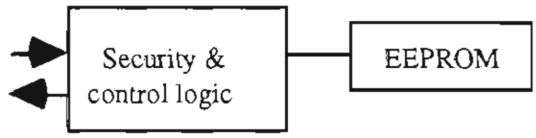
The main advantage of non-volatile memory (NVM) is that it can store memory when power is disconnected. There are three main types of NVM used in smart cards:

(i) Read Only Memory (ROM) which retains its memory for the life of the card. ROM is therefore used to store operating systems, security information such as encryption routines or fixed applications. The manufacturer *burns* the memory into the semiconductor material to give the card its basic functionality during the manufacturing process.

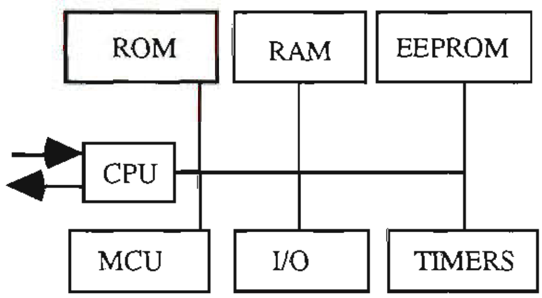
(ii) Erasable Programmable Read Only Memory (EPROM) which is similar to ROM except that it can be erased and reprogrammed. However, all the data needs to be erased.

(iii) Electronically Erasable Programmable Read Only Memory (EEPROM) which is the most versatile memory because it can be selectively erased and reprogrammed or written to.

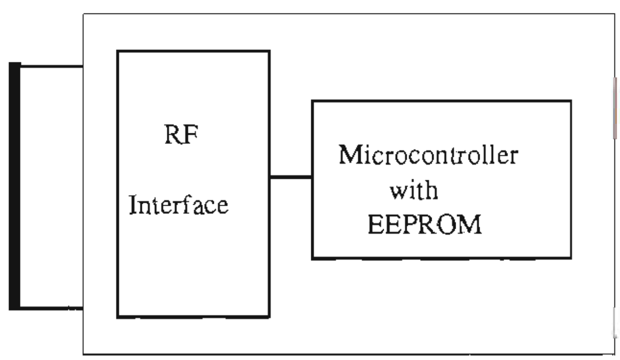
As can be seen, smart cards can be designed to perform a variety of operational and control functions by combining different forms of memory.



(a) Intelligent Memory Chip



(b) Microprocessor Chip



(c) Contactless Microprocessor Card

Figure 2-1 **The diagram shows a schematic of: (a) an intelligent chip; (b) a microprocessor card; and, (c) a contactless microprocessor card.**

There are therefore a range of smart card chip types. For example there is an intelligent memory chip consisting of a security and logic control unit with EEPROM memory to be used as a phone card or to carry portable files (Figure 2-1: a). A microprocessor control chip could typically contain a CPU combined with a combination of ROM, RAM, EEPROM, MCU or timers for applications requiring greater security or flexibility and control such as in banking or for EDI transactions (Figure 2-1: b). Contactless microprocessor chips could also combine a microprocessor controller and EEPROM with an RF interface to be used for access control or ticketing (Figure 2-1: c).

One example of how the flexibility and functionality of a smart card can be improved by using a combination of different memory types is provided in Figure 2-2. The example shows the ST6XYZ manufactured by SGS-Thomson. The ST6XYZ is a high security microcomputer based card with a user defined ROM, RAM and EEPROM memory.

2.3 Card types

Because of the large range of possible smart card memory configurations and functionality, smart cards are generally referred to by the following generic memory group names highlighting the key distinguishing feature.

2.3.1 Memory only cards

Memory only cards are simple storage devices. They may contain one or more storage circuits. This family of cards can be further subdivided into Small Memory Cards and Large Memory Cards.

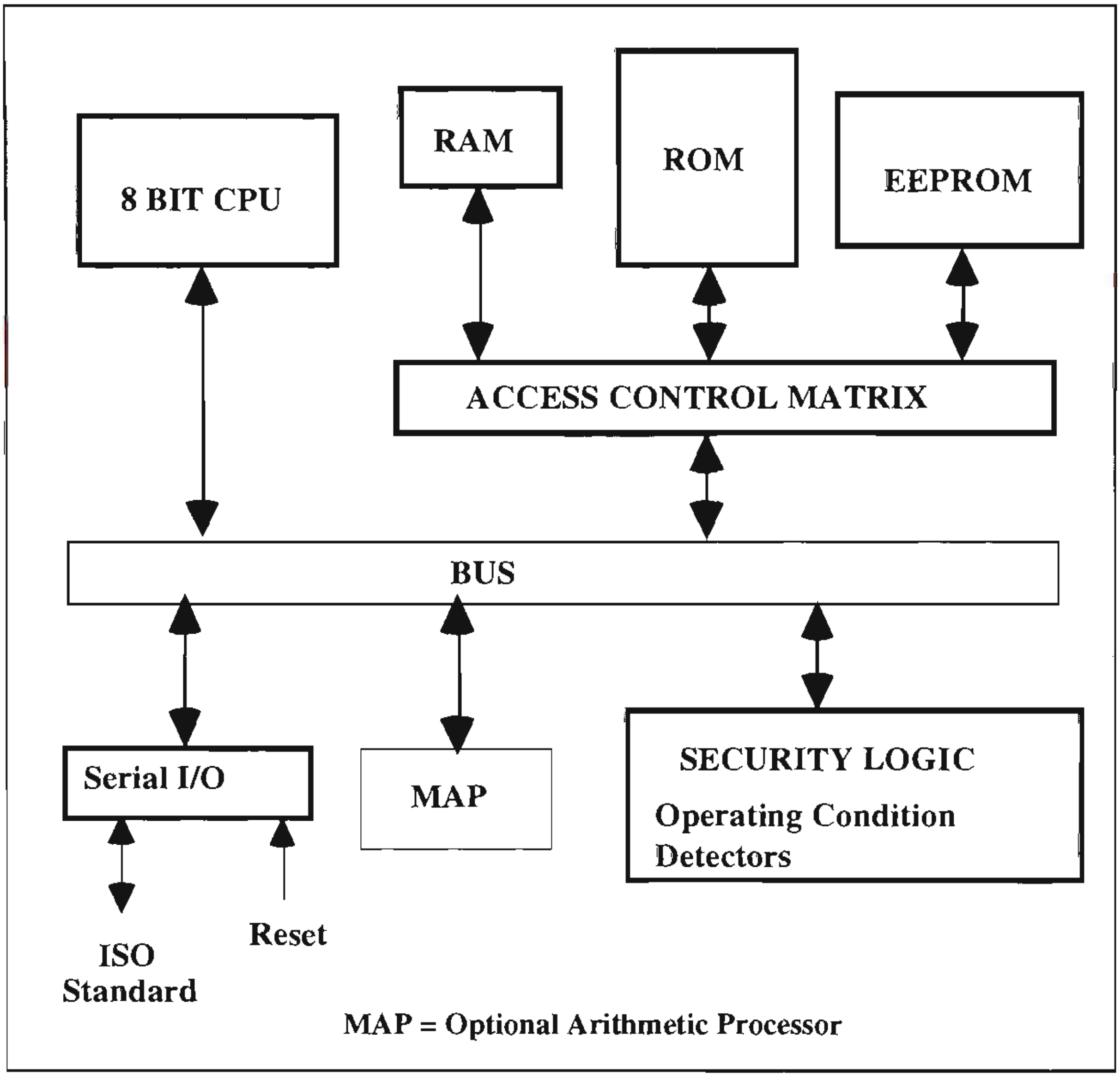


Figure 2-2 The ST6XYZ flexible microcomputer for smart card ICs manufactured by SGS-Thomson Microelectronics. The Central Processing Unit (CPU) acts as the gateway to the memory.

Small memory cards are the simplest and least expensive form of smart cards. Typically, they contain 256 bits of non erasable write-once memory on a standard plastic credit card media. Small memory cards are used as disposable prepaid token cards to replace cash. French and Spanish payphone systems and the Hong Kong Transit Authority use simple memory cards. The technology used by most of the cards now in operation around the world, are based on electronically programmable read only memory (EPROM) chip technology. This means that the cards can only be decremented and the security features are very rudimentary.

Large memory cards typically contain multiple storage units that provide 32 Kbytes to potentially 64 megabytes of storage. These cards are thicker (around 5 mm) as they usually require that their own battery operated power supply be mounted on the card. They typically communicate through 68 high speed edge contacts as defined by the PC Memory Card Industry Association (PCMCIA). Because of the enhanced technical functionality of this family of cards, many industry commentators often exclude these devices from their definition of smart cards.

2.3.2 Microprocessor smart cards

Microprocessor cards typically contain both their own operating system in mask in a separate area of ROM as well as logic and memory capabilities in the IC chip. This enables the card to process instruction sets as well a store data. This family of cards is therefore useful for applications requiring network security. At the simplest level of operation, a password or Personal Identification Number (PIN) is able to be compared with a previously stored version. At a higher operational level, a microprocessor card can process a wide range of instructions, execute predefined user routines, cipher data and control access to complex directories and file structures. With erasable electronically programmable read only memory (EEPROM) technology, these cards can also be recharged many times.

Microprocessor smart cards may therefore be considered as a personal tamper-proof, cryptographic engine capable of secure file protection, managing access code systems such as a user's PIN, and providing encryption facilities. File protection is fundamental to the security system. Directory and file access rights are usually controlled by a security block forming part of a security policy. The predetermined security policy provides the basis for a preprogrammed set of conditions that must be met before access will be permitted. For example, a particular file may only be read after a PIN code belonging exclusively to the user has been entered. A file may also be made available only to the operating system to protect encryption key information such as is deployed in mobile phone GSM subscriber identifier module (SIM) cards.

It is this range of cryptographic functions such as security access controls and file protection features, that enable the selective application of a number of International Standards Organisation (ISO) security services in smart cards. ISO security services defined involve the encryption, authentication, non-repudiation and message integrity functions to underpin the security of a range of applications - both online and offline. At present, the majority of smart cards in circulation are simple memory cards. The smart card industry by card memory type (1994-5) is shown in Figure 2-3.

2.3.3 Electronic purse or wallet cards

When a card is programmed to accommodate more than one application it is often referred to as an *electronic purse* (or *wallet*). Electronic purse cards are similar to small memory cards, except that they contain small amounts of erasable memory (approximately 400 - 1,000 bits), and an associated set of predefined security functions.

They are typically designed to enable secure recharging of stored value cards (SVC) or, to enable the re configuration of security access privileges in security related applications. However, generally, the memory is pre-allocated and the security functions are hard wired into the IC by the suppliers so that cards are not programmable, but offer a range of security features such as the ability to verify a user's PIN. Electronic purse cards are designed to replace disposable prepaid token cards in applications where larger cash transactions requiring greater security are required, or when there are economic benefits to be gained from recharging cards a number of times.

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Figure 2-3 Smart card industry by card type (1994-5)
(*Data Source:* Seidman, 1995)

2.3.4 Contactless cards

Contactless cards have been developed for applications requiring speedier transaction times or for those operating in harsher environments. Contactless smart cards have the same security and storage options of contact smart cards. However, they do not have to be inserted into a terminal. They are designed to operate with an inductive or capacitive coupling over short distances (usually less than 2 cm). There are also some methods of using radio frequency (RF) communication to allow for more remote coupling to occur over distances of up to a metre. Other remote communication devices with battery power can be designed to communicate over much longer distances using infra red (IR), radio or microwave frequencies. The card is simply placed on top of, or in close proximity to the read/write device. This reduces the chance of physically damaging the card or the terminal; and it provides for faster and more efficient transactions. This also means that the life of each card and terminal can be extended. However, the cards are expensive in comparison to contact smart cards at the present time.

Although commercial production of contactless cards has only begun in recent years, this innovation was stimulated by the results of early debit card trials that reported a high rate of technical failure. The need for improvements in time per transaction for transit applications, the ease with which contactless cards could be used, and the promise of less mechanical wear and maintenance of the system enabling more repeat uses for each card, have also helped to support the growing demand for contactless technology. Early user surveys involved in contactless SVC trials involving small cash transactions have also supported the technology. In a recent survey of users involved in the Australian SVC Transcard trials, it was found that 87 per cent of users were generally satisfied with contactless technology (Smith, 1996).

2.4 Smart card manufacture

The manufacturing of smart cards is complex and involves several steps: silicon fabrication; introducing of the operating system; assembly of the micro module; card assembly; and finally, the card is printed and the application(s) loaded. This section will consider certain aspects of the manufacturing process which have implications for smart card innovation.

2.4.1 Chip density

The complexity of a smart card chip and consequently its functionality will be constrained by two factors: the maximum allowable physical size of an ISO chip (24 sq mm); and the physical size of semiconductor technology. Current chip technology is at around 1 micron.

Given the rapid pace with which semiconductor technologies have decreased in size it is not inconceivable that 0.2 micron chip technology will be available in the near future. The smaller chips also require less power and future voltage requirements could be around 1.5 volts. Today a typical high density card such as Siemens SLE 44C80 multiapplication card has a 16 Kbyte ROM, 32 byte PROM, 8 Kbyte EEPROM and 256 byte RAM. It also incorporates DEC security features. A higher density chip with 40 Kbyte ROM, 1 Kbyte RAM and a 20 Kbyte EEPROM could feasibly be mass produced within the next four years. Processors could also change (eg. RISC devices).

2.4.2 Embedding the chip

From the card manufacturer's perspective, embedding the chip is a slow and difficult part of the manufacturing process. A cross sectional view of the chip embedding components is provided in Figure 2-4. This limits the maximum number of cards that can be produced by a manufacturer in a given time. First, the chip dies are supplied in rolls that need to be separated. Second, the chip needs to be carefully positioned, glued and soldered to the printed circuit (*stamp*). Third, the whole module is then positioned and glued to the ISO position in a pre-formed hole on the plastic card. The gluing process alone involves several steps and requires the glue to be injected in the correct locations.

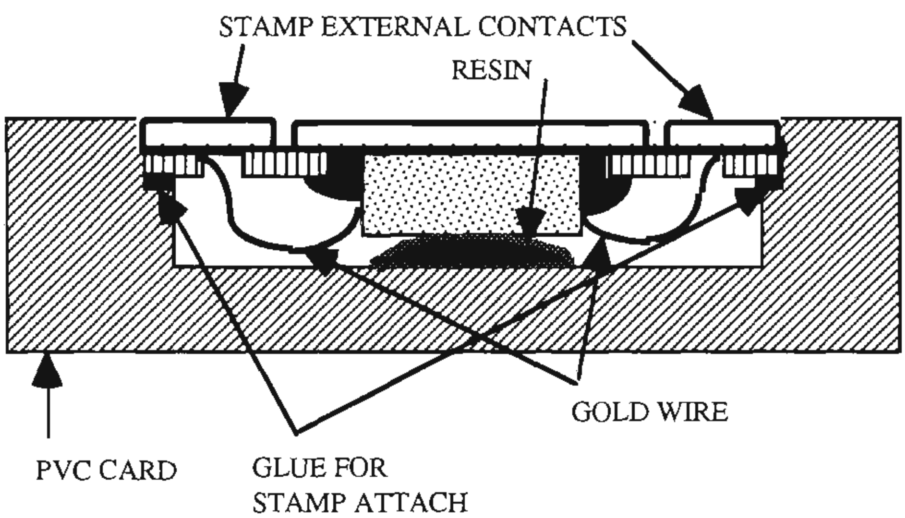

Figure 2-4 A cross sectional view of the smart card chip embedding components.

Static charge is also a problem during manufacture. Charges of up to 1000 volts that could quickly *kill* a microchip are frequently generated. Antistatic techniques must therefore be a part of the manufacturing process so that cards reaching the market are able to withstand charges generated by the human hand or the environment.

At present a lot of R&D efforts are going into improving the present chip embedding techniques and technologies. By decreasing the time factor, significant production costs can be saved.

2.4.3 Personalisation

The writing of user specific information (*personalisation*) onto the card is the final stage in the manufacturing process. The process involves two main stages: First, the outside of the card is inscribed by a thermal or laser printing process. Then the personal or card identifying information is written to the EPROM - or EEPROM - area in the IC. This stage takes place in a high secure environment and the data must be verified within the IC itself. If the data cannot be validated, then the IC denies access.

Because of the complexity and the number of steps involved in the production of a smart card, there is at present no single smart card producer that can perform all of these functions. This also means that there is considerable scope for further innovation in the production processes in the future.

2.5 Industry development trends

In this section, some key smart card industry development trends will be examined. The objective here is to identify those which have influenced smart card development to now.

2.5.1 Slow rate of diffusion for the period 1974 to 1991

The first thing to be noted about smart card technology development since Roland Moreno introduced the world to the first prototype of his *Electronic Bank Manager* in 1974 is, that like many other new technologies, smart card has undergone a number of changes and has had to be diffused over an extended time. In this case it has been more than twenty years before the technology is considered to have matured enough to be able to relace older technologies such as magnetic stripe cards and to be accepted as a new technology offering a range of new services that have not been possible in the past.

Although world smart card sales, have been rising rapidly since 1992, a parallel and more perplexing industry development observation is that the majority of known smart card trials initiated in the period 1991 to 1994 have failed to continue past the trial stage. As it has become more evident that many new smart card trials were failing to proceed to the implementation stage, industry analysts have begun to question the role that non technical factors might be playing in the smart card innovation process. A key question arising from these observations is, "Was the failure of many previous smart card trials due to the technology driven design approaches adopted?" The importance of the role of the user as a critical success factor has only emerged recently as an important issue and this issue will be addressed in the following chapters.

Another observation, and related to the previous point, is that the vast majority of the 580 million smart cards in circulation in 1995 are *low tech*. That is, most of the cards in use involve single applications, require a low level of security and are owned and operated by a single managing organisation. The vast majority of chips used in smart card at the present time are based on 8-bit micro controller architecture such as Intel's 8051, Motorola's 68HC05 or Hitachi's H8. All of these were designed around 15 years ago.

Another important industry development trend, is that although smart card was invented in 1974 and mass production commenced over a decade ago, the rate of uptake of the technology has not been rapid until the early 1990s. Figure 2-5 provides an indication of the estimated world sales for the period since mass production began in 1986 through to 1995.

The present rapid growth rate is also likely to be further enhanced by the proposed introduction of several major international smart card projects. Table 2-3 provides a list that includes projects such as Mondex, Visa and Mastercard that have all recently announced their intentions to introduce global smart card systems. These projects potentially involve millions of users and span many countries. Because of the number and potential scale of such projects, it is estimated by Remy de Tonnac, the Managing Director of Gemplus Technologies Asia, that the size of the global market will continue to escalate to more than 2 billion by the year 2000 (Tonnac, 1995).

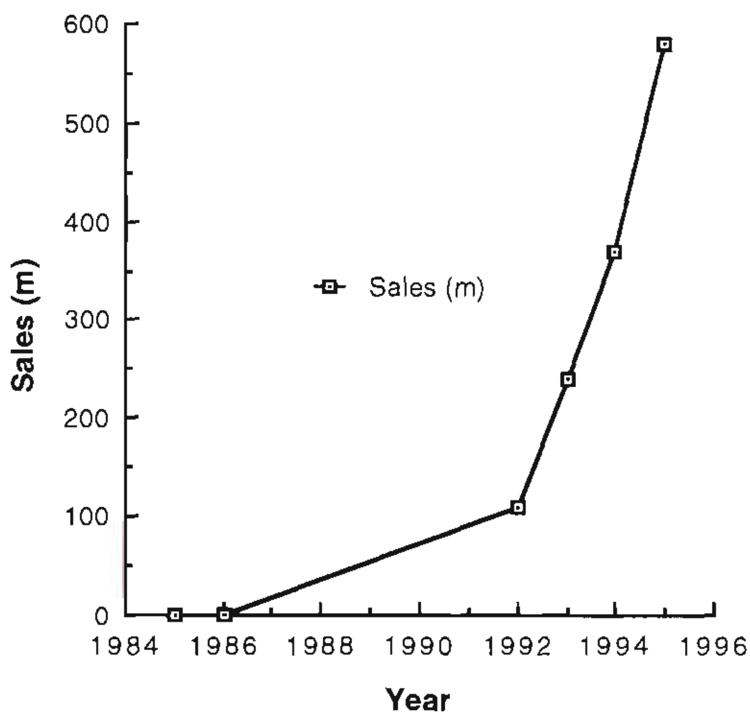

Figure 2-5 Growth in world smart card sales 1986 to 1995.
(*Data source:* Gemplus)

Avant	Finland	Launched in 1994
Banksys	Belgium	Trial since 1994
Danmont	Denmark	Launched since 1993
EPS-MAC	USA	Trial in 1995
Mastercard	Global	Intention announced
Mondex	UK	Trial in 1995
NETS	Singapore	Trial since 1994
Quicklink	Australia	Trial in 1995
S.A. Interbank E.P.	South Africa	Trial since 1994
SIBS	Portugal	Launched in 1995
Transcard	Australia	Trial in 1995
VISA	Global	Trial in 1996

Table 2-3 **List of some of the world's first large scale SVC, or true electronic purse projects emerging (1996).**

2.5.2 Development has relied on advances on other industries

A second significant observation is that like many new technologies, some important changes introduced along the way, have relied upon advances in other industries. In this case, smart card development has combined the historical advances and expertise of two leading information industries: These are the computer industry and the telecommunications industry. Figure 2-6 shows the historical sequence of the more important industry advances that have helped to shape the development of the smart card industry. It has also relied on the further development of the card printing industry, and the read/write device hardware industry. This observation is in agreement with a quantitative study of the development of television by Arnold (1985). Arnold showed that inevitably, the interdependence between technical innovations (ie. convergence of technologies in the sense used here) in the internal component parts and the increasing complexity and functionality of the external design produced for the user.

If you combine the advances of these industries with recent progress made by the telecommunications industry in areas such as intelligent networks and broadband communications services, then you now have a technology that has evolved into a small piece of plastic that has the potential to bring dramatic changes to the way we live and work. However, the most important technological advances influencing smart card innovation, have occurred in the microchip industry. During the time of smart cards' incubation, the microchip industry has advanced to a stage where miniaturisation, and cost reductions have meant that the smart card chip *engine* can now be manufactured with greater memory capacity for less cost. The first reports of projects being able to achieve cost savings were highlighted before the 1990s (Takac, 1990). Smart cards also now

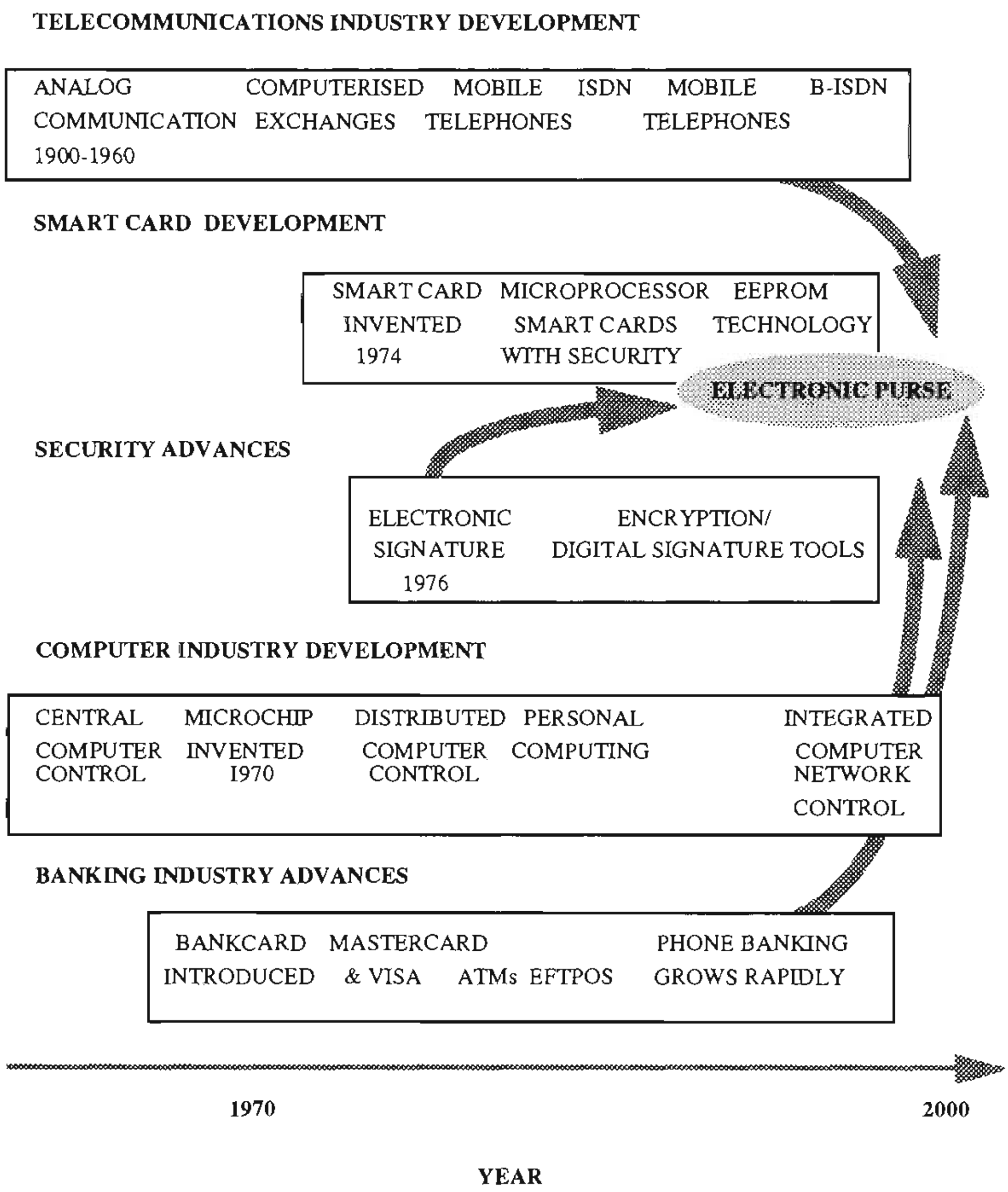

Figure 2-6 **A schematic diagram showing the historical sequence of the more important industry advances that have helped to shape the development of smart card technology.**

require less power for operational use and control. They can also be manufactured to meet a wide range of functional requirements.

Advances in the computer security industry mean that it is now possible to incorporate an arsenal of security features into smart card chips such as disabling technologies to prevent fraudulent use and the latest cryptographic tools to provide greater security.

2.5.3 Recent rapid globalisation of the technology

A third key industry development trend is the rapid globalisation that has also occurred in recent years. Figure 2-7 shows the present distribution of smart card sales for each major geographic region. The figures are for 1993 and 1994. The globalisation of the industry in recent years, has resulted in rapid increases in relative market share for Asia (increasing from 8 percent to 25 per cent); and North America (increasing from 2 per cent to 15 per cent). Both of these regions can be considered to be relatively late adaptors of the technology. Although the market share for Western Europe has declined from 70 percent to 40 percent, the market growth in absolute terms has increased because of the rapid uptake of the technology during this period.

2.5.4 Competitive nature of the industry

Because of the high level of recent and forecast market activity, the global smart card industry has rapidly become very competitive as evidenced by both the scale and number of firms involved in the industry. Another indication, is the high level of R&D expenditure now being spent on smart card development. At present, companies like ERG of Australia which specialises in public transit cards, are spending around 24-25 per cent of their total revenue on further R&D. Suppliers too, are now investing considerable R&D funds to initiate the implementation of large-scale commercial systems. This mobilisation of resources has now embraced the manufacturers of semiconductors, the readers and terminal manufacturers, the card manufacturers, the software designers and the key industry sectors who plan to introduce smart card systems to their customers. In fact, smart card technology may soon be used by much of the banking industry to replace magnetic stripe technology and it may be necessary for international exchange. Moreover, it should soon become possible to use smart card technology anywhere in the world to make purchases or access telecommunications services.

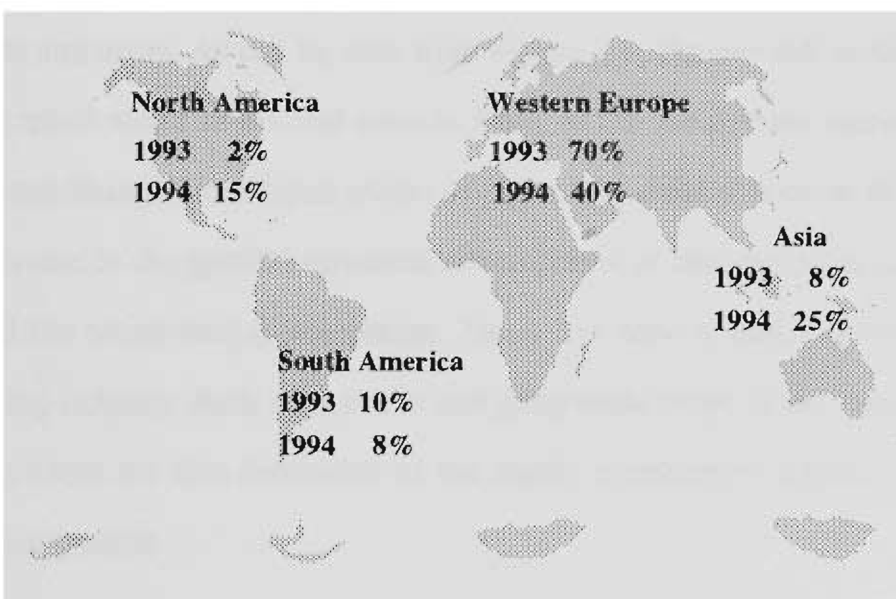

Figure 2-7 Smart card use by geographic region in 1993 and 1994.
(Data Source: Gemplus)

Another important observation, and one that is also indicative of the highly competitive nature of the industry is that in 1995, no supplier had the capacity to produce all the necessary manufactured parts. The smart card industry is resource intensive by its nature. However, this observation might also reflect the cross-industry experience and technology that smart card innovation has so far relied upon for its development.

2.5.5 Clustering

A parallel observation is that internationally, there still exists a strong correlation between the incidence of local suppliers and smart card application users in the industry. For the period before the late 1980s, Europe accounted for the largest number of suppliers and users. As can be seen from Figure 2-7, Europe still accounted for around 70 per cent of world smart card sales in 1993. At the level of the individual nation, it is still France (Europe) and Japan (Asia) that show the greatest number of both. This could be partly due to the parallel historical development of the microchip industry - the raw material for smart card development. Japan has been a leader in the microchip and computing industry. Both the number and geographic range of the major semiconductor manufacturers are also indicative of the highly competitive nature of the smart card industry at present.

However, one region with a high incidence of firms with the technology to manufacture chips cards is the USA. At present, this appears to be a market anomaly. The anomaly can be partly explained by the Federal Government's inconsistent approach to industry policy and regulation in recent years. These inconsistencies have had an impact on local smart card development and they have been cited as one of the key reasons for the establishment of the United States Smart Card Forum in 1994. The Smart

Card Forum consists of members of the US smart card industry. The key objectives are to ensure that US based firms are positioned to address new market opportunities.

By 1995, virtually all of Europe's leading manufacturers of smart cards had established a US presence in anticipation of US market growth. At this time, some US manufacturers commenced joint ventures with the more experienced European card makers as a way of limiting exposure while positioning themselves to meet the anticipated demand. For example, the French conglomerate Schlumberger has recently moved to acquire Malco Incorporated, the large card manufacturer based in Owings Mills, Maryland, US. Malco was developing a smart card strategy before the acquisition. Now that it has received a boost from Schlumberger, it could gain a competitive advantage over other domestic card producers.

Because of the importance of the microchip industry to smart card developers, it is also worth noting the present geographic location of the main semiconductor manufacturers currently known to be manufacturing card chips. These are shown in Table 2-4. As can be seen, the large number of Japanese firms would help to partially explain the reason for the recent rapid increase in applications in Japan.

2.5.6 Technological convergence

Another observation is that, like many other information technologies, several lines of technological convergence have appeared as the product has developed. There has been a convergence in card type. Most applications now involve the ISO standard smart card. Although the French originally used cards with the microchip located in the top right hand section of a card *(Amphor* position), most of their applications are now being developed using ISO standards. Most GSM smart cards are also now based on ISO standards. Second, several countries have now adopted similar smart card objectives for project development. For example, the objectives of many healthcare projects involving smart card have the primary objective of generating cost savings and are to be nationally focused. The projects have also developed similar attitudes to patient privacy with many OECD nations giving strong support to the development of international privacy guidelines for legislative implementation at a national level.

SEMICONDUCTOR MANUFACTURERS	LOCATION OF HEAD OFFICE
Amtel	USA
Catalyst	USA
Hitachi	Japan
Motorola	Scotland
NEC	Japan
Oki	Japan
Philips	Netherlands
Samsung	Korea
Siemens	Germany
SGS - Thomson	France
Texas Instruments	USA
Toshiba	Japan

Table 2-4 A list of the world's major semiconductor firms capable of supplying card chips (1995).

Technological convergence has also resulted in a gradual change in the traditional role of the smart card manufacturer as the smart card industry has developed. This convergence is shown in Figure 2-8. This has resulted in a reduction in the role and responsibility in the smart card manufacturing *value chain* (Porter, 1990). That is, the local card providers now play a greater role in the manufacturing processes traditionally performed by the major chip manufacturers as the market has developed and become more customer driven.

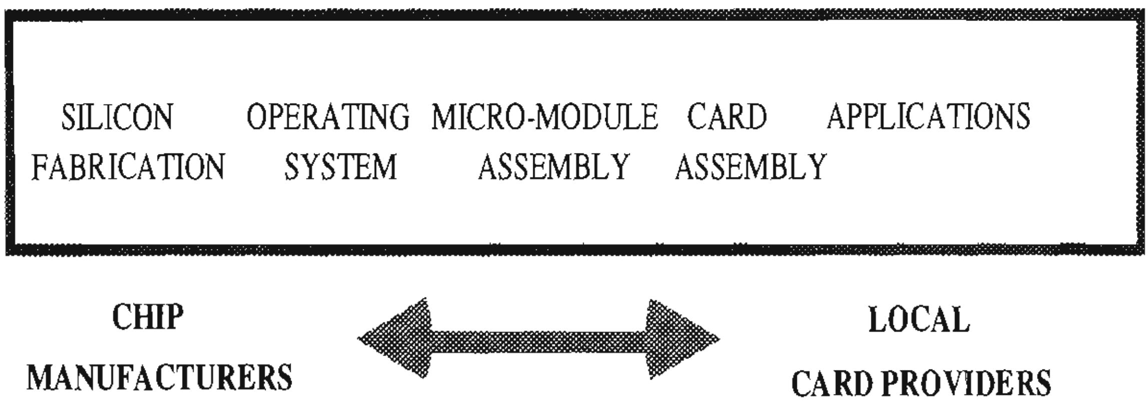

Figure 2-8 Diagram showing the gradual changes in the traditional role of the manufacturer as the smart card industry has developed. This has resulted in a reduction in the role and responsibility in the smart card manufacturing value chain.

2.5.7 Underdevelopment of the smart card industry

A more general observation is that the smart card industry itself could be considered as still fairly underdeveloped. Most applications currently in use are operated under the umbrella of a single managing organisation. A further indication is the observation that industry itself recognises the difficulties of managing shared information in the open systems environment. The present degree of cooperation is not nearly sufficient to facilitate the development of the shared infostructures and infrastructures that will be required for the successful creation of complex networks, capable of interfacing with a wide range of card technologies. Yet, many such projects are being planned by individual organisations.

2.5.8 *Declining cost of the technology*

Although it is outside the scope of this thesis to review the commercial aspects, it is worth giving an indication of the comparative costs of some of the cards. Table 2-5 provides a rough guide based on 1995 pricing. Prices can vary depending on the volume and other factors. As can be seen, the costs of smart card technology have reached a fairly low level in comparison to competing technologies. The pricing of equipment has also reflected the competitive nature of the industry during this present phase of rapid market expansion.

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Table 2-5 Comparative cost of alternate technologies *circa* 1995.
(*Data Source:* AEG Australia)

Currently the typical microprocessor smart card costs around $4.00 depending on the volumes, capability and functionality of the card. Quite often the cost of the card for small volume applications will be small in comparison to the overall cost of the project. For example, the banking industry might prefer a multiple security application card that requires large memory with a coding algorithm. In this case the cost of the card itself will be higher, but this may be of less significance as the technology offers a service that is not available from alternate technologies. The microprocessor card could provide a higher level of security, a greater degree of freedom of movement and provide information access audit trails for bank employees.

However, when volumes are high - say 100,000 units or more - then the cost of the individual cards will be critical. In the case of a transit authority with several hundred thousand passengers each day, a simple chip card with minimum memory and low replacement cost would be required as an incentive for passengers to change to the new technology and to bring gains in efficiency. While cost may influence the choice of the technology in this instance, costs are now considered to be low enough that it is not a major factor inhibiting smart card acceptance.

2.5.9 The smart card regulation-innovation quandary

Government has tried to be a catalyst for local smart card industry development in many countries. Yet, no two countries have adopted a similar or comparable strategy. The result has been a range of unique experiences - each with its own set of messages for future smart card development. Another unintended consequence of this outcome has been that standardisation has been slow and leading to intense rivalry on product and feature improvements at a national level.

The Governments too have been a major inhibitor. In many cases where governments have been actively involved, a decision has been made to adopt simpler technology. For example, in the case of the NSW SVC project called Quicklink which was initiated by the NSW State Government in Australia, the chosen technology has been a simple IC contact card. This system, will have the support of a large number of government agencies yet it will have to compete with a privately owned SVC project called Transcard. In comparison, Transcard has decided to choose a technologically more advanced contactless card using Ferro-electric RAM (FRAM) technology. The FRAM chip enables smart cards to retain information without a battery. They are therefore placed in contacless smart cards that use radio waves to respond to signals from remote card readers.

Government decisions have also tended to favour older technology so as to avoid a possible backlash regarding social concerns for security and privacy. In addition, Governments have aimed to limit the cost of the technology itself, as well as the costs associated with the management and maintenance of the infrastructural resources required to administer the whole system. However, such choices have done little to provide local market incentives to develop the more advanced technologies involving high security and memory requirements. This is despite the fact that a cluster of new technological developments now seems imminent.

2.6 Active security functions

One of the most important issues in smart card innovation, and also in all fields of data communication, is the security of the data exchanges (Zoreda and Oton, 1994). The aim of this section is to combine discussion of smart card security features with possibilities for implementations of cryptographic signature functions to highlight some critical issues influencing smart card innovation.

2.6.1 The role of security functions

For electronic information technologies, security encompasses the broad set of technical and administrative procedures designed to protect informational systems against unwanted disclosure, modification, destruction, and to safeguard the system.

Smart card data security covers four main functions:

(i) authentication;

(ii) integrity;

(iii) non-repudiation; and,

(iv) data secrecy.

To guarantee to the recipient that the message really has originated from where it claims to have done, smart card can incorporate an authentication procedure. For some applications message integrity is important to guarantee that the message sent is identical to the message received. To guarantee to the recipient of a message that the sender cannot later deny having sent it, a non-repudiation procedure would be added. For data security, the messages could also be encrypted, or converted to an unintelligible language using a cipher for transmission.

These security features are also what distinguish smart card chips from standard micro controllers and are essential for the security functions performed by smart card operating systems. Using its ability to incorporate any, or all of these functions, smart card data security features can include the ability to protect information stored within the smart card IC chip as well as the capacity to be securely used at stand-alone or online terminals. The potential to add bio identifiers such as photographs, retinal scans, signatures and fingerprints offer additional methods to validate the user's identity.

Furthermore, smart cards can be programmed to become ineffective when there are attempts at illegal access, unauthorised usage, or physical tampering.

2.6.2 Digital signatures

By combining recent technical advances in the microchip industry with breakthroughs in the security industry, it is now possible to ensure that smart card provides all, or some of the security functions specified above by incorporating various digital signature methods initially pioneered in the late 1970s (Guillou *et al* 1992). In fact, the term *Digital Signature* (sometimes referred to as *Electronic Signature*) is used by the security industry to imply a number of the above security related functions for the purposes of electronically signing documents. A Digital Signature has been defined by the ISO as,

> *Data appended to, or a cryptographic transformation of, a data unit that allows the recipient of the data to prove the source and integrity of the data unit. It protects against forgery, even by the recipient.* (ISO 7498-2)

So that it can legally emulate the paper signature, a digital signature system will require that it:

(i) can only be created by the owner;

(ii) can be readily verified by anyone and at any time; and,

(iii) cannot be duplicated on other documents (*viz.* that it should rely on the contents of the document).

