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

Robyn Alice Lindley

University of Wollongong

Follow this and additional works at: https://ro.uow.edu.au/theses

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

Robyn Alice Lindley
University of Wollongong


This paper is posted at Research Online.
NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.
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

Robyn Alice Lindley, B.Sc. (Sydney University)
Grad. Dip. Ed. (Sydney University)
M.Info.Tech. (University of Wollongong)

Department of Information and Communication Technology
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.
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.
Contents

2.5 Industry development trends .............................................. 54
  2.5.1 Slow rate of diffusion for the period 1974 to 1991 ................. 54
  2.5.2 Development has relied on advances on other industries ........... 58
  2.5.3 Recent rapid globalisation of the technology ......................... 60
  2.5.4 Competitive nature of the industry ................................ 60
  2.5.5 Clustering ............................................................. 62
  2.5.6 Technological convergence .......................................... 63
  2.5.7 Underdevelopment of the smart card industry ....................... 65
  2.5.8 Declining cost of the technology .................................. 66
  2.5.9 The smart card regulation-innovation quandary ...................... 67

2.6 Active security functions .................................................. 68
  2.6.1 The role of security functions ..................................... 69
  2.6.2 Digital signatures .................................................... 70
  2.6.3 Cryptographic functions ............................................. 72
  2.6.4 Regulations and constraints on the use of cryptographic methods 75
  2.6.5 Can smart cards be duplicated? .................................... 77
  2.6.6 Computer virus spread .............................................. 79

2.7 What role do standards play? .............................................. 84
  2.7.1 The development of ISO smart card standards ..................... 85
  2.7.2 Scenario I: Minimal ISO standards development ................... 88
  2.7.3 Scenario II: ISO standards developed into full architecture ....... 89
  2.7.4 Manufacturers attitudes to standardisation ........................ 90

2.8 Technological development and smart card innovation .................. 94

2.9 Conclusions ..................................................................... 97

Chapter Three

Some Industry Case Studies .................................................. 99

3.1 Smart card in the healthcare industry .................................. 99
  3.1.1 The imperatives ...................................................... 101
  3.1.2 National Health Insurance Card ................................... 103
  3.1.3 Data specific patient cards ......................................... 107
  3.1.4 Factors influencing smart card innovation in the healthcare
        industry ................................................................. 108

3.2 Smart Card in telecommunications ....................................... 116
  3.2.1 Prepaid telephone cards ......................................... 116
  3.2.2 GSM cards ........................................................... 116

3.3 Smart Cards in the Banking Industry .................................... 117
  3.3.1 Home banking ....................................................... 118
  3.3.2 Banking and smart card innovation ................................ 119

3.4 Transportation ticketing systems ......................................... 120
  3.4.1 Ajax Transit Authority (Canada) ................................... 120
  3.4.2 Glennorie Bus Company (Australia) ................................ 120
  3.4.3 Hong Kong Transit Authority ...................................... 121
  3.4.4 The evolution of transit payment systems ........................ 122

3.5 Smart cards in the retail industry ....................................... 123
  3.5.1 Vision Value card (United States) ................................ 123
  3.5.2 The emergence of large scale SVC projects ....................... 124
  3.5.3 Retail applications and smart card innovation ................... 127

3.6 Other Applications .......................................................... 128
  3.7 Conclusion .................................................................... 131
Contents

Chapter Four
The Role of the User in the Public Domain ........................................... 133
4.1 What have we learnt from smart card trials to date? ......................... 134
4.2 Privacy and surveillance .................................................................... 137
4.2.1 The concept of privacy ................................................................. 137
4.2.2 Privacy and the convenience-control conundrum ......................