It is important to emphasise that the digital signature is not the electronic equivalent of a hand-written signature. Although a digitised image of a hand-written signature can be easily stored and used, the range of possible digital signature functions that can be incorporated into electronic information systems, mean that smart card chip technology is able to provide far more security than is currently possible for their paper-based equivalents. Digital signature functions may therefore be used in smart card technology as a means to perform two of the above important security functions. They can be used for authenticating the claimed identity or, as a means of ensuring the integrity of electronic information sent.

The signature may be incorporated into smart card to verify that the identified individual really was there when the signature was created. The digital signature links the electronic signatory to the document or message that is signed. The recipient of the message or document is then able to securely verify this. In this way, users may be authenticated, the mutual authentication of communicating partners or authentication of the origin of a message or document may be verified. In more secure smart card systems, the authentication problem not only relates to the communicating individuals, but to organisations, machines and some of the processes occurring may also need to be identified and authenticated.

In addition to authenticating the identity of the sender or that the origin of an electronic message really is as claimed, digital signature functions may be used to check the data integrity of the message. In other words, the digital signature can be incorporated into smart card to guarantee that the electronic message content received is identical to when the attached signature was created. Thus, any attempt to alter the contents after the digital signature has been attached can be detected. Smart card technology also offers the potential to incorporate several other related digital signature functions. These might include a non-repudiation function so that the origin of a message or actual receipt of information cannot be denied. In addition, it is possible to add time-stamping and the ability to exchange encryption keys for confidentiality.

Thus, it is now possible to incorporate various digital signature methods to produce a high level of security in smart card systems. The development of smart card as a device offering secure transactions or exchange of information has relied upon advances in data security that began with the world's first digital signature conceived by Whitfield Diffie in 1976. Using these methods, there now exist techniques based on more recent cryptographic advances that can provide the user with not only a high level of security, but also unconditional anonymity. In fact, secure digital signatures are now becoming widely used in smart card technology and typically rely on cryptographic techniques. These will be briefly described in the next section.

2.6.3 Cryptographic functions for smart cards

Cryptographic tools can be used to enable the electronic document to satisfy all three of the requirements specified in the previous section. In practice, a digital signature can be created to satisfy all the above security requirements by first passing the contents of a document through a hashing algorithm that is designed to reduce the document to a short data block. Because the result depends on the contents of the document, this step satisfies the need to ensure that the document cannot be duplicated. Typically the data block can be around 128 bits long. The data block is then encrypted using the signing encryption key and the result is added to the original electronic form of the document as a digital signature. If the signing key used is known only to the owner, then this means that the document could have only been created by the owner. Finally, if the verification key for the signature can be widely known, then the document can be verified by anyone at any time.

The creation of secure digital signatures typically relies on cryptographic techniques such as the Data Encryption Standard (DES) or the Rivest-Shamir-Adleman (RSA) standard. There are two families of cryptographic functions that can be used in smart card systems. One uses symmetric keys (code = decode) and the other using asymmetric keys (encode = public; decode = secret). The most frequently used are the DES and RSA systems respectively.

DES systems require short secret keys (say 64 bit), they are easy to implement and reasonably quick to calculate by software residing on the smart card microprocessor unit (typically around 10-20 ms to process a 64 bit DES).

In comparison, the RSA, like most public key systems and zero knowledge proofs, uses large keys typically 512 to 1024 bit in an exponentiation based operation to achieve a high level of security. If they are software processed, they take 10-15 sec to process RSA for 256 bit keys. So there is a strong need for a solution that can speed up the process such as the development of the Modular Arithmetic Processor (MAP) by SGS-Thomson. Public key cryptography is relatively - but not totally - secure. In 1994 Arjen Lenstra was able to crack a RSA encrypted message. However, his efforts required over 1600 PCs and the best part of a year to do. Thus a new range of smart cards capable of providing public key encryption capabilities and providing the user with unconditional anonymity are emerging.

As an example, an asymmetric algorithm such as RSA that has both a signing key and a verification key can be used to generate a digital signature. Although the signing key and the verification remain related mathematically, it is generally agreed that it is computationally infeasible to deduce one from the other. In this case, the verification key can be widely published or known without the risk of compromising the signing key. The problem then becomes one of ensuring that the signing key is issued securely. A smart card microprocessor chip provides an ideal medium to safely store the signing key once it is issued. The signing key can be located in a separate file protected by the user's PIN. It is also relatively simple to pre-program the card so that the signing key never leaves the card by passing the hash result into the card to be encrypted, rather than by exposing the signing key in a less secure environment for the encryption step to take place. In this way, a highly secure and easy to use digital signature can be created.

Recently, some more advanced and faster security tools that are based on exponentiation and offering confidentiality, authenticity and integrity have been developed (Beth, 1994: 1-17). Applications of these have been the Electronic Exponential Signature (EES) scheme used for the purposes of offering unconditional anonymity and confidentiality, data integrity, authentication as well as audit control. Such security tools are now being developed for smart card applications and now represent the more advanced security systems that are available.

Nevertheless, one main problem remains. How do you accurately ensure that the person using the card is actually who they say they are: The use of PIN codes is not completely reliable. Although there have been a number of important breakthroughs in the use of bio identifiers in recent years, there are none at present that are quick, cost effective and accurate. A quick easy personal identity check is required for users of smart card. There is also the problem of designing and structuring information security awareness programs for staff within an organisation. The major problems that organisations have experienced in this regard are the problems associated with achieving major changes in security attitudes and behaviour within the organisation itself (McLean 1992).

It is therefore reasonable to assume that smart card technology armed with the latest advances in cryptography can provide a very secure medium for data transfers in practice. It also now has the potential to offer the user unconditional anonymity as well as a high level of security. However, current regulatory restrictions on the use of cryptographic tools mean that this is not likely to become a widespread feature of smart card technology in the short term. A major area of concern regarding the processing of personal information using public key encryption is the prospect of ready access to private information by outside sources such as federal government departments. This could be done through existing regulatory arrangements. However, because of the uncertain regulatory and legal requirements of the digital signature, and because of the high costs associated with the implementation of high level security functions, most smart card projects to date have relied on low level security measures. Thus, the application of electronic signature techniques in smart card applications requires a degree of awareness about its potential and limitations. This point is to be elaborated on in the next section.

2.6.4 Regulations and constraints on the use of cryptographic methods

Legislation explicitly requiring the recognition and use of digital signature procedures is already in use in a number of countries and spanning several industry sectors. In many countries in Europe, for example, legislation explicitly requires the use of a digital signature on some healthcare documents used with smart card systems. In this case, the professional medical societies exert considerable authority and influence over determining what is acceptable procedure in the use of certain medical information, and they often have important opinions on the associated use of digital signatures. In some cases these are manifested in legislation or in formal codes of conduct.

There are also digital signature requirements dictated by the financial industry, or determined by the business needs of some sectors. For example, there may be a need for sufficient information to be retained in case of a contractual dispute. However, the form of the digital signature to be used is often not defined.

These factors now influencing smart card innovation, also have historical roots. Originally, cryptographic techniques were used mainly for national security purposes. As a consequence, cryptographic algorithms and associated devices have remained under the control of national security agencies. Yet, cryptographic developments in the academic arena since the mid 1970s, in parallel with the improved performance of computer hardware, have meant that it is now difficult to prevent the use of encryption technology. At the same time, new technologies like smart card are increasing the demand for such techniques. In many smart card applications, the use of effective and high level security measures is a pre-requisite for its use.

Thus for historical reasons, there now exist a wide range of national and international controls on information technologies relying on the use of encryption (Spri, 1994: 44-45). In the US at present, all software containing encryption software is controlled for export from the US either under the authority of the Export Administration Act or the Arms Export Control Act. A small number of applications such as those used for banking applications are controlled by the Export Administration Act (EAA). With the exception of only a few weaker security products, the National Security Agency (NSA) approves file encryption only to a limited number of agencies. The result is that in the US, many smart card systems developers cannot buy American product containing file encryption. This means that they are also likely to have problems developing - or acquiring - products for authentication or digital signatures. Products containing the RSA algorithm for digital signatures cannot be exported. At present, the recently formed Smart Card Forum in the United States, is lobbying on behalf of the US smart card industry to change these tight restrictions. It is argued that the present regulations relating to the development, sale and use of cryptographic tools are severely restricting the development and use of more advanced smart card applications, and hence indirectly having an adverse impact on the development of this relatively new industry.

In Germany, France and the Netherlands, the government also retains a strong control over software containing encryption. In comparison, Britain does not control encryption software as a military item. Thus, technologies using encryption software can be exported as general software.

In the future, national government regulations relating to software using encryption are likely to significantly influence smart card innovation. They are also likely to have ramifications for other new information technologies that have a need for secure data transfers such as mobile telephones, electronic banking technologies, or computer equipment.

2.6.5 Can smart cards be duplicated?

One other main reason for the interest in the security features of smart card technology is that they can replace magnetic stripe technology and hence reduce the threat of fraud because of the difficulty of duplicating the technology.

There have been numerous documented reports of magnetic stripe card fraud highlighting the exposure risks faced by the credit card industry. Credit card fraud totalled $38(US) million at Barcelona at the 1992 Olympic games. The Hong Kong Police have estimated that worldwide credit card fraud was now costing around $1.9(US) billion each year (Gosman, 1995).

Magnetic stripe card technology can be easily copied and read. All that is then needed to attack ATM and EFTPOS accounts is the cardholder's PIN. One recent incident exposing the resulting risk involved a hacker who allegedly stole more than 1000 credit card numbers from AUSNet, an Australian Internet service provider. The hacker sent journalists details of how it was done in an attempt to alert the public about the security risks associated with electronic trade over the Internet using credit cards (Higgins 1995). The hacker, who went by the name of *Optic Surfer*, left a trail of credit card details involving Bankcard, Mastercard and Visa card users. Investigations by the Australian Federal Police have since found that an employee of AUSNet had inadvertently left a file containing confidential information in an unsecure computer disk area. However, in this case, it is not the magnetic stripe card technology that has failed to prevent the incident. It is the lack of adequate security provided by the caretaker of the information. This incident highlights the need to rethink security practices - reinforced by privacy legislation that places responsibility on all individuals who are responsible for the security of private information. It is also of concern that in 1996, it is an offence to carry counterfeit money. Yet it is not a legal offence to carry a counterfeit credit card in countries like Australia. This further highlights the unpreparedness of the regulators for new information technologies like smart card.

In comparison to alternate technologies, smart card can provide highly secure features that are extremely difficult and expensive to reverse engineer and then duplicate. The chances of this occurring for multi processor cards using multiple chips and involving internal transistors making up the chip measuring only in a thousandth of a millimetre are greatly reduced.

The best evidence supporting the ability of smart card technology to reduce fraud is provided by the French bank industry. Data showing the relationship between the decreasing level of fraud and the corresponding increase in the rate of uptake of smart card as a replacement for magnetic stripe technology, supports the view that the level of exposure risk by banks can be reduced. Data for the period 1988 to 1993 showing this trend is provided in Figure 2-9. The level of fraud indicated includes the number of cards stolen or counterfeited. The 1988 figures include only 10 per cent of microprocessor cards with the remainder being simple memory only cards. However, by 1993, all the cards were microprocessor cards.

2.6.6 Computer virus spread

While electronic computer crime continues to escalate, the threat to the more advanced smart card applications needs to be continually assessed. In the UK for example, a UK Audit Commission Report found that not only was the threat of electronic crime increasing rapidly, but that there were inadequate safeguards to protect government computer networks and databases. It also showed that the fastest growing threat was from virus attacks (Davies, 1994: 15). The figures are shown in Figure 2-10.

A general lack of security safeguards to protect computer systems against virus attacks is also evident in other countries such as Australia (Hilvert 1995a; 1995b). In a report tabled in the Australian Federal Parliament in November 1995, it was claimed that an audit by the Federal Privacy Commissioner of 152 government agencies found that there were gross security inadequacies (Hilvert, 1995b).

What is of most concern, is that while many incidents and reports reflect the vulnerability of government agencies to virus attacks, governments are also planning to introduce large scale smart card applications potentially linking each card to several government agencies. This situation presents some real challenges and the outcomes in the years ahead are likely to have a considerable impact on smart card innovation patterns as large scale multiapplication systems develop.

Please see print copy for image

Figure 2-9 **Graph showing the relationship between the increase in smart card use and the level of bank card fraud in France for the period 1988 to 1993.** (*Data Source:* G.I.E. Carte Bancaire, cited in Tonnac, 1995.)

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Figure 2-10 Graph showing the comparative rate of electronic crime incidents reported by Government Departments in the UK for 1990 and 1993. (*Data Source:* J. Davies, 1994: 15)

At present most smart card applications involve the use of single applications and data which is not critical or sensitive for the user. In other words, most smart cards are at present operating in a *closed systems environment* and are relatively free from the risk of electronic crime. However as more advanced applications are developed, the characteristics of the operating environment will change.

Many future smart card applications will have large numbers of users and involve the use of multiple applications. Sensitive data, and the use of multiple protocols and architectures might also be factors. In other words, as the smart card systems become more complex and develop to rely on more advanced technologies, the systems will gain more of the features of an *open systems* environment. The features characterising the migration from a smart card system operating in an essentially closed operating environment, to an open systems environment are shown in Figure 2-11.

As a smart card system develops to adopt more of the defining characteristics of an open systems environment then the risks of electronic crime are likely to escalate. The exposure to virus attacks and other electronic fraud risks are multiplied as a result of both the increase in the number of users, and the potential for more electronic communication links between otherwise independent networks. This enhanced vulnerability of multiapplication smart card systems operating in an open systems environment is depicted in Figure 2-12.

Although both the number and type of viruses known to have been created has been increasing at an exponential rate, the rise in actual incidents of virus attacks has risen at a more constant rate. Most of this increase has been attributed to highly localised software

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Figure 2-11 **The defining characteristics of a closed and open operating environment for smart card systems.**
(Lindley 1994a)

sharing. However, what is not yet known is the threat resulting from the increased opportunity arising from a larger number of users accessing the networks with smart card devices. It also seems to highlight the importance of developing a mutually supportive combination of security theory and observation of actual incidents, hand-in-hand with the development of a more open smart card system. Nevertheless, the present situation does indicate that the threats are real and the associated risks are growing as more communications technologies continue to share the interconnected global network.

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Figure 2-12 A schematic diagram showing the increased exposure of a multiapplication smart card system operating in an *open* systems environment. (Lindley 1994a)

2.7 What role do standards play?

For many new technologies, standardisation has advanced hand-in-hand. However, in the domain of smart card technology, this has not been the case. To date, standards have been largely created by manufacturers as the applications being developed have dictated. Multi industry standards do not exist yet. Although preliminary standards development work has commenced on the basics, the future standards in global smart card markets hangs in the balance. The aim of this section is to investigate these developments and to establish if they have played a role in directing and shaping smart card technology.

2.7.1 The development of ISO smart card standards

Internationally, there have emerged three key organisations in the domain of smart card standards. These are the *International Standards Organisation* (ISO), the *Comite Europeen de Normalisation* (CEN) and the *European Telecommunications Standards Institute* (ETSI). However, it is the ISO set of standards that has gained the widest acceptance to the present time. Work by the ISO involves multiple contributions from national standards organisations, manufacturers' associations (eg. The European Community Manufacturers' Association - ECMA), user groups and other industry associations such as the Unites States Smart Card Forum. At present many smart card vendors offer smart card systems conforming to ISO standards, and their own propriety standards. There is also a push for the development of ISO standards so that applications can be interfaced.

The card characteristics defined address issues such as temperature characteristics, required flexibility, and other quality requirements. The position of the IC on the smart card defined in the ISO standard is different from that of the original position designed by the French Banks (Amphor position). The standardisation of the position of the IC chip on the card occurred in the late 1980s. The ISO standard position was selected so that the smart card can also incorporate a magnetic stripe. By adding magnetic stripe technology to a smart card with a chip located in the Amphor position, there is a very real possibility that the card will run through a magnetic card swipe with the IC chip facing down. This has the potential to cause damage to both the magnetic card reader and the IC chip on the card. The more central ISO Position for the IC chip eliminates any possibility of this occurring.

The low level protocol is also defined in the ISO smart card standards. This is to ensure that a card supplied by any manufacturer will be capable of performing the read/write functions as defined. However the higher level operating system, and how these relate to the lower level functions, is not defined by the standards. The individual manufacturers each produce their own propriety higher level operating system designed to interface between the application(s) to be run and the ISO interface protocols. However, in nearly all cases, ISO standards have precedence of interpretation over other functionality requirements. Table 2-6 provides a summary of ISO standards developed. The next steps in ISO standards development will involve:

1. Complete chip card and terminal specification
2. Specific application standards (SVC, multipurpose cards)
3. Global infrastructure for interoperability (online payment service network)
4. Multi industry IC card specification

With regard to these developments, two main possible outcomes can be identified: The first represents the OSI framework being developed and used as a minimal standards framework, in which these standards will fail to be able to achieve major worldwide acceptance and provide a platform to achieve universal smart card standards. The second represents a scenario where ISO standards develop into a full architecture specifying card, network, security and software functionality. Both scenarios reflect differences in the way the roles of standards are perceived as being demanded by the potential users and industry.

ISO 7816-1	Card dimensions are specified as: length 86 mm; width 54 mm; and card thickness 0.8 mm
ISO 7816-2	Contact positions
ISO 7816-3	Exchange signals and protocols
ISO 7816-4	Inter-industry file structure and commands for data exchange (standards still not complete at the time of writing)
ISO 7816-5	Registration requirements for the *Application Provider* (standards still not complete at the time of writing)
ISO 10181-2	Information technology - Open Systems Interconnection (OSI) - Security framework for OSI, Part 2 Authentication framework (standards still not complete at the time of writing)
ISO 9594-8	Data exchange between OSI - Catalogue - Principles of authentication
ISO 9798-3	Information technology - Security techniques - Digital signature scheme giving message recovery
	Examples of other standards:
European standard CEN/TC 224, EN 726	Requirements for IC cards and terminals for telecommunications use - Part 3: Application-independent card requirements (standards still not complete at the time of writing)
ASS000	Defines ASS000 (Allterminal, Security layer Specification) developed by the Swedish Agency for Administrative Development defining (general basic level security functions) specifications for interfaces.

Table 2-6 **ISO standards have been developed for the essential and now form a basis for some other more developed propriety standards.**

2.7.2 Scenario I: Minimal ISO standards development

In this scenario, the ISO smart card standard is developed and adopted only as a framework for propriety development while the smart card industry continues to put many of its resources into the development and marketing of propriety products and systems. At the present time this is the case, and many products conform only in the sense of providing minimal functionality when systems are interconnected.

This investigation has also found that most major manufacturers who claim to have adopted ISO standards, are in fact conforming at this minimal or degraded level only. For example, many industry manufacturers such as Gemplus, Bull and Philips, are still relying on strategic alliances with card suppliers such as Mondex, Visa, Europay and Mastercard, to use much of their innovation resources for the development of propriety systems for competitive gains. In the case of Mondex, they have adopted an ISO card system, yet they are also rapidly developing a range of propriety hardware and software applications with the stated goal of becoming, "the world's preferred and dominant payment method..." (Mondex, 1995). A typical card reader manufacturer is therefore likely to continue to produce cards that are capable of being read when used in conjunction with propriety card readers and providing full functionality only when using propriety application and management software applications.

It could also be argued that, under this scenario, the smart card market might gradually become suspicious of ISO conforming smart card systems. It might be considered preferable to choose manufacturers' products that adopt the propriety protocols and technical standards so that user choice is not lost, and to achieve more convenient and superior performance. Nevertheless, in the short term at least, it seems likely that smart card products conforming to an ISO framework will continue to be developed.

2.7.3 Scenario II: ISO standards developed into full architecture

In this scenario the smart card industry becomes sufficiently confident in the ISO future processes to cease trying to lock customers into propriety systems by providing enhanced application and management software functionality for a range of hardware and card technologies. It is not inconceivable that in the future, the global smart card industry will work together to achieve the goal of full compatibility and integration so that the potential users do not view their efforts as a degraded mode of service delivery. For example, the Visa-Mastercard-Europay (VME) standards now being developed could achieve this goal.

If this scenario eventuated, interconnection and accountability in terms of establishing and maintaining user trust for the complex set of administrative and operational systems required to support the system, could be guaranteed. That is, if this scenario occurs, the ISO aim of inter connectivity of propriety architectures and standards would develop into a full architecture in its own right. In particular, it would mean that systems and network management and other functions such as security not currently specified, would be developed in a standard form. One key implication is that more resources would need to be used to develop the greater functionality required in propriety systems if they are to become operational within the ISO framework. This would mean that interfaces, say between the banking industry and public information network domains, need to be developed in a way which might also generate trust between international service providers and local firms, or between user groups. The syntax of the interfaces, the security access architecture and the systems overlay applications would all need to be agreed. However, the subroutines could, for security reasons remain secret.

If such standards were developed and based on OSI standards, a standard data interface could be developed to become the smart card industry standard for interoperability communication within the open systems multiapplication environment described in the preceding section. The development of an interface standard in addition to the relevant communications and security protocols using ISO smart card standards could occur within existing OSI communication frameworks.

2.7.4 Manufacturers attitudes to standardisation

Since the smart card industry has become more competitive in the late 1980s, the acceptance of smart card ISO standards by manufacturers has shifted from being one of "it's a nice idea" to one where they are now generally accepted by suppliers as forming the only possible basis for future standards development. The development of ISO standards is now well underway, and although much can be done to speed the process, there remains little doubt on the level of commitment to ISO standards. At present, all major manufacturers, including Bull, are supporting this effort.

Nevertheless and despite these observations, ISO standards do not yet appear to be sufficiently advanced to induce leading manufacturers and suppliers to drop the development work on their propriety offerings. Also there are two major problems to be solved before ISO standards can realise their potential for users and interested organisations. The first is the question of directory structure for the large range of applications now emerging, and the second is related to the more sensitive issues associated with applications requiring a high level of security. In each of these areas, agreed industry standards may not become a practical alternative. In particular, it has been the normal practice to develop propriety standards governing the security features such as the encryption algorithm to be used, and the operating system because of the complexity of some security requirements. Hence, there is more than one reason why a shift towards the development of standards for full architecture seems unlikely in the short term.

Another set of issues influencing manufacturers' attitudes to the development of standards are related to the underlying tensions between the manufacturers' will to cooperate at one level, while remaining competitive at another. It is generally agreed that it is in the interest of the consumers to develop standard devices for communications purposes and to develop technology that is manufacturer independent. Yet, it is also recognised that there may be some applications requiring unique - non-standard - card technology.

There are also other factors contributing to these tensions. At present, only a handful of organisations in the smart card industry have the resources to establish their own propriety smart card systems. There is also the added realisation among manufacturers that it takes a long time for the development of a system which can be easily understood and trusted by users. There is also the problem for retailers to acquire and manage different smart card support hardware and to meet new administrative requirements. The conflict arising from the perceived benefits of cooperation and competition among project participants also needs to be resolved.

Here, it is worth noting that an instructive parallel can be drawn between smart card standards development and the development of the OSI standards for the computing and telecommunications industry. In both industries, there is not one single supplier in a powerful enough market position, to effectively influence the direction of standards independently of the users' demands. Nevertheless, it is recognised that the recent alliances such as that between Gemplus and Visa are using their influence to promote and further develop ISO standards at one level, while attempting to use the development of their own standards for competitive purposes. These conflicting attitudes are highlighted by the views of industry leaders such as Robin Townend, the Senior Vice President of Mastercard International. At a recent industry conference he stated:

> *"Mastercard will help to lead the industry to enable the development of the Chip Card platform to deliver global payments and information services at the point of interaction."* (Townend, AIC Conference, Sydney, September 1995)

Such statements clearly highlight a conflict between the intent of Mastercard's push for competition and market leadership at one level; while at the same time remaining actively and openly committed to the development of agreed ISO standards. As is the case with the computing and the telecommunications industry, the balance between the need to establish industry standards on a propriety basis, and between the perceived benefits to be gained through cooperation and integration of systems on a global scale, has yet to be achieved.

In addition to the above observations, there are also a number of other identifiable factors clearly limiting the scope of the manufacturer's tactical responses to the development of a uniform cooperative development of standards.

First, there is the problem of limited resources. Setting standards requires a high level of specialist skill inputs spanning the whole industry and all industry groups. Most recognise that this is a time-consuming activity and it requires special skills.

Second, there is the general lack of a supportive public policy framework. Issues of economic and industry policy require public policy support and infrastructure oriented towards the development and testing of uniform standards. It is also observed that in almost all countries leading the way in smart card development, the government has played a key role in providing support for the nature of the smart card environment now operating. In France, the highly regulated banking industry has led the way. The French national telecommunications and health organisations policy on smart card use have also helped to develop the local smart card industry. In each case projects have evolved hand-in-hand with policy development. Other national smart card schemes in countries such as Germany, Sweden, and Singapore are also developing within the confines of public policy sets designed to support the further development of the local smart card industry.

Another factor is the time lag between technological development and user acceptance. This has been a recurrent theme in interviews conducted for this study. The importance of developing user awareness, through education and the ability to maintain trust have been highlighted as critical to the success of smart card systems.

In addition, there are the general technical issues relating to the technology itself, and extending across the whole field of telecommunications standards. At present, the telecommunications industry is also undergoing considerable change in terms of standards as public networks prepare to migrate to a digital broadband network offering full integration of real-time systems. Finally, there are the practical considerations associated with the development of software and security management systems. In particular, questions and issues relating to the introduction, implementation and management accountability are also yet to be addressed.

Clearly the push to develop ISO standards that would result in a greater choice between equipment or card suppliers, and covering a wide range of applications is now supported by the industry. Nevertheless, it is concluded here that the former scenario is the most likely outcome for smart card standards development. That is, it is likely that ISO standards will continue to provide a minimum framework for cooperation and development among manufacturers. However, it should also be noted that in the causal change in such circumstances, it is not clear whether support for these scenarios is based on the assumption that user needs will stimulate standards development, or that standards development will generate market demand.

At a theoretical level too, it has been recognised that standards play an important role in the development of new technologies for the marketplace. Although smart card development has not yet found a place in this literature, there are many studies relating to standards development in the fields of computing or telecommunications. For example, there are some researchers, most notably Reddy (Reddy, 1987: 47-66), that have argued that standards play a crucial coordination role that harnesses and directs the shape of technology. In agreement with Reddy's conclusions, it is concluded here that the lack of sufficiently developed standards are likely to continue to inhibit the innovation diffusion process of smart card for some time.

2.8 Technological development and smart card innovation

In the light of the many technological factors influencing smart card innovation highlighted in the preceding analyses, this section considers smart card innovation in the broader context of technological development.

If we now examine the diversity and pattern of maturation of the smart card projects in the light of this analysis, there emerge four identifiable stages of development. These are summarised in Table 2-7.

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Table 2-7 Four stages of smart card innovation.
(*Source*: Lindley, 1994a)

Although the dates for each transition stage must remain somewhat arbitrary, the four identified stages each have different defining criteria. These are:

Stage I: Feasibility trials.

During the first decade of smart card's existence, the technology underwent a series of feasibility trials which were mostly conducted in France. During this time, there was no manufacturing facility capable of mass production of the technology and most of these early trials were small in scale. Although certain technological aspects developed during this trial phase were considered to be feasible and to provide a superior technology to competing technologies such as magnetic stripe cards, it was not considered to be an economically feasible alternative.

Stage II: Single applications.

From the mid 1980s when mass production of the technology became possible, a number of new trials and some of the first implementations emerged. Although many of the possible applications considered were technically feasible at this time, economic considerations meant that most projects were not developed past trial stage. However, in the French Banking industry where security was considered to be more important than cost, some applications requiring a high level of security were introduced. Later in the 1980s, when mass production of simpler smart cards meant that large numbers of cards could be produced for around US$4 each and the cost of readers was around US$100, then some telecommunications and transit organisations started to use large numbers of cards to replace cash. Nearly all the trials or projects implemented, involved only one application and were generally managed and operated under the umbrella of a single controlling organisation. Yet, by 1993 plans to develop a number of large scale project trials that would potentially involve a number of managing organisations and involve more than one application began to emerge for the first time.

Stage III: Multiple applications.

During 1995, a number of project trials involving multiple applications began to emerge. It is also worth noting that many of the first multiapplication card systems announced prior to 1995 have been designed around the concept of the *electronic purse* discussed earlier. Both the scale and technological requirements of these systems indicate that smart card sales are likely to continue to rise rapidly. Many of the projects being conceived will also need to rely more on the development of infostructure rather than infrastructure. Further comments on this point are made in Chapter Seven.

Stage IV: Market maturity and standardisation.

Given the many technological and industry factors likely to inhibit or delay the development of applications requiring industry and organisational cooperation, it seems that it could be several years before smart card will begin to show signs of maturing as a technology. Smart card technology could be considered to be approaching maturity when the market begins to decline.

2.9 Conclusions

The above analysis has revealed that there appears to be many historical and technological factors influencing smart card innovation. One of the most important is the potential for smart card to replace other technologies by virtue of its capacity to incorporate multiple applications. This means that it provides the opportunity to combine historically incompatible services on the one card. For example, a user can be permitted physical access to a building, provide payment for transport and fast food services, as well as use it to facilitate access to healthcare services.

Other important factors include the rapid growth and competitive nature of the industry in recent years. The development of standards as well as innovations in other industries have also played important roles. Another finding is that the manufacturers' attitudes to standards development are not likely to result in a full commitment of the necessary resources for the development of ISO standards to full architecture - at least in the short term. In the smart card industry, propriety interests and a number of standards organisations are likely to continue to exert considerable influence over the direction of standards.

Another factor influencing smart card technological development is the observation that smart cards and data security are synonymous in the sense that the security features of smart card are what provide the technology with advantages over competitive technologies: So, it would be true to say that smart card systems innovation relies heavily on the development of its active data security functions.

Collectively, the range of factors examined also help to explain the long incubation period for the technology. However the main conclusion drawn is that smart card innovation needs to be understood in the context of a wide range of technological factors that may be characterised by the following basic principles:

Flexibility	There is a large range of technological options.
Adaptability	Applications can be modified - or new ones introduced. Upward compatibility is also possible.
Evolutionary	The design of a system can allow for evolutionary development of the technology.
Security	A high level of security means that smart card can provide user security not offered by any other palm technology at the present time.

Chapter Three
Some Industry Case Studies

Given the flexibility inherent in smart card technology, this chapter examines how smart card technology is now being adapted to create a range of applications. By examining some applications within the industry sectors that now account for most smart card sales, this analysis offers an indication of both the diversity of applications, and their global spread.

The relative importance of the industry sectors considered in terms of annual card sales for 1994 is shown in Figure 3-1. The purpose is not only to demonstrate the flexibility of the technology in practice, but to also show how the technology has evolved to meet specific industry requirements.

3.1 Smart card in the healthcare industry

During the period 1985-1990, there were already 30 health card trials known to be underway in Europe: 16 in France; 6 in Italy; 4 in the United Kingdom; 3 in Spain, 2 in Belgium; and 1 in Portugal (Nguyen Nam *et al*, 1993). Here, the goal is to examine some of the applications arising from these early trials to reveal a range of emerging themes which are of particular relevance to this thesis.

Please see print copy for image

Figure 3-1 Worldwide smart card use by industry in 1994.
(*Data Source:* Atkinson, 1995)

The first major medical application that used smart cards was the *Carte Sante* in France which was introduced in 1984 in the town of Blois. Initially the card was issued to 5,000 volunteer patients and 100 sites were equipped with stand-alone read/write terminals (Takac 1990). The aim of these early trials was to test the efficiency of the technology in the health sector. Since then, there has been an escalation in both the number and the scale of implementations. The net result has been that smart card sales in the healthcare industry have grown from around 3 million in 1992, to an estimated 62 million in 1994. So, what have been the main factors fuelling such acceptance?

3.1.1 The imperatives

The interest shown in health smart card systems all over the world can be correlated with the increasing concerns of governments as a result of rapidly escalating health costs (Monod, 1995). In member Organisations for Economic Co-operation and Development (OECD) nations, healthcare now represents around 7 per cent of the GNP and is in second place behind defence. The concerns for rising costs associated with delivering effective healthcare services is reinforced by the aging of most OECD populations as well as the associated growing frequency of medical visits and increasing demands for more home visits. As a consequence, the cost of providing healthcare is doubling every ten years for many OECD nations at present. This escalation in expenditure cannot be matched by real economic growth in the foreseeable future and already the strain on health insurance providers is evident. Cost is therefore considered to be a prime driver responsible for smart card implementation in the health industry. In this context, the stated associated aims of improving the quality of healthcare appear to be only secondary considerations.

In an effort to gain considerable cost savings and administrative benefits, several national smart card systems are now at various stages of implementation in countries like Sweden, France and Germany. Holland has five pilot projects underway. In Austria two pilot schemes have been implemented in order to simplify the process of consulting medical practitioners and billing for medical services. Italy is trialing its more ambitious *citizen card* project. The United Kingdom has been trialing projects since the late 1980s and has announced its intention to bring in a compulsory national health insurance card. An added advantage for European countries too, is that some institutions have actively supported and promoted the smart card technology industry through programs such as the Advanced Informatics in Medicine (AIM) of the Commission of European

Communities. Many other countries have also made initial moves to introduce national health insurance card systems in an effort to improve the overall efficiency of national healthcare schemes. The European community has also been conscious of competition threats from American and Japanese companies. However, one of the main uniting goals of the European health industry and research groups has been the creation of a fully integrated health information environment for the EU.

Yet, not all nations agree that there are obvious cost benefits in adopting smart card technology for the healthcare industry at present. Many also recognise that there are a number of problems associated with effective implementation. The one most often cited, is the need to satisfy privacy concerns in relation to patient records. This uncertainty is reflected in the failure of many trials to proceed to full implementation, and the policy decision of some governments to delay the introduction of the technology. In the case of the US, Bill Clinton had earlier announced the intention to introduce a national health insurance card to begin in 1996. However, a more recent revised decision will now mean that the next cards to be issued (late in 1996) will be based on magnetic stripe technology.

The Australian Government too, has considered whether smart card might be used as part of the national public Medicare scheme in recent years. However, in a press statement issued in 1992, by the then Minister for Health, Housing and Community Services, the Hon. Brian Howe, it was announced that the government would reject the use of smart cards because of the associated implications for privacy (Howe 1992). More recently, similar assurances have been issued to the general public in statements made by the Minister for Industry, Science and Technology, Senator Cook and the Minister for Human Services and Health, the Hon. Carmen Lawrence (Cook and Lawrence 1995). Although, the Warren Centre for Advanced Engineering, at Sydney University, have just recently commenced work on the development of a smart card system for use by authorised pharmacists, there have been no smart card trials in the healthcare industry in

Australia. With the help of the local smart card industry, it is anticipated that patients' prescription records could be stored to allow dispensing pharmacists to monitor the patient's use of drugs - including overuse and conflicting medications. Future directions for smart card in the Australian healthcare industry are also likely to be shaped by the privacy legislation now being introduced at both Federal and State levels, as well as the development of the national health communications network.

Despite these differences in approaches, and after reviewing the many reports of experiences alluded to here, it is evident that cost is a prime factor influencing decisions to proceed with the implementation of large scale smart card projects in the health industry. However, the cost effectiveness of projects is not the only factor that appears to be influencing smart card development. Privacy is also recognised as a major concern in the healthcare industry. This will be considered in greater depth in Chapter Four. To reveal the nature of some of the additional problems and benefits, two leading smart card types that are now in use and offer potential benefits for the healthcare industry, are examined. These are the *health insurance card*, and the *specific patient data card.*

3.1.2 National Health Insurance Card

Germany and France are leading the way in implementing national health insurance card applications.

The French healthcare card is a microprocessor card designed to ensure data integrity, confidentiality and authentication through the use of an electronic signature. Two separate microprocessor smart cards have been developed. The first is used by health professionals. The second is a patient card used for administrative purposes. A schematic diagram illustrating how the French health card system has been implemented is shown below in Figure 3-2.

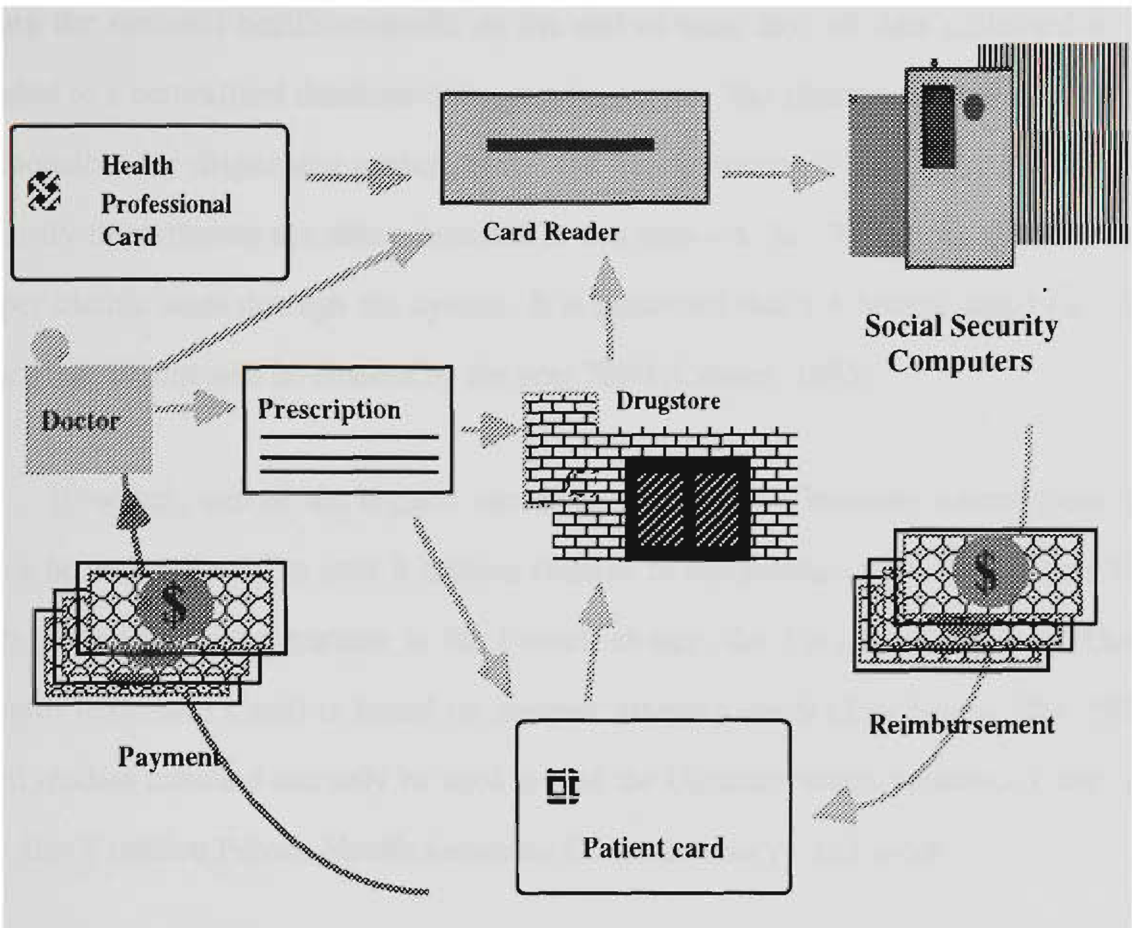

Figure 3-2 **A schematic diagram showing how the French health card system (*Sesam Vitale*) has been implemented.**

The 35 million administrative Vitale/*Sesam* patient smart cards now in circulation, provide personal identification information and health coverage status. The 1.2 million health professional smart cards are used to provide secure access to centralised databases for health professionals. The *Carte de Professionnel de Sante* (Health Professional Card) uses the highest level of security available and is based on Schlumberger technology. Different levels of security access are programmed for each healthcare worker. This is similar to the approach taken by the Swedish health care INFOSEC program on information security (Swedish Institute for Health Services Development Report, 1994). All of the 1.5 million smart card readers in the system are identical and interconnected using the national health network. At the end of each day, all data collected is down loaded to a centralised database management centre. The pharmaceutical organisations responsible for dispensing prescriptions, the health insurance providers and the social security departments are also connected to the network. In 1994, more than 1.2 billion paper claims went through the system. It is predicted that 1.5 billion smart card based electronic claims will be entered by the year 2000 (Crozier, 1995).

However, one of the biggest successes so far is in Germany where smart cards have been distributed to over 8 million citizens in conjunction with the national health care program. In comparison to the French choice, the *VersichertenKarte* (German Health Insurance Card) is based on simpler memory cards (256 bytes). The 150,000 card readers installed can only be used to read the German Health Insurance Card. There are also 8 million Private Health Insurance Cards (memory - 512 bytes).

The cards contain personal details, contact information and health insurance details - but no medical data. They are used to provide faster, more accurate registration of patient data when the patient is seeking services or making a claim. The main difficulty has been in convincing private medical practitioners to buy a computer to use the cards. This problem is not unique to Germany. Although paper documents are also difficult to store and retrieve, medical practitioners in many countries still rely on paper based files and do not have a computer on their desk (Benson, 1993).

Finally, and from a sociotechnical perspective, one should also not neglect the current European trend towards the introduction of *telematics* networks based on the use of smart card technology. Here, the role of the cards and the networks might appear to be in competition. One of the questions arising from this trend is how can we harmonise the complimentary functions. That is, current innovation trends have not yet made it clear if the networks and the cards are complimentary. One objective of these telematics network projects is to coordinate the development of Health Card systems with Health Telematics networks.

One of the most significant European telematics projects in this area is the *REseau Multimedia Europeens pour Doctuers et Etablissements de Sante* (REMEDES) established by Olivetti and the Sema Group. The main goals of the project are to:

1) Control the costs of health care provision;
Costs can be controlled by enabling medical practitioners to compare alternate treatments, pharmaceutical prescriptions and surgical techniques on a cost performance basis. It also helps to control over prescription and test abuses within the system.

2) Improve the quality of information flow and access;
Quality can be improved by supplying relevant clinical information when it is needed, by offering a choice among healthcare providers, by giving general practitioners continuous training, by enabling the medical practitioners to have overall visibility of the medical processes, and by linking primary to secondary health care.

3) Improve access to healthcare service for rural and other disadvantaged groups;
Access to disadvantaged or remote groups can be improved by decentralising access to secondary care providers using the concept of the *virtual hospital* to increase the range of action and advice of nurses and medical practitioners.

The underlying infrastructure for the REMEDES program makes use of existing telecommunications services such as Euro-ISDN. In the near future, GSM technologies will be deployed to deliver services requiring greater bandwidths.

Other Eupopean telematics networks also being developed include the European Health Telematics Observatory (EHTO) that is offering a coordinated approach to the dissemination and visibility of other existing telematics projects that are now emerging within the different European healthcare systems. The Coordination of the primary care information network known as the Co-Co Project, aims to use EDIFACT messaging and multimedia services to improve the coordination and continuity of healthcare and social services. The Diabcare quality network (DIABCARE-Q-NET) is a telematic network set up to improve the care of diabetes in 20 countries across Europe. The Planning of the care of the elderly in the EU (PLANEC) is a decision support system established to improve care for the elderly.

3.1.3 Data specific patient cards

Although there have not been many data specific patient card trials to date, and most systems are still in their early stages of development, the outcomes of the trials reviewed have reported significant potential benefits and cost savings. For this reason, two different card programs will be briefly reviewed to demonstrate how the basic design approaches adopted have been able to achieve their objectives.

The first example is the European *Diabcare/Diabcard* Program. Schlumberger, which is a part of the European Diabcare/Diabcard programs, provides a portable medical file on smart card for diabetes patients. The objective of the system currently being tested and sponsored by the EU, is to improve the quality of diabetes care through the use of smart card technology by making data collection easier, more accurate (eliminating the need for handwriting) and to ensure data authentication, security and integrity. The system incorporates the use of a user friendly pen-based portable device for healthcare providers to input data. The data is centralised and managed by Diabcare Q-net in

Munich, Germany. Hospitals, medical practitioners and patients will be able to access the system. To date there have been some significant benefits reported (Engelbrecht *et al*, 1995). It has been developed into an efficient form of patient records and at the same time it has been proven to be a useful tool for communications between the different health institutions involved in the trials. It has also been valuable as a tool for quality assurance in managing and administering diabetes patient care.

Another data specific patient card system is the Belgium Hemacard program which provides a portable medical file on smart card for patients requiring frequent pathology services. For example, the groups targeted included pregnant women, some cancer patients and chronically ill patients requiring regular pathology tests. The treatment of these patients often involves a number of medical practitioners or specialists, as well as requiring the patient to visit several pathology laboratories attached to different public hospitals or clinics within Belgium. The aim of the system is to improve efficiency and the accuracy of records as patients move within the national health system.

At Nemur University, the developers of the system have noted that implementation has resulted in a reduction in the amount of duplication and paperwork associated with each patient visit (Nguyen Nam *et al* 1993). The Hemacard program has also removed many of the previous difficulties that healthcare providers have had in reading the hand written notes of other service providers as patients move around the healthcare system.

3.1.4 Factors influencing smart card innovation in the healthcare industry

A number of factors that appear to be influencing smart card innovation emerge from the above brief review of healthcare industry smart card trials to date.

(i) Reduce administration costs

The first, is that there is an overriding imperative to design and develop new systems that are able to improve the efficiency and hence the cost effectiveness of delivering and administering healthcare services on a national scale. Already it is evident that efficiencies can be achieved by striving to improve communication, promote immediate and accurate emergency information, reduce the need for paperwork, and using the card as a tool to promote additional and preventive follow-up patient care for chronically ill patients (Hausken and Bruening, 1994). However, it should be noted that such claims can only be made on the basis of anecdotal evidence. There have been no studies which can prove - or disprove - such assertions. It is also noted here that there have been no definitive studies that relate smart card implementations to improvements in the quality of the health care delivered. These could be the focus of future research efforts.

(ii) Enhance relationship with insured

A second factor, and one related to the first, is the apparent need to guarantee timely, accurate and more personalised services for patients so that health insurance organisations can gain a closer relationship with the insured.

(iii) Ethical and legal issues

Ethical and legal issues are important considerations in the specification and design of new healthcare systems (Bruening, 1995; Reimer and Robnagel, 1995). International regulatory frameworks governing the rules for accessing and use of personal health file information are also influencing smart card innovation because of the need to develop secure and trusted systems. In fact, it is *a priori* consideration, that any smart card system containing data, or access to data that is sensitive, also be secure and that the technology is designed to meet the regulatory requirements.

(iv) Protection of privacy and confidentiality

The preceding analysis has identified privacy as one of the most important concerns impacting the introduction of smart card in the healthcare industry. The competing demands for the individual's right to privacy and administrative efficiency when new information systems are introduced is already an observed social trend. In particular, one must bear in mind the social context for any new system to be considered. Already, data matching systems are used by many government agencies with most members of the public unaware of the extent of the linkage that already exists between the different public database systems in place. Although there has been some progress in adopting the principles contained in OECD guidelines for information privacy as a basis for national privacy legislation, the current regulatory regimes in many countries are inadequate to cope with the introduction of smart card systems (Mcgregor, 1993). Given the public's concern for privacy in relation to health information, it also appears that regulatory and administrative guarantees would need to be in place before proceeding with the design and implementation of large scale health systems based on smart card technology, and that these would significantly influence the choice of technology to be used. These will be discussed further in Chapter Four.

A related factor is the need to guarantee patient confidentiality, and security of records by limiting access to those who *need-to-know*. Using existing frameworks for the development of infostructure, it is possible to respond to regulatory and other authorisation requirements by restricting access to data through the use of a secure professional smart card system. The objective would be to limit access to private and confidential information, to only a few individuals who have a justifiable *need* to know (Brannigan, 1994). In fact recent legal developments in the US now make the introduction of such a system mandatory for healthcare institutions. It has been recognised for some time now that smart cards can play an important role as *active* security devices (Vedder, 1993: 630-635). Limiting data access to a clearly defined small number of individuals within a national scheme is feasible and preferable to basing security access rights on the identification of the organisations within the system as many of the healthcare workers employed are required to work at a number of different locations.

(v) Resistance by medical practitioners

Another factor, and one that also appears to be inhibiting smart card development in the healthcare industry, is the resistance from medical practitioners. While computer networks have presented a new context for privacy concerns, other countries have noted the difficulties associated with increasing the dependence of the medical service providers on electronic records. It seems that widespread resistance to the introduction of new technologies like smart card, will require careful preparation, adequate training and the choice of a system that is likely to maximise benefits for the operators and users alike (Royce, 1991; Benson, 1993). A resistance to electronic records by medical practitioners also now mean that there is a shortage of appropriately skilled information staff within the health industry. This too, has been identified as a factor likely to influence the rate of diffusion of any new system developed (Brittain, 1989; Brittain and Maggs 1993; Fung 1993).

(vi) Resistance to organisational change

Another factor is the need to significantly alter existing health administration infrastructures and infostructures to accept the new smart card systems. The modifications will mainly consist of software upgrades plus the addition of readers and the issuance of cards. However, at the organisational level, this is likely to be accompanied by much change. Not only will current work practices need to be modified significantly in organisational terms, but there will need to be a major shift in responsibilities and work practices of many employees as well as a change in the way the public interface with the healthcare system in general.

(vii) Convenience of integrated services

The possibility of integrating a range of patient applications is also a factor influencing current innovation trends. For example, a prescription card could be useful to transmit or check information with the medical practitioner who ordered the prescription. Additional functionality could be to support repeat prescriptions, store or access prescription histories, patient identification and billing. Hospital staff could also use a card with differing security levels to have immediate and secure access to patient records and history from a number of locations within a building or healthcare system. Patients could carry a basic card from admission to discharge which would help the hospital to identify the patient and to aid with record access, care after discharge administration and billing. Another promising application is a card storing emergency medical data to be used by paramedics, including other emergency administration data such as next of kin, blood type, previous medical history. The same card could also be programmed to store outpatient treatment and administration records; and it could be used to help administer and monitor outpatient, home nursing, ante natal, diabetic and community care programs. For example, in Japan, Sharp has developed a wallet size electrocardiograph in which a smart card can be placed to capture readings.

As can be seen, the range and scope of health applications involving patient care is extensive. It is also important to realise that within each industry sector, there are three separate user groups: the patient; medical personnel who are responsible for the delivery of the services; and, the organisational or departmental personnel responsible for the management of the system. Consequently, the possibility of extending the information held and the range and type of applications that can be used to support the healthcare industry could be expanded accordingly using the suggested range of applications shown in Table 3-1.

Please see print copy for image

Table 3-1 Health smart card applications. (*Source*: Lindley 1994b)

(viii) Information ownership and control

Finally, and at another level, there is also the familiar ground for the control of information by divergent interest groups. The governments right to be able to prevent fraud in the healthcare industry and to protect the *public interest* must be continually interpreted at a functional level. These rights must also compete with organisational demands for information for the purposes of accountability both within the organisation and among the users of the system. Government organisations may also justify the need to maintain centralised health records based on smart card systems on the grounds that the data will enable them to improve the quality of health care in terms of improved outcomes. However, there is also a third party -- the users. The card users of the system may in turn challenge the rights of government to information as well as with organisational demands. This triparted battle for control between the government, the health care providers and the patients will be a continuous and permanent aspect of healthcare smart card systems.

The main conclusion that can be drawn here then, is that many healthcare providers are moving quickly to introduce smart card - largely because of rapidly increasing economic pressures. There are also many other identifiable benefits that are realisable in practice. Yet, there are also a number of concerns that need to be addressed. Privacy and data access rights are most important among these. A summary of smart card applications in the healthcare industry and the associated key objectives based on the above findings is provided in Table 3-2.

However, it should be emphasised, that nowhere is there a smart card system being developed that would be a comprehensive medical file from birth to death. All the known projects incorporated only summary information with some including WARNING data (Lindley and Pacheco, 1995). Finally, it is also now evident that smart card use in the healthcare industry will be on a national scale in many countries. This is justified by the need to establish a coherency, compatibility and interoperability among all the health insurance providers and healthcare organisations; as well as to increase the scale and scope for cost savings as a result of the improved efficiencies noted above.

CLASSIFICATION OF CARD SYSTEM	SYSTEMS USES/OBJECTIVES
1. NATIONAL HEALTH INSURANCE CARD:	
HEALTH PROFESSIONAL'S CARD (France)	* ENSURE SECURE AND LIMITED ACCESS * PROTECT PRIVACY AND CONFIDENTIALITY
PATIENT CARD (France)	* REDUCE ADMINISTRATIVE COSTS * SIMPLIFY PROCEDURES * ENHANCE RELATIONSHIP WITH INSURED * REDUCE RECORD/SERVICE DUPLICATION * AVOID MEDICAL INCOMPATIBILITY * HELP STATISTICAL COLLECTION OF DATA
HEALTH INSURANCE CARD (Germany)	* REDUCE ADMINISTRATIVE COSTS
2. SPECIFIC PATIENT DATA CARDS:	
HEMACARD (Belgium)	* OFFER SPECIFIC SERVICES FOR CHRONIC PATHOLOGY * REDUCE RECORD/SERVICE DUPLICATION * SIMPLIFY ADMINISTRATION * HELP STATISTICAL COLLECTION OF DATA * FACILITATE COMMUNICATION BETWEEN HEALTH PROFESSIONALS AND INSTITUTIONS * AVOID MEDICAL INCOMPATIBILITY
DIABCARE/DIABCARD (Europe)	* EMERGENCY FILE INFORMATION * FACILITATE COMMUNICATION BETWEEN HEALTH PROFESSIONALS AND INSTITUTIONS * HELP STATISTICAL COLLECTION OF DATA * SIMPLIFY ADMINISTRATION * REDUCE RECORD/SERVICE DUPLICATION

Table 3-2 Classification of some health insurance card systems currently in use and their associated objectives.

3.2 Smart Card in telecommunications

The use of smart card in telecommunications, like many other industries, was also pioneered in France in the late 1980s. It has been reported by French Telecom that 58 per cent of calls were made by smart card payments by 1989. Currently in France, new French Telecom phones accept prepaid cards from Gemplus, Telecom credit cards from Bull and Philips. Bank credit cards are also being tested.

3.2.1 Prepaid telephone cards

By 1995, the telecommunications industry accounted for around 80 per cent of all smart cards sold in over 55 countries worldwide. However, the majority of the telephone smart cards sold are simple debit cards used to make calls from public telephones. In fact, the use of throw away smart cards that began in Europe in France and later Germany in the late 1980s, is now quite widespread internationally and, smart card technology has become cheap enough to replace magnetic stripe technology which is easily counterfeited. The smart card alternatives may be purchased with a particular value on the card - like their magnetic stripe counterparts. The smart card is pre programmed by the manufacturer with a certain value on the card. The value is decremented and when the value on the card has been used, the card is thrown away.

3.2.2 GSM cards

Smart cards are also now widely used in telecommunications as a secure identifier for GSM mobile equipment. The smart card developed for GSM communications is known as a Subscriber Identity Module (SIM). A SIM is a smart card that contains all the necessary information to uniquely identify a mobile network subscriber when using any

GSM mobile equipment (ME) units that are designed to accept a SIM card (Moorhead, 1994). The SIM card security features are designed to manage GSM network access and to prevent misuse. A 4-8 digit Personal Identification Number (PIN) controls access - unless it has been voluntarily disabled by the subscriber. The SIM card also stores and manages network and subscriber related information. For a subscriber to access the network, the SIM card must be inserted into the ME unit. The standards for the SIM card (ID-1) conform to ISO 7816 standards and are of normal credit card size. There is also a *plug-in* SIM measuring only 25 mm x 15 mm that is intended for semi-permanent installation in GSM equipment.

The SIM therefore uniquely identifies the user for incoming calls and for accounting purposes. This means that any GSM mobile phone can be personalised by the person who holds the GSM smart card. Because of the security features and the ability to personalise call accounts, smart card SIMs may find a wider range of applications in the rapidly growing area of personal communications. It also seems likely that the needs of the mobile phone industry will continue to exert significant influence over the future development of the technology. As with the health industry, smart cards superior security features are what make it a viable alternative.

3.3 Smart Cards in the Banking Industry

The French banking industry was the first industry sector to implement smart card systems. In fact, smart card was originally conceived and patented worldwide by a Frenchman as an electronic banking medium in the early 1970s. When Michael Ugon of the French company Bull added a microprocessor to incorporate advances in cryptography, it was the French Bank Group, *Cartes Bancaires* that conducted the world's first trials. Despite the success of these trials, and the technological advances that the French continued to make, it was not until the late 1980s that banks from other countries began to take an active interest in what appeared to be a French technology. Since then however, smart card has become widely accepted by banks around the world.

Although primarily used as a more secure electronic payment card by the industry, it has also been adopted to manage and audit secure online access to information and resources within the industry itself (O'Connor, 1996). Its security features have made it possible to be used as a secure and portable piece of plastic to conduct secure transactions and to gain secure physical and electronic access. Using public key cryptosystems, a range of new banking applications are also now being developed for secure large cash transactions.

3.3.1 Home banking

As an example of smart card's progression into home banking, Keyline Home Banking has already begun implementing a home banking system based on smart card technology. It aims to have 3-4 million home terminals in the UK by the year 2000 providing a range of services. These include home banking, financial and travel information. The Commonwealth Bank of Australia also uses smart cards to manage access to information. Commonwealth Bank employees are issued with a smart card that has both personal details and the access authority level for each employee to access, create and modify information stored in the bank's databases. Planning for the project began in 1988, and the full system was launched in 1994. It has been designed to provide user identification to conduct secure database sessions from a number of branch locations within the banking system. The Commonwealth Bank project involves the participation of around 40,000 employees.

3.3.2 Banking and smart card innovation

Smart card now seems ready to be the preferred media for mainstream payments. With the total US magnetic stripe Bankcard fraud reaching US$666 million in 1993 (Borowsky 1995: 22-26), Visa International, Mastercard International and Euromoney International have been quick to agree upon worldwide smart card and terminal specifications to meet their particular needs. The emerging standards are now often referred to as the V-M-E standards. Both Mastercard International and Visa International have begun to implement card pilot programs that involve thousands of users in both Australia and the US. The development of smart card systems within other industries - in particular the retail and telecommunications sectors - is also likely to continue to develop in a way that could envelop the banking industry. Although it is expected that smart card ecash (electronic cash) flows will rise rapidly, there are some law enforcement problems that could inhibit future innovations. For example, in 1995 the Office of Strategic Crime Assessments (OSCA) warned of an increase in the international transfer of illicit funds, the inability of law enforcement agencies to trace money flows, electronic counterfeiting and the associated problems of law enforcement (Lapworth, 1996).

Smart card innovation history has therefore been strongly linked to the needs of the banking industry. In particular, early systems development and improvement have arisen from the efforts of the French banking industry. It is also worth noting that the use of smart card by the French banks in the earlier trials has given rise to the strong concentration of manufacturing and systems implementation expertise that has arisen out of several French and other European companies. The scale and projected scope of some of the smart card projects now being initiated by the banking industry also now suggests that the banking industry will remain a leader in smart card innovation and development. The employment and development of more advanced technologies are also likely to continue to emanate from this industry because of the growing need to replace older technologies and to reduce electronic fraud.

3.4 Transportation ticketing systems

In recent years, smart card has also been readily accepted by rail transit authorities and bus companies throughout the world.

3.4.1 Ajax Transit Authority (Canada)

In 1991, the Ajax Transit Authority of Ontario, Canada became the world's first large public transit operator to adopt a smart card system. The card used was locally developed and manufactured by Precursor Limited of Toronto. According to McGugan, a writer for *Canadian Business*, the result has been a 10 to 15 per cent increase in efficiency and a fare evasion rate of less than 1 percent, compared with as much as 15 per cent in manual transit systems (McGugan 1994: 28-29). There are no more buses on the road, but the number of fare-paying passengers has doubled. It has also been reported that passengers board faster and drivers have experienced less stress. Ajax's system uses two types of reusable card: One for passengers and one for drivers to download data at the end of each working day.

3.4.2 Glennorie Bus Company (Australia)

Most transit systems now used are based on simple memory cards that are purchased with a predetermined amount already loaded. The card is debited after each use of the card. Transport operators have claimed greater efficiencies as a result of faster boarding, the need for operators to handle cash and improved revenues as a result of a reduction in cash *leakage* (Todd, 1994). These cards have been reported to eliminate the need for pre-printed ticket stock, increase security, reduce fraud and are reusable. For example, in Gladesville, Sydney, the Glenorie Bus Company has been using a smart card fare system since 1989. The company operates around 70 buses in the Hills District of Sydney. The Managing Director, Mr Keith Todd, now has 2000-3000 smart cards supplied by Associated Electronic Services (AES, Perth) in use. Passengers are required to pay a AU$10 refundable deposit for the use of a card and receive a discount on fares. Pre-payment for fares is made on any bus in multiples of AU$10. Passengers with a smart card put their card in a reader to print their ticket. Passengers without a smart card pay by cash for their ticket. In-house research has indicated that smart card saves time, saves paperwork, and is more accurate than the cash payment system. Passengers surveyed rated ease-of-use and convenience ahead of the price discount as a benefit. There were no apparent drawbacks reported and use of the card was promoted by the distribution of promotional pamphlets that also contained simple instructions on use. However, a batch of 100 malfunctioning smart cards was introduced and had to be withdrawn. This incident did cause some consumer reaction. It is also interesting to note that of the 2,500 residents of a retirement village that were serviced by the company, 35 per cent chose to use smart card. Children of regular fare paying adults are also often given their parents' card for weekend travel purposes. Some parents have found this more convenient. Around 50 per cent of peak hour commuters (6.45-8.45 am and 4.30-6.00 pm) now use a smart card.

3.4.3 Hong Kong Transit Authority

In the case of the Hong Kong Transit Authority - a joint venture between several major transport operators - a smart card system capable of handling approximately 1.5 billion passenger journeys per year has been developed to replace a magnetic ticketing system. Although the magnetic ticket technology was efficient, the system required a high level of maintenance to remain functional. There were also problems with the reliability of magnetic stripe tickets themselves. Operated by a company called Creative Star Ltd which initially managed a mix of magnetic and paper ticket technologies, the new systems now being introduced use contactless smart card technology. The new cards are based on an ISO 10536-1 size, 250 Kbps, 1 Kbyte chip technology capable of long range operation (up to 10 cm). Full implementation is to proceed in 1996 and 1997 when it is expected to have 4-5 million cards in circulation. To date, this is the world's largest contract awarded for the development of a contactless system. The Greater Manchester Passenger Transport Executive (GMPTE), the public transport authority in Greater Manchester in Britain, also plans to introduce contactless smart card fare technology.

Initial market studies have revealed a high market acceptance of the contactless technology. However, in both of the above reported trials, the suppliers of the technology have been unable to deliver true microprocessor contactless cards in volume. At present, the vast majority of manufacturers and card suppliers have little more than memory cards and prototype reader experience. In this case, it is the technology itself that is one of the reasons cited for the slow migration to more advanced technology in the transport industry.

3.4.4 The evolution of transit payment systems

For transit authorities with a large number of fare paying passengers, it is now evident that smart card has been able to provide considerable benefits. In the 1980s magnetic stripe technologies provided operators with gains in efficacy. However, with costs in smart card technology continuing to decline, smart card is now able to replace magnetic stripe technology. Given the high level of acceptance of smart card by transit passengers, the transport industry might soon be able to enjoy the added convenience, lower maintenance and faster throughput that contactless smart card technology could introduce. However, costs need to be further decreased, and the reliability of the technology needs to be improved. There are also still some concerns that users may not readily accept contactless technology because of the potential risk of the card being read without the owner's consent or knowledge. This evolution in transit card technology is shown in Figure 3-3.

3.5 Smart cards in the retail industry

Some retailers are now issuing their own credit cards and customer loyalty cards based on smart card technology. The store credit cards provide an added level of security while the customer loyalty cards are able to provide a more reliable way to identify the customer, and to handle the various rebates that may be offered at a particular time. Smart cards are also now used in the retail industry to replace cash. A smart card that is designed to replace cash at multiple points of sale is known as a *stored value card* (SVC) or *electronic purse* (or wallet). The service provider is reimbursed through a cash clearing house that administers and manages the scheme. Cards may be disposable or rechargeable. Electronic purse cards have the potential to operate simply as a secure substitute for cash by allowing anonymous or identifiable cash transfers between individuals or agencies such as banks.

3.5.1 Vision Value card (United States)

One of the world's first smart card retail applications was developed for supermarket stores in the United States in 1989. In the United States, Vision Value smart card Advanced Promotional Techniques (APT) trialed a smart card system in a Dahl's supermarket branch in Des Moines, Iowa. The results were reported in terms of the increase in sales, and the number of requests for cards. Approximately 70 per cent of households served by the supermarket had requested a card and a 20 per cent overall increase in sales was reportedly achieved (Lindley and Scott, 1992). This performance was then compared with 29 other stores. The trend continued with a net growth of 15 per cent. There was also no slow-down at the check-out. The checkers did their job while the customer interacted with an Apple touch-screen to authorise payment for the goods. Points were gathered and coupons were issued as an incentive. Since the development of early trials such as this, similar projects have grown considerably in size and become more advanced both in terms of the technologies adopted and the complexity of the services provided.

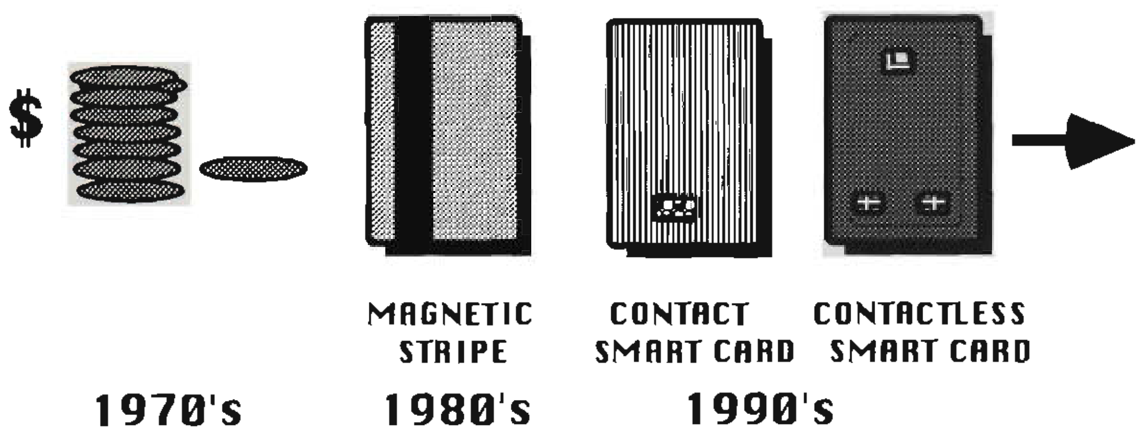

Figure 3-3 The evolution in transit payment systems (1970s - 1990s)

3.5.2 The emergence of large scale SVC projects

Already, there are a few major SVC projects in operation in the retail industry. Some of these, noted previously, have announced their intentions to become global schemes over the next few years and there is a push for convergence between the banking, transport telecommunications and retail industries. However, at the present time there are no global scale smart card projects involving the retail industry.

One scheme, which was one of the first to publicly announce its intentions to offer global services is Mondex. The Mondex card is now actively promoted as, "The worldwide alternative to cash" (Manning, 1995). The card system relies not only on the Point of Sale (POS) points in retail stores, but also on the integration of the system with the banking industry. At present integration is achieved through ATMs and telephones fitted with smart card read/write devices. It will also be unique in that it aims to be the world's first multi currency alternative to cash and it will be language independent. Providing ATM, EFTPOS or telephone loading, and linked to bank accounts, it will also be able to handle high and low value cash transactions. So far Mondex has been developed and tested in the UK. Midland Bank and National Westminster Bank (Natwest) jointly acquired the Mondex franchise in the UK in 1993, and with British Telecom (BT), launched the first Mondex services in early 1995. Already, the Hongkong and Shanghai Banking Corporation Limited (Hongkong Bank) have been contracted to franchise Mondex in Hong Kong, China, India, Indonesia, Macau, Philippines, Singapore, Sri Lanka, Taiwan and Thailand. These were the first nations outside of the UK to announce involvement with Mondex.

In Australia, the New South Wales (NSW) government's Stored Value project called Quicklink is also an example of a centrally managed and open system retail project. When the project becomes fully operational, the intended card users will be able to migrate between suppliers and use different applications. There is also a requirement for funds to be cleared between project participants. Quicklink, which is currently being managed by the NSW Government's Commercial Services Group, is now set to offer a range of competing card services to the NSW public. All services are designed to encourage customer loyalty (Olsen, 1993; McIntosh, 1994). It is anticipated that the scheme now being trialed, will be able to reduce some of the retailer concerns about the costs and risks associated with the handling of large quantities of cash securely during major events such as the Olympic Games due to be held in Sydney in the year 2000. It is also likely that the adoption of smart card technology will help to reduce the large amount of fraud often associated with magnetic stripe technologies during major international sport events. The cards offered are anonymous and reloadable. The emphasis is on smaller cash transactions. Participating retailers include fast food retailers, public transit authorities, sporting organisations, entertainment venues and small goods retailers. Project trials are now underway in Newcastle, an industrial city north of Sydney. The cards will also be able to access ATM debit card facilities and telecommunications services.

The Danmont card was Europe's first pre-paid SVC (or *electronic purse*) card scheme. The cards were launched in Denmark on a national basis as an anonymous electronic purse in December 1993. The joint venture between the Danish bank's payment organisation (PBS) and the Copenhagen Telephone Company (KTAS), involved the use of pre-paid disposable smart card technology for which no direct costs were passed on to the users. The cards were useable at certain car parks, vending machines, kiosks, laundrettes, and at railway stations. However, despite these features, the card did not gain a wide acceptance. One of the main reasons identified has been the lack of outlets where the card can be used (Worthington 1995). The result was that by the end of 1994, only 175,000 cards had been issued since the first trials began in 1992. The problem of co-operation and competition between the joint venture partners also contributed to the poor market outcomes. Competition between the KTAS pre-paid telephone cards already in existence, and the Danmont card for use in card-accepting telephones, may have undermined the utility value of the Danmont card. The case of the Danmont card has also demonstrated that a crucial link in the development of a successful system is the users. The attitudes, perceptions of convenience need to be carefully examined before rolling out a new design.

Although the Danmont card has not been able to meet the early objectives of its planners, there does seem to be scope for optimism for other large scale SVC project operators. At present, 75 per cent to 80 per cent of all retail transactions are less than US$2.50 (figures based on worldwide aggregates), and over 80 per cent of these payments are made in cash (Chapman, 1995). Anonymous SVC projects targeting food, drink, telephone, retail and transit organisations therefore now seem to present a viable alternative to cash. In the case of larger electronic cash transfer systems, Visa alone has more than 2,000 transactions per second worldwide and over 387 million cardholders performing 700 billion transactions per year (Welsh 1995). It seems that here too, there is considerable scope for smart card technology. Figures such as these, combined with the other application experiences are now being used to justify the development of the large scale SVC projects listed in Chapter 2, Table 2-3.

3.5.3 Retail applications and smart card innovation

Although the above overview can provide only a glimpse of the range and scope of the many retailer smart card projects now underway, the range of applications illustrates that the technology is developing very rapidly to meet the needs of the retail industry right now. However, it is interesting that most of the retail applications reported to date, have been developed to restrict the use of private information - or to offer complete customer anonymity. It is widely recognised that there are still many issues to be resolved about who controls the card and about regulations governing the management of the schemes outside the established banking industry. The scale and number of the global electronic purse applications announced or in use at present also attest to the fierce competition likely to be experienced by the firms involved over the next few years. The conjoining of the banking, telecommunications and retail industry sectors in some projects is also likely to have ramifications that will significantly influence smart card innovation in the future.

3.6 Other Applications

In addition to the above industry uses, a wide range of other smart card applications have also emerged since the many trials that began in the late 1980s. The examples highlighted below, demonstrate the scope of some of these applications.

Smart card is also now being used in welfare. For example, the Mexican government's Department of Social Security has introduced a smart card system to help manage welfare payments. The system has been operating since 1992. In Mexico, welfare payments are made in the form of tortilla and milk that are redeemable at selected stores throughout Mexico. Before the smart card system was introduced, bar codes which could be taken to the selected stores and redeemed for tortilla and milk were issued. However, fraud was rife as the bar codes issued could be easily photocopied to receive additional quantities of tortilla and milk. The smart card provides weekly welfare entitlements that are preprogrammed into the card. Fraud has been reduced because of the difficulty of tampering with the card. The suppliers benefit too. The smart card reader is capable of down loading the daily/weekly supplies provided onto a high capacity smart card making the reporting, audit and ordering functions more efficient. The high capacity smart card is then taken to the *Conasupo* where it is read and payment is made. A *hot* card list is also down loaded onto the retailers' high capacity card that the retailer then loads back onto their reader.

Smart card has also been identified as an ideal medium for identification and small cash transactions on university campuses. In Italy, it has been reported as early as 1988, that 1500 students at Rome's La Sapienza University, and 4,000 students from the University of Bologne participated in an initial trial conducted alongside the traditional record system. Students were issued with smart cards for student information and records using terminals placed around the campus. Staff members were issued with a smart card programmed to record examination results. It was claimed by one staff member that it saved many days of labour, and was most effective in stamping out fraud associated with examinations marking (Bright, 1988).

Similar schemes have also been trialed in the United States since the late 1980s. For example, it has been reported that Marriott introduced a Campus DataCard as a prepaid card that could be used to make a variety of payments within a closed systems environment. Applications included student and staff identification, food services, security access, book stores, convenience stores, vending activities and copying. At Queens College, Charlotte, North Carolina, a 16 bit data card was introduced in late 1990 for all campus purchases and tickets. Other university trials reported include North Carolina State University which introduced a 2 Kbyte Bull smart card test late in 1990 for purchasing and vending, and Murray State University, Kentucky which introduced a 2.6 Kbyte Bull smart card for vending machines and purchasing. Since then, smart cards have been successfully used on many other University campuses for both students and staff. The cards can be used to buy goods and services, and/or to access services such as photocopying, gymnasiums, swimming pools or tennis court bookings.

Organisational multipurpose smart card projects have also been developed. Due to the ability of smart card to run multiple applications, there are now several public and private organisations using smart card as an employee management and audit medium. The multipurpose cards are being used for physical access, service and sports facility access, and as an employee electronic purse. One of the earliest trials reported was a project developed by Matsushita Electrical Industrial Co. in Japan. Matsushita has been using Panasonic 8 Kbyte multipurpose smart cards as an employee system since 1991. Applications included cafeteria self-service purchases, office access, and employee time management.

A more recent and advanced application of smart card technology was announced by the Swedish government in mid 1995. It is the smart card based electronic driver's license (EDL) - to be introduced soon. Using the new smart card licence scheme being developed by the Swedish National Road Administration, drivers will be required to insert their licence into an onboard computer that is to be fitted to all registered vehicles. The onboard computer will not only require a valid licence to be inserted before the engine can be started, it might also require the driver to pass a fitted breathalyser test. The police will also be able to communicate remotely with vehicles to stop the engines of cars that are reported stolen. Alternatively, it could be used to stop drivers who break traffic rules or have outstanding fines. Drivers in cars with unpaid registration fees or those who have been driving for more than the stipulated time might also be stopped. Police will be able to transmit information on road congestion to a display on the radio sized unit. People might also be permitted to contact the driver in case of an emergency.

It is predicted that the number of road fatalities will be significantly cut by reducing the number of stolen cars, alcohol affected drivers, unlicensed drivers and fatigue related accidents. The cost of motor vehicle insurance is also expected to decrease as a result of the anticipated fall in vehicles reported stolen. The new licence card could also store important medical information for use in an emergency. In Sweden, where citizens have had a national identity card for over sixty years, and where the population has a great deal of trust in government agencies, the scheme is welcomed. In this situation, any concerns for privacy appear to be outweighed by the advantages sought.

Other applications developed using smart card technology include the replacement of *dog tags* by the External Affairs and International Trade Canada - Arms Control and Disarmament Division. Smart card is also being introduced as an employee card by the Canadian Federal Government Revenue Department to control secure access to computer systems within the taxation division and for internal audit purposes. Many pay television service providers have also incorporated smart card technology into their services to reduce fraud and assist with billing tasks. For example, BSkyB in the UK now has 2-3 million smart cards being used by the public to access pay TV services. British Gas also has a large number of smart card users to provide secure access and payments for gas. Gambling is another area where smart card has proved successful as a secure method of providing payment and as an identity card.

3.7 Conclusion

If we go by the smart card innovation trends revealed by examining the above range of applications, it seems the success of the smart card is assured and the generic market could aptly be described as wide open at present. It is also evident that the range of applications introduced to date have been limited in scope. Most cards in circulation are simple memory cards, anonymous and involve low levels of security. What this analysis of some of the applications and trials to date has also revealed is that ultimately, the least predictable variable in any of the new systems to be introduced, will be user acceptance. That is, even though there are many historical, regulatory, technical and organisational factors influencing smart card innovation, one of the most consequential is the role of the user.

One of the most important organisational factors influencing the decision to introduce a particular innovation emerging from the range of applications considered, is the ability of smart card to generate cost savings for organisations. This is true in health where the cost of managing paper files is high; in retail where the cost of handing large amounts of cash is large; and, in transit organisations where the boarding and payment times can be greatly reduced. However, social concerns relating to privacy and security do need to be addressed. When viewed collectively across the various industry cases discussed, the reasons for a high acceptance of anonymous and simpler smart card technology become self evident. This is largely because the migration process to larger and more complex systems will require both social and organisational adjustments over an extended time. This will require an evolutionary approach to smart card systems development.

Given the scale and scope of some of smart card projects described above, it is also not surprising that in many countries, consideration has been given to introducing - and even combining - national government services. The innovations required for the development of national schemes have the potential to significantly influence the future development of smart card technology. In particular, such systems will require the use of more advanced cards with higher levels of security and it will be necessary for a number of organisations to cooperate.

Chapter Four
The Role of the User in the Public Domain

Whilst the outcomes of Chapters Two and Three have primarily served to outline the technological development and applications of smart card from 1974 to 1996, they have also served to illustrate how smart card innovation depends on a large range of interrelated factors spanning technical, organisational - as well as social issues. Of special relevance here, is that one of the least predictable factors for more advanced applications, is the user in the public domain.

In addition, they have served to highlight an apparent contradiction concerning smart card development. Smart card industry development has been slow in comparison to other new information technologies such as the magnetic stripe card technology, ATMs, the VCR and colour television. In historical terms, it is also a fact that the smart card industry is still in its infancy as the majority of projects involve single and anonymous applications. This is despite the large amount of R&D funds being spent on the development of new systems, the low cost of the technology itself, and the competitive nature of the industry. The question addressed here is: Are there more dimensions to user acceptance in the public domain than so far considered by the industry? To shed more light on the issues these questions raise, this Chapter is therefore directed to examining the many aspects of smart card user acceptance. The focus is on the user as a private citizen in a democratic society.

4.1 What have we learnt from smart card trials to date?

Until recently, the apparent slow market development was attributed to a lack of social or user perspectives in the design approaches adopted (Walters, 1991: 288-189; Alexander, 1992: 20). Although there are no reported studies that provide information on attitudinal or behavioural data, several researchers have flagged user acceptance as being the most critical - as well as the most often overlooked - factor in the development of smart card systems. Yet, in a great deal of the literature, user acceptance has continued to be narrowly interpreted. In many cases, it has been equated to the rate of uptake of the technology.

Nevertheless, in recent years there is some evidence of a growing awareness of the importance of social issues such as privacy and the management of personal information (Cooper *et al*, 1996). It is also true that an innovation strategy that incorporates social considerations has been identified as an important aspect of technological development for new technologies where programmable personal information can be stored, retrieved and manipulated; and when the technology forming the basis for the system offers the potential for pervasive surveillance (Chaum, 1992). Smart cards possess all of these features. In addition, the majority of the potential users of smart card technology are private citizens. Studies focusing on user acceptance issues associated with trials and the implementations examined in Chapter Three, act to reinforce these findings. A comprehensive list summarising the collective findings emerging from the analysis of smart card trials to date has previously been identified by the author (Lindley, 1995b). A copy is provided in Appendix I (a) - (c). The factors identified have been aggregated into what can be broadly identified as: (a) technical factors; (b) social factors; and, (c) organisational factors. However, the interdependence of many of the factors is also recognised.

As can be seen, the extensive list of social considerations relating to user acceptance, suggests that user acceptance is a critical factor influencing smart card innovation. Along with other critical considerations such as organisational factors like cost and technological performance criteria, this would mean that a significant amount of innovation effort should be focused on social considerations.

At the heart of the identified user concerns is the issue of information management. Sensitive social issues, namely privacy and confidentiality, must be recognised as significant and these should be carefully addressed. Other areas of concern include, unauthorised access to data in the card, and a concern that existing services may be removed; or that new services will only become available to those with smart cards. There is also a need to ensure that the perceptions regarding security of the technology are soundly based and that clear operational guidelines governing the management and control of information will be developed. The need for availability, clarity, self-descriptiveness, conformity to user expectations, controllability, flexibility and reliability is also noted. From this perspective, and at an operational level, these factors may be further categorised into eleven (11) key user acceptance criteria. These are listed in Table 4-1. Some specific operational design objectives coupled to each of the identified criteria are also included.

At a more general level, it is worth noting that the classification provided in Table 4-1, could also be applied to the development of other information systems. For example, in the field of information systems (IS) analysis and design, these criteria have been incorporated into systems design tools to ensure that the systems developed meet the needs and expectations of the users. However, because of the nature of computing, the focus has been on ergonomic and software useability features of the system - and

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Table 4-1 **Classification of smart card user acceptance criteria with the associated operational objectives.** (*Source:* Lindley, 1994a) within the organisational setting. In the ATM industry, the same principles have been identified as being of importance. Yet, comparable tools for the development of smart card systems incorporating all the factors identified in Table 4-1 are as yet underdeveloped because there are a number of additional factors that are of special concern for the smart card system's design team. In particular, other information technologies do not have the capacity to provide a secure and portable information storage device that can be used for a wide range of applications.

The aim of this Chapter is therefore to examine a number of smart card user acceptance issues. In the context of emerging smart card applications, some of the dimensions revealed here have so far not been considered in the literature. In particular, a number of social dimensions unique to smart card technology, and underpinning the reasons for the concerns of the users and their relationship with this new technology will be described.

4.2 Privacy and surveillance

Privacy is a theme that continues to emerge from this study and has been identified as the area of most concern to smart card users. But what do we mean by the term privacy and how is it related to our understanding of confidentiality and security?

4.2.1 The concept of privacy

Although a highly complex concept, privacy is defined here as the right of an individual to limit access by others to some aspect of the person. By adopting this definition, privacy associated with smart card use is based on *informational privacy* so that personal information can only be accessed with specific authorisation. Thus, privacy is a broad term referring to the *unauthorised use* of personal information. In this sense, *confidentiality* is a special form of information privacy characterised by a predefined relationship between two parties such as between a bank and its customer; or, a doctor and a patient (Ware, 1993: 195). That is, confidentiality can be considered as a special status accorded to some information to indicate that it is sensitive and must be protected.

It is also important here not to confuse privacy with security. The idea of privacy, as defined here, is a social consideration and is based on cultural and ethical values. In comparison, the concept of security relies on technical considerations. In terms of the electronic information security required for many smart card systems, security considerations therefore encompass a set of technical and administrative procedures designed to protect informational systems against unwanted disclosure, modification, destruction, and to safeguard the system. The active security features of smart card have been considered in Chapter Two.

From these definitions, emerge a relationship between the concepts of information privacy, confidentiality and security. In the context of smart card technology, the relationship can be edified by the following example. If the security of a bank's smart card system is penetrated by an unauthorised individual, and results in a breach of confidentiality, then the users' right to privacy can be violated. As can be seen from this example, the concept of privacy in relation to smart card is tacitly linked to technological, organisational and social aspects.

Privacy in relation to smart card use must also be viewed in the context of all digitised versions of what are considered to be private information. That includes a vast range of information resulting from increased computerisation. When a range of new smart card applications is added to the already busy communications networks, large numbers of users are potentially linked to the additional service providers, retailers, the banking system in conjunction with government agencies. In this case, information will become far more difficult to protect (Plunkett, 1996). Already the issue of privacy and personal information held on computers is sparking major public debate.

> *Ironically, many of the conveniences being promoted to us as consumers - such as smart cards which can be loaded with credit, a bit like the way phone cards 'store' money - open more opportunities for data collection.* (Choice, February 1994)

It is this realisation of the increasing interrelatedness and vulnerability that is of central importance to the work reported here and may be summarised in the form of the following smart card privacy axioms:

(i) Individual smart card users prefer anonymity and value their privacy;

(ii) The concepts of privacy, confidentiality and security are closely coupled together; and,

(iii) The concept of informational privacy implies a relationship between social, organisational and technological considerations.

4.2.2 Privacy and the convenience-control conundrum

In Chapter Three, the range of possible smart card applications reviewed has demonstrated that this small piece of plastic can offer a lot of user convenience and can provide secure access to a whole new range of services and applications. However, associated with the many possible applications, is the potential for a surveillance society that would rival even George Orwell's vision.

Many now believe that digitisation is leading to further centralisation of government control and that this centralisation is creating what Roger Clarke, previously a reader in Information Systems at the Australian National University, Canberra, Australia has called "digital individuals" (Robotham 1995: 7) - those who will be subjected to increasing dataveillance and data matching by government and private agencies. Already considerable data matching surveillance systems are in use. Improved biometric identifiers are being used, digital telecommunications services making Calling Line Identification (CLI) possible, Closed Circuit Televisions (CCTV) deployed in public places in many major cities around the world are but a few examples of the surveillance systems now in use.

In Australia data from several organisations including the Land Titles Office, Australia Post, the Australian Customs Service, the Department of Social Security, the Department of Health can be matched. This is despite the assurances of the then Prime Minister Mr Paul Keating in 1988 that the Tax File Number (TFN) scheme would be used for tax purposes only. The Australian Government, like the governments of many other OECD nations, have learnt that when you introduce surveillance schemes, you apply them to projects that people are most concerned about such as road safety, tax evasion or social security fraud. The rational that is used to justify the massive increase in digital surveillance is that if you have nothing to hide, then you have nothing to fear. Smart card has the potential to rapidly increase the data profiles of individuals by bringing electronic surveillance more into the home. Home banking, home shopping, access to telecommunications services and digital home entertainment could be made securely. However, in an environment where privacy protection and regulation is inadequate to be able to address the privacy concerns of individuals means that not only our way of life, our habits, but also our perceptions of ourselves and social values will be altered. Do we want convenience at the cost of becoming *plugged in* digital entities?

How we as societies and individuals address this fundamental question, will exert considerable influence on future smart card innovation patterns. This choice also has the potential to significantly alter the social fabric of our society (Privacy Commissioner of

Australia, 1995). Further questions to be addressed are: Do we move towards becoming fully *plugged in* individuals and accept that our present concepts of privacy need to be altered to meet the changed needs of our supporting social structures? Or, do we need to work harder to retain our perceived rights to privacy and retain the social value system assumed by the present OECD guidelines, and consequently only accept technologies that retain our anonymity? Alternatively, do we forge ahead with our gradual acceptance of new technologies and hope that privacy regulation can keep pace with new developments and in the meantime accept that the price of personal and government convenience is a change in our perceptions of what we call *privacy*? Because all of these questions involve change that is social and regulatory in nature, smart card innovation will continue to require a high level of interaction between the users, the regulatory agencies and the technologists.

Smart card's potential as a personal medium for document storage and secure access is not in doubt. What is in doubt is the willingness of the legislators and regulators to address the users' concerns for privacy. The cost of providing secure and personal freedom through absolute user anonymity, is to be weighed against the social cost of escalating electronic fraud and abuses of the taxation and social security systems. This situation where the public's right to privacy and convenience has to compete with the government's right to be able to reduce fraudulent expenditure or misuse of public resources has come to be known as the smart card *convenience-control conundrum*. This is one of the most important factors that are likely to influence the shape and form of future smart card systems. As a consequence, there are growing concerns that smart card technology is emerging in a legislative and regulatory vacuum.

Nevertheless, as the amount of data about our own lives increases, the public continue to be told by governments to value the new technology for the administrative benefits it provides in the belief that the administrative advantages outweigh any disadvantages. The general claim is that the expanded use of new information technology will generally improve the quality of out lives, and help to provide us with a more informed or *information rich* society. Large interlinked national databases already exist in most nations. It is also not common knowledge how extensive and pervasive these networks have now become. In Australia for example, the process of numerous government departments swapping information is referred to as *data matching*. However, the Commonwealth Privacy Commissioner Kevin O'Connor describes it as "driftnet fishing" and the process occurs with minimal constraints. This process is conducted out of the public view as most are unaware of the extensive nature of the data matching now occurring. This invisible nature of data swapping stands in stark contrast to the publicly visible information exchanges that would occur as a result of the use of smart card systems. In the United States of America, it is also claimed that the arguments for unrestrained use of personal information are generally weighted in favour of the government. This national counter privacy posture is described by Ware as, "the fox watching the chickens in the coop" (Ware, 1993: 199).

Overall, the inconsistencies - and the degree of emphasis on public rather than private concerns - present a situation for privacy infractions to occur in the proposed multiapplication smart card systems. Already, it has been noted by researchers such as John Birmingham that the governments claiming to support democratic rights actually present a direct challenge to the underlying principles (Birmingham, 1995: 45-47). The anti-privacy postures now being taken by governments in relation to new smart card systems approximates George Orwell's vision of 1984 in which Big Brother is able to invade all aspects of an individual's personal life.

Many also now feel that the government is simply not seriously committed to data protection legislation (Birmingham, 1995). The general perception is that there is too great a time delay between developments in the technology and the legislative action required to address the concerns of the individuals. The actual resulting legislation is also seen to be weak and unable to address the concerns of the private citizens in an effective and practical way (Rowe, 1990:169). The lack of detailed codes of conduct and legislated exemptions to the regulation requirements are designed to better meet the needs of bureaucracies than the individuals they are supposed to protect and serve. The following section will therefore briefly consider the current trends in privacy legislation as a result of the impact of new information technologies - including smart card.

4.2.3 Inadequate privacy safeguards

The absence of a universally agreed definition of privacy, has been identified as a major impediment to the development of an international privacy doctrine upon which coherent regulatory and legislative frameworks can be developed. In the opinion of Sheila McGregor (1993) of Freehill, Hollingdale and Page, a legal firm based in Sydney Australia, the privacy of personal information that has been stored in digital form encapsulates the legal right of an individual to assume that the information:

- won't be subject to unauthorised access and dissemination;
- won't be retained or used for purposes other than those for which it was collected;
- won't be altered; and,
- won't contain prejudicial inaccuracies.

An associated user concern is the present lack of adequate safeguards to protect the unauthorised access of information. At present, several large smart card projects are being developed. A parallel observation is the inadequacies of existing government security of existing databases and the escalating costs of computer crime. In an Australian report recently tabled in Federal Parliament (Hilvert, 1995b), it was claimed that an audit by the Federal Privacy Commissioner of 152 Government agencies has found that:

- 7 out of 10 government systems had inadequate safeguards to protect against unauthorised access by staff to personal information;

- only 55 per cent of agencies covered computer security in their employee training programs;

- only 53 per cent had undertaken internal computer security or user access audits during the previous three years;

- only 41 percent of agencies had security policies endorsed by senior management;

- in outsourcing contracts 70 per cent failed to require their suppliers to adhere to the Federal Privacy Act;

- only 12 per cent had installed encryption protection on their national communication networks; and,

- only 4 per cent had encryption tools in use on their communication links between regional and State offices.

It is not the individual cost effectiveness or sensitivity of each agencies' data management that is of concern as these may vary. What is of concern is the overall low level of awareness and application of security measures to ensure that individual privacy can be safeguarded.

This relationship between concerns for privacy and inadequate security practices by government agencies is also paralleled by experiences in the UK. To illustrate this point further, James Davies reported on the spiralling costs of electronic crime in the UK and the associated lack of weak internal controls of information in government offices. It was noted that the value of computer fraud had risen by 183 per cent in the four years since the previous Audit Commission report conducted in 1990. Most fraud reported was committed by staff. It was also found that 60 per cent of staff had no security awareness training (Davies, 1994: 21). Yet, in the same issue of the *International Express*, it was reported by the Home Secretary Michael Howard, that a multi purpose identity card based on smart card technology would be issued to everyone in Britain by 1996 (Craig, 1994). The association between the two articles clearly ignores the failures by government agencies to address the problem of most concern. That is, the apparent lack of proper security practices on the networks that would form a critical part of the infrastructural support for such large scale smart card use. Such announcements also reflect the range of public opinions spawned by the apparent paradoxes arising from these developments. This is highlighted by the following comment:

> *But what a splendid way of keeping track of yobs and habitual criminals. One zap from a policeman's supermarket-type checkout gun and all would be revealed. Invasion of privacy? Absolutely right. And about time too.*
> (Brian Hitchen 1994: 30)

As can be seen by the above examples, smart card user concerns must also be viewed within the broader framework of privacy concerns relating to all information technologies. In particular, individual concerns for privacy, government aims of minimising crime, and the goal of creating administrative efficiencies all need to compete with the rights and privacy perceptions of the individual. In this context, it would seem that one of the reasons for the high level of demand for user participation is a result of user concern over control of access to personal information. User participation should ensure that user requirements and concerns are incorporated into the design of the system and its safeguards.

4.3 Privacy Protection

4.3.1 International treaties for privacy protection

For several decades, there have been a number of international treaties that recognise the growing public concerns about privacy of electronic information systems. These include the European Convention on Human Rights and a United Nations treaty that has been signed by nearly one hundred countries. However, the privacy goals are stated as principles that remain open to interpretation by the respective signatories. In the case of the United Nations treaty, the Covenant says,

> *No one shall be subjected to arbitrary or unlawful interference with his or her privacy, family, home or correspondence, nor to unlawful attacks on his or her honour and reputation.* (Article 17)

With the arrival of personal computers and the establishment of a global network of databases in the late 1970s, such statements quickly became obsolete or irrelevant in the light of the information handling capacity of the new technologies. As a consequence, the OECD had issued the "Guidelines for the Protection of Privacy and Transborder Flows of Personal Information" in September 1980. The guidelines were developed to address concerns about international data flows and to set out general requirements relating to the collection, storage and use of personal information. Since then, many member nations have established privacy legislation and codes of practice for handling personal information. Today, the guidelines remain the international benchmark, and they provide the main impetus for the development of national privacy protection laws in many countries.

In recent years, an Ad Hoc Expert Group of the OECD, has extended the 1980 OECD guidelines by providing more specific guidelines for the security of information systems to further direct national policy and legislative development. These are also intended to provide a uniform set of practices and procedures for the security of information systems that would apply to national border data flows and across public and private sectors.

4.3.2 OECD guidelines for the security of information systems

In 1990, the OECD's Information, Computer and Communications Policy (ICCP) Committee created a group of international experts to prepare Guidelines for the Security of Information Systems. The Group first met in January 1991 and was chaired by the Hon. Michael Kirby, President of the Court of Appeal, Supreme Court of New South Wales, Australia. The Guidelines based on the deliberations of the Expert group which met six times between January 1991 and September 1992, were submitted in October 1992 for approval by the ICCP Committee and the Council of the OECD. On 26 November 1992, the Council of the OECD 24 Member countries, adopted the Guidelines for the Security of Information Systems.

In brief, the Guidelines addressed the security of all information systems in both the public and private sectors (Kirby, 1993). It aimed to promote international cooperation in achieving security of information systems. The accountability principle states,

> *The responsibilities and accountability of owners, providers, and users of information systems and other parties concerned with the security of information systems should be explicit.* (OECD Guidelines, 1992: 8)

Clearly the intention is for accountability at the level of the individual. This focus on the individual is also clear in similar statements for principles of awareness and ethics. The multidisciplinary and democracy principles also emphasise the need for information systems to be viewed as embodying not only the technology, but also viewing the managing organisation and the individual users as a part of the system.

4.3.3 Legal and social consequences of International Privacy Rights (IPRs)

Already this push for international Information Privacy Rights (IPRs) has resulted in the development of legal and social consequences at the urging of the OECD. In determining the scope and constitutional right to privacy, the following example illustrates a shift in emphasis (Lindley, 1994a). In the US versus Westinghouse case, a US federal court of appeals has described five (5) factors that need to be balanced in determining the scope of the constitutional right of the individual to privacy:

- (i) the type of record and information;
- (ii) the potential for harm resulting from unauthorised disclosure;
- (iii) injury from disclosure;
- (iv) the adequacy of safeguards to prevent non consensual disclosure; and,
- (v) the degree of need of access.

In comparison, previous assumptions were based on the organisational protection of information. Now the emphasis is on the safeguards and individuals. The following case also reflects a shift in emphasis.

In another important US court decision on medical privacy, Doe versus Doe, a Federal Court of Appeals found that individuals have a constitutional right to privacy in data concerning HIV status (Lindley, 1994a). This ruling has at least two important legal implications for smart card development:

(i) Government officials who are found to violate an individual's right to privacy can be held liable for both damage and attorney's fees.

(ii) Information systems operators may be enjoined by the courts on the grounds that the system violates constitutional rights. In such a case, plaintiff's do not have to prove damages, only the possibility of data loss.

In the context of the above two examples, a carefully structured infostructure based on restricting data access to the smallest number of individual's possible becomes a constitutional imperative. Such a system is referred to as a *need-to-know* system. In the context of user acceptance of emerging smart card systems, it would need to meet the following challenges:

- security;
- individual power and control of information; and,
- management of the *need-to-know* system.

As a consequence of these developments, the regulation of privacy has occurred at many levels. It has developed within the suprastructures of several major international organisations spanning many nations and industry sectors. At the level of the individual nation, it has occurred at national, regional or state, and local levels. At the micro level within individual organisations it has also developed along differing policy levels as determined by the perceived privacy needs. However, in each layer within the broad privacy regulation arena, there is a convergence of attitudes in the sensitivity to privacy and policies continue to be developed within an agreed international policy framework.

Another type of privacy framework emerging is related to a move away from voluntary compliance with international guidelines and towards what can best be described as a coercive approach based on specific industry needs. The experience with electronic monetary exchange and trade for example, indicates that there are penalties for non compliance. In the case of global smart card systems, a particular organisation or nation might be excluded from participating in certain applications at some future time, if they do not have in place an appropriate privacy and security strategy.

Thus, from the point of view of privacy, it is concluded here that smart card innovation will be significantly influenced in two ways: First, the public's concern for privacy will continue to inhibit user acceptance of smart card technologies requiring the use of personal information. Second, concerns for privacy in the face of the development of international treaties on electronic privacy will act to bring about a convergence in national privacy legislation and implementation strategies. This convergence will be reflected in the type of technologies developed.

4.4 The level of need of the user

Another social factor that has influenced smart card innovation is the level of need of the user. Previous researchers have noted this as a key factor influencing the varying lengths of the time gaps observed between when the original idea was known, and when the users felt a need for the product. For example, in discussing the innovation of technologies such as the telephone, the x-ray machine and transistors, Cook and Morrisson (1961) discuss 4 degrees of felt need:

First, the case when need is felt in advance. In the case of smart card, the inventor, Moreno was motivated by his vision for smart card as a secure technology for the French banking community. However, the need was not felt in advance by any industry that might have potentially benefited from the technology. This has meant that smart card technology has often been described as, 'a solution looking for a problem'.

Second, there is the case of inventions where the need is felt only after the discovery or invention. Here too, the smart card industry has had to use considerable resourcefulness to convince the potential users of the advantages of using smart card technology.

Cook and Morrison's third category of need included those inventions where need was not felt until a long time after the discovery. In the case of smart card in the banking industry, it is apparent that the credit card business has finally found a need for smart card. The rapid escalation of fraud and the increasing level of sophistication of the perpetrators of credit card fraud is costing the industry millions. In fact, the levels are now so high that the banking industry is investing heavily in smart card technology. Similarly, escalating healthcare costs are now forcing many OECD economies to consider the introduction of healthcare smart cards in an effort to make administrative efficiency gains. It could be argued that it is these pressing needs that may be responsible for smart card technology finally being able to offer a solution for users who might be in the organisational setting or public domain. Thus, at one level it could be argued that the delay in adoption of the technology is at least partially due to a corresponding delay in the needs of the users.

Finally, a fourth category of need is what Cook and Morrisson call negative need - or actual rejection. The literature here too is sprinkled with cases where smart card has been rejected by the potential users and hence delaying the rate of diffusion. In Australia for example, the Australia Card debate raised such concerns for privacy of the individual, that the notion of a national identity card based on smart card technology was shelved (Smith, 1989). This is also supported by recent consumer research conducted by Mastercard on smart card acceptance. In January 1995, Mastercard released the findings of the first global qualitative study on consumer interest in SVCs (Malloy, 1995). The research was conducted in 10 countries around the globe. In brief, the study showed that:

(i) consumers would use a stored value card as an anonymous replacement for cash and not as a substitute for credit card transactions;

(ii) there was little difference between markets and across age groups; and,

(iii) the perceived benefits included convenience, flexibility, safety/security and peace of mind.

From these findings it becomes evident that potential users are not yet prepared to accept a smart card system where anonymity cannot be guaranteed. In other words, the needs felt are not yet great enough to convince users that they should give up their rights to privacy.

As can be seen, experiences to date reveal that a key factor influencing smart card innovation is the varying lengths of time observed between when smart card systems became technically and organisationally feasible; and when the users in different industry sectors actually felt a need for the product. In this sense, the level of need felt by the potential users has been a significant factor shaping the technology.

4.5 Social resistance to change

Another social mechanism that has influenced smart card innovation is social resistance to new technology. All societies have a built in resistance to change and major inventions often require social change to occur during the process of diffusion. This resistance is caused by individuals and by conservatism at the micro level. That is, it occurs at the individual user or small group level.

In the case of smart card, peoples' work and private habits are potentially changed. This is because smart card potentially alters their idea of money, privacy and security. Smart card users will be required to develop new relationships and trust the manager(s) of the new technology. They will need to be assured that their information is not only secure but also private. Additionally, they will want to be aware of the use made of their information and be able to assert some control over its use and distribution. In this sense, resistance to change is harder to address without also considering a wide range of other social factors that influence user acceptance.

At the operational level, the social resistance to change resulting from user concerns for privacy and a need for trust, has been effectively addressed by limiting the scope of the projects actually implemented so that anonymity is assured while at the same time designing the system to guarantee security. In other words, the fear of resistance to change, has been addressed by the industry by inhibiting further technical development and innovation. The alternative of developing the social tools to effectively address this resistance is only now being considered so that more advanced systems can gain user acceptance.

Finally, in looking at user resistance to change, it is also important not to overlook the experience of the banking industry. The banking industry's experience with magnetic stripe card technology has shown that there will often be strong, long-term and long-lasting resistance to change from the user (Bottge, 1989: 212). The process of adjustment is usually extended and continuous before a fundamental change in attitude or habit can occur. The industry has been made acutely aware of this and maintains that the expectations of the customer have not changed significantly over the last 30 years and that interest in new technology is only generated if the identified user criteria are met.

If we are to learn from the experience of the banking industry and from the findings of previous smart card studies, the success of the smart card industry will be highly dependent on overcoming social resistance to change. By addressing user acceptance criteria, smart card designers may ultimately avoid costly delays or rejection of newly installed technology.

The need to address the issue of social resistance to change, also foreshadows how multiapplication smart card systems are likely to give rise to new conflicts between the individual demands for personal privacy, and the demands of governments and private organisations to extend their surveillance nets. The conflict already represents a significant social trend and helps to emphasise the importance of the role of user concerns, regulations and data type criterion in the development of new smart card technologies. It is also likely that our understanding of the concept of privacy will develop dimensions far beyond what has so far been visualised. Some of these issues will therefore also be considered in the following sections.

4.6 User acceptance from the point of view of data type

Smart card innovation needs to be considered from the point of view of data type that is stored on smart card, and how this will directly affect technological design considerations such as the type of network required, cost considerations and consequent user acceptance. This dissection here focuses on the data type that directly influences user acceptance through: the type of data stored; card replacement costs; and, the likely level of user acceptance.

There are essentially 3 categories of data that can be stored in the memory of smart cards:

Token: Many smart card systems developers have realised that they could create a network similar to the Electronic Funds Transferral Point of Sale System (EFTPOS) where a customer can use the smart card as a simple debit/credit card in shopping centres, on public transport and at banks.

Security access: Another attribute that can be added to a smart card is identification for security access purposes such as building access, banking identification and validation that could reduce telecommunications cost and time.

Descriptive: Smart cards can also hold descriptive information such as passport details, driver's licence data or health information.

A generic form of a multiapplication card would involve the use of two or more different types of data. Each category of data can be further categorised as *volatile* or *non-volatile*. Volatile data needs to be updated while the card is in use. For example, a patient's medical history would need to be updated to record each set of new observations or drugs administered while being a patient at a hospital or as an outpatient. Non-volatile data may relate to a patient's profile such as their date of birth, address and sex. It is also worth categorising data as *critical* or *non-critical*. Critical data relates to data that the user cannot do without such as information vital to the user's identity or emergency treatment. Information that is non-critical is typically data that the patient can do without such as information relating to previous healthcare services.

Multiapplication smart cards can be used as data specific multiapplication smart cards, or as generic multiapplication smart cards. The data specific multiapplication smart card requires only one type of data used in a variety of applications. For example, the token card could be used to make payments at petrol stations, retail outlets or banks and operate like the EFTPOS system already in place. The use of a pre-paid data specific multiapplication smart card environment already exists. A generic multiapplication form would involve the use of two or more different categories of data. For instance, a generic travel card may be used for cash payments, whilst it may also contain medical records and insurance details.

Using these data type categories, a single application - or multiapplication - a decision table can be developed to provide a clearer decision-making process for the design team in the initial stages. The likely impact of data type on costs and user acceptance is shown in Table 4-2. These include how the type of data will affect replacement strategies and the different types of replacement strategies available. From the organisational perspective, multiapplication smart cards incorporating a combination of token, descriptive or security access data, provide network managers with a choice on what type of system to use when controlling the cards. However, the manager's choice is more restricted than the literature lets the reader believe. How long does it take? What steps are involved in the replacement process, what user acceptance issues need to be addressed and at what cost? The literature has yet to address many of the issues surrounding off-line processing and the procedures needed to guarantee a user that replacement cards are duplicates of the original. The complexity increases when different types of data are on the same card. It then becomes necessary to distinguish what one is to be manipulated at a given time, and what method of backup and security is required. In this case, the system should rely on both a distributed and centralised backup facility. By adopting this procedure, organisations can keep the volatile, critical data duplicated after every transaction, but leave the non-critical data alone.

DATA TYPE		DATA TYPE	REPLACEMENT COSTS	USER ACCEPTANCE
NON-CRITICAL	Static	Token	Not high	Very high
	Volatile	Token	Not high	Very high
CRITICAL	Static	Security	Not high	High
	Volatile	Descriptive	Very high	Low

Table 4-2 The likely impact of data type on smart card replacement costs and user acceptance.

Descriptive data that typically comes under the category of *critical, volatile* data is where card replacement costs are the highest. Other issues that plague this type of data include social acceptance issues such as privacy, ownership of information, information use and security. These are the areas that have been identified as extremely important before the possibility of descriptive, critical, volatile data becomes a mainstream reality both in terms of card replacement costs and user acceptance. Multiapplication smart cards that contain token or security access data and permit users to move between a number of different organisations, or from one service to another, without hindrance, appear to provide a real mainstream possibility. This is because the likely card replacement costs, data management requirements and user acceptance issues will all be easier and less costly to address. The fact that smart card technology can rely on centralised or distributed database networks also emphasises the need to develop ideas about network planning options for particular applications and user acceptance in relation to data type.

As can be seen from the above discussion, data type can directly influence the effectiveness of smart card systems through three key factors: the type of data stored; card replacement costs; and, the level of user acceptance.

4.7 The concept of an electronic silhouette

In examining the role of the user in smart card development to date - and as a by product of the research conducted - this study has found that smart card introduces an additional dimension of reflexivity. Smart card technology not only potentially enables the user to securely access a vast range of information and services, it also has the potential to provide the managing organisation(s) with a detailed trail of surveillance information relating to a whole range of user activities which other information technologies would otherwise not be able to obtain. In this sense, smart card has the potential to introduce a new more dynamic personal dimension to personal chip technology. Because of the potential of smart card systems to generate a very detailed and dynamic set of data that provides a uniquely identifiable lifestyle profile it can best be described as an *electronic silhouette* of the user. The electronic silhouette, as defined here, provides a digital image capable of mirroring a person's private and professional life. As a consequence, it could also dynamically alter an individual's lifestyle choices at different times. Hence, this additional dimension is also reflexive in nature. An electronic silhouette is therefore capable of adding another dimension to our perception of ourselves in relation to the technological systems that could become a part of our environment and social systems in a shareable and potentially public way.

Viewed from this intrinsic viewpoint, smart card is distinguishable from the other chip based technologies by a dynamic, reflexive and pivotal duality that has not yet been fully recognised. From one stand point, smart card can be applied to automate security functions, perform secure cash transactions and provide access to information according to a predefined logic. However, with smart card, these processes can provide more control, continuity and become more personal as they are related to the identity and lifestyle habits of the user. At the same time however, the technological systems have the potential to generate information about the individual(s) using the system. It provides a detailed electronic image by potentially combining all the activities of the card holder that would not be possible using existing technologies to deliver the same services.

Smart card therefore has the capacity to threaten our concepts of personal privacy and trust in data systems in ways that no other new information technology has so far challenged. That is, there is a recognition of the additional reflexivity that could exist between the individual and the design of a smart card system, that computerised systems alone could not introduce.

This duality is also not mutually exclusive. The ability of a smart card system to produce a trail of information about the user, like many chip based technologies, both derives from and enhances many of the functions the system has been designed to perform. It is quite possible for systems to be designed with an emphasis on automation and efficiency while ignoring the contribution or unintended consequences of information use - the core resource for the technology. It is at this point where there needs to be a full recognition of this dynamic and reflexive duality of smart card systems so that fully informed choices can be considered by all the stakeholders. There is the potential for managers to choose to exploit the technology's information potential. However, past trials have shown that the users will not readily accept the technology when this is a possibility.

The idea of these dual effects of the informational potential of technologies like computers are not new. In the context of computerisation, they were characterised by Zuboff (1988). Professor Zuboff has managed to bring together the future changing patterns of work and their wider philosophical significance as a result of the impact of computerisation. It is also evident that the true impact of advanced databases is only now becoming apparent. What is new here, is the added dimension of dynamic reflexivity and the capacity of smart card systems to provide an electronic silhouette capable of altering our fundamental perceptions of ourselves as a part of the technological systems introduced. This is where a further convergence of the sociologists and the technologists is foreshadowed.

However, when we consider smart card technology, another distinguishing factor is also to be noted. Smart card can be owned and operated by the user from anywhere on the network and thereby becoming one of a very large number of potential users in an *open system.* It also replaces functions which traditional methods provided - but with absolute anonymity. To pay for a bus journey using cash meant two things: First, anyone could use the same cash in the transaction. Once transacted, there is no record of the transaction that can identify the user. Once a smart card system is introduced that does not, or cannot guarantee anonymity, all the funds stored on the card or potentially accessed through use of the card become vulnerable. How does the user know how visible these transactions are to others on the network? How can the user be assured that increased access does not translate to increased vulnerability? It is a fear of many that frequent electronic transfers often taking less than 0.2 seconds, could become compulsory; thus making the user highly visible in a real time/location context that doesn't yet exist. When this type of electronic silhouette is compared to the case of computers, there is a fundamental difference in user perceptions. On the network a fixed computer is the only identify known to the network, unless otherwise programmed. By using the computer, the user can be sure of remaining relatively anonymous. The types of applications designed for a computer are also less reliant on the identification of the user and it would be more difficult for the user to perceive themselves as a part of the system. For example, to use a computer for word processing, there is no need for the user to be identified for the service to be provided. However, if the same user wants to use smart card for pay TV access, there is a need for a higher level of security and hence the need to increase the informational or electronic profile of the user. The system needs to be capable of identifying the individual, or individual account to be billed, plus the time and type of viewing service that was provided.

In this examination of smart card user acceptance issues, it is therefore maintained that it is the potential for smart card systems to create a dynamic electronic silhouette of the user, that brings about the need for radical change in the way user acceptance is perceived. In this context, it also has the potential to alter the intrinsic nature of the way information is perceived and used by society. In addition, it also presents fundamental new choices for our future and the way in which the individuals both in society and within organisations, will each become more accountable in managing and using the informational capacity of intelligent technology involving personal information. It is this realisation of the sense of dynamic reflexivity implicit in the concept of an electronic silhouette created by smart card technology that has relevance for the central problem of this study.

Further, it is concluded here, that if this duality is not considered to be an important factor influencing smart card user acceptance, then the unintended consequences will be predictable. Already, the slow uptake of the technology has not been predicted. Yet, we have only begun to consider the introduction of systems that will challenge our ability to understand this duality. It is contended that smart card has so far evaded conventional categories of description that are used to understand the innovation process, because the technology is not understood in these terms.

4.8 The growing gap between smart card technology and the creation of new social structures

Another factor identified as inhibiting user acceptance is the time delay between the introduction of smart card technology and the implementation of appropriate social structures to support its use. The hiatus between technological development and working out the details of the new political and social orders resulting from the implementation of the new technologies was first described by Lewis Munford in his classic work entitled *Technics and Civilisation* (Munford, 1934: 417) in the context of computerisation. He also referred to the need for "irrational and instinctive" thought input to produce the social transformation for the new order. More recently, Shoshana Zuboff, has also observed that,

> *So far patterns of morality, sociality and feeling are evolving much more slowly than technology.* (Zuboff, 1995: 162)

At the regulatory level, the regulators themselves have also noted the challenges associated with ensuring that the development of the legislative frameworks keeps pace with new technological advances. Researchers such as Hilvert (1995a) have noted that this slow progress made by governments could severely inhibit new technology innovation. In addition, there is the realisation that the process can result in conflict between the design team and the potential users of a system (Guimaraes and McKeen, 1995). The full extent of the role of the potential user has been largely ignored. Many smart card projects have already experienced considerable financial loss resulting from the lack of understanding of the system in this broader context. However, the realisation of the lack of understanding has also meant that the potential of the technology has been limited to the closed system environment where our new understanding has not been challenged. By neglecting the unique capacities which smart card offers, and by ignoring the need for new visions of the role of the technology, we might continue to forfeit the benefits it can deliver.

Here it is foreshadowed that as the large multiapplications projects potentially enveloping the telecommunications, banking, health, home entertainment and retail industries become a reality, this hiatus will widen unless we adopt a more broadly based view of the relationship between technological development and society. This implies the adoption of a new paradigm that can be used to develop a new social vision of our view of what binds our social, technological and organisational systems together during the process of innovation. As a consequence, part of this thesis has been devoted to examining ways to create the organisational and social conditions in which new smart card concepts can emerge that will be able to exploit the unique and as yet largely untapped capacities of smart card technology. Will there be designers who understand the crucial nature of these interactions in a way that can add value to emerging smart card systems? If not, we will continue to be stranded with a new technology offering only old solutions. That is, the public will prefer to continue to accept applications and based on non-critical data or when user anonymity is assured.

4.9 Defining the relationship between smart card and society

The absence of a universally agreed definition of technology is recognised as a major impediment to the development of our understanding of the emerging relationship between smart card technology and society. For the purposes if this investigation, Dosi's (1982) definition of *technology* has been adopted. According to Dosi, the concepts that technology embodies are broad and may be conceived as:

> ...set of pieces of knowledge, both directly "practical" (*related to concrete problems and devices*) and "theoretical" (*but practically applicable although not necessarily already applied*), know-how, methods, procedures, experience of successes and failures also, of course, physical devices and equipment. (Dosi 1982: 151-2)

This definition is useful here in that it is sufficiently general to include the possible application of new or established theoretical understanding of technology, whilst recognising the practical aspects. This is important as one of the features characterising new and more complex information technologies in today's society is the growing interrelation between the applied and theoretical aspects of technology, and innovation. At a more general level, the blurring of the boundaries between the applied sciences and technology is one of the defining characteristics of the information industries in the new information based society and noted by industrial economists such as Freeman as early as 1974 (Freeman, 1974). This point is expanded upon in the analysis provided in Chapter Eight.

This is also important here, as the definition is sufficiently broad to embody social inputs such as those built on experience. That is, as the technology grows more dependant upon human inputs, the social system within which smart card exists and the smart card system itself, become more a part of each other. These boundaries will become blurred as the technology develops to become more of an integral support system for our lifestyle and our work organisations. In doing so, it becomes a part of the social system, just as much as the social inputs become a part of the technological system. Thus, social intelligence and human creativity become a greater part of the technology as the technology becomes a greater part of the social system. This conceptualisation of smart card is necessary here if we are to include society as a part of the technological system. At a more general level, this view of technology is also supported by previous researchers such as Westrum (1991).

> *Technologies are not isolated things; rather, they are parts of systems of human action.* (Westrum, 1991: 5)

We need social institutions that are able to respond to the growing complexity of technologies. This requires social intelligence and regulation. But is society now ready to cope with the interventions that widespread smart card use could introduce? Are our regulatory bodies equipped to cope? In the context of this analysis, these are important questions because the ability of our institutions to predict and respond to changed social conditions which smart card could bring is crucial to the development of the technology and the type of relationship that will develop between the technology and society. Learning to cope with this new technology will also therefore require a degree of human creativity and it will rely on immediate feedback.

4.10 Conclusion

As can be deduced from these remarks, user acceptance is not a simple issue to address. Nor has there always been an awareness of the importance of the user in smart card innovation. Initially, most research efforts and designers of smart card systems viewed user acceptance as the number of users, or the rate of uptake of the technology. However, this interpretation does not allow for the many other dimensions that also need to be considered as integral parts of the innovation process.

It is therefore concluded that, in the case of new information technologies like smart card, it is now necessary to adopt a broader view of user acceptance. In this sense, any new view needs to be able to integrate the dimensions identified here and which are related to individual perceptions, social issues, the technology itself, as well as the organisation managing the technology. The data types, database network structure and cultural interpretations of privacy and security related issues, are all interdependent factors to consider. Smart card technology should therefore incorporate an *open systems* approach based on the need for the user to be viewed in a social context, and as an active - and reflexive - part of the technological system. Together, the technical and social components of the system become actively engaged in some task that is managed by an organisation(s), or social group(s).

This conclusion also foreshadows the emergence of a new paradigm governing our thoughts on technologies like smart card that emphasises the more active and reflexive relationship between the new technologies and society. That is, as more advanced smart card systems are developed, our perceptions of ourselves through the creation of our own personal *electronic silhouettes* will be enhanced as we become more aware of our relationship with the technology. It also foreshadows the need to adopt what Davenport (1994) has referred to as a more human centred approach to the design and use of new information technologies like smart card.

Given this perspective, a comprehensive approach to developing our understanding of smart card systems' design that emphasises the possible social dimensions in the public domain, as well as organisational and smart card systems interaction, becomes essential. This implies the adoption of what is traditionally termed *sociotechnical* design principles. Sociotechnical theory describes the complex relationships between people, organisations and technology. In the past, it has provided a basis for analysing and designing new technological systems so that social, technical and organisational objectives can be optimised. In the light of the combined findings of Chapter Two and Three, Chapter Four therefore examines sociotechnical schools of thought in an attempt to advance a sociotechnical framework that can be used as a theoretical organiser for the research reported in the chapters following.

Chapter Five
Smart Card Innovation as a Sociotechnical Process

A critical evaluation of the outcomes of the preceding analyses suggests that there are a number of interrelated forces that have influenced smart card innovation. These forces span social, organisational and technological considerations. This suggests two things: First, it does not make sense to talk about smart card as a stand-alone technology. It needs to be viewed as only a part of a system that requires the support of technological infrastructure, organisational infrastructure and social acceptance. In this sense, smart card technology implies a *sociotechnical* system. Second, the results also support and suggest that there is a need to review and reframe our understanding of innovation by extending existing paradigms.

In the context of these findings, the aim of this section is to examine smart card innovation from within a sociotechnical framework. The key question asked is: Is a sociotechnical framework useful as a theoretical organiser for furthering our understanding of smart card innovation?

5.1 The foundations of sociotechnical theory

5.1.1 What is sociotechnical theory?

The term *sociotechnical* implies two fundamental concepts: a social system and a technical system (Cummings 1985: 168-169). It has been reported that the term *sociotechnical* was first used in the belief that,

> *... organisational objectives are best met not by the optimisation of the technical system and the adaptation of a social system to it, but by the joint optimisation of the technical and social aspects, ...* (Cherns 1978: 61-71)

In the past, sociotechnical systems theory has provided a basis for analysing and designing systems so that social and technological systems are jointly optimised. However, it is important to realise that because there are diverse conceptualisations of the organisational social system and technology, many dimensions of the term *sociotechnical design* exist.

Sociotechnical theory is therefore both a philosophy and it is a method. As a philosophy it is able to support and justify the need to value empowerment of the individual through education and participation in the innovation and design process when new technologies are being introduced. As a method, sociotechnical principles can be used to deliver jointly optimised solutions. This also means that a systems approach to the development of new technology is implicit. This combination of philosophy and methodology provides the basis for theoretically informed innovation strategies that can be used to deliver a more informed approach to the development of new technological systems.

In this sense, all new technologies involving users and organisations can be viewed as a sociotechnical system. Today every organisation contains both a technical and social subsystem that combine to produce output and to make a profit. The purpose of the organisation is defined by the individual employees who constantly strive to achieve the long term goal of improving organisational performance by designing and redesigning the structure, processes and technology.

Modern society too contains both a technical and social subsystem. However, the individual members of society, or citizens, combine to produce a better quality of life as defined by their cultural value system. Both the organisation and society can in this sense be viewed as purposeful sociotechnical systems undergoing a process of design and redesign. In other words, they both have the characteristics of flexible and adaptive systems.

5.1.2 Sociotechnical experimentation

The development of Sociotechnical research can be traced back to a paper by Trist and Bamforth (1951) on the social and psychological consequences of the longwall method of coal mining (Herbst 1974: 3-20). Sociotechnical theory also became the guide for the Work Democratisation program in Norway in the 1960s, and to a lesser extent, Australia in the 1970s (Fox 1990: 259-280; Mathews 1989: 92-94; Sandberg 1985: 79-91). There has been renewed interest recently and it has evolved on broader principles to accommodate the sociotechnical changes that have arisen since its inception (Taylor 1986; Mathews 1989; Aungles and Parker 1989; Laudon and Laudon 1991).

The main principle that has emerged from previous studies has been that an effective new technological system might evolve as an interactive, time-dependent process in which technological aspects and social values are played off against one another in the search for a durable overall systems design. Figure 5-1 provides a summary overview of the development of sociotechnical theory and its application.

Until 1959, the chief purpose of sociotechnical studies had been in trying to find a solution to the problems of the mining industry. Work continued and in 1959, Emery, in a review of the field, stressed the importance of viewing sociotechnical organisations as *open* systems (Herbst, 1974). The result was the realisation that any objective to be achieved would need to be through the joint optimisation of the technical and social aspects viewed as integral parts of an open system.

Sociotechnical theory also became the theoretical beacon leading the Work Democratisation program in Norway in the 1960s, and to a lesser extent, Australia in the 1970s. It was associated primarily with the work of three identifiable social scientists: Australian Fred Emery; Briton Eric Trist; and Norwegian Einar Thorsud (Sandberg, 1985; Mathews, 1989). It is also the sociotechnical school of thought that is credited with the development of the notion of workplace autonomy as an alternate to a bureaucratic, hierarchal Taylorist model of work organisation. These works also had a distinct advantage in that it was dependent upon the successful outcomes of experience.

A new stage of development became possible after 1962 when sociotechnical experiments in a number of industries began. In most of the studies that were done before 1974, the approach had been to study a technological system, and then design a more appropriate social system. Possibly a more critical problem emerging, and in part accounting

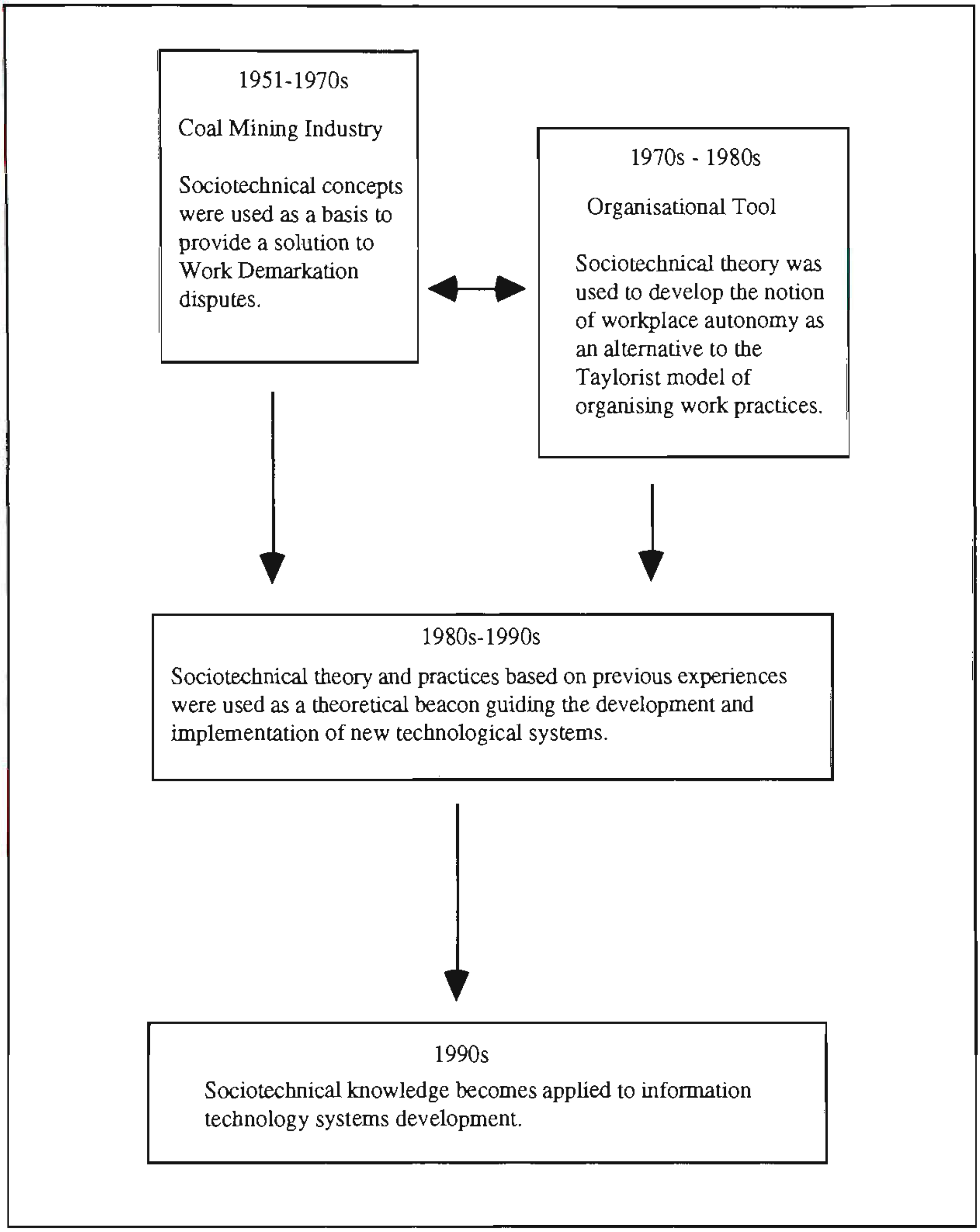

Figure 5-1 Summary overview of the development of sociotechnical theory and its application since its inception in 1951.

for the growing attention focused on these early efforts, was the increasing rate of technological change and the revelation that work on the organisational side of the problem by itself, would not be sufficient. Another difficulty was that technological development itself was previously viewed as a process over which we have no control. It was not considered that the development of technology could make possible a choice between a wide range of technically, socially or economically feasible alternatives.

A good way of illustrating how the sociotechnical tradition of design and analysis for solving problems is provided by the Telecom Australia case study leading to the *Technological Change Agreement* of 1980 (Mathews 1989: 70-2). In the 1970s, Telecom investigated the replacement of electromechanical exchange technology with computerised equipment. The Australian Telecommunications Employees' Association (ATEA) did not oppose the proposed technology - but the work reorganisation proposed by Telecom. In settling the dispute strike, the Arbitration Commission decreed that the two systems be trialed and evaluated in parallel for an experimental period. The criteria for evaluation included were work efficiency, job satisfaction and public interest. The manner of settlement proffered a unique method of evaluating competing claims regarding the social impact of the new technology through a controlled experiment. The outcome of the evaluation was that the ATEA approach proved superior.

This sociotechnical experiment led to the historical Technological Change Agreement of 1980 that acted as a model for other industries in Australia. The agreement required Telecom Australia (now called Telstra) to inform unions of its plans to introduce new technological systems at each of four stages: (1) at contemplative and feasibility; (2) at specifications, tender and purchasing; (3) at trial; and, (4) at operation stages.

This case also helps to support the view that technological change and restructuring takes place in the smoothest fashion when firms adopt a consultative process and the actual implementation is generally better and faster because of a prior commitment. However, in using this historic Australian experience, it is important to realise that the particular sociotechnical approach adopted need not be restricted to solving disputes, nor to reaching agreement between the unions and the organisation. The principles involved can be extended to provide a practical tool for the effective design and implementation of new technological systems in many organisational settings.

As a baseline for comparison with other experiences, some North American experiences will be briefly reviewed and compared.

Among the earliest interest shown in the use of sociotechnical systems in North America began with the design of the Aluminium Company of Canada's (Alcan) continuous processing ingot casting plant in Arvida, Quebec in 1968. Sociotechnical knowledge was used for several redesign efforts involving continuous process operations, maintenance and materials handling. Another North American pioneer of sociotechnical knowledge was Proctor and Gamble (P&G). P&G adopted their own propriety open systems planning methodologies for training managers and engineers as well as designing new plants many times. More recently, a previous employee of P&G has published a review of the systems methodologies developed during this period that provides considerable insight into the propriety sociotechnical strategies pioneered during the period 1968 to 1980 (Hanna, 1988). In 1973, General Motors (GM) also began its commitment to sociotechnical plant design principles as they had much to learn from the Scandinavian successes reported by companies like Volvo and SAAB. Other continuous process facility designs involving sociotechnical intervention strategies have been reported in North America (Taylor and Felton, 1993).

In the public sector, government agencies have also used sociotechnical interventions since the early 1970s. However, collectively these experiences have shown that employee participation alone is not sufficient for the principles to work in practice. It was found that the organisational interests and objectives of the bureaucratic establishment involved also needs to be incorporated into any methodologies adopted that require the participation of upper and middle management. It could be argued that this should have been obvious to the systems developers. However, what is not fully appreciated by some of the critics is that the idea of viewing processes from a system's framework has evolved slowly and it is experiences such as these that have enabled our knowledge on the practical considerations to develop.

Even in the late 1980s and in the 1990s our understanding of what constitutes a sociotechnical design has undergone considerable change in the light of new industrial realities and our cumulative experiences. Several high tech companies such as Digital Equipment Company (DEC) and Hewlett Packard (HP) have also redesigned their manufacturing processes in the 1980s. The first application of sociotechnical knowledge to engineering work also began in about 1982 (Taylor *et al*, 1986).

Sociotechnical analysis has now entered the computer-based system's design arena. In a study reported by Wilkof (1991), sociotechnical theory was used to highlight the importance of developing relationships between the technology service groups and the end users within an organisation. Such studies have also emphasised the necessity for the technology service groups to develop a different view of their role within the organisations. That is, the technologists responsible for designing the computer-based system need to view the users as an essential part of the technical system rather than as a nuisance or uncontrollable external factor.

It is also evident that there is little consistency between the methodologies adopted across sites. However, all of the studies reported a similar understanding of the importance of the main sociotechnical goals and the objective of goal oriented participation. The emerging principles and how these relationships can be used to provide a basis for the sociotechnical methods used in practice, are summarised in Figure 5-2.

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Figure 5-2 **A model of a sociotechnical system. A sociotechnical system is one that is developed to blend the needs of the organisation with technological efficiency goals and with sensitivity to the social considerations.** (*Source:* Lindley, 1994a)

In practice, sociotechnical design methodologies aim to produce a technological system that blends technological efficiencies with organisational needs and social sensitivity. A sociotechnical system may therefore be thought of as a system in which all of the key stakeholders are required to participate in the development of an agreed program for the development and implementation of a new technological system. Over the past thirty years, sociotechnical systems theory has been developed as a methodology. The major shift in understanding of the application of the systems paradigm has been from its focus on improving overall organisational effectiveness to include TQM and productivity, through to emphasising the need of empowering participants with information in the information industries of the 1990s. This means it can be expanded to embrace multi dimensional technologies such as smart card.

However, there is one major difference. Smart card technology often requires the participants to be outside the organisational setting, thus adding a key focus and emphasis on the understanding and workings of a public dimension. Society and the regulatory systems that support and represent social interests in the public sphere therefore become a necessary part of the sociotechnical framework. It is this later shift in emphasis that will be the key focus of this study. The increasing amorphous nature of the organisational environment and the social system with which it interacts, now makes it necessary to embrace a multi dimensional framework for analysis purposes. Accordingly, there is a renewed interest in sociotechnical theory and a wide range of active sociotechnical design and redesign approaches are now in operation. There are also numerous sociotechnical training courses designed for employees and practitioners in the field and across many industries.

5.1.3 The development of sociotechnical thinking

As can be seen from the preceding discussion, sociotechnical concepts have evolved from the early 1950s, when it was viewed as a process response to the introduction of new technology. Since then, it has become, firstly an area of sophisticated inquiry; and secondly, an analysis approach suitable for gaining an understanding of the essential nature of an organisational system. It has also become a perspective suitable not only for the individuals working in a work environment, but for the organisation as a whole, and an effective approach to designing and redesigning systems. Most recently, sociotechnical systems theory has been used as an application tool - to design and improve the development and implementation of new systems. It is the latter application that provides the broad theoretical framework for the approach adopted in this study. Furthermore, it should also be noted that the sociotechnical school has never become a dominant force. Yet, it has now been adapted and based on broader principles to accommodate our changed understanding of technological systems since its inception.

In parallel with the development of practical sociotechnical experience, universities too have expanded our theoretical understanding of sociotechnical systems theory. They have also produced case studies and theoretical contributions. The current level of interest in the development and application of sociotechnical theory ensures that it will remain entrenched as a holistic and systemic method for developing a more comprehensive approach to systems design. The pace of continued structural and technological change also provides a proven paradigm for emphasising its use as a method of advocacy for people and their values as we design and redesign new systems.

5.2 Sociotechnical theory as a methodological framework

The most important aspect of sociotechnical analysis emerging from the preceding analysis, is that it has been useful in establishing practical and theoretical alternatives to Taylorism; and, it has provided the guiding principles needed to develop new technologies with better social relations.

It has also become evident that there is no single model of a sociotechnical system. New forms need to be generated, drawing on experience obtained elsewhere, but solving their own unique problems. The study of smart card innovation therefore presents a unique opportunity for analysis from a sociotechnical perspective; with particular emphasis on information aspects of the technology relating to previous and potential innovation changes. The focus of the sociotechnical framework adopted is thus to emphasise the importance of the maintenance of this freedom of a society to manage the new information technology systems in an agreed manner. Another important consideration emerging from the previous section is the steps involved in the sociotechnical process itself. These stages are summarised in Table 5-1.

The first point to be noted is that the sociotechnical process begins with the development of an appropriate system's model. Questions relating to whether the system is confined to the setting of a single organisation, or to the global environment need to be addressed. The process then involves the identification of the organisational objectives, the user sensitivities and the technological parameters within which a system can be developed. A process of optimisation, redesign and evaluation then occur. Because of the reiterative nature of the sociotechnical process itself, these are then repeated so that the system can continue to evolve during its lifetime.

At another level, it can also be seen that the development of our sociotechnical thought has involved a paradigm shift in the way technological development is viewed. In the process, our gaze has shifted from the technology and towards open systems thinking where the technology exists as only a part of a social system - and also mediated by organisational considerations. In the case of smart card, it enables us to observe that the technology cannot exist as an independent item.

This means that, in adopting a sociotechnical view of innovation, the technology itself takes on a broader contextual meaning. Instead of being limited to passively shifting resources to where the returns appear to be greatest, the real issue becomes one of how organisations, potential users and the technologists work together to gain mutual benefit and reward from a new technological system.

THE SOCIOTECHNICAL PROCESS

1. DISCOVERY

- PARADIGM SHIFT, DEVELOPMENT OF SYSTEMS MODEL DEVELOPMENT OF SOCIOTECHNICAL METHOD

2. SYSTEMS EXPLORATION

- SYSTEM SCOPE AND OBJECTIVES DEFINED
- ENVIRONMENTAL SCAN TO IDENTIFY ENVIRONMENTAL DEMANDS

3. SYSTEMS ANALYSIS

- TECHNICAL ANALYSIS (VARIABLES IDENTIFIED)
- SOCIAL ANALYSIS (SOCIAL SYSTEM PARAMETERS AND CRITERIA)
- ORGANISATIONAL ANALYSIS (ORGANISATIONAL PARAMETERS AND OBJECTIVES)

4. INITIAL DESIGN BY JOINT OPTIMISATION

- DESIGN PRINCIPLES
- FEEDBACK AND CONSTRAINTS
- RISK ASSESSMENT

5. REDESIGN AND IMPLEMENTATION

6. EVALUATION AND REDESIGN AS A REITERATIVE PROCESS

Table 5-1 Stages of the sociotechnical process.

Instead of simply maximising within fixed constraints, the question of innovation then becomes one of how to change the constraints. Instead of only deploying a fixed pool of organisational resources, a more important challenge is how the potential users and managing organisations can improve the quality of factors and hence together design new technological systems that improve the quality of life. Where the factors are, can be tapped through individual, local, national or global strategies.

It also becomes apparent, that in the case of complex smart card systems, a good test for predicting organisational behaviour in relation to the management of private information and large financial transactions, is the legal framework within which the managing organisations operate. It makes sense for the interests of all organisations and potential users of a system, to operate in an environment where the operational control and management of the new systems are regulated in advance. From this point of view, the current regulatory and legal environment influencing smart card development is too fragmented and behind the user needs now expressed, if smart card is to solve problems. For example, if smart card is to used for gains in administrative efficiencies in the health industry, then the appropriate regulations covering concerns such as privacy and patient confidentiality need to be introduced in advance.

5.3 Sociotechnical thinking and smart card innovation

If we now turn our attention to smart card innovation in the public arena, two main sociotechnical issues that have been highlighted in previous chapters, need to be addressed. These are the public concern for the protection of privacy and the misuse of personal information; as well as the subsequent demands for user participation. In an attempt to view smart card innovation as a sociotechnical process, each will be considered.

5.3.1 Public concerns for privacy and the misuse of data

Unfortunately citizens in many developed nations, have begun to think of privacy as an endangered right and as something that can only be protected through public action. The invasion of computers in the 1980s has caused the need for a new look at privacy issues. The rise of such concerns is also now reflected by the social restructuring of, and accountability for, personal data management and control (Rule 1980: 23-5; Flaherty 1989; Kirby 1993). Together, these experiences have also served to illustrate how the emergence of new ways of recording, transmitting and handling information will result in the need for new approaches to innovation for systems involving the use of personal information. By far the most frequently expressed concerns for personal privacy, have been those relating to the demands of governments and powerful private organisations. The current growth of modern organisational and institutional surveillance now represents a major public concern.

These experiences would suggest the need for a sociotechnical approach to the design of new technological systems - particularly new smart card systems that are required to manage personal information. It seems that protecting privacy by limiting the extent of unwanted surveillance is now a vital activity since it is likely that individual users cannot do it for themselves in the face of new changes to information management procedures.

One of the early claims made was that smart card could protect the privacy of the user because information could be stored and held by the owner of the card without the need for access terminals to be on-line (Bright 1988: 148). However, in practice this may be difficult to demonstrate to the public, particularly as telecommunications networks become more advanced and extensively used. In fact, in today's network environment users may have to rely on trust that the operators of the system will not manipulate or access information without the user's knowledge. The operators will also need to be able to convince the public that their security systems are also adequate to prevent other interests from accessing the system.

A sociotechnical approach to smart card involving user participation would thus seem indispensable for limiting collection and usage of the personal information of smart card users. Consequently, the appropriate sociotechnical model for smart card technology therefore requires a balancing of competing interests or values by both organisations and users, and is dependent upon a properly informed user base. In such a framework, the user claims to privacy must compete with the organisational right to use personal information for legitimate purposes - subject to fair information processes.

This raises another issue of concern, 'How can we avoid technologies which we do not want to have?' This question clearly illustrates the central problem - the control and distribution of power in controlling the technology. According to Chaum, the choice between keeping the control of information in the hands of individuals or the managing organisations is being made each time another set of transactions is designed and automated (Chaum, 1992). Here, the problems associated with the control and distribution of information are also related to power, and the growing knowledge gaps between the potential users and the organisations gathering the information, are far more difficult to address in the longer term.

Thus, it can be seen from the considerations highlighted so far, that it is not smart card technology that will be of greatest concern. It will be the ability to implement the principles underlying a sociotechnical approach. This will be necessary to be able to identify and attend to the needs and concerns of the users who are in the public domain.

5.3.2 Participation and sociotechnical design

The Aristotelian mode of participation has been passed down through the ages. Rousseau, and others believed that participatory society was a desirable end in itself, irrespective of how it managed its affairs. Yet, it has only been in recent years that participation has been considered to be a beneficial part of the process of technical change. Politicians are now seen to talk more about the need to involve the public in technology and security policy formulation. Trade unions are making similar efforts and corporate management programs now involve more employee participation in the decision-making process.

The potential beneficiaries of the new technology may also prefer a participatory approach because they believe that participation is a democratic and moral right that people should be able to determine their own destinies. In this sense, participation may be seen as a way to produce a committed and aware potential users' group; and therefore assisting in the avoidance of problems as a direct result of the introduction of change in the way people manage, store or retrieve information. It is also possible however, that some could favour participation as a means to persuade potential users to accept change that would otherwise be rejected. That is, for what appears to be a negative reason. For example, bank customers could be persuaded to conduct most of their banking and payments from home through fee structures. In this case, participation becomes manipulative rather than democratic.

The question now remains for those that believe in the participation process - either for pragmatic or ideological reasons - how can we make it work at every level. One pre-requisite for a participatory approach is that it is desired and accepted. This requires the development of shared values and objectives, as well as allowing mechanisms for human and social development to emerge. In general, it is a quest for *socially acceptable* control, rather than for authority. Mechanisms to enable the locus of power to shift if difficulties arise, also need to be developed.

Participation in this sense may therefore be seen as an essential element of the process of change which new technologies like smart card may introduce. Here, the demand for user participation in smart card innovation becomes desirable. This would also suggest the need for a sociotechnical approach in which participation can be used as a valuable educational and democratic decision-making tool for the development of an appropriate strategy for the design and introduction of smart card.

5.3.3 A sociotechnical view of smart card innovation

How then do we develop a sociotechnical approach suitable for the effective design and implementation of smart card systems? The first thing to be noted from the previous discussion is that a lot depends on the objectives. Once these are established, we can communicate any principles of sociotechnical design in this context. In practice, the process of optimisation of a social and technological system is complex and will require an understanding of the following: (1) the organisational and social processes that occur; (2) the technological processes used by the organisation and the user as well as the constraints that these may place on the design features; and, (3) the most acceptable mechanisms for change both in the execution of the initial design and in providing for ongoing adaptation to new environmental demands.

It is also important to realise that sociotechnical theory describes the complex relationships between people, tasks and technology, and helps us to determine how these can be used to advantage. According to Pasmore and Sherwood, sociotechnical system theorists view an organisation as an open system that is actively interacting with its environment (Pasmore and Sherwood 1978: 4). As organisations have themselves become more amorphous in the mid 1990s, it has now become essential to adopt this view. Thus, sociotechnical theory is itself susceptible to change and sociotechnical design is, by its very nature, a reiterative process. As soon as a design becomes implemented, its outcomes may indicate the need for redesign.

In practical terms, the two key principles of sociotechnical design emerge from this analysis and which can be stated with brevity as:

(i) make the technical design compatible with the organisational goals and users' concerns; and,

(ii) provide a high quality of life and allow the design to be flexible to meet changing demands.

These principles may of course be studied at any level. However, the joint optimisation of the technical and social aspects is not easy unless social scientists take the time to learn enough about the technology to understand the kinds of options that the technology can offer. The design team must therefore be multifunctional. In the process of designing information based technology products there needs to be constant interchange among the stakeholders: the technologists; the users; and, the organisation.

If we translate these basic principles to smart card, then the smart card innovation process itself may be viewed as a sociotechnical process. That is, if we incorporate the technical, organisational and social considerations previously identified as influencing smart card innovation, then the process of innovation can be viewed from within a sociotechnical framework. Using the factors identified in Chapters Two and Three, this process is represented in the model shown in Figure 5-3.

5.4 Implications for theory and practice

The applied behavioural sciences have been enriched both in theory and practice by the many who have made contributions to the field of sociotechnical systems. Innovators such as Fred Emery, Eric Trist and James G. Miller have made both theoretical and experimental contributions which have improved the quality of life of those using new technologies.

In many industries, sociotechnical theory has been used as an applied behavioural science to successfully develop practical organisational change strategies for the introduction of new technologies. The strength of the sociotechnical system concept lies in its experimental approach to planned change. It has remained robust because its theoretical roots lie in the continuing efforts to refine the systems variables and rearrange knowledge gained from various disciplines that bear on technical, organisational and social concerns to improve the overall design of a new technological system.

From a practical perspective, a benefit is that the sociotechnical system's approach belies the complexity of human behaviour and has therefore caught the attention of managerial imagination for introducing technological transformation for the betterment of organisational goals. Here, these ideas have been applied to understanding the process of smart card innovation. The idea of arranging peoples information needs and concerns around a well-defined and flexible system is far easier than arranging a complex set of human relationships in the context of a pre existing system. Because of this, sociotechnical theory has developed in parallel with traditional technologies such as mass assembly lines, coal mining in the UK, textile mills in India and even telecommunications switching systems.

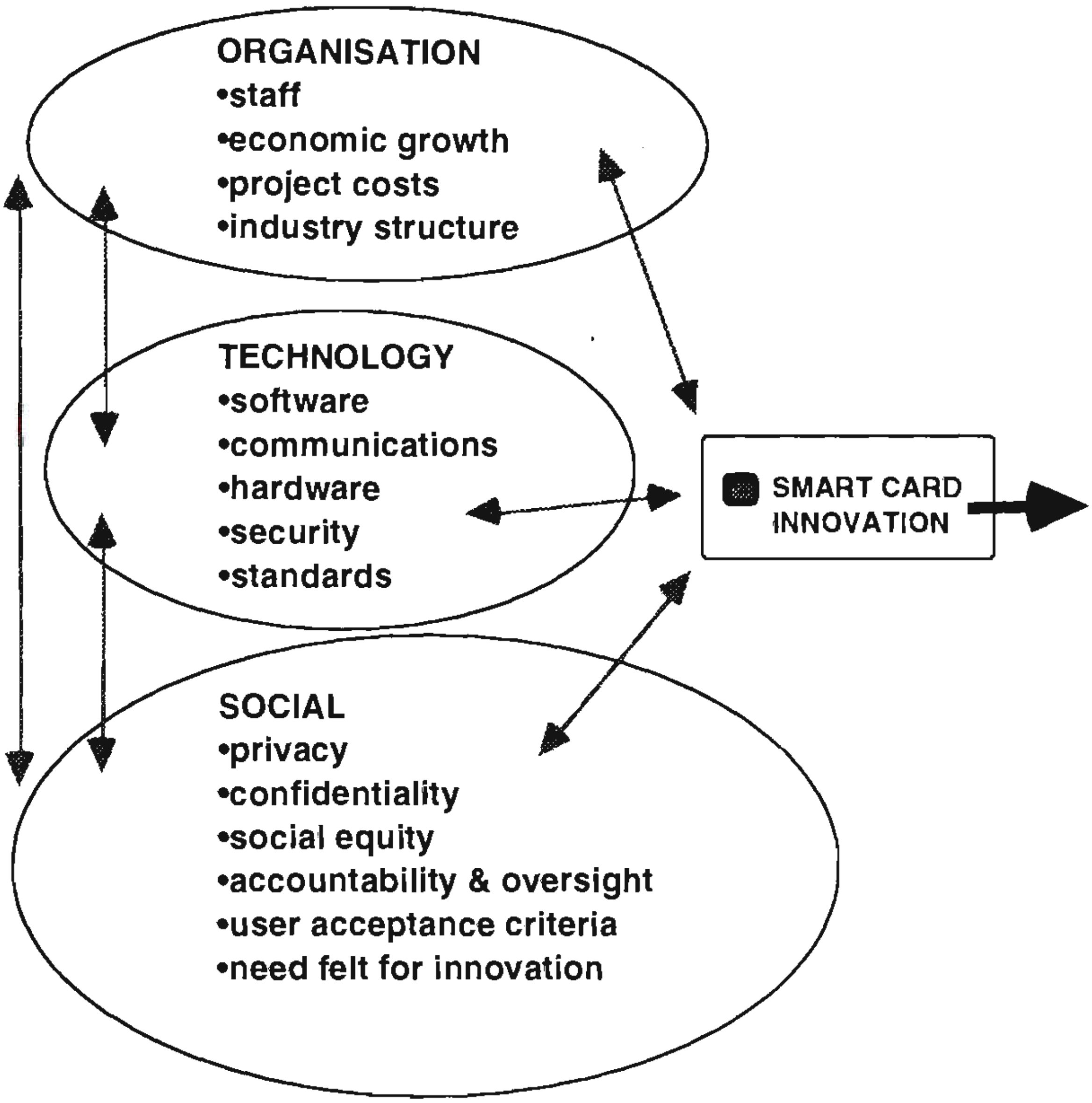

Figure 5-3 Model showing the relationship between sociotechnical factors influencing smart card innovation.

However, when a sociotechnical design methodology is applied to smart card systems, the onus is on the systems' design team to meet new experimental design challenges. The system under consideration will no longer be localised. The users will be members of the public. The main difficulties will be the result of user concerns for privacy and security, rather than as a result of changes in work practices or organisational restructuring. Thus, as smart card technology comes directly into contact with the public who represent the customer base of the managing organisation, a sociotechnical view of innovation will help the design team to develop an understanding of the underlying processes at play. It will also empower the designers to direct innovation in a way in which all of the stakeholders' needs are able to be satisfied.

5.5 Conclusion

Sociotechnical systems theory thus provides a basis for analysing and designing smart card innovation so that the relationships between social, organisational and technological influences can be better understood. These considerations need to be jointly optimised before a system can be considered to be viable. Conversely, this analysis has also shown that the processes underlying smart card innovation are inherently sociotechnical in nature. That is, any such jointly optimised smart card innovation, is more likely to be successful if the system is designed to:

(i) provide information flow support systems to reinforce the behaviours that the system is designed to elicit;

(ii) allow design flexibility to meet changing environmental conditions;

(iii) be compatible with users' needs, technological efficiencies and organisational goals; and,

(iv) provide for an improved quality of life.

A sociotechnical approach to smart card innovation therefore allows for more flexibility, and the possibility for systems to be redesigned and reorganised towards states of greater heterogeneity and complexity. It also emphasises the importance of viewing other new information systems as a sociotechnical entity. This realisation of the causal relationship between the application of sociotechnical principles to direct the process of innovation also adds another dimension; reflexive reinforcement. That is, the social support system that a sociotechnical approach demands, acts to reinforce the behaviours and values that it was designed to elicit.

Chapter Six
Sociotechnical Experimentation: A review of an Australian case study

In the preceding Chapter, the development of sociotechnical theory and practice has been reviewed and discussed. The sociotechnical framework developed by the author for smart card systems, is used here as the underlying theoretical framework for the design of a previously reported case study (Cooper *et al*, 1996). On the basis of the findings summarised in the previous sections, and to better understand why smart card acceptance has been comparatively slow in Australia, it was decided to conduct a national case study in early 1993 to examine the current smart card system design practices adopted by all Australian firms known to be adopting smart card technology from a sociotechnical perspective.

6.1 Background to the study

Work reported in the preceding Chapters has found that it is the emphasis on technological factors rather than social concerns that has often been cited as the main reason for the lack of success of early technological systems. A system's design methodology that incorporates social considerations has therefore been identified as a crucial aspect of effective design and implementation where programmable personal information can be stored, retrieved and manipulated, and when the technology forming the basis for the system offers the potential for pervasive surveillance.

Unlike Europe, Japan, and the US, few individuals in Australia possess a smart card at present. Most Australians are only now becoming aware of the services smart card can provide. Increasingly in Australia, as in many other western countries, it is also now being recognised that user acceptance issues may be the key determinants in the successful implementation of smart card. This would suggest the need for firms to apply a smart card development strategy that incorporates social considerations, if smart card is to become more widely accepted in Australia.

The anticipated growth of the worldwide smart card market also raises several questions concerning the Australian experience to date. The recent past has seen the development of a number of trials and applications, but with limited success and considerable cost to firms and users alike. This would seem to suggest that the principles underlying a sociotechnical approach are important if the designers of new technological systems are going to be able to identify and attend to the needs and concerns of the potential users.

To better understand why smart card acceptance has been comparatively slow in Australia, it was decided to examine the smart card system design practices actually being adopted by Australian firms in early 1993 (Cooper *et al*, 1996). The study in which the collective smart card experiences of Australian firms known to be adopting smart card technology has been analysed. The main aim of the study was to determine if a lack of emphasis on social concerns could be one of the reasons for the slow rate of uptake of smart card in Australia - a country where other technologies have been rapidly diffused. The study did not seek the opinions of the actual users: The scope of the study was limited to the current design practices of Australian organisations from a sociotechnical perspective. The findings were reported in four main sections:

- Methodology
- Results and discussion
- Implications for research and practice
- Chapter conclusions

The study also represents the first reported study that seeks to highlight the importance of adopting an appropriate sociotechnical design perspective for the implementation of smart card technology - both from a theoretical and practical perspective.

6.2 The case study

The collective experiences of Australian firms known to be using smart card technology was analysed from a sociotechnical perspective. For the purpose of the study, the sociotechnical principles discussed in the previous Chapter were operationalised by adopting the model presented in Figure 5-2 as a basis. This means that any examination of the systems design strategies actually implemented by each project would need to include the operational objectives listed in Table 6-1.

An important factor in determining whether a project was actually using sociotechnical principles, was indicated by the inclusion of these requirements in the system's design strategy adopted. In this context, the study has provided an overall view of sociotechnical principles' involvement at each stage of smart card project development. That is, from the contemplative through to the trial and operational stages.

KEY SOCIOTECHNICAL OBJECTIVES FOR SMART CARD SYSTEMS DEVELOPMENT

- Establish an appropriate user awareness effort
- Conduct pre-design user consultation
- Conduct design stage user consultation
- Conduct implementation stage user consultation
- Develop an on-going user consultation plan
- Maintain existing or alternate means to access the service provided
- Make the design provide an improved quality of life
- Produce a design compatible with both user and organisational goals, and within the pre-determined technological parameters
- Ensure that the system has ongoing design flexibility

Table 6-1 Identified key sociotechnical objectives for the effective development of smart card systems.

Two key dimensions of smart card system's development were analysed: These are the level of application of sociotechnical knowledge, and a preliminary examination of some of the difficulties experienced by project staff that may illuminate additional possibilities as to why smart card acceptance has been relatively slow in Australia. However, it should be noted that the primary focus of this analysis was the application of sociotechnical objectives by the design team at the operational level. It was not within the scope of the study to provide a definitive or comprehensive analysis of user perceptions. Nor was the scope of the study all encompassing. It did not consider all the issues that might require consideration in any analysis to determine why smart cards have been treated with apprehension by Australian organisations.

6.3 Methodology

The study was conducted from January to March 1993. A field of 36 projects in diverse organisations located across Australia, and known to be involved with smart card projects, was used to investigate the research questions. A project was included in the study if:

1) the system's users were easily identifiable;

2) it had been involved with smart card use at the operational level for at least one year;

3) it was willing to participate by completing the questionnaire;

4) it was willing to participate in a follow-up interview; and,

5) it came from different levels of management and different functional areas within the organisation.

Of the 36 projects identified as satisfying the above criteria, there were 26 projects that agreed to participate in the questionnaire. A list of the organisations participating in the study is shown in Table 6-2. However, because of the commercial and public sensitivity of some of the projects approached, 9 were unable to participate in the questionnaire. In addition, some of the participants from the 26 projects meeting the established criteria were unable to supply all the information requested.

BHP Steel Electronic Trading Project
Camms Systems Pty. Ltd.
Commercial Services Group (NSW Government)
Commonwealth Bank of Australia
CRA Finance Ltd.
EFTPOS Engineering Pty. Ltd.
Fortronic Technology Pty. Ltd.
Glenorie Bus Company Pty. Ltd.
Hamersley Iron Pty. Ltd.
Hobart Coaches Pty. Ltd.
Ingenico International (Pacific) Pty. Ltd.
Intellect Australia Pty. Ltd.
Keycorp Ltd.
Memtech Australia Pty. Ltd.
Omron Electronics Pty. Ltd.
Optus Communications
Pacific Coal Pty. Ltd.
Reserve Bank of Australia
Scandic International Pty. Ltd.
Security Domain
St Ives Bus Services Pty. Ltd.
Tasmanian Redline Coaches Pty. Ltd.
Telecom Australia Advanced Network Products
Telecom Australia Mobile Communication Services
Telecom Australia Research Laboratories

Table 6-2 An alphabetical listing of the Australian organisations that participated in the 1993 study *(N=26).*

As can be seen, the projects span a broad range of industry sectors and represent many organisational structures. The size of the individual projects also varies widely. For a summary profile of the individual projects surveyed see Table 6-3.

To improve the validity and reliability, data was collected using both a questionnaire and interviews. The 25-item questionnaire focused on five major areas:

Section A: Organisational profile (company details, size, industry; position of person completing the survey)

Section B: Smart card profile (type of smart cards used; card costs; the number of users involved)

Section C: Smart card applications (type of smart card applications in use; user and organisational use criteria)

Section D: Sociotechnical objectives (level of user involvement in the design process before, during and after implementation; identification of key user concerns and requirements; alternative options for users; flexibility of system)

Section E: Project difficulties (the success of the project; identification of organisational, user and technical difficulties encountered by project design staff)

Questionnaire Design

A questionnaire was chosen as the primary means to collect data for several reasons. The most important reason is that it provides a more structured and formal method of data collection (Skidmore and Wroe, 1988: 80). According to Burns (1995: 363), there are also several practical advantages in using a questionnaire to obtain information: It is an inexpensive method of data collection; the respondents can answer questions in their own time and at their own pace; and, it is less likely that any third party biases will influence the outcomes.

The questionnaire was also designed along the impersonal practical guidelines suggested by Leedy (1993: 187-190). That is, the questionnaire:

1. Focused on what was actually done within the organisation;
2. Was worded in clear and simple language with no ambiguities;
3. The questions were designed to fulfil the research objectives; and
4. The introduction and background was carefully structures to introduce a personal level to the study and increase the response rate.

The questionnaire used sought both subjective and objective information through the use of yes/no responses, scale type answers using a semantic differential scale and open ended questions. The questionnaire was also "quality-tested for precision of expression, objectivity, relevance, suitability to the problem situation, and for the probability of favourable reception and return" (Leedy, 1993: 188). A pilot study was conducted to check the readability and content validity of the instrument. A revised questionnaire was then distributed to the managers of the 26 smart card projects who agreed to participate in the study.

Key personnel responsible for the development of the smart card systems' design strategy from each of the 26 projects were interviewed immediately after the completion of the questionnaire. In the case of the smaller organisations, the person interviewed was the Managing Director. For the larger organisations the position of the project manager interviewed could be categorised into one of the following groups: Account Executives, Business Development Managers, Senior Strategy Analysts and Systems Managers.

INDUSTRY SECTOR	NO. OF PROJECTS	TYPE OF CARDS IN USE	APPLICATIONS
Information technology	10	Mostly contact and memory cards with one project using super smart cards.	• Replace cash transactions • Secure data transmission • Token system • Subscriber ID and billing • Security access
Public transport	4	Mostly contact cards with one project using memory cards.	• Replace cash transactions • Secure data transmission • Token system • Security access
Telecommunications	4	Mostly contact cards with one project using memory cards.	• Replace cash transactions • Secure data transmission • Token system • Security access
Heavy industry	3	Mostly contact cards.	• Replace cash transactions • Secure data transmission • Token system • Turnkey system
Banking and finance	3	Mostly contact cards with one project using memory cards.	• Secure data transmission • Token system
Public Service	1	Memory, contact and contactless cards.	• Replace cash transactions • Secure data transmission • Token system

Table 6-3 Profile of the Australian smart card projects surveyed (1993).

All interviews were structured and conducted by telephone on an individual basis. Each interview lasted about twenty minutes. Interviews were conducted by telephone rather than face-to-face because it was deemed to be more efficient and economical as well as the fact that the companies interviewed spanned a large geographic area. The follow-up telephone interviews also enabled the interviewee to receive better responses for open ended questions.

The purpose of the interview was to confirm and clarify the questionnaire response and see if there were other factors associated with the response to the questionnaire. Written notes were taken during the interviews. However, despite the degree of structure, the interview also sought to identify the individual's design ideas in use. The interviews for this study were structured using guidelines developed by Hawryszkiewycz (1991): They began with an introduction in which the interviewees were reminded of the contents of the questionnaire and its goals. Then the information provided in the questionnaire by the interviewee was confirmed and any follow-up points were queried in greater depth. The interview ended with the interviewer summarising the findings from the interview to ensure the interviewee has understood the interviewees responses.

With the aid of both instruments, two key dimensions of smart card systems design were analysed: the level of application of sociotechnical knowledge; and, a preliminary examination of some of the difficulties experienced by project staff that may illuminate additional possibilities why smart card acceptance has been relatively slow in Australia. To reiterate, the primary focus of this analysis was the degree of application of sociotechnical objectives at the operational level. It was not within the scope of this study to provide a definitive or comprehensive analysis of some of the additional difficulties experienced by project staff, nor encompass all issues that might require consideration.

6.4 Results and Discussion

6.4.1 Application of sociotechnical principles

The study has investigated smart card systems design strategies used by Australian firms in early 1993. Survey instruments based on the sociotechnical framework developed were used to provide an indication of the level of application of sociotechnical principles and the identification of the difficulties experienced to that time. Table 6-4 represents a summary of the key findings of the study.

The results of the study indicate that there was already a high level of use of sociotechnical principles across the various projects and that this high level was maintained at an operational level through all stages of design from planning through to implementation. Almost all the firms surveyed had implemented an appropriate degree of use of sociotechnical principles and have adopted methods of design and on-going development that embodies this knowledge.

If sociotechnical principles are necessary for the success of a smart card project design, then these results would seem to suggest that the majority of Australian firms were meeting the different requirements of sociotechnical theory for smart card applications currently being developed. This then is the first observation: A lack of emphasis on sociotechnical aspects of design criteria is not responsible for the slow rate of adoption of the technology in Australia. Rather, it seems that the problem involves other factors.

SOCIOTECHNICAL OBJECTIVES	LEVEL OF APPLICATION (%) *(n=26)*	IDENTIFIED DIFFICULTIES EFFECTING FIRM'S DECISION TO PROCEED FURTHER *(n=22)*
USER - Define User Requirements		
User awareness effort	63%	
Pre-design user consultation	71%	
Design user consultation	68%	
Implementation user consultation	86%	
On-going user consultation	73%	
User difficulties experienced		9%
ORGANISATION - Establish Organisational Objectives		
Alternative service options remain available	50%	
Organisational objectives met by systems design (no difficulties indicated)	60%	
Cost was a prohibitive factor		41%
Marketing difficulties experienced		32%
TECHNOLOGY - Determine Technological Parameters		
Technical difficulties experienced		5%
Supply difficulties experienced		5%
* *'Other'* difficulties indicated		*Nil*

Table 6-4 **Level of use of sociotechnical principles and identified difficulties affecting the firm's decision to proceed further.**

One possible reason for these findings is that there was already a growing level of awareness of the importance of social factors in systems requiring the manipulation of personal information and that we were witnessing the first manifestations of this awareness at the operational level in firms. The second suggested reason for these findings is that the project staff's knowledge and understanding of smart card systems design criteria can now be based on experience - although limited at that stage. The observation that system requirements of the users are largely related to productivity and performance measurements, is an area that has only in recent years been based on user input and feedback in technological system's design approaches. This, by necessity, requires information to be managed in a way that is acceptable and not always understood by the system's design team without feedback.

6.4.2 Ranking of key design criteria

The study also invited project staff to indicate the relative importance of system's design issues such as security, privacy, productivity, efficiency and the potential for surveillance. A ranking of the relative importance of these design criteria based on the survey results reveals security as the primary concern common to both corporate and public users, and reflecting a unity of purpose in specifying design criteria. Project staff regarded a consideration of security issues as being very important to the system's design. Overall, only 4 projects (15 per cent) regarded security as relatively unimportant. These were projects involved in data transmission, token, and physical access systems. None of these applications involved manipulations of personal data. Efficiency, productivity, privacy and user satisfaction were also regarded as relatively important issues. The results are summarised in Figure 6-1.

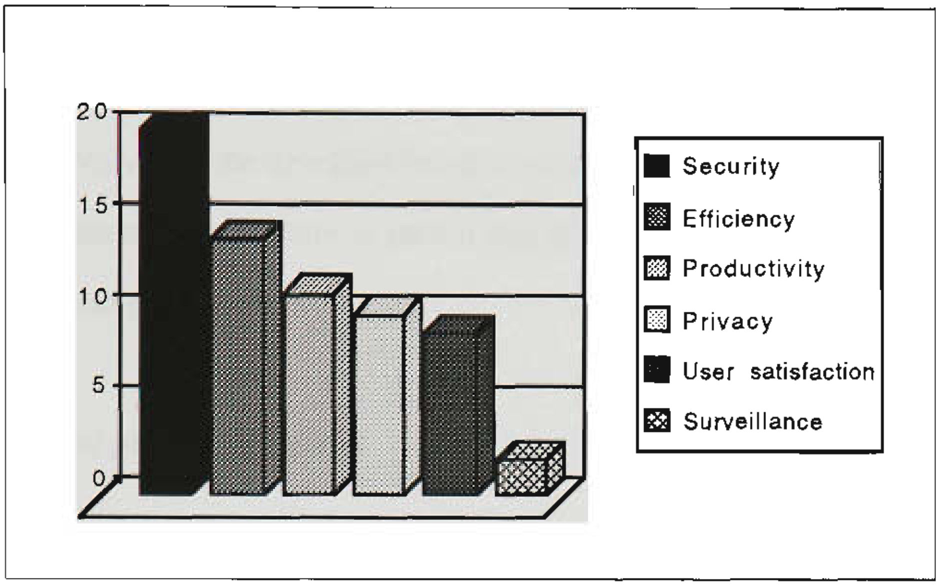

Figure 6-1 **User design criteria identified by project staff** *(N=24).*

Consistent with these findings was the additional concerns regarding privacy and security issues that were illuminated at interview. John Guild of the Pharmacy Guild of Australia, made a statement that was reflective of a number of the views expressed by project staff on these issues during interview. He said,

> *"As soon as information is placed on-line, the privacy of individuals is seriously compromised as most Australian's do not want another Australia Card."*

Here, reference to a serious compromise can be directly linked to the possibility of unauthorised government use of private information. During the intense and very public debate surrounding the announcement of an *Australia Card* by the Federal Labour government in the mid 1980s, it became evident that most Australians did not want a national identity card linking individuals to online databases spanning several government agencies (Smith, 1989). The opinion that smart card systems would fare better in the hands of the private sector was also noted at interview. This opinion is also reflective of the view that smart card might fall victim to suspicions raised by the Australian public as a result of their mistrust of government agencies. Another interviewee involved in the development of smart card payphone systems emphasised the need to maintain user anonymity as part of any system that is more likely to be accepted by the Australian public.

6.4.3 Identified project difficulties

Together, the survey and interview outcomes provide additional support for the key findings of this study. Both serve to reinforce the importance that project staff are now placing on sociotechnical values. These findings also support and suggest the need for project staff to continue to adopt sociotechnical design principles in an Australian context. The effective implementation of a sociotechnical design approach involving user feedback and systems flexibility, can mean that a system may be designed in a way that enables the design team to address the more sensitive issues such as privacy and security needs of the people who will use the technology.

In this context, it is therefore necessary to examine more closely the difficulties indicated by the project staff. See the right column in Table 6-4. These preliminary findings indicate that other factors that can be broadly classed as organisational and economic may be significant inhibiting factors. The interdependence of these factors is also noted. However, as stated previously, this analysis of the difficulties indicated by project staff is not definitive. It does, however, seek to provide a basis upon which further research can proceed.

Cost

The first and most significant inhibiting factor indicated is related to the cost of the technology. The results show that the costs were still high for Australian firms in 1993 and it was noted as an inhibiting factor for further development by all projects indicating that the organisational objectives were not met. The cost of the technology was judged to be prohibitively high in 8 out of 22 projects responding to the question. These findings are reinforced by the survey question that asked projects to indicate the cost of each card bought and to identify the type of card(s) in use. Although a number of projects could not respond to the question, a total of 7 out of the 10 projects who were able to respond, indicated the cost paid for an ISO standard contact smart card as being A$20 or more. The main reason would be the relatively small batch sizes required by the projects. The costs were not indicated as a problem for firms where the high security that the technology offers is difficult to place a price on. For the projects planning to deal with large numbers of the public, the cost was considered to be prohibitive. However, costs have fallen significantly since this study was conducted. This has been largely due to the recent rapid development and growth of the global smart card market.

Project size

An additional problem confronted was the small scale of the projects operating, and helping to ensure that the overall costs per user remained high. The small scale of most projects is also possibly preventing the realisation of the full potential of the technology itself. Of the 14 firms indicating the number of users involved in the project, 4 indicated that they were only pilot projects involving five or less users. A further five involved fewer than 100 users. The scale of the projects participating in the study is shown in Table 6-5. Only the Commonwealth Bank indicated that a large number of users were involved. Their experiences were based on feedback from around 40,000 users. One of the projects was a supplier of the technology and reported large numbers of international users as well as predicting rapid growth in the total number of users of smart card worldwide. Two projects involving the use of smart card systems as an essential part of GSM communications systems also indicated a large anticipated growth in the use of the technology over the next few years.

SCALE OF PROJECTS	NO. OF PROJECTS
Pilot projects *(less than 5 users)*	5
Small projects *(6 - 100 users)*	6
Large projects *(101 - 40,000 users)*	0
Very large projects *(more than 40,000 users)*	1
Projected very large number of users	3

Table 6-5 Scale of Australian smart card projects (1993).

Cooperation

A third stumbling block is the identified lack of cooperation among firms. This was also limiting the possibility of reducing costs by sharing expertise and initial development and establishment costs. The cost of the card in small batches, as well as the cost of the infrastructure to manage and maintain the system can be prohibitive. One organisation that had looked at smart card options decided that it was not viable for them at that time. What they needed was an estimated one million users before it would become worth considering and that they would be prepared to "piggy back" on other applications for the card.

Lack of local expertise

A fourth inhibiting factor was a lack of local expertise - indicated by only one of the firms surveyed. It was reported that they had experienced technical difficulties that did adversely affect their decision to proceed further. West Bus was satisfied with the technology trialed. However the reason that they did not proceed further was due to a lack of local expertise and support from the firm supplying the cards and equipment when technical difficulties arose.

Local industry presence

Finally, and providing an alternate possible explanation for the slow rate of acceptance is the historical lead that other nations have had in the technology by nations such as France, Sweden, and Japan. Internationally, there exists a strong relationship between the incidence of local suppliers and smart card application users in the industry. France and Japan show the greatest number of both. Thus it is possible to account, in part, for the slower rate of acceptance by other nations such as Australia.

6.5 Wider implications for research and practice

If we go by the international trends, it seems the success of the smart card is not yet assured in Australia and that the generic market could be described as wide open at present. Even though the number of smart card projects known to be using smart card has increased significantly since this study was conducted, smart card use still has not become widespread in Australia. The scope of the systems applications too has remained limited and mostly confined to applications in which the user remains anonymous. This hinges on the fact that the evolution of smart card technology innovation has historically been associated with the development of systems that satisfy the organisational and social requirements of local users. The design standards and systems adopted are then largely determined by these same needs and hence require systems developers to adopt a sociotechnical view.

It also seems that many of the above issues reinforce the benefits of co-operation among Australian firms. In examining the aspects highlighted, there appears to be strong technical and financial justification for a closer examination of the concept. During the interviews, a number of project staff identified the area of public transport as one where together, agencies could force prices down, offer the user anonymity as well as flexibility. They also recognised that smart card offered the potential to provide an efficient way to administer government concessions and travel passes. There are already similar co-operative projects currently being trailed in France and Norway.

The observation that a number of smart card projects were being negotiated and developed in secrecy reflects the social and organisational sensitivities of such ventures. It also indicates that smart card itself may be viewed by many firms as an integral part of the organisational culture at this time. It was strongly emphasised in a number of interviews that the smart card system trialed was being considered because of the potential to satisfy key organisational goals such as efficiency and productivity. Some examples of the stated application and the reason for its implementation, and which illustrate this point is indicated in Table 6-6. The technology itself can often be considered as a possible strategic tool for market positioning.

Together, these observations would seem to suggest that smart card systems cannot be viewed in absolute terms as a single technological system and that ultimately smart card innovation diffusion will occur successfully because of its ability to first satisfy organisational goals. The ability for smart card to securely store, manipulate and retrieve data then becomes a means to derive certain organisational benefits. In this context, it would also seem that sociotechnical considerations are also only implemented by project designers as a necessary means to attain the benefits of successful innovations - rather than as a social process itself. In this sense, a basic design approach developed within a sociotechnical framework is perceived as a way to significantly influence and direct the smart card innovation process itself.

SMART CARD APPLICATION	KEY ORGANISATIONAL GOAL IDENTIFIED
Security device	Validate an EFT project
Personal computer access	Greater employee productivity
Token (electronic) purse	Administrative cost savings

Table 6-6 Some examples of project smart card applications and the key associated organisational goal.

Fundamentally then, a sociotechnical approach to smart card systems innovation can be viewed as part of a social purpose in both the organisational and public arenas. In a more closed environment where smart card use is to be limited to the needs of the individual firms and its employees, the organisational social purpose expressed as organisational objectives become paramount. However, in a more open environment that may involve other firms or members of the public, social issues such as privacy and security are perceived differently and choice then becomes an important feature of any new system.

Another feature of smart card - and one related to the preceding discussion - is that it is really a generic technology. Eventually it may lose its identity and become to be viewed as only a part of a larger system. In this sense, the card itself may lose its technological identity as a *smart card* and become more popularly identified by the application or use such as a cashcard, electronic purse, access card, canteen services card or phone card. The uses do not refer to the technological considerations, but relate more to the service being offered. New technologies that incorporate smart card systems such as digital mobile (GSM) communications also now seem poised to significantly influence the standards and the direction of innovation for smart card. Smart card is essential for the use of GSM technology. It may soon become essential for the use of other information technologies such as cable television or home banking. This means that there will be a rapid increase in the number of users worldwide and that the security, backup support systems for customers, for communications management, and operational control will also be in place. As a result, we can expect a host of associated applications to arise in Australia. GSM type applications and financial transactions such as those to be offered by Mastercard and Visacard are also likely to be the catalysts required to promote a rapid diffusion of the technology over the next few years. This could be accompanied by large scale cooperation among local and international firms and involve a range of services. It would also require some degree of architectural standardisation and flexibility with regard to target algorithms for control and flexibility protocols for the isolation of communications of personal information and the resolution of problems discussed above.

Finally, and from a theoretical perspective, this analysis has shown for the first time that sociotechnical systems intervention can work in practice as a framework for the development of basic design tools and has an important role to play in the development of new smart card systems. It is therefore likely to continue to be the focus of much interest and effort. Although no previous study has defined and applied sociotechnical theory to smart card systems innovation, sociotechnical theory is likely to continue to be expanded and redefined to deal with the changing social and task systems of organisations. Thus, the study of sociotechnical systems has become, and should continue to be a solidly entrenched behavioural science discipline in the field of new information technology innovation such as smart card. Its basic principles are already being adopted at an operational level, yet much of its potential remains to be discovered.

6.6 Conclusion

The study reviewed in this Chapter, leave us with two key findings. The first is that the slow rate of uptake of smart card technology by Australian firms does not appear to be due to the failure to attend to the needs and concerns of users. Of course, the design approaches used to address the needs of the user are as yet underdeveloped and many of the experiences represented work still in progress at the time the study was conducted. The projects involved in the study also have limited experience where smart card technology involves multiple applications, several organisations, or when it becomes a necessary part of another technological system such as in GSM technology.

Nevertheless, the study reviewed here has demonstrated in a practical way how theoretically informed basic systems design approaches are now being used to influence the rate of smart card innovation diffusion. This then is the first observation: We are witnessing the birth of a new capacity to understand in a practical way, how technology and society work together to hold one another and to support each other during the evolutionary smart card innovation process. However, it must be reiterated at this point that this study is restricted to the number of projects known to supply and/or manage the technology in an Australian context, and who were willing to participate in the questionnaire. Hence generalisability of the findings is limited to this domain.

The second finding is to do with the identification of other possible factors inhibiting smart card innovation in an Australian context. It appears that these inhibiting factors have been due to a combination of economic and organisational issues, possibly combined with the historical lead that European, American and Japanese firms had in the development and adoption of smart card technology. In brief, these additional possible factors include: the high cost of the technology and ongoing support; the small scale of many of the projects; and, the apparent reluctance of firms to share resources, expertise and experience at a time when all are working to introduce new smart card innovations and so achieve a faster rate of diffusion of the new technology. These factors all serve to highlight the importance of increased cooperation among firms. The gains from such cooperative efforts in smart card systems design appear to be potentially large enough that each of the various parties to benefit. The distribution of the benefits among them, however, must be such that all parties have sufficient incentive to actively participate.

The lack of public awareness, user consultation and trust identified previously, are now recognised at the operational level as essential elements of the process of smart card systems innovation. In this sense, we are now witnessing how the role of the user has become an integral part of the innovation process for smart card technology.

In addition, there is at present an expectation that smart card will become a key aspect of new technologies such as GSM, secure cash transactions and pay television. Thus, access and control of smart card operations to meet these expectations may not be realised quickly by Australian firms unless the criteria identified here are addressed. The strength of the projected market growth and the identified need for smart card partnerships among Australian firms will be of strategic importance to many of the firms surveyed. However, the ability to align social, economic, organisational and technological factors, and the marketing of smart card services remains high on the list of success criteria and future research should be directed at providing further support for this task.

From a theoretical perspective, the study reported here also highlights the need to adopt a new paradigm for innovation theory when the products involve technologies that are held and operated by the user and involve the access, manipulation and use of personal information. The sociotechnical approach adopted in this study has provided an adequate framework to help us to increase our understanding of the complexity and interrelationships between the major stakeholders in the technology and the evolutionary innovation path that has resulted from this process. Although the framework used here is not intended to represent a definitive model, it does show, in a practical way, the need to extend our thinking on innovation. In the case of smart card, the user, organisation and technology all appear to play an important role in the negotiations required to produce acceptable new smart card systems.

Finally, the model of a sociotechnical design system presented in the preceding Chapter, along with the analysis of sociotechnical implementation strategy heuristics presented, will be a useful guide for other firms attempting to actively influence smart card innovation. Although the study reported here, has been able to capture only a snap shot view of the collective smart card experiences and design practices of Australian firms in 1993, it has shown that there are good reasons why the slow rate of smart card diffusion in Australia should be of concern for other Australian firms contemplating the introduction of smart cards. Their experience is represented in the identification of critical development and basic design criteria influencing the innovation process and provide a new perspective for marketeers and designers of future smart card systems based on a sociotechnical framework. Collectively, the findings highlight the importance of adopting a broad multidisciplinary and process based framework for the analysis of smart card innovation. The experiences represented in the identification of critical development criteria should provide an additional perspective for marketeers and designers of future systems.

This study also notes that, given international differences in social and market circumstances, it would be naive to assume that a particular set of user acceptance design criteria could, or should be transplanted into a different environment. Interdependencies and externalities associated with the smart card systems evolution are also noted.

Chapter Seven
Smart Card Innovation: Organisation and execution

So far attention has been focused on understanding the innovation process as it applies to the collective evaluation of information and data relating to what has already been done in the smart card innovation process. The possibility of analysing smart card innovation in terms of a sociotechnical paradigm has been the central focus. Here, the role of the design team in the organisation and execution of new smart card systems is considered in the context of the collective contributions of the preceding chapters.

The organisation and execution of new smart card innovations are examined in the context of the multifunction cards operating in the open systems environment. This is important as the increasing complexity of the relationships required to design and manage these projects will challenge the ability of people to develop applied basic design concepts, address uncertainties and introduce an appropriate regulatory framework. As we shall see, these three capabilities provide important keys to the organisation and execution of new smart card innovations. These three keys are also not mutually exclusive. In the context of the next generation of smart cards, they will be considered under the following headings:

- smart card innovation by design;
- assessment and control of risk; and,
- the promotion and control of innovation by government.

7.1 Smart card innovation by design

In view of the new challenges for more complex smart card systems that have been highlighted in the preceding chapters, this section reflects on a few of the more predominant perspectives that have made connections between innovation and the role of basic design. In the context of this analysis, a need for the development of design tools suitable for future smart card innovation is also considered.

7.1.1 Innovation paradigms and design concepts

By shifting our attention to basic design considerations for emerging large scale projects, the importance of how people work together to produce a new technological system then becomes the focal point for consideration. This shift in emphasis from the technology and towards basic design considerations, is justified by the underlying assumption that the innovation process for technologies like advanced smart card systems is more to do with how people use the technology. Among those who have previously noted the importance of making this conceptual transition when dealing with more complex technologies is Peter Drucker (Drucker 1970):

> *Technology is not about tools, it deals with how Man works.* (Drucker, 1970: vii)

In making this conceptual transition, it is also necessary to emphasise the importance of relationships. How "Man works" is based on social structures and relationships between individuals, groups and organisations. In this sense, design, risk assessment and regulations all form an important part of the innovation process.

At another level, but also from the perspective of viewing innovation as a process involving people, any basic design approach for new technological systems needs to recognise the resulting process of innovation that occurs as a series of patterns of human problem solving activity. Here, Dosi's notion of *technological trajectories* as patterns of problem solving activity - or technological "progress" - has influenced contemporary thought on innovation processes (Dosi, 1982: 152). In this context, smart card innovation involves two key concepts: The first focuses on how people work together to produce a system, and how the users will use the system. The second involves the notion of technological trajectories centring on aggregated patterns of human problem solving activity. Both of these perspectives recognise the different roles the stakeholders play for further development. Thus, innovation as conceptualised in this thesis, can be considered as essentially a human centred activity that occurs as a part of an evolutionary process.

By extending existing innovation paradigms in the light of the findings reported in Chapters Two to Six, it therefore becomes apparent that smart card technology - like television or computing technology - will begin to be seen in the context of its own particular paradigm as it advances and becomes influenced by changed political and social realities. In particular, if the technology is new, and our understanding of the technological changes it brings about begin to test the limits of existing technology paradigms, then it can be expected that, in time, several versions of what constitutes good design practice will be forthcoming. Each will be supported its by its own paradigmatic framework. However, after a time, and when the technology itself matures, it is also expected that only one form, or a small number of design approaches will become dominant at the operational level.

In the context of developing new design approaches for smart card, these comments are not intended to imply that future innovations will be *deterministic* in nature. That is, they will not necessarily be caused in a predictable way by antecedent conditions. Many of the innovations to be introduced, will occur in an environment characterised by increasingly complex interrelationships also resulting in changes in the technology paradigms themselves as we set our understanding at a wider contextual level. This realisation of technological development being characterised by increasingly complex patterns of diversification or "branching" was first pointed out for other new technologies by Piore and Sabel (1984: 39).

To give an example to illustrate this point, a smart card system's design approach for security, might become accepted for a time. However, it could be made redundant by new technological options created through advances in telecommunications networks. The provision of broadband public network options to support systems involving several independent or dependant applications could make it necessary to begin the development of new smart card security systems based on new concepts. Alternatively a security approach could become obsolete because of the possibility of breaches in confidentiality related to new regulatory requirements. That is, if it becomes necessary for the design team to develop a new technological system to meet altered operational objectives. Such changes might also require a shift in the accepted technology paradigm relating to information technologies at a more conceptual level.

7.1.2 Smart card innovation and associated design stages

It is against this background that one can begin to associate the need to develop different design approaches for smart card systems innovation for each phase of technological advancement. If we link the basic design approaches required for each of the key smart card innovation stages previously identified in Table 2-6, then we can observe this conceptual shift occurring at the operational - or *basic design* - level. This association is shown in Table 7-1.

STAGE I : Feasibility trials (1975-1985)

Basic design principles focused on technological considerations.

STAGE II : Single applications (1985-1995)

Basic design principles focused on technological and organisational considerations; and, involve the design of single applications to be used

in a *closed* systems' environment. That is, both technical and organisational considerations were required.

STAGE III : Multiple applications (1995-2005)

Basic design principles need to be more comprehensive and focus on technological, organisational and social considerations; and, involve the integration of multiple applications to be used in an *open* systems environment.

STAGE IV : Market maturity and standardisation (2005-)

Basic design principles will standardise in parallel with the expected maturation and standardisation of the technology itself. Only one form, or a small number of basic design approaches is likely to become dominant at the operational level.

Table 7-1 Smart card innovation stages and the associated conceptual shift occurring at the operational - or basic design - level.

As can be seen, as each stage of smart card innovation has become more complex, there has been a need to adopt a more comprehensive approach to basic design at the operational level. In particular, as we enter the third stage of smart card innovation, a comprehensive approach involving social, technical and organisational factors to smart card innovation is required. In this sense, the basic design concept required at each stage provides a guidepost - or *design framework* - that can be viewed at the concrete and applied levels for further innovation.

What can also be seen from this analysis is that as the design framework needs to become more complex for each stage of innovation, and as smart card systems become more open, the focus of the design team will change. That is, the following characteristics of open smart card systems will require changes in the basic design focus developed:

(i) Increase in the need to access public networks interlinked to private and government networks.

(ii) Increase the need to interlink existing networks.

(iii) Increase in user demands for anonymity and privacy.

(iv) Increase in the need to duplicate records.

(v) Increase in both the number and types of records available on the networks supporting the system.

(vi) Increase in the total number of users of the system.

In particular, there will be a need to shift from a focus on data management and towards information management and use. This will be particularly true for applications involving private information relating to an individual. In this case, concerns for privacy (management and use of information) are likely to be considered to be more important than data security. The need to address user concerns within a social context also means that there will need to be a flexible and ongoing process of design and redesign. Because of the complexity, many agencies might also need to be involved in the process. These shifts in the focus of the design team as smart card systems evolve from being essentially closed systems to what can be referred to as open systems are summarised in Table 7-2.

Closed systems architecture	Open systems architecture
Focus on *data*	Focus on *information* use and sharing
Permanence of design	Assume flexibility of design
Stop design process when system is completed	Continuous design process to ensure desired outcomes and behaviour
Build organisationally focused systems	Build multi agency systems
Assume compliance with privacy and security requirements	Assume that compliance is gained through influence over time
Organisational control of users' information environment	Individual users' design own information environment

Table 7-2 The changing focus of the smart card system's design team.

7.1.3 Developing a Comprehensive Analysis for Smart Card (CASC) design approach

The design concepts for smart card emerging from the preceding analysis, and in the previous chapters, may be interpreted collectively as a set of principles that can be stated as follows:

(i) Comprehensive: It will be necessary to ensure that for large scale multiapplication projects, the design approach adopted is comprehensive. That is, it needs to be designed for whole system's capability where the technology is viewed as a part of a system that includes a wide range of social, technical and organisational considerations.

(ii) Evolutionary: It will need to be evolutionary and iterative so as to be continually responsive to changed environmental needs and circumstances.

(iii) Cognitive: It will be necessary to retain cognitive processes as a part of any design approach adopted. This aspect, might also lead towards a more cognitive approach to the process of innovation.

(iv) Reiterative: Any design process developed for evolutionary systems and involving a wide range of dynamic factors will - by necessity - need to be reiterative. In other words the design process itself becomes a dynamic and crucial aspect of the innovation process.

These basic design principles can also be adopted to suit the level of generality and abstraction required. For example, they can be applied at the strategic level to clarify the basic design principles required to achieve strategic objects and systems integration as required. At a more operational level, the design can be implemented to control and manage the design, redesign and ongoing operations management framework - both at an integrated control level, or as a distributed management function for more complex smart card projects. At the operational and functional support and implementation level, the principles can be used as a framework to develop the necessary *blueprints*. A schematic framework developed by the author to adopt the above principles required to implement a comprehensive analysis of smart card (CASC) design approach is shown in Figure 7-1.

The components at each level should be further disaggregated into the key elements: social, technological and organisational. That is, at the strategic planning level, design functions need only consider groups of elements. For example, what security considerations might be required. However, at the management level the type of cryptographic techniques might need to be specified. At the control and operational level, technical specifications relating to the implementation of a particular public key security system involving several organisations and many potential users may need to be known.

The starting point for the development of a comprehensive list of essential design elements, could be the list of variables previously identified as influencing the smart card innovation process that have been provided in Appendix I (a), (b) and (c). These are meant to familiarise the reader with the underlying concepts of the approach. A complete set of guidelines detailing the CASC design tasks for each stage will need to be developed by the designer for each smart card system (Lindley, 1994a). It is up to the designer - based on the analysis of the technical requirements and the user group characteristics - how to adopt and operationalise these guidelines, and to create new components and criteria as they can be identified. However, it is important to note that, at each design level the principles remain the same and an appropriate approach can be developed by implementing the sequential stages shown in Table 7-3.

Once the design team have completed steps 1-5, a comprehensive listing of all the components of the system and evaluation criteria needs to be drawn up. This is the most important step in the CASC approach and it is critical that properly informed advice is sought so that the components cover a comprehensive range of issues. The process of evaluation for each stage of the system's development then needs to be put in place and operationalised. Steps 9 and 10 are also integral parts of the CASC approach. The Evaluation Report will mainly be based on the ratings and explanations attributed to the findings. Interpretation should also involve cross-references between different criteria so that examination and re-evaluation of the system can commence for the implementation of the next stage of development.

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Figure 7-1 A schematic diagram of the Comprehensive Analysis of Smart Card (CASC) design framework. *(Lindley, 1994a)*

As can be seen from this analysis, the principles involved in adopting a CASC approach to smart card systems design, also mean that the central aim is to develop a design process that focuses on whole systems capability. Yet, it should be recognised that even when the suggested range of tools and technologies are used to enhance a CASC design process, the system will continue to evolve over time. This means the design process must be evolutionary and reflect the paradigmatic framework used throughout this study - and be adopted as an organic process with a constant need for response, feedback and renewal capabilities built in.

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Table 7-3 **The comprehensive analysis for smart card (CASC) systems design approach may be operationalised by adopting the ten steps listed.** (*Source:* Lindley, 1995a)

7.1.4 Which evaluation methods can be used?

Evaluation should be an integral and ongoing aspect of the CASC approach from the beginning. Although the costs of applying them may be high, the eventual success or acceptance of a smart card system may depend on its existence. It is also important for the design team to realise that incorporating the user acceptance evaluation procedures suggested here, mean that the development comes from a more *bottom-up* approach.

That is, it becomes a more user focused design process, rather than adopting a technologically driven design methodology.

The evaluation criteria can be measured using a range of methods and based on the users' perspective on the differences between a smart card system's performance factors, and its desired performance. System performance is a system's effectiveness in accomplishing a goal or task. The desired performance can be measured by pre-determined goals and design principles. The measurement will involve both a method (the *process* by which it is done) and an outcome statement or resulting *product*. However, what this study has revealed is that any evaluation of more complex smart card systems will need to involve both qualitative and quantitative methods. This is because the factors identified as influencing the design of a system span social factors which often require value judgements as well as those that are able to be based on more objective evaluations. It is therefore evident that although a range of evaluation methods is available, no one method is sufficient alone. These may be broadly categorised into subjective, objective or expert evaluation methods.

Subjective: Subjective evaluations are based on the user's judgement. In this sense, the user is the source of the evaluation, possibly even its initiator. The answers then become based on the user's cumulative experience. The drawbacks are a tendency to produce *soft* data that are open to interpretation by the design team. There will also be difficulties relating in general to subjective evaluations such as a tendency to produce exaggerations.

Objective: The advantage of objective measurements by users, or interface team members, is that they are not based on subjective judgements. They may be based on a range of tools such as checklists, experiment or the maintenance of log files on user behaviour where the observation may be concealed. However, one of the advantages of objective evaluation is that it limits the scope of the observation to pre-determined outcomes.

Expert: These methods lie at an intermediate stage between subjective and objective evaluation methods and the outcome depends on the expert's examination of the system. The expert methods of inquiry are subjective. However, the assessment is objective since it is based on precisely formulated questions with clear test rules and traceable conditions. It is a fast method, requires few resources, provides an integrated view and can address a wide range of behaviour. Its disadvantage is that the reliability of the expert will vary and there is no way of detecting bias or incompleteness of an evaluation.

There is therefore no single best evaluation method to be used in conjunction with a comprehensive design approach. All methods have advantages and limitations. What is required is a combination of different evaluation methods. This means that for each criterion - as a focus of evaluation - a specific method is chosen. For example, to explore the characteristics of the card users by interview, may require subjective interviews combined with the use of an interview report. The tasks, supported by smart card software interface design conditions, can then be evaluated using task analysis methods based on objective methods (observation report). Such an approach would not assume a given set of pre-determined outcomes. This is important for more advanced smart card systems as the users' responses might often be based on new contextual concerns.

7.1.5 Limitations of the CASC approach

Ongoing evaluation and re-evaluation of the user characteristics is required as the organisational setting, the technology and the social system are all in constant change. The CASC approach is, by its very nature a reiterative and time consuming one. An expert with a grounding in human factors is therefore needed. Another weakness is that such a system can be biased to a certain degree, by the judgments of the expert regarding the relevance and rating of the evaluation criteria. Finally, no experimental tests are available that demonstrate the validity and reliability of the CASC approach. Nor are there any other evaluation approaches suggested for user acceptance aspects of smart card technology systems right now.

7.1.6 Altering our perceptions of the role of the design function in innovation

In essence, the essential argument for adopting the comprehensive design approach suggested above, proceeds from the observation that in complex interdependent evolutionary systems such as large scale and complex smart card projects, designers will be continually confronted with irreducible uncertainty and holistic interactions that may simultaneously involve many aspects of the system. This is *a priori* assumption of any sociotechnical system in which all of the parts are in some sense dynamically stable. Collectively the steps involved in such an approach also involves a degree of planned methodological confidence to continue the smart card innovation process.

The future of sociotechnical systems as a useful tool for designing smart card systems therefore seems both fruitful and exciting. It offers a framework that can provide for the required flexibility and evolutionary aspects of future systems. However, it also highlights how our understanding of technological innovation for systems involving the use of technologies like smart card fundamentally alters our perceptions of the role of the design function in innovation.

7.2 Risk assessment and the development of smart card technology

With the impending introduction of multiapplication smart card projects involving the participation of large numbers of users, the risks associated with delivering effective services escalate in a way that is far more rapid and difficult to assess: In this case, both the number and type of risk factors impacting the effectiveness of the project will increase along with the escalating scale and complexity of the system. The concerns too, for costs associated with delivering effective services are difficult to relate to social considerations, organisational constraints and technical risks. Reinforced by the increasing demands for more regulatory control, customer choice and preferences for privacy revealed in the previous chapters, this escalation in the scale and scope of projects highlights a requirement for reliable risk assessment (RA) methodologies. This section will therefore focus on a critical evaluation of the risk assessment needs of large scale smart card projects.

7.2.1 Why develop RA tools?

Because emerging large scale smart card projects offer a new way to store and exchange money or information, and because the new technologies will require users and organisations to change their habits, a number of new project management requirements that relate to RA arise and will need to be met. These include:

- The number of users will be large.
- The users will need to be mobile (ie. *nomadic*)
- Users will need to be able to access distributed services.
- The service(s) must be able to provide a high level of security.

- The users may not necessarily be individuals; they may be organisations or *virtual* communities.
- The smart card may also be able to incorporate a range of additional services (eg. cellular network access).
- The card can be used with a PC.

To be able to meet the above management requirements, there will also need to be cooperation among a large number of organisations. Agreements will be complex and they may need to be flexible to meet altered market conditions. In addition, the nature of the projects and the technology mean that a number of fundamental aspects of a large scale project will need to be shared. The challenge will be to develop the management supports to effectively share the following:

- money (including income and the investment required to develop and support a system);

- technology (including technical planning and operations control, communications infrastructure and security); and,

- fraud risk (including the risk of fraud from card users, service providers and project partners).

It is also evident from trials to date, that it will be necessary for ten or more partners to work together to implement a large scale SVC project. Clearly, the complexity of sharing the necessary resources introduces a number of additional risks that need a careful consideration.

Another important consideration that relates to the risk management of projects is the need to effectively manage the information and money domains in a way that minimises risk. In large scale smart card projects, the *domains* for the flow of information and money need to be restricted and clearly defined - or mapped. Here, a *money domain* is defined as, "a virtual space that contains the entire amount of money of an individual" (Cordonnier, 1996: 15). Similarly, information that is considered to be critical or private in nature could be confined to information domains represented by the virtual space within which the information associated with an individual might exist.

In accepting these concepts, the notion of the domain as a virtual space is restricted to what the smart card user can access - or related to the provision of user services. That is, the focus is on the user - not on the organisation(s) involved. In using these concepts it is also important to realise that both money and information can appear in various forms within a domain. For example, money forms within a domain could be: stored on a SVC in the form of cash; stored in a personal bank account to be accessed by a smart card; or it may be held centrally for the users by a Clearing House that then acts to provide secure access and storage of money. The permissible domain money movements may be reversible, and some must be paid for. The movements may also be considered as internal or external to the domain under consideration. In the case of personal information relating to the user, information may be stored on the card itself, it may be stored in a centralised database that can be accessed by a limited number of individuals, or it may exist in a *virtual network space* that can only be accessed by the user. However, the concept of a virtual network space is new. Further research needs to be conducted before the concept can become a practical alternative for protecting privacy and ensuring that a lost card could be replaced with identical information.

Based on these brief considerations, it becomes evident that a number of factors contribute to the inherently risky nature of large scale project innovation. The creation and management of information and money domains introduces many risks. The complexity of sharing the fraud risk associated with increased exposure through larger numbers of users, the technical risks associated with more complex networks, the social risks as well as administrative difficulties associated with co-ordinating a number of organisations, all add to the *risk* faced by project managers. This means that new RA management tools will need to be developed. But in the context of the new smart card environment alluded to here, what do we mean by RA?

7.2.2 The concept of risk and large scale smart card projects?

Risks associated with complex projects are perceived for many reasons. The risks associated with introducing new technologies such as smart card that may involve the use of personal information by large numbers of individuals are perceived as being even *riskier*, because information about the risks involved may be limited or non-existent. In this case, the technology too may cause anxieties because the outcomes are not yet known or observed. Thus, any RA approach adopted also involves the need to monitor the public's (or card user's) perceptions of certain risks. For example, as the project develops and matures, statistical data on user perceptions might be collected and correlated with observed movements in patterns of card usage. This is important as it presumes that any social setting in which a project will operate, will establish its own acceptable balance between the risks and the benefits. However, this is not to assume that any of the variables or social structures will remain constant over time.

If we adopt Lewis' definition of risk as, 'exposure to loss, injury, disadvantage or destruction' (Lewis 1990), SVC project *risk assessment (RA)* becomes the process of managing in a way that will control, limit, reduce, minimise or manage to avoid the affect of the identified risk factors. However, this assumes that the risks are known in advance.

The idea of choice in the process of innovation and decision alludes to the future, meaning that project changes introduced today will affect tomorrow's outcomes. Thus, risk is also concerned with trying to control a range of variables today, to reduce the impacts in the future (Gough 1990: 5). Evaluating the options and then deciding the best alternative implies that the future can be changed. The impact of a decision on the course of action to combat or reduce risk needs to be known in advance so that the course of action that will result in what are considered to be the best outcomes can be taken. For example, the introduction of personal identification numbers (PINs) may be used to decrease the likelihood of unauthorised access to personal or financial information on the smart card itself. However, management needs to know how these actions are likely to impact user usage patterns or management costs. Thus in a smart card risk assessment methodology we also need to be able to distinguish between risks, costs and benefits; but also relate them to each other: If for example, the consequence of an event is a loss of card user trust (social risk factor), then the altered user acceptance level becomes a cost to the organisation (usually expressed in monetary terms).

Any large scale smart card project RA methodology will therefore need to be a fully dynamic system able to accommodate changes for a wide range of social, technological, and organisational dimensions. This means that like the design approaches considered in the previous section, any methodology adopted will require input that is both objective and subjective. It also means that risk implies uncertainty about the probability of a particular outcome, but not of the form of the risk. For example, a misuse of personal data used by SVC project staff presents a risk factor that can be identified. The RA process then involves the quantification (with limits) of the possible impact on the project. To reiterate, risk management procedures also need to ensure that the actual risk is minimised by planning and that the possible outcome(s) can be addressed through modifying other variables in the RA model. For example, the implementation of a "need-to-know" system where all employees are accountable for their use of private information would reduce the risk of project staff misusing user information.

This means that as a starting point, any major smart card project RA methodology used will need to:

(i) identify a wide range of risk factors spanning social, technical and organisational factors;

(ii) be able to modify the design to minimise the impact of the risk factors; and,

(iii) be able to incorporate both qualitative and quantitative aspects so that all risk factors can be included in any scenario tool developed.

Herein lies a research problem: How do we develop a suitable general framework for advanced smart card project RA? The main difficulty associated with the development of a RA model that is able to meet the above criteria, is that there is a need to be able to integrate quantitative values (eg. costs), with those that require social knowledge about the user (eg. privacy concerns). This requires general knowledge inputs that only human beings possess about each other to apply specific knowledge relating to a particular situation.

A major smart card project RA framework therefore needs to be able to incorporate qualitative judgements at one level, and relate them to quantitative values that can predict behaviour - as well as provide a causal explanation derived from an identifiable simple quantitative description. This is exactly what the newly developing field of qualitative reasoning (QR) attempts to do (Werthner, 1994). A general schematic view of such an approach is shown in Figure 7-2. The upper part of Figure 7-2 represent efforts to automate the processes. The framework also recognises that first, a qualitative description of reality isnecessary. It recognises that a qualitative description of a time ordered sequence of events relating to user reactions to privacy for example, is required before a quantitative and abbreviated model can be applied. It is also necessary to understand that, the steps involved in translating qualitative interpretations to a quantitative model is time consuming. In addition, the computations involved need a special consideration.

7.2.3 What are the risk factors?

Complex smart card projects involve a number of risk factors that are ultimately likely to affect the cost effectiveness and user acceptance of a particular system. A sociotechnical framework can be useful as a theoretical organiser to facilitate the development of a list of factors relating to a particular project at the operational level. Here again, reference to the factors identified as influencing innovation and listed in Appendix I (a)-(c) may be used as a starting point for the identification and aggregation of risk factors. As can be seen, the *social* risk factors primarily influence consumer acceptance. Here, concerns for privacy are paramount. Second, there are a range of *organisational* factors that introduce risks. Most of these relate to profit control and customer loyalty. The third group relate to security, hardware and network considerations and may collectively be called *technological* risk factors.

In addition to the range of risk factors previously identified, the type of risk can also be reclassified according to some additional risk dimensions. In particular, the risks that can be identified as causing a possible disaster for the system, might need to be given a higher priority.

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Figure 7-2 A general Quantitative Reasoning (QR) framework for predicting future smart card project outcomes derived from an identified simple structural description. (Lindley, 1996b)

The project planners would also need to incorporate ways of avoiding or minimising their impact through appropriate disaster planning. Some factors too - such as impending regulatory change - may be considered to be *uncontrollable*, whereas other industry factors may be viewed as changeable; providing the project mentor is able to lobby effectively.

Some examples of additional smart card risk dimensions which might be considered include:

- voluntary vs involuntary
- failure vs disaster
- ordinary vs catastrophic
- immediate vs latent
- controllable vs uncontrollable
- quantifiable vs qualitative
- internal vs external

7.2.4 Smart card risk assessment in practice

There are as yet no reported studies of risk assessment methods used by smart card projects in practice. In addition, investigations related to this study have found that there are currently no organisations utilising a fully integrated approach to the problem of risk assessment for smart card projects. However, in making this observation, it is also important to recognise that most organisations were reluctant to reveal full information about risk *in-house* assessment procedures. Yet it is widely acknowledged among project managers that there will be a need to develop new tools as smart card systems advance. This opinion is related to the fact that at the present time, there are no large scale multiapplication projects involving large numbers of the public that are fully operational.

However, some general observations about risk assessment practices of organisations involved in the development of projects are worth further comment.

Of the senior project managers of Australian smart card projects approached informally at industry meetings and by telephone in 1995, it was found none had yet developed a comprehensive approach. However, there was a wide recognition of the importance of developing comprehensive tools for future smart card projects. Nor was there any observable consistency in the approaches reported to be used in practice. Of particular relevance here, was the finding that the Westpac Banking Corporation (WBC), in Sydney Australia, which was not using a model reported experiencing some problems. The Smart Card Project Manager, Mr Paul Jennings, reported difficulties such as confusion about what the results produced mean (ie. difficulty in providing a qualitative interpretation of events). The results reported by different employees were also found to be inconsistent leading to "misunderstandings" among staff. In comparison, project leaders from QuickLink, Transcard, Mastercard International and the Commonwealth Bank of Australia (CBA) reported using RA methods. However, in each case, the social, technical and economic risks were treated independently. This would mean that as projects grow in scale and complexity projects advance, there will be a growing need to integrate RA tools and methods. Managers of several projects also responded by requesting to be kept informed of developments in research relating to RA for smart card projects.

Collectively and at another level, these observations also provide further indirect evidence in support of the growing importance of developing closer relationships between our theoretical knowledge and practical methods used for the organisation and execution of new smart card innovations. That is, innovations associated with the emerging stages of smart card development are likely to become more closely linked with associated developments of our theoretical knowledge and understanding at the level of paradigm.

7.2.5 Risk assessment using scenario tool GVE

The GVE scenario tool is one software package that has been identified by the author as probably meeting the SVC RA criteria identified here. At the present time, the author and colleagues are not aware of any other existing tool that may have also met the requirements specified in the preceding analysis.

The package is a generic scenario tool GVE that has been developed by Daimler-Benz in Berlin. It has been made available for research purposes to Professor Graham Wrightson, Director of the Monetary Systems Engineering Group (SMEG) of the University of Newcastle Australia. Using the GVE scenario tool version 3.1, the first smart card RA model has been designed and tested for inconsistencies (Lindley, 1996b). Initial efforts focused on the development of large scale SVC project needs. However, it should be emphasised that this research is in its early stages and future practical implementations based on these early efforts are now being planned. Although it is not within the scope of this thesis to provide a full description of the GVE software tool, the essential features are reviewed. The main aim here is to briefly describe the scenario tool GVE in an effort to highlight some of its features that make it suitable as a RA tool for smart card projects involving a large number of risk factors.

GVE-Tool version 3.1

The GVE scenario tool has the capability to enable flexible construction of specific smart card project scenarios representing possible future quantitative developments. Existing prognoses can also be checked for consistency and our own risk assessments can be proved or disproved for a given scenario. A number of unrelated prognoses with differing inputs can also be tested, adjusted and made into a consistent prognosis. This is important here, as not only will any smart card project differ from the others, but the impact of the input factors may also vary over time. The GVE-Tool is based on QR methods and it has the capability to:

- Perform calculations using uncertain numbers (mean value with deviation);
- Test for internal consistency of the model used; and
- Automatic forward and backward calculations.

The most important risk factors identified for a particular smart card project scenario such as the level of customer acceptance, transaction amounts and frequency together with their logical connections to organisational factors such as net profit, can be represented in a model. A scenario is built by filling out the model with numerical values. For example, the forecast transaction traffic flow and profits to the year 2000 can be generated for a project using a wide range of inputs - both qualitative and quantitative. The model is executed as a semantic network connected by the four mathematical operators (+, -, *, /).

Data Input

First the risk assessor assigns values in intervals/bandwidths (mean value with deviation) to each variable. Each input is individual, possibly uncertain, and each is based on best estimate assumptions/assessments - or given prognoses' values for a particular scenario. The size of the deviations included are approximate estimates of the degree of uncertainly on the underlying assumptions, the quality and accuracy of the uncertainly estimate as well as the assumed risks associated with decisions. The GVE-Tool then derives from the input data new information - which may be unknown up to now (eg. new user registrations), and optimises the given assessments by changing the bandwidth.

The resulting estimated intervals may not always correspond to the logical connections initially defined by the assessor. In these cases, the GVE-Tool will attempt to construct a non-conflicting network of values by readjusting the supplied values within the given scopes. In some cases the one or more related assumptions may need to be revised and the scenario model rebuilt.

Building a model

To illustrate how the GVE-Tool can be used for a large SVC project, details of a simple SVC model are provided. This model has previously been tested and run for inconsistencies (Lindley, 1995b). This type of project was chosen for consideration because many of the more ambitious smart card projects currently being trialed are of this type. In the case scenario included here as an example, hardware stock is related to turnover through user acceptance levels based on the number of users, the frequency of use, the size of the transactions and the rate of uptake of the SCV system by retail outlets.

This model will quickly evaluate the gross turnover of funds for a certain time point. The basis for the model here represents only a sub-model of a complete SVC model, which is realised by a semantic sub-net. All the logical relations of the parameters for the sub-model are represented in an example of a semantic sub-net shown in Figure 7-3.

Running the model

In the forward calculation mode, the semantic sub-net will calculate from top to bottom all unassigned parameters on the basis of the input values. However, it is also important to note that with the GVE-Tool, that filling all model quantities with values first, could lead to inconsistencies.

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Figure 7-3 Sample semantic net for a simplified model of a large scale SVC project. (Lindley, 1996b)

An example of an inconsistency:

Input value:	*100.00 ± 10.000*
Calculated value:	*140.000 ± 10.000*

As a consequence, only some model quantities are suggested or specified as input quantities. On the basis of the input values, the semantic sub-net of the model will be calculated from top to bottom, and all unassigned parameters will be filled in with values. In the backward mode, the GVE-Tool will then try to balance the existing difference between supply and demand by calculating backward through the semantic sub-net (from bottom to top) and adjusting the intervals within the parameters indicated. When running the program, all the unknown values will be calculated and all known values will be optimised according to their logical connections.

In the simplified model shown here, a value for each of the key objects and systems design parameters is required. The system will calculate those not given where sufficient other information is provided. For any given scenario, the set of variables and calculations, the sub-models will be tailored to meet the specific risks identified at the time. The GVE-Tool would then be able to quickly calculate (with limits indicated) the expected impact of these modifications on turnover and profit. It would also be able to recalculate within revised system's limits closely related scenarios until the most acceptable set of variables is provided as the alternatives for the system are contemplated.

Usefulness of the GVE Scenario Tool

The main limitation of the utility of the GVE tool is that the outputs need to be considered within the limitations of the computational basis for the inputs. That is, it is often difficult to fully justify the inputs - especially those based on predicting human behaviour. However, the GVE tool does provide the basis for incorporating a comprehensive range of risk factors and it has the potential to quickly optimise design outcomes. Thus, it should be useful in meeting the RA needs for complex SVC projects.

Although it is not within the scope of this analysis, to provide a more detailed analysis of the specific computational capability of the GVE scenario tool, this brief analysis has particular relevance to developing our understanding of the underlying processes of smart card innovation: The GVE scenario tool described here can be used to develop a fully comprehensive and integrated RA tool required to meet the needs for large scale smart card projects. It provides the computational ability and generic flexibility required to meet the evolutionary and complex nature of more advanced smart card projects. What can also be seen, is that by developing and implementing tools that are able to meet the specified criteria, the smart card project team will be able to significantly influence both the rate and direction of future smart card innovation patterns in a more informed way.

7.3 The promotion and control of innovation by government

What is evident from the analyses so far is that the balances regarding the relationships between society, organisations and smart card technology are different from those of other new technologies for which we have found it necessary to introduce regulations governing their use. For example, the use of personal computers, television, radio communications and mobile phones have all required a different approach and regulation. In each case, it is also true that regulation has become an unending and constantly changing challenge to create and maintain a balance between the stakeholders. To date, innovation in information technologies has not proved to be an easy job for regulators. However, it is recognised that innovations in information technology must coexist with, and be supported by correct government regulations and policy. Yet, this belies the complexity and multi dimensional nature of government responsibilities and the relationships with privately owned organisational activities.

The innovation management literature also bears witness to the potential for governments to influence both the direction and rate of innovation in new technology based industries. In an effort for local firms to gain a competitive advantage, the development of new technologies has been consistently emphasised. At the heart, is the problem of how governments can best organise industries for industrial innovation. According to Rothwell (1994: 202), this can be achieved with seven broad, though not always independent, policy sets. These are:

(i) Procurement (Government as a customer);

(ii) Standards regulation (eg. safety standards and environmental regulations);

(iii) Linkage formation between suppliers and users;

(iv) Direct influence over the volume and demand;

(v) Direct influence over any aspect of the innovation process (eg. R&D funding, commercialisation incentives);

(vi) Encourage diversity in the search for technological improvement; and

(vii) Influence the rate of diffusion (eg. equipment purchase subsidies or tax incentives).

In the case of smart card too, the governments of many nations are playing a significant and varied role in smart card development. The French Government has actively supported local innovations through implementing policies to achieve all the above objectives. The government, through the public banking and health sectors, has been the major purchaser of smart card technology since the 1970s. The preferred technological standards have been those adopted and developed by local industry such as Bull and more recently Gemplus International. The French government has also maintained an active role in the development of international standards so that the local smart card industry will maintain a pre-eminent market position. Large R&D projects have been funded such as that established at the University of Lille to encourage further innovation and a diversity of approaches. The government, through the health industry has also subsidised the cost of introducing a large number of cards to the public. While smart card trials were being conducted in other countries in the 1980s and using similar technologies, many found that the technology would not produce the efficiencies forecast. Smart card looked like remaining an essentially French technology. Even in the early 1990s, the costs associated with the introduction of the technology appeared to outweigh the benefits for trials in many countries. In one study conducted by the author (Cooper *et at* 1996), the cost of the technology had been identified as a major factor influencing the decision not to continue with a project. Other governments introducing smart card have also sought to encourage local smart card innovations. In the case of the SVC project of NSW Australia, the government was the creator of networks, and the provider of resources to encourage the local smart card industry to become actively involved in the collaborative project. In each case, the government was an early user of the technology. It was accepting the risks and directly subsidising early development.

Another important role of government - considered in Chapter Four - is the need for governments to protect the rights of its citizens. Of most concern for smart card technology is privacy. Here, the government role is viewed as one of ensuring that regulations relating to privacy and security are universally acceptable and relatively easily enforceable. This also alludes to the importance of humanising new technology before it will become accepted by society. This means organising or designing new technology so that society leads the direction the technology takes. The critical requirements then focus on social innovation, organisational innovation or collective innovation through entrusting government regulation. Ramos (1983: 10-113) has referred to this concept as the *society-technology-liberty triangle.* In adopting such a framework to explain new technology innovation, he has also recognised that the forces linking the need for the government to impose order, control and stability in society are essentially opposed to its role in ensuring liberty and democratic rights of individuals.

Nowhere is this opposing force more evident than in new information technologies involving the use and manipulation of personal information such as smart card. For a smart card system to work, these forces can also be understood in terms of the *convenience-control conundrum* discussed in Chapter Two. When inappropriate regulation governing the control and use of the information potential of smart card systems are in place, the users are not likely to willingly accept the full potential of the technology.

By implication, this means that if we adopt Ramo's two conceptual centre of society and liberty, and are going to adopt smart card technology potential to improve our lives, then we will be only able to do so as an organised society. This will mean performing a balancing act between the individual right's to freedom and privacy and the opposing forces of the government's need for control and accountability. It will also mean that the government's role as an inhibitor or catalyst for future innovations as a result of a whole range of industry policy sets will also become important. However, actually doing something to meet this challenge equates to government action. Legislative bodies responding to public opinion are often the result. But the most important point here is, it is ultimately the government's responsibility to accomplish the task of integration of citizen's rights to liberty, privacy and choice against the need for regulatory control if such technologies are to become an integrated part of our society.

Yet, this picture is also too simplistic: It ignores the technological aspects of the smart card system itself. The kernel of technological innovation has always been based on scientific discovery. As a result of continued scientific discovery, a number of additional technological design options could become available. Fundamental breakthroughs in the science of cryptography, scientific discoveries enabling the manufacture of thinner wafers, and network advances creating a plethora of new management and control options for smart card systems, are but a few of the parallel innovations that might shape future smart card systems. The direction and pace of technological innovation might also be influenced by the level and type of R&D funded. However, this does not exclude the possibility of influences radiating from organisational and social influences acting to determine which advances are incorporated or fostered. Yet, the role of the government in encouraging new discoveries will also play a critical role in smart card innovation outcomes.

In this case however, industry self-regulation might well be another alternative in the case of smart card as it has been with other new innovations such as the VCR. It then becomes the public's responsibility to reject changes that they are not happy with. It becomes the organisational responsibility to provide and justify a particular system's design to ensure that: the needs of the potential users of the system will be met; the design process is flexible and will meet their changing needs; and, that full disclosure of the systems design and accountability is both verifiable and legally enforceable. The government role then becomes one of ensuring that regulations relating to public concerns such as privacy and security are universally acceptable and relatively easily enforceable.

While it is impossible to predict the future role of government in the organisation and execution of smart card innovation, it is manifest that the consequences are likely to continue to play a significant role in smart card innovation. The set of observations and analyses provided in this thesis also serve to exemplify how a sociotechnical design approach based on the notion of the importance of information - rather than data or technology *per se* - contrasts with the standard technology approach which governments have so far adopted in practice.

7.4 Conclusion

The aim here has been to demonstrate how the interaction of a range of diverse implementation and execution capabilities can drive smart card innovation. The main conclusion drawn is that choice of technologies is no longer between a selection of card types; it now involves skills in organising and using them. Smart card innovation then becomes more a way of learning to organise people, combined with realistic expectations about future developments along various competing innovation pathways.

From the level of implementation and execution of emerging smart card innovations, it is also evident that without an understanding of smart card innovation as a *sociotechnical process*, many opportunities for effective intervention or enhancement could be missed. In both the case of risk assessment and systems design approaches, the sociotechnical analysis reported here has provided a basis upon which new smart card innovation tools can be developed. An understanding of the relationship between technology, governments and society can also be understood within a sociotechnical framework. In other words, the process of sociotechnical analysis has shed a new light upon the type of tools that now need to be developed to design, manage and support a flexible and evolutionary smart card system. It is also important to view each of these approaches as an integral and consequential part of the process of the smart card innovation process itself.

Chapter Eight
Towards a Smart Card Innovation Paradigm

In the previous Chapter, the development of conceptual frameworks for the organisation and execution of smart card innovation were the focus. That is, analysis was at the operational level. The frameworks required for the basic design, risk assessment and policy regulation approaches considered have also led to a more general level of analysis in terms of paradigms that is the main focus of this chapter.

In this chapter, the analysis proceeds towards the multifunction card in a truly open systems environment. Here, the collective insights gained from the preceding analyses have also been useful in terms of connecting the smart card technological trajectory with the development of our understanding of smart card in terms of its own emerging paradigm. The predictions made are supported by the explanations provided in the previous sections, as well as the interrelatedness between the innovation patterns characterising the emerging smart card innovation paradigm.

8.1 Smart card as a major innovation

At first glance, smart card can be viewed as merely a minor innovation in card technology: It can be viewed as a small piece of plastic with an embedded chip that has the potential to offer improvements over magnetic stripe technology. However, if we view smart card innovation in the context of the collective findings of Chapters One to

Seven, then one can see that it bears many of the characteristics of a major innovation. The characteristics that smart card development has in common with other major innovations are:

(i) *High costs associated with gaining acceptance of the technology*

Already many smart card projects have failed, or have not continued past the trial stages. Although there are no studies that have focused on smart card project failures to date, some industry leaders interviewed during the study have put that figure as high as 80 per cent. The high failure rate and the large amount of R&D expenditure required also reflect the difficulty that the smart card industry has had in bringing this technology successfully to the potential users.

(ii) *Alters user behaviour*

Because of the design flexibility, and the high level of security that smart card is able to provide, it has the potential to significantly alter our patterns of behaviour. The importance of considering the needs of the users of the technology, as well as the complexity of many of the social issues that could arise when personal data is used, has therefore been one of the main foci for this thesis.

(iii) *Produces major adjustments in organisations adopting the technology*

Because smart card places a portable device in the hand of the owner that may perform many functions, smart card also has the potential to alter the way organisations allow staff secure access to buildings or database records, to be able to access organisational services, or to perform organisational functions. It is the added level of access security and the nomadic nature of the possessor of a card that enables organisations to rethink how a number of work functions can be performed.

(iv) *High risks associated with the social, organisational adjustments required during the innovation process*

The reported large percentage of smart card trials not proceeding further is also indicative of the high level of risk associated with the introduction of this new technology.

(v) *High R&D costs*

At present, companies like ERG, an Australian smart card company specialising in public transit cards, are spending around 24-25 per cent of their total revenue on further R&D. Although comparable figures are not publicly available from other smart card companies, it is likely that the level of R&D expenditure will be comparable to this figure.

(vi) *High commercialisation costs*

Most organisations introducing smart card now appear to recognise the high costs associated with the commercialisation of new projects. Most costs are associated with design, implementation and management rather than the technology itself.

(vii) *Requires interdisciplinary know how to commercialise the technology*

Early trial results and the findings of this study indicate that the introduction of smart card requires a multidisciplinary approach. That is, it requires cooperation among the social scientists, the technologists and the organisations involved.

(viii) *Relies on the development of several other new technologies*

Smart card development has continued to rely on parallel innovations in several other industries - including the telecommunications, computing, security and SVC card industries.

(ix) *Extended period of product development before it is considered mature enough to replace existing technologies*

Like many other new technologies, smart card has had to be proven over an extended period of time before being adopted and utilised in major applications.

Although a smart card could be considered to be merely a small piece of plastic with an embedded microchip, its pattern of technological development indicates that it has many of the characteristics of a major technological innovation. These defining characteristics also serve to highlight the point that the reason for the slow development is due to a number of factors - some of them interrelated. The key factors within the sociotechnical framework used here include: industry and historical development trends; regulatory factors; standards development; social considerations; as well as many organisational factors such as cost and human resource impacts. It is in this context that the proceeding section will consider the next stage in smart card innovation.

8.2 MFC/Os: The next generation of smart cards

The future of the next generation of multifunction smart cards does not seem to be in doubt. What is in doubt is when, and how the emerging applications will be differentiated in the third stage of innovation. However, there are some emerging themes that highlight the key defining features of the next generation of smart cards.

The direction of the key innovations now being developed is towards more customised cards with larger memory capacity, programmable operations and security functions. The innovation trends in smart card technologies all over the world at present can also be correlated with a rapid increase in the scale and scope of card projects being developed in four key industries: retail, banking, health and telecommunications. Already several large stored value card (SVC) projects with applications spanning several industries are emerging. For example, projects such as Mondex, highlight how there will be a convergence between the retail, telecommunications and the banking industry. Smart card applications in the health industry in Europe also demonstrate the trend towards the integration of applications for Government purposes on a scale that will place a smart card in the pockets of increasing numbers of citizens.

Not only do to these trends indicate an innovation shift towards cards offering multiple applications on an increasing scale; they also indicate that the migration path for the development of smart card technology itself is now being planned in a way that will appear to be seamless to the users of the system. In other words, the developers of emerging systems are planning a gradual - or *evolutionary* - innovation path. By placing more emphasis on the functionality of the system rather than the card technology itself during the later stages of card innovation, and by planning for the gradual migration towards the introduction of more advanced systems, the card type will no longer be the key focus of innovation efforts. The evolutionary system itself will be the focus of the design team and several types of cards may be developed to coexist within one large operational environment. A number of CADs and networks may also be integrated.

8.2.1 Defining MFC/Os

It was revealed in Chapter Two that most definitions of smart card to date relate to the functionality of the card technology itself. That is, smart cards might variously be described as *small memory cards, large memory cards, integrated circuit cards* or *supersmart cards*. However, as the focus of smart card innovation shifts from the functionality of the technology and towards the environmental factors influencing the development of a system, there will be a need to place more importance on the functionality of the system and the environment within which the card exists. For this reason, a multifunction card (MFC) operating in an open systems environment (O) can be defined and referred to as an MFC/O (Lindley, 1995a). An MFC/O might then refer to a supersmart card, an electronic wallet or a pocket computer. In the context of current innovation trends revealed so far, the defining characteristics of an MFC/O are provided in Table 8-1.

8.2.2 Advantages of MFC/Os

The reason MFC/O systems now seem to be the preferred direction for the next major stage of smart card innovation, is that they offer a number of advantages over single application cards.

Improved profitability: It is anticipated that the increased scale and convenience of MFC/Os will generate the interest and support of a greater number of users - and so bring economic benefits associated with project scale effects. For example, in the case of national health cards, it is anticipated that efficiency gains will significantly arrest increases in the cost of providing national healthcare in the years ahead. However, this will also need to be balanced carefully against the increased costs associated with developing systems of far greater complexity.

Standards: The emergence of true MFC/Os will be associated with a convergence of consumer choice as applications spanning several industries develop and mature. This means that both users and organisations are likely to continue to push for the development of standards to eliminate the logistic problems and costs associated with maintaining separate cards during the period of transition to MFC/Os.

Please see print copy for image

Table 8-1 **List of the defining innovation features characterising a Multifunction Card operating in an Open system's environment (MFC/O).** (*Source:* Lindley, 1995a)

Reliability: The introduction of MFC/Os will also make it possible for organisations and industry sectors - such as the health or banking industry - to share ongoing support and development costs as well as innovation experience associated with full scale implementation.

Customer service: The added convenience of additional services, one card, transportability and the ability of service providers to enhance or augment existing services will mean that there are opportunities to improve customer service.

Flexibility: With the recent announcements of several global MFC/O projects, the new smart card systems will need to be more flexible. Flexible pricing, level of service and currency options will be features of the more mature systems. It is also not inconceivable that at some stage in the future, smart cards might evolve into generic pieces of plastic that can be fully customised.

Customer loyalty and contact: As the new more customer focused view of business associated with an increasing number of customer loyalty plans unfolds, it is anticipated that the MFC/Os will be developed to maximise the opportunities to create customer loyalty and to maximise the contact with the customer. Thus, MFC/Os present a plethora of new possibilities which might be considered by smart card project developers. However, associated with these developments will be the possibility of MFC/Os being used to gather large amounts of personal information that could be used for the quantification and prediction of future markets and group trends.

The above range of benefits is not extensive. However, they do serve to suggest why the smart card industry is at present investing heavily in MFC/O R&D in anticipation of realising some of the many possible benefits.

8.2.3 Challenges in migrating to MFC/Os

In addition to the promises that can be derived from the planned development of true MFC/Os, there are also a number of new challenges in migrating to the MFC/O environment. For example, the development of MFC/Os involving a number of organisations also greatly increases the vulnerability of the system. The interconnections between public and private databases will be increased as the need to share resources and data is increased. As the number of users and the number of service access points increases, so too does the risk of invasion of privacy, fraud and viruses. The probability of the need to duplicate database records as well as the number and type of records available also increases. In addition, there are a number of other parallel innovations that are likely to occur during the transition phase. These could include innovations related to the technology in semiconductor materials, or in network communications technology. There could also be innovations in design practice and in the regulatory environment.

However, one of the main concerns associated with migrating to MFC/O technologies, is the growing complexity and vulnerability of the networking environment. The integration of a large number of users and managing organisations relying on large scale public networks means that smart card security will be an ongoing concern. These changes also highlight the need for the development of more industry standards and network integration, application integration and the associated development of multiple protocols and architecture.

Thus, it seems reasonable to predict that most of the innovation challenges associated with the development of MFC/Os will be connected to the *environmental* influences rather than technical considerations. In other words, smart card innovation then becomes a matter of whole systems innovation and there will be a shift in emphasis away from the product itself and towards the evolutionary processes. However, this *evolutionary* aspect of smart card innovation, raises some important underlying philosophical and research implications for smart card innovation so far not considered.

8.3 Innovation in an evolutionary open systems environment

In this analysis so far, many analogies have been made between the observed sociotechnical changes underlying smart card innovation and biological evolutionary systems development. In fact, an evolutionary approach is implicit in any sociotechnical process and it has been a recurring theme emerging from the findings of the previous chapters. For this reason, this section will briefly consider one of the broader and more philosophical realisations of this view. That is, the emerging parallels between smart card innovation as it has been revealed in this study, and recent changes in evolutionary thought for biological systems.

Up to the present time, *trial and error* models for choosing some technology innovations in preference to others (comparable to *survival of the fittest* models for biological selection) have often been described in neo-Darwinian evolutionary terms. For example, in looking at the process of new technology development from a different perspective, Sharp (1986) has argued that a wider and evolutionary understanding of technology is required. After examining the development of six key industries in Western Europe, she concluded:

"The evolutionary nature of new industrial activities in turn reflects the evolutionary process of much innovation." (Sharp 1986: 271)

The idea of trajectories, first described by Dosi (1982) has also helped to reinforce this evolutionary view of innovation. A *trajectory,* or innovation pathway, is described by Dosi as the innovation path taken by a technology over time, subject to continuous and incremental innovation change. During this process there are also discontinuities that might add to the irregularity of the process of development.

In each case previous references have assumed the *survival of the fittest* as the true underlying paradigm. In the past, these fundamental perceptions of ourselves and our genetic heritage, have been in harmony. The natural view of innovation in such an environment was clearly one based on the assumption of much trial and error.

However, emerging smart card technologies are now being designed to become more closely interwoven with the social fabric of our society. As these technologies become a more important part of our lives, the systems cannot easily be designed to *fit* with the dynamic and social nature of the environment within the *trial and error* model alone. It therefore becomes a logical link to develop systems where a greater allowance for human or social behaviour is considered so that *feedback* can become an integral part of the innovation process. Many social groups that exist in a society are required to develop interrelationships based on constant feedback and negotiations if they are to function as a whole. By extending the logic of this argument, it can be deduced that any new complex technological system that evolves as an integral part of the social structures, must also be viewed as an evolutionary and dynamic entity dependant upon environmental feedback if the system is to be improved.

Thus, at an abstract level, the new age in informatics emerging which will be based on technologies like smart card, is likely to require our society to undergo a paradigm shift at a number of levels: self perception and the relationship of technology with society; and, how society chooses to become master of the new technologies and coexist over time with it. Because of the complexity of the emerging systems, it is also evident that new regulatory frameworks will be required to maintain a balance between describing the technology and its social systems, and staying a sufficient analytical distance to allow for a more abstract analysis. In fact, if some nations are to continue to maintain and nurture a democratic framework for our governing political systems, then the new personal chip technologies such as smart card, will need to be developed to coexist with society and develop in guided evolutionary terms by constant feedback mechanisms.

Here, a parallel can be drawn between this view of smart card innovation and biology's recent profound concern with Lamarckian inheritance of acquired characters during one's lifetime. What is emerging from recent biological studies is that there is now a growing acceptance of the need to view biological evolution both in terms of natural selection and the notion of somatic selection that involves alteration of the genome so that altered characters are inherited in the next generation (Rothenfluh and Steele 1993). This is of particular relevance here. The Lamarckian paradigm can be compared to our altered view of ourselves as a part of a technological framework that has been designed by us to support our social structures and cultural values. In this case, the smart card innovation process can be viewed as occurring as a carefully guided sociotechnical process in which the design blueprint becomes genetic material for the system evolving and is able to be altered by way of Lamarckian feedback loops.

In this context, parallel paradigm shifts are occurring in the way we perceive biological and information systems *evolution*. Using a combination of Lamarckian and neo-Darwinian selection processes, some biological systems are now considered to be shaped by internal and external factors. In other words, they have inbuilt and directed flexible design and redesign processes based on feedback loops that allow them to evolve in a changing environment. However in making this analogy, the reader should be aware that at present our scientific understanding of Lamarckian evolution is limited to the immune system. Yet, it is not inconceivable that in the future the mechanisms involved could be proven to occur in other biological systems (Rothenfluh *et al* 1995). So, in this sense, the sociotechnical approaches suggested do not rely on a rigid all encompassing systems theory, but rather view the system as analogous to a live organism seeking its existence in a changing habitat and able to consciously alter its genetic make-up in response to environmental stimulation in a directed way.

Thus, our understanding of smart card innovation as a sociotechnical process - as revealed in this study - can enhance our altered view of technology and its evolutionary relationship with society in terms of contemporary paradigms. That is, in parallel with our growing scientific acceptance of environmentally driven evolution. This higher level of awareness of ourselves as part of the process of innovation, and our relationship with the technological environment that supports our social structures, means that we become the observer observing ourselves: Implicit in this relationship is the notion of innovation as an evolutionary process involving both Darwinian and Lamarckian selection forces. These changed perceptions also demand that the designer of a purposeful smart card system that interacts more with its environment, acquires new skills, develops new tools and emphasises the importance of infostructural design considerations.

The question of sociotechnical knowledge and reflexivity is also of relevance to understanding smart card innovation as a sociotechnical process. Yet, during the last decade, the question of reflexivity and its importance in the sociology of knowledge has largely been neglected. At the same time, the range of information systems research activities amenable to social analysis has expanded. In addition, there has been little recognition of the implications of viewing the knowledge generated by the social scientists as a social construct. This also raises questions about the production of social knowledge associated with information systems research as a social activity itself and its reflexive nature. According to Woolgar and Ashmore (1988: 2), the recognition and exploration of reflexivity has been viewed more as a 'problem' for the social sciences. Extending the arguments posited in the preceding sections, reflexivity might also be considered as a part of a 'solution' by recognising it as a part of the natural evolutionary processes that occur as information systems like smart card develop. That is, if we adopt the view of Bruno Latour (1988), that arguments or explanations of certain phenomenon, feed back on themselves to nullify the original claims. Bruno suggests that such a system can be viewed as self-contradicting. However, it might also be viewed as a part of the feedback loops required for future improvements in information systems that rely on social acceptance and inputs for development. This appears to be a fertile and natural outcome of the research undertaken here and one that might be pursued further in future research.

In this sense, we have the potential to direct the basis for defining the relationship between new information technologies like smart card and society as a result of our increasing awareness of ourselves as observer and as a part of the directed process of mutation: The mutability of ourselves and the technological systems we are designing to support our social structures then become one. The delivery of a new sociotechnical system as a part of the process of innovation is a way to consciously conceive an innovation pathway for smart card systems to be designed for performance. In other words, ultimately all our interactions with evolving smart card systems designed to support our social structures, all become part of a larger living system.

8.4 Dealing with evolutionary smart card systems

In the case of smart card technology, the conception of smart card innovation as an evolutionary system involving feedback, also presents new challenges to be confronted. To illustrate this point, some of these are briefly considered.

8.4.1 A change in engineering focus

Until recently, the smart card industry has been essentially a high technology industry that was technologically driven. However, in the last few years the product itself has changed, costs have declined and the product is now more market driven. As a result, cards are now being designed to support multiple applications in an open systems environment. These cards are more complicated than those of the past and a whole systems approach is needed to incorporate the competing interests between engineers, managers and users. This change in engineering focus means that it is no longer a matter of choosing what to design. What is now required is a whole systems engineering approach to design more complicated systems to meet the added demands of users.

8.4.2 Managing infostructure

Another problem that needs to be addressed is the requirement for expanded information systems. Because the user, regulatory and business functions will largely be guided by information usage, infrastructure considerations will be secondary to the infostructure considerations required for the development and implementation of a system that will be able to simultaneously satisfy the needs of all the key stakeholders. The technological options also need to be flexible and diverse enough to be able to meet changed information requirements of a system. In fact, an emerging theme here is that the ongoing flexibility, accountability and control of information requirements will be the most critical design considerations for MFC/O systems. At the same time, there will also be a need to introduce into the innovation process, inhibitors so that information overload does not occur and so that only those who need to know, are able to access the relevant information. The early smart card systems required an emphasis on technology and infrastructural needs. For emerging smart card systems, it is therefore infostructure design considerations that will be most crucial for the overall continued systems' effectiveness.

8.4.3 The need for the generalist and specialist

Third, there is the need for the smart card system's design team to become generalists at one level to cope with the broad range of social, economic, organisational and technical issues at stake, while being more highly specialised at another. The technology hardware and software have an increasing range of options. The networks too are rapidly changing and as the product becomes more market driven, social considerations will become more complex and important.

8.4.4 Managing a large range of environmental variables

Fourth, because of the complexity of optimising the competing interests of the key stakeholders, there will always be a tendency to increase the number of variables or factors that need to be a part of the management and design process. However, this must compete against the pressures to reduce the number of processes involved. If the number of factors is permitted to become too great, the amplification effect of groups of factors may cause modifications to be introduced without the realisation of the relative importance of another group or set of factors. Similarly, if the range of variables considered is not sufficiently broad, it is possible to overlook the impact of critical factors influencing the outcomes. In this case, it is possible for the system being developed to deviate from its original purpose.

8.4.5 Future technological convergence

Another factor is that many major telephone and computer companies are at present striving to procure the next generation of *intelligent personal devices*: A cellular phone, palm-top computer and a smart card combined into what futurist Frank Feather has referred to as a "single pocket-sized gizmo" (Feather 1995:39-40) could be the result. New devices could also make bricks-and mortar banking obsolete. Tellers' positions could disappear. Many shopfronts could also disappear as electronic banking and secure electronic trading make home shopping and home entertainment easier. Video stores and newspaper stores could all become obsolete. Grocery stores could become warehouses and many other shopfronts could disappear. In other words further technological convergence centred on smart card capabilities could mean that electronic mobility and our digital profiles will replace many of the reasons we currently have for physical mobility and a physical presence at a specific location. For example, gaining bank loans and buying a house, our education and entertainment, ordering the weekly groceries could all soon be done from the home.

However it is important to realise that based on our findings of smart card acceptance to date, none of this will become possible without the functionality of a smart card for secure access and identity. Although the social and organisational structures that will form the basis of future smart card systems are still uncertain, the functionality of the cards now being developed does have the potential to change our daily lives far more than any previous information technology.

8.5 The emerging smart card innovation paradigm

If we examine the diversity and patterns of maturation of smart card projects in the context of the preceding factors, there emerge four quite distinct stages of smart card innovation. These may be summarised as:

Stage I: Feasibility trials. 1974-1985

During the first decade of smart card's existence, the technology underwent a series of feasibility trials that were mostly conducted in France.

Stage II: Single applications. 1985-1995

From the mid 1980s, when mass production of the technology became possible, a number of new trials and some of the first implementations emerged. Although many of the possible applications considered were technically feasible at this time, economic considerations meant that most projects were not developed past trial stage.

Stage III: Multiple applications. 1995-2005

Over the past two years, a number of projects involving multiple applications and operating on a national or global scale were announced and associated trials began. This period of development can be associated with the potential use of multiple applications, the increased scale of projects and involving the need for several organisations to cooperate.

Stage IV: Market maturity and standardisation: 2005 -

Given the many technological and industry factors likely to inhibit or delay the development of applications requiring industry and organisational cooperation and the development of complex supporting infrastructures and infostructures, it seems that it could be several years before smart card will begin to show signs of maturing as a technology. Smart card technology could be considered to be approaching maturity when the market begins to decline.

It is against this background that one can only begin to associate the need to develop different innovation approaches for each identified phase of technological advancement. If we go one step closer to developing this association it then becomes apparent that we can also observe a fundamental conceptual shift occurring at the operational - or basic design - level. This association is shown in Figure 8-1.

As each stage of smart card innovation has become more complex, there has been a need to adopt a more comprehensive approach to innovation at the operational level. It can also be observed from Figure 8-1 that as the technology has matured - and become more market driven - there has been a need for analysts to adopt a more process focused framework for analysis. That is, the technical functionality of the product itself has ceased to become the sole focus for innovation efforts. An emphasis on innovation as a process that involves social and economic considerations has assumed a greater importance as the product has developed. However, in noting the pattern observed, it does not imply an orderly transition or even progression in product and process focused innovation developments. What is new here, is the observed pattern of the relationship shown here that is unique to smart card technology.

From the point of view of analysing such changes to the technology itself, this analysis has also shown that the *product-process* dichotomies discussed in Chapter One have been closely linked. That is, this analysis demands and supports the need for a convergence between the product and process schools of innovation thought. First, and from the product point of view, the neoclassical expectation would be that smart card innovation has proceeded as a result of suppliers examining the existing alternative methods of production and design on the basis of what are considered to be the most economically feasible decision. While such analyses might lead to comparative price differentials and changes in methods of manufacture might result in cost efficiencies, these factors are assumed to operate only in relation to the production of a given product. The neoclassical assumption of a perfect market based on a competitive industry environment is also evident in the current smart card industry. However, the product school of thought, does not allow for a consideration of possible product flexibility in relation to exogenous factors.

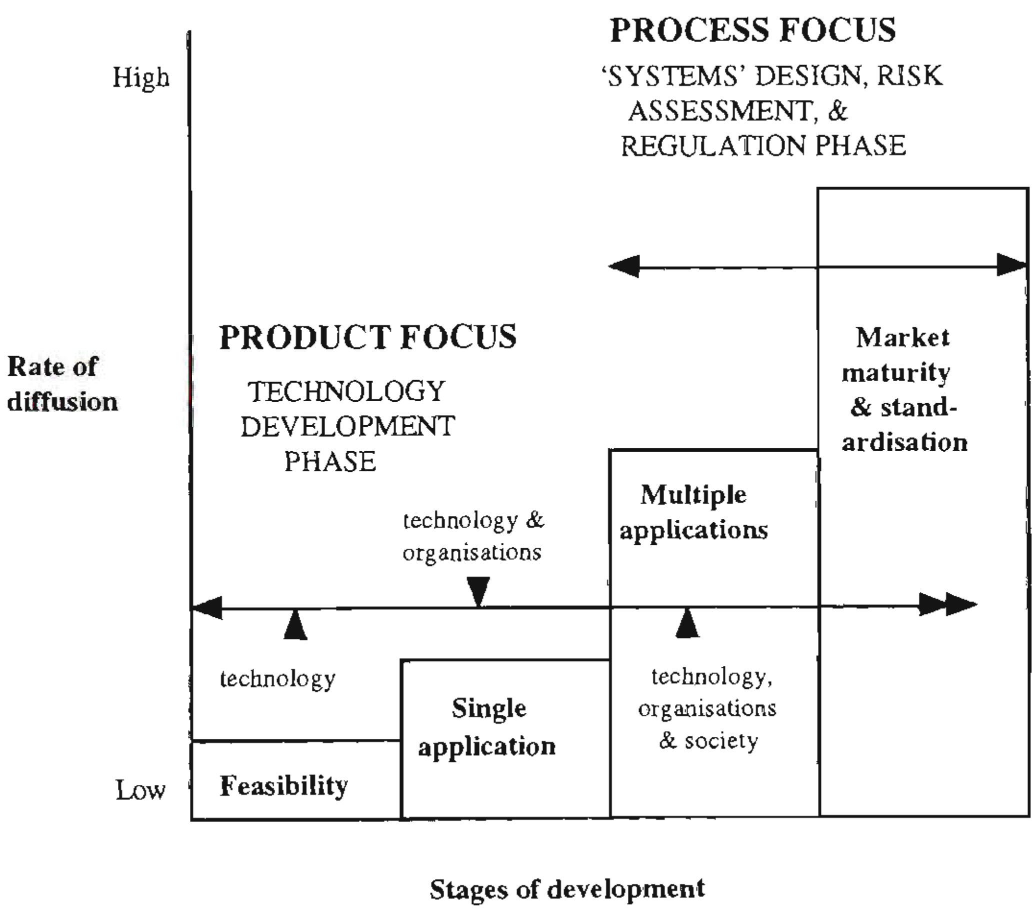

Figure 8-1 **A pictorial representation of smart card stages of development showing the close relationship between the *product* and *process* view of innovation.**

In comparison, and to be able to consider even a minor modification such as those methods that might result in further miniaturisation and improvement in reliability of smart card microchip technology, advanced smart card systems require a process approach. In the context of the analyses here, it can therefore be deduced that smart card innovation needs to be understood as a process involving economic factors as well as a number of exogenous influences. That is, smart card innovation as revealed by this study, inherently involves process and product changes and highlights the interrelation between product and process perspectives and their implications for innovation thought.

8.6 The virtuous cycle of smart card innovation

In considering these observed stages of development, and the issues impacting smart card development highlighted in the previous section, a unique innovation pattern emerges: This is the underlying smart card innovation paradigm. The essential features of the emerging paradigm can be summarised as follows:

(i) There are a number of unique factors associated with the parallel development of innovations in other industries that have significantly influenced the pattern of smart card innovation. Some of the major factors influencing this pattern have included the reliance of the technology on key innovations occurring in other industries such as microchip advances; and, the increasing complexity of the system and the nature of the interaction of the technology and the users in regard to privacy perceptions.

(ii) The evolutionary aspects of smart card innovation are apparent. Smart card innovation has not been shaped by singular events. It has been shaped by many factors interacting over time.

(iii) A convergence between the *process* and *product* view of technological development is becoming self-evident as smart card itself becomes an integral part of a more complex system. A shift from an emphasis on the technology and towards the system within which the technology exists is becoming the key focus for innovation efforts at the operational level.

Other relevant concepts for the study of smart card innovation at a lower level of abstraction than paradigm, are the applied design concepts that arise out of this paradigmatic analysis. In particular, as we enter the third stage of smart card innovation involving larger numbers of users and multiple applications, a comprehensive analysis and approach to smart card innovation is required. That is, it becomes necessary to develop basic design approaches and risk assessment methodologies that are able to meet technical, social and organisational needs. As more advanced smart card technologies become a reality, this consideration will open up whole new areas of research bringing together a number of disciplines. The emerging relationships between the many social, organisational and technical factors discussed here can be represented as a smart card innovation virtuous cycle. This representation is shown in Figure 8-2.

This analysis also suggests that an understanding of smart card innovation cannot be deduced from within the existing innovation frameworks reviewed in Chapter One. Technological perspectives, social considerations, economic data or abstract measures of organisational functioning alone - which characterise much of the existing innovation

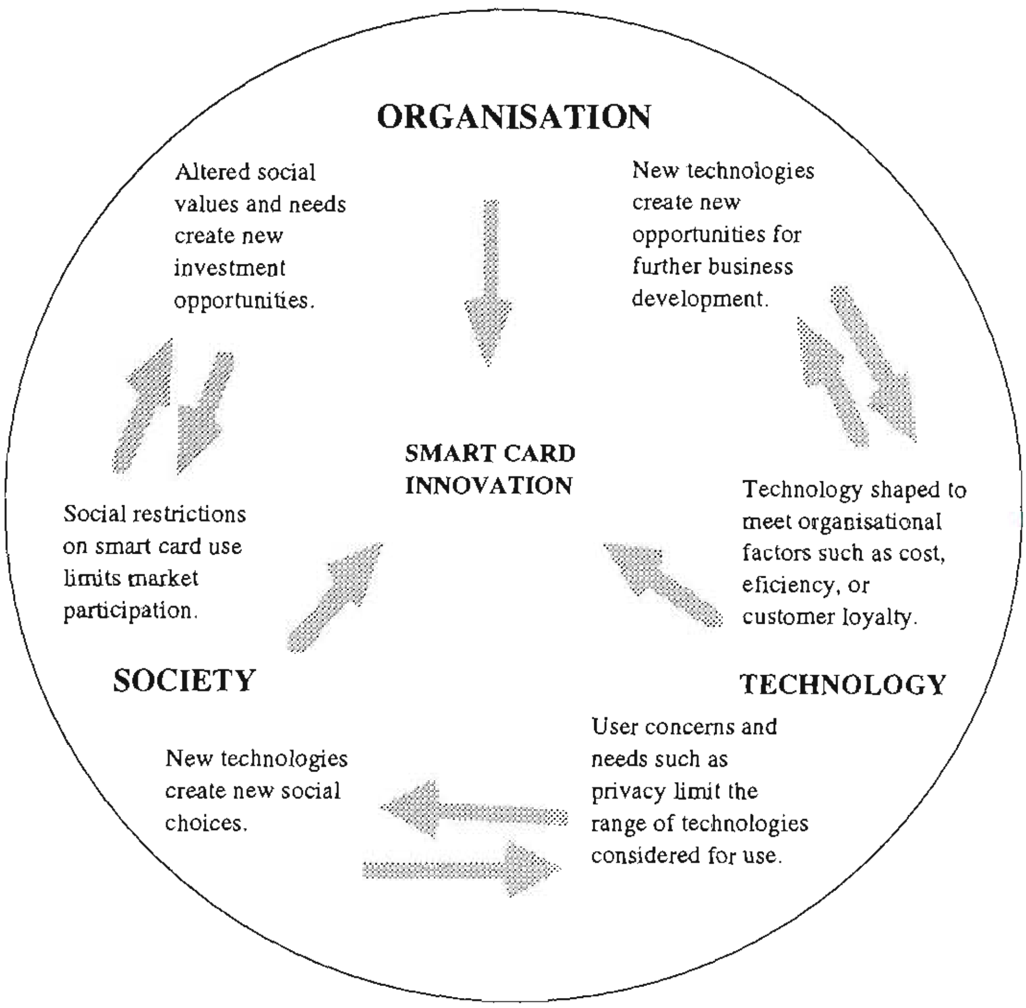

Figure 8-2 **The smart card development virtuous cycle showing the interrelatedness between organisational, technical and social changes during the smart card innovation process.**

literature - will not help us to develop a meaningful understanding. What is required is an understanding of smart card innovation patterns emerging from a broad range of exogenous and interrelated factors which result in the emergence of a unique smart card innovation paradigm.

8.7 The smart card innovation quandary

If we define innovation as the commercial introduction of a new technology or process, we can see the interaction between the process of innovation and technology. This interaction has been evident in the preceding analyses based on the development of smart card. Smart card technology is one of a range of new information technologies that can offer a new way of electronic communication or information sharing. Throughout history, humans have worked at developing more efficient means of sharing information. Yet in recent years, notable historians of technological development such as Lubar (1990) have noted that the process of innovation remains:

> *"... a complex economic, sociological, political and technological puzzle."*
> (Lubar, 1990: 9-16)

The current *Information Age* based upon the development of a range of new information technologies, has carried such concerns forward. Information technologies like smart cards, mobile telephones and networked personal computers can substitute for - and augment - the human ability. However, because the technology needs to be used, controlled and managed by individuals, there is now a growing recognition that the design of new information based technologies needs to be rationalised along more comprehensive social and organisational lines. That is, technological innovation as it has been defined here, needs to be expanded to include an increasing range of exogenous factors that play a role in the process of technological development.

This means that if smart card innovation is to be better understood in terms of these other factors, then we must expand our innovation frameworks hand-in-hand with the development of the technology itself. This then is the *smart card innovation quandary* that highlights the need for further research to develop our understanding of innovation processes for new personal information devices that will be a key feature of the emerging Information Age.

8.8 Conclusion

What the current analysis has achieved is to provide our very first insights into smart card innovation in the context of its own emerging innovation paradigm. Collectively, the defining characteristics of the emerging innovation paradigm also help to explain the long incubation period for the technology.

In the context of advanced smart card technologies, the main conclusion drawn is that the development of advanced smart card technologies needs to be understood in the context of the emerging smart card innovation paradigm: Awareness of this both demands and empowers the view that smart card innovation is what has been traditionally called a *sociotechnical* process. That is, its evolutionary development has been influenced by many intersecting technological, social and organisational factors. For the practitioner, these observations also illuminate new possibilities for the development of more theoretically informed smart card systems and placing the smart card design team in a position to significantly and positively influence the more advanced smart card innovations.

From a theoretical perspective, preliminary investigations here reveal that an understanding of smart card innovation cannot be deduced from existing innovation frameworks: Technological perspectives, social considerations, economic data or abstract measures of organisational functioning alone will not help us to develop a meaningful understanding.

Chapter Nine
Conclusions and Implications

In this, the last Chapter, a summary of the key findings of this study is provided and related to evidence about smart card development presented in Chapters Two through to Eight. In the light of the different innovation perspectives revealed by the study, some limitations of the study and some suggestions for future research are highlighted. An attempt to specify ways in which innovation thought could be further refined in the light of the evidence is also made. Finally, some concluding remarks relating to the practical and theoretical implications of the findings are drawn.

9.1 Summary of key findings

At the outset, four major research objectives were formulated. The first, and most important was to explore a range of sociotechnical factors influencing the development of smart card technology for the period 1974 to 1996 in order to discover the main factors characterising the smart card innovation process to now. This is the first reported attempt to examine the research topic of smart card innovation. As such it represents the first view and interpretation of smart card innovation during the first two decades of the development of the technology from a sociotechnical perspective.

The second objective was to analyse and interpret the current smart card design practices used by Australian firms known to be adopting smart card technology from a sociotechnical perspective. The case study reported represents the first analysis demonstrating how a basic design approach centred on a sociotechnical framework is now being used in a practical way influence both the direction smart card innovation and the rate of diffusion of the technology itself.

The third objective was to determine how implementation and execution capabilities of the design team can influence smart card innovation in the context of the many large scale multifunction smart card projects now emerging. This has been done at both the conceptual and operational levels. The main contribution has been to demonstrate how a diverse range of implementation and execution strategies can be used to drive smart card innovation. It has been argued that smart card innovation is more about the way skills and knowledge used by the people introducing the technology, combined with social values such as the expectations about future technological developments along various competing innovation pathways. The collective findings have demonstrated for the first time how the growing complexity of the skills and knowledge in the areas of regulation, risk assessment and design will mean that each of these processes themselves become an integral and consequential part of the smart card innovation process. These processes are also not mutually exclusive.

Facilitated by the multidisciplinary approach adopted to achieve the above three objectives, a fourth objective was to assess whether the sociotechnical approach applied as a theoretical framework for developing our understanding of smart card innovation, has in fact, been a reasonable and useful paradigm.

Facilitated by the multidisciplinary approach adopted to achieve the set objectives, this thesis therefore highlights several important and original contributions to the field of technology innovation.

Firstly, it is the first attempt to examine smart card innovation in a historical context. This is the first study providing a history and interpretation of smart card development since its inception. It does this by tracing key technological, industry and social developments for the period 1974 to 1996 within a historical framework. It is the first attempt to explore smart card innovation from a broad analytical framework. In this study many factors influencing smart card innovation have been identified. When these factors are viewed collectively, some important and distinctive development patterns also emerge which characterise the process of smart card innovation in terms of its own technological paradigm.

Secondly, when the findings are viewed collectively, they both support and suggest that smart card innovation is inherently a sociotechnical process. The idea that the non-technical factors play an important role in successful innovation provides significant insight. Conversely, it also suggests that the sociotechnical view of innovation is necessary to understand smart card innovation. That is, the innovation process cannot be divorced from the organisational, social and technical factors as many previous innovation models have suggested. Rather, smart card innovation appears to be a matter of overall strategy.

Thirdly, the sociotechnical view of smart card innovation revealed, has facilitated the development of predictive statements about the dynamics of the innovation process. In particular, the theoretical contribution made by previous innovation studies are stressed as important factors in which disequilibrium effects within an evolutionary system is of central importance to this study. The framework used has also provided a basis for understanding some ideas of possible and plausible explanations about why the observed systematic variations in the identified innovation stages have occurred as smart card technology itself has developed.

A fourth significant contribution is that the findings provide compelling support for the view that the user is now recognised as an important part of the technological system during innovation. It has been argued that the development of large scale and more complex multifunction smart card systems might only exist because of the user and that their needs will be the most important factor shaping future innovation patterns. This finding has also highlighted the need to contribute to more systematic design approaches by developing tools to incorporate the needs of the user in the ongoing process of development.

Finally, this study has revealed how new information technologies like smart card are making it necessary to change our view of the innovation process itself. Acceptance of the view that smart card development is an evolutionary process also implies a number of changes in perspective and interpretation of technological innovation. Most importantly, it emphasises awareness of innovation as a process involving feedback which empowers the design team to influence the diffusion by selecting the types of innovations which best meet the needs and expectations of the users within a given time and contextual setting. These findings are summarised in Table 9-1.

9.2 Limitations of the study

Many problems remain before the exploratory findings here can be more fully investigated and supported.

One of the main limitations of this study is that there is no single innovation theory - or set of theories - that can be used as a basis for the study undertaken. It also does not attempt to formulate a new integrative theory of innovation. To do so would, impose too rigid a structure on the exploratory nature of these initial studies. The imposition of a rigid framework would not conform to the reality of innovation as it has been revealed here. On the contrary, for each of the aspects of smart card development considered, material is presented which relates the aspects of smart card innovation processes and to each other - within a broad sociotechnical framework. But this is also not done to the extent of providing a complete set of linkages. It is emphasised, that in the absence of an existing paradigm suitable for the study of smart card innovation, the sociotechnical framework is merely used to provide a framework for analytical convenience.

In the context of this limitation, it is also important not to overlook the fact that this, the first study of smart card innovation can only provide an introduction to the idea of sociotechnical thinking as a paradigm for understanding smart card innovation; and as a basis for developing an effective systems design and implementation approach. It can only represent a window to view how smart card innovation occurs as a process, and how this knowledge can influence the process of innovation through improved design and redesign. However, it has produced a new basis for understanding sociotechnical systems use and theory and it has helped to increase our broader understanding of the process of innovation at a more general level. That is, the application of sociotechnical systems thought to innovation, requires using its principles to realise that a paradigm shift in our understanding of innovation is actually occurring.

A further limitation is that the analysis has been restricted to smart card systems that limits the possibility of generalisation to other information industry technologies. Given international differences in social and market circumstances as well as historical changes, it would also be naive to assume a particular set of technological design criteria could, or should be transplanted into a different environment. That is, each analysis is time and location dependant. In particular, the emphasis on the individual interdependencies and externalities associated with a particular smart card system's evolution is also fully reflected in the research. However, the study has served to highlight some interrelated factors with implications for a wider informatics industry context.

SUMMARY OF KEY CONTRIBUTIONS
1. ***It is the first attempt to examine smart card development in a historical context.***
This is the first study providing a history and interpretation of smart card development since its inception. It does this by tracing key technological and industry developments for the period 1974 to 1996 within a historical framework.
2. ***It is the first attempt to explore smart card innovation from a broad analytical framework.***
In this study many factors influencing smart card innovation have been identified. When these factors are viewed collectively, some important and distinctive development patterns also emerge which characterise the process of smart card innovation in terms of its own technological paradigm.
3. ***Viewed collectively, the findings both support and suggest that smart card innovation is inherently a sociotechnical process.***
The idea that the non-technical factors play an important role in successful innovation provides significant insight. Conversely, it also suggests that the sociotechnical view of innovation is necessary to understand smart card innovation. That is, the innovation process cannot be divorced from the organisational, social and technical factors as many previous innovation models have suggested. Rather, smart card innovation appears to be a matter of overall strategy.
4. ***The sociotechnical view of smart card innovation revealed, has facilitated the development of predictive statements about the dynamics of the innovation process.***
In particular, the theoretical contribution made by previous innovation studies are stressed as important factors in which disequilibrium effects within an evolutionary system is of central importance to this study. The framework used has also provided a basis for understanding some ideas of possible and plausible explanations about why the observed systematic variations in the identified innovation stages have occurred as smart card technology itself has developed.
5. ***The findings provide compelling support for the view that the user is now recognised as an important part of the technological system during innovation.***
It has been argued that the development of large scale and more complex multifunction smart card systems might only exist because of user and that their needs will be the most important factor shaping future innovation patterns. This finding has also highlighted the need to contribute to more systematic design approaches by developing tools to incorporate the needs of the user in the ongoing process of development.
6. ***Finally, this study has revealed how new information technologies like smart card are making it necessary to change our view of the innovation process itself.***
Acceptance of the view that smart card development is an evolutionary process also implies a number of changes in perspective and interpretation of technological innovation. Most importantly, it emphasises awareness of innovation as a process involving feedback which empowers the design team to influence the diffusion by selecting the types of innovations which best meet the needs and expectations of the users within a given time and contextual setting.

Table 9-1 Summary of main original contributions of thesis.

Another shortcoming, is that the approach adopted emphasises the evolutionary characteristics of technological innovation. It does not build on the possibilities of the impact of the introduction of other major or alternate technological innovations. It also does not consider the role of innovation in terms of the economic development of organisations or groups of organisations. It merely presents an attempt to develop our understanding of smart card innovation as it relates to a range of sociotechnical considerations. However, to do this it has been found necessary to go beyond orthodox technology innovation theory and to broaden the scope of analysis. The role of innovation policies or state intervention was also not considered in depth.

Finally, and at a conceptual level, the thesis has been limited by analysing change from within a sociotechnical framework. The paradigmatic framework adopted has been analysed as a first approximation of the analysis of smart card diffusion from a broader perspective than offered by traditional innovation paradigms. Alternate frameworks were not considered. In turn, alternate inputs from other information technologies were not considered. Part of the problem with studying innovation of smart card technology has been the revelation of the emerging complexity of the issues relating to technological convergence of other existing technologies and caused by the interaction of information technologies with society. In fact, one key observation relating to this thesis is the need to recognise the interplay of several paradigms as the technology itself has undergone a number of developmental stages. For this reason alone, the sociotechnical system's view adopted for this study seems to be appropriate because it can involve the use of one or more paradigms.

As can also be seen from these brief remarks, in any exploratory innovation study, choices have to be made regarding the theoretical background and whether to incorporate particular contributions. Against a backdrop of the vast array of previous innovation studies reviewed in Chapter One, the contributions chosen for comment have been limited to focusing on the mainstream collective contributions. This has also been done in a way that recognises the important contributions and continuing influences of previous innovation works. The emphasis here is on the elaboration of sociotechnical system's thinking as an alternative contribution. This is in agreement with many of the central tenets of recent contributions that have emphasised the need for a more broadly based understanding of the innovation process. Of particular relevance here, is the recent work of Bijker which was brought to the attention of the author in the final stages of the studies reported here (Bijker, 1995). Using the bicycle as an example, Bijker has suggested that innovation can be viewed as complex composites that he has referred to as "sociotechnical assemblages".

9.3 Suggestions for further research

The exploratory character of this thesis is generally accepted in many social sciences, but is largely neglected by the industrial economists, even though the earlier works of some industrial economists have made important contributions to our present understanding of the evolutionary character of the technological innovation process. The viability of the theoretical and conceptual design of the study, although different from the familiar ones, has also been tested and validated directly by the outcomes of the research reported in this thesis, and indirectly by the heuristics and information presented in the analyses. Arguments in favour of more in depth analyses in the study of smart card technological innovation itself limits the choice of factors or key elements to be considered in a study, but is does offer future researchers the opportunity to highlight information that might not be otherwise possible. In making this point, it should also be remembered that smart card is a new major technological innovation and that this thesis only represents the first step in the analysis of smart card innovation. Future researchers are therefore encouraged to take a more in-depth and focused view to attempt to draw and refine the general propositions relating to the findings reported here, if we are to achieve a more comprehensive and useful understanding of smart card innovation.

9.4 Concluding remarks

Industry is now beginning to recognise in a practical way, that new forms of knowledge and skills are needed to truly exploit the potential of an intelligent smart card technology. However, this has come at a cost, and the learning process itself has been protracted. After some twenty two years, smart card designers are now directing more resources towards creating new technological systems that are flexible, and able to evolve over time. This implies that the system itself becomes more abstract as it grows more dependant upon the understanding and manipulation of information. These observations also mark the beginning of our recognition of a smart card innovation paradigm based on our understanding of innovation as a sociotechnical process. At the same time it provides the opportunity to imbue the smart card innovation task with a more comprehensive and multidisciplinary meaning.

In this context, smart card as a major new information technology, could be viewed as a contemporary canonical example of innovation that confronts many pre-existing theories of technological development. Most importantly, the different perspectives coalesce here to greatly enrich our understanding of smart card innovation as it evolves within the framework of its own innovation paradigm. The study has also served to demonstrate the basic unity of theoretical and practical knowledge in understanding the process of innovation as the product and process views converge.

As smart card systems become more complex and develop to form a more significant part of our social infrastructures, the smart card innovation patterns identified here, also serve to highlight the need to view innovation as an evolutionary and reflexive process involving many sociotechnical factors. Therefore, collectively the findings on smart card innovation have served to demonstrate the advantages of opening up technology development phenomena to sociotechnical inquiry. That is, we need to examine social, technical and organisational factors to further our knowledge of how nontechnical factors influence design and development: Thus, the central insight revealed is that smart card innovation is inherently a sociotechnical process which relies on contemporary dynamic conditions, and a multidisciplinary understanding of the innovation process itself. This realisation has required us to extend our thinking on innovation processes and a number of sub-themes can be distilled:

The first concerns the revealed complexity of the innovation process itself. Smart card innovation - as revealed here - is far more complicated than a linear model might have otherwise suggested. The underlying processes are both interactive and reiterative - allowing for feedback influences to take effect.

A second sub-theme worth comment, and related to the first, is the continuous or evolutionary nature of the processes observed. Some of the innovation literature has looked at innovation as a series of discrete events that have caused change. Evidently, such analysis would reveal little about the continuous nature of the changes observed. Even when a *discrete* smart card innovation event has been noted, such as the development of the electronic signature, the resulting innovation processes involving the use of the signature have been slow and evolutionary. They were also influenced by many other factors such as chip technology advances and international regulations governing the use of cryptographic advances. By adopting a process focused view of innovation this analysis has therefore been able to extend our understanding of smart card development.

The third sub-theme emerging is related to the growing complexity of sociotechnical systems. The more complex the sociotechnical system is, the more vulnerable it becomes to oversights and obstructions during innovation. At the same time as smart card systems become more sophisticated in scale and scope, the knowledge needed to understand the technical and network operations, the organisational fabric required to support the system and the complexity of the social system within which these exist, are all likely to become highly esoteric to the majority of people. The loyalty card program marketeers, the sociologists, the chip engineers and the network security managers for example, all need to become highly specialised. At the same time they risk alienation. Because of the scale and complexity of emerging systems, there could be unprecedented and quite unintended outcomes relating to monetary or privacy issues.

This conjecture leads quite naturally back to the arguments originally posited: There is a need to emphasise the increasing importance of the evolutionary and multidisciplinary nature of the processes underlying technical change. A consideration of the changed nature of externalities impacting new technology innovation and of the possible evolutionary consequences has been foreshadowed by researchers such as Nelson and Winter.

> *The processes of change are continually tossing up new 'externalities' that must be dealt with in some manner or other.* (Nelson and Winter 1982: 368)

For smart card innovation, it is therefore maintained here, that the dynamic nature of externalities, such as privacy concepts and their relationship to privacy legislation, provide the justification for continuous and evolutionary reassessment of the overall impact of the benefits that a new system might bring. This also leads us back to the management of environmental externalities of innovation change such as privacy. Governments too will continue to be faced with a major challenge. What will be the future role of governments in smart card innovation? Will it be as arbitrator, regulator, social engineer or economic manager? More research on social-technology-organisational aspects of smart card innovation is also needed.

APPENDIX I

List of Factors Influencing Smart Card Innovation

APPENDIX I (a): TECHNICAL FACTORS

SECURITY

- TYPE OF IDENTIFICATION (EG. BIOMETRICS; PIN USE)
- CRYPTOGRAPHIC TECHNIQUES (PRIVATE VS. PUBLIC KEY)
- SECURITY PROCESSING TIME
- LEVEL(S) OF SECURITY (EG. TYPE VALIDATION, AUTHENTICATION, NON REPUDIATION FUNCTIONS)
- DATABASE ACCESS, NUMBER, SIZE, LOCATION, STRUCTURE AND TYPE
- PERSONALISATION VS. ANONYMITY
- VIRUS & HACKER THREAT (EG. USE OF KILL-SIGNAL OR ISOLATION TECHNIQUES)
- CARD MANUFACTURING AND PRODUCTION (EG. DIFFERENT KEY CODES FROM MANUFACTURERS; ISSUE)
- SECURITY EVALUATION PROCEDURES AND METHODOLOGIES

HARDWARE

- TYPE OF CARD (EG. CONTACT VS. CONTACTLESS; LEVEL OF SECURITY REQUIRED; READERS TO DETECT IF CARDS HAVE BEEN HARD-WIRED OR, IF CONNECTING WIRES BETWEEN CHIPS MAY BE TAPPED IN CARDS WITH MORE THAN ONE CHIP)
- NETWORK ARCHITECTURE (EG. CENTRALISED DATABASE VS. DISTRIBUTE)
- ISSUANCE
- NUMBER OF USERS
- NUMBER & TYPE OF APPLICATIONS (EG. DIFFERENT LEVELS WITHIN
- APPLICATIONS, DIFFERENT SECURITY REQUIREMENTS, DIFFERENT CODES, INTEROPERABILITY, INDEPENDENCE OF APPLICATIONS REQUIRED, SECURITY & OPERATIONAL COMPLEXITY)
- STANDARDS
- TRANSACTION TIMES
- TRANSACTION SIZE
- TRANSACTION TYPE
- PHYSICAL ROBUSTNESS (EG. CARELESSNESS, BENDING, WASHING, MISUSE,
- ACCIDENTS, ELECTROSTATIC DISCHARGE, CONTAMINATION, GENERAL WEAR & TEAR, FLEXIBILITY/BRITTLENESS)
- REPLACEMENT
- RELIABILITY (EG. DEPENDABILITY, MTBF, MALFUNCTIONS, DISASTERS)
- LIFE OF ALL CARDS & EQUIPMENT
- RECORD/SERVICE DUPLICATION
- COMPATIBILITY (EG. UPWARD VS. NEW TECHNOLOGY)
- STATISTICAL COLLECTION OF DATA

SOFTWARE

- TYPE OF APPLICATION(S)
- FUNCTIONALITY (EG. RECHARGEABLE)
- TAKE-OVER OF ROUTINE FUNCTIONS
- DATA TYPE (EG. CRITICAL VS. NON-CRITICAL; VOLATILE VS. NON-VOLATILE; PERSONAL VS. IMPERSONAL)
- SYSTEMS BACKUP & DISASTER RECOVERY PROCEDURES
- SOFTWARE RELIABILITY FOR ALL CARDS, EQUIPMENT & MANAGEMENT FUNCTIONS
- SOFTWARE DEVELOPMENT & MAINTENANCE COSTS

COMMUNICATIONS

- RELIABILITY (MTBF) FOR ALL COMMUNICATIONS LINKS
- PUBLIC CARRIER COSTS
- EXTENT OF DEPENDENCE ON EXTERNAL PERIPHERALS FOR I/O
    ONLINE/REALTIME/OPEN SYSTEMS/DISTRIBUTED SYSTEMS/
    REMOTE TERMINAL PROBLEMS

APPENDIX I (b): SOCIAL FACTORS

PRIVACY
- 'NEED-TO-KNOW' SYSTEM IN PLACE
- ACCESS (EG. LIMITS TO ACCESS, LEVELS OF ACCESS)
- DISCLOSURES (EG. DATA DISSEMINATION, MANIPULATIONS, CODING SYSTEMS)
- PERSONAL DOCUMENTATION
- SYSTEM SURVEILLANCE AND CONTROL
- TRACEABILITY
- AUTONOMY OF USER
- DEGREE OF CHOICE IN DISCLOSURE
- DEGREE OF CONTROL OVER DISCLOSURE
- WHAT IS THE INFORMATION TO BE USED FOR? BY WHOM? WHEN? WHERE? HOW? WHY?
- LEVEL OF RESENTMENT OR RESISTANCE

CONFIDENTIALITY
- 'RIGHT-TO-KNOW' SYSTEM IN PLACE
- LEVEL OF TRUST
- SOCIAL OR MARKET DATA COLLECTION METHODS

FAIRNESS
- INDIVIDUAL ACCESS
- ACCURACY
- TIMELINESS
- CURRENCY OF INFORMATION
- COMPLETENESS
- CHECKS FOR COMPLETENESS & INTEGRITY
- FREEDOM OF INFORMATION

SOCIAL EQUITY
- CHARGE COSTS
- SERVICE ACCESS AND FLEXIBILITY
- DISTRIBUTION OF BENEFITS
- DEFAMATION
- METHODS OF PERSUADING CUSTOMERS TO 'SELL' THEIR RIGHTS TO PRIVACY OR, TO 'BUY BEHAVIOUR' FOR BONUSES
- SOCIAL IMPACT (EG. RESISTANCE TO CHANGE)
- RELATIONSHIPS
- COMMUNICATIONS
- CHANGE IN WORK PATTERNS
- CHANGE IN CULTURAL VALUES (EG. TOWARDS 'PRIVACY' OR 'CONVENIENCE')
- DIFFUSION PATTERNS (EG. DEMOGRAPHIC SCALE, SCOPE AND TIME FRAME)
- PUBLIC EDUCATION OR SOCIAL ADJUSTMENT PROGRAM ABOUT TERMS & CONDITIONS OF USE, CONSUMER CHOICE, RISKS AND COSTS
- INFORMED USER BASE (EG. TECHNOLOGY AWARENESS, INFORMATION MANAGEMENT PROCEDURES)
- KNOWLEDGE GAPS BETWEEN DIFFERENT USER GROUPS
- PUBLIC PARTICIPATION (EG. CONSULTATION AT ALL STAGES, INCREASE AWARENESS, INCREASE TRUST, AWARENESS OF USER RIGHTS & RESPONSIBILITIES

ACCOUNTABILITY & OVERSIGHT
- LIABILITY
- LOSS OF CARD
- PROCEDURES FOR FORGETTING SECURITY CODES/PINS
- HUMAN ERROR
- FRAUD
- ELECTRONIC COUNTERFEITING
- ABUSE

REGULATORY REQUIREMENTS

- UNIVERSAL ACCESS/AVAILABILITY OF SERVICES REQUIREMENTS
- COMPETITIVE LEGISLATION
- PRIVACY LEGISLATION
- SECURITY REQUIREMENTS TO MEET LEGISLATIVE REQUIREMENTS
- STANDARDS
- INDUSTRY REGULATIONS
- CITIZENS' RIGHTS
- CONSUMER RIGHTS
- EQUITABLE DISTRIBUTION OF BENEFIT, COST AND RISK
- AFFORDABILITY
- PROCEDURES FOR THE RESOLUTION OF DISPUTES
- LIABILITY REQUIREMENTS (EG. LOSS, DAMAGE, CONSEQUENTIAL LOSS, RESPONSIBILITIES TO CONSUMERS, UNAUTHORISED TRANSACTIONS, TECHNICAL FAILURE OR DISASTER)

USER ACCEPTANCE CRITERIA

- CULTURAL (EG. DIFFERENCES IN VALUES, PRIORITIES, RELIGIOUS BELIEFS AND PHILOSOPHY)
- SERVICE INTERFACE (EG. USEABILITY, SUITABILITY, CLARITY, SELF-DESCRIPTIVENESS, CONTROLLABILITY, OBSERVABILITY OF EFFECTS & PROCESS)
- USER EXPECTATIONS
- DATA PROTECTION
- USER DEMANDS
- FLEXIBILITY
- ATTITUDES
- CONVENIENCE
- DEMOGRAPHIC (EG. AGE, SEX, LEVEL OF EDUCATION, INCOME, MARITAL STATUS, PERSONALITY)
- PERCEIVED BENEFITS (EG. CONVENIENCE, EFFICIENCY, PORTABILITY)
- PERCEIVED ACCEPTABLE LEVELS OF RISK
- LEARNING CURVE
- SATISFACTION (EG, SPEED OF TRANSACTION, RELIABILITY, MEETS NEEDS)
- TESTABLE ON A TRIAL BASIS
- PERCEIVED RELATIVE ADVANTAGES OVER OTHER TECHNOLOGIES & SERVICES
- COMPATIBILITY WITH OTHER USER PATTERNS AND VALUES
- OWNERSHIP WITHOUT LIABILITY
- COMPENSATION MECHANISMS FOR INACCURATE INFORMATION OR UNWANTED DATA DISCLOSURE
- FREEDOM TO ACCESS PERSONAL INFORMATION
- RIGHT TO KNOW INFORMATION USE AND CONTROL SYSTEMS, BY WHOM & FOR WHAT PURPOSES
- INFORMATION OWNERSHIP RIGHTS OF INDIVIDUALS, ORGANISATIONS & GOVERNMENT AGENCIES
- CUSTOMISATION
- DIVERSIFICATION OF SCOPE AND SCALE OF SERVICES
- LAW ENFORCEMENT DOSSIERS
- TRANSFER OF POWER FROM USERS AND ORGANISATIONS TO THE GOVERNMENT
- TRUST

APPENDIX I (c): ORGANISATIONAL FACTORS

DIRECT PROJECT COSTS

- CARD TYPE (BASED ON DEGREE OF FUNCTIONALITY REQUIRED)
- HARDWARE
- SOFTWARE
- COMMUNICATIONS
- SECURITY
- MARKETING
- STANDARDS
- REGULATORY REQUIREMENTS
- CONSUMER ACCEPTANCE
- INFORMATION MANAGEMENT (EG. PERSONAL DATA FILE ACCESS & CONTROL, MARKET INFORMATION ACCESS & CONTROL; LINKAGE BETWEEN DATABASES)

ECONOMIC GROWTH

- COMPETITION
- REGULATION
- STANDARDS
- EFFECTS ON OTHER INDUSTRIES
- RELATIONSHIPS BETWEEN CITIZEN'S AND GOVERNMENTS; BUSINESS AND GOVERNMENTAL
- NATURE OF AGREEMENT(S) AMONG ORGANISATIONS INVOLVED (EG. IMPLICIT/)EXPLICIT)
- LEVEL OF COOPERATION REQUIRED AMONG ORGANISATIONS
- NUMBER OF ORGANISATIONS INVOLVED
- DIFFERENCES IN BUSINESS GOALS AND OBJECTIVE AMONG PARTICIPATING ORGANISATIONS
- LEVEL OF PROFIT
- INCREASE IN MARKET SHARE
- CUSTOMER LOYALTY PROGRAM
- NEW PRODUCTS AND SERVICES
- NEW CUSTOMERS
- NEW ORGANISATIONAL PARTNERS
- DIVERSIFICATION AMONG ORGANISATIONAL PARTNERS
- HANDLE CASH EFFICIENTLY
- ACCEPTANCE OF MULTIPLE CURRENCIES
- MATCH CUSTOMER NEEDS
- GATHERING OF MARKET INFORMATION
- RATE OF DEVELOPMENT
- DEGREE OF INNOVATIVENESS
- READINESS OF THE ORGANISATION FOR CHANGE
- INVESTMENT & BUDGET CONSTRAINTS
- MANAGEMENT ROLES & RESPONSIBILITIES
- COORDINATION
- CONSISTENCY
- PUBLIC REPUTATION
- ORGANISATIONAL & EMPLOYEE LIABILITY FOR LOSS, DAMAGE, CONSEQUENTIAL LOSS, RESPONSIBILITIES TO CUSTOMERS, UNAUTHORISED TRANSACTIONS, TECHNICAL MALFUNCTIONS
- EXTERNAL FACTORS (EG. GOVERNMENT, INTERNATIONAL, COMPETITION, MACRO ECONOMIC EFFECTS, POLITICAL, SOCIAL)
- ALIGNMENT OF BUSINESS, TECHNICAL & ORGANISATIONAL STRATEGIES
- ALIGNMENT OF BUSINESS, TECHNICAL & ORGANISATIONAL INFORMATION OWNERSHIP & CONTROL OR USAGE PATTERNS
- BALANCE OF POWER AMONG ORGANISATIONS; BETWEEN USERS AND MANAGING ORGANISATIONS; & BETWEEN ORGANISATIONS, THE USERS & THE GOVERNMENT(s)
- LEVEL OF VULNERABILITY OR 'OPENNESS' OF THE SYSTEM
- RANGE OF TECHNOLOGIES USED
- RANGE OF SERVICES OFFERS
- SCALE OF SYSTEM

RETAILERS

- AFFORDABILITY
- USEABILITY
- INCENTIVES
- COMPETITIVE CONSIDERATIONS
- EFFICIENCY
- CUSTOMER RELATIONSHIPS
- RIGHTS TO INFORMATION
- DEPENDENCE ON SVC ISSUERS, MAINTENANCE, SERVICE
- LIABILITIES
- DISPUTE RESOLUTION PROCEDURES
- FINANCIAL APPRAISAL TECHNIQUES
- DISTRIBUTION OF COSTS, PROFITS & BENEFITS
- ESTABLISHMENT COSTS
- RATE OF RETURN

STAFF

- LEVEL OF COMMITMENT & SUPPORT
- ORGANISATIONAL CULTURE(S)
- MANAGEMENT PHILOSOPHY
- LEVEL OF KNOWLEDGE OR INFORMATION ABOUT RISK FACTORS
- UNDERSTANDING, EXPERIENCE & KNOWLEDGE OF THE TECHNOLOGY
- TECHNICAL SUPPORT EXPERIENCE
- MANAGEMENT SUPPORT EXPERIENCE
- USER/SOCIAL ACCEPTANCE EXPERIENCE
- TRAINING FOR READINESS TO COPE WITH RISK FACTORS (EG. WHO, TYPE OF TRAINING, AVAILABILITY)
- PROCEDURES (EG. FAILURE & DISASTER RECOVERY PROCEDURES)
- FLEXIBILITY & ADAPTABILITY
- INTERNAL PROTECTIVE MECHANISMS (EG. 'RIGHT-TO-KNOW' SYSTEM, SECRECY, DATA & SYSTEMS INTEGRITY, FORGERY, DATA MANIPULATION TO ALTER FEATURES ON CARDS, SIMULATION OF CARD FUNCTIONS)

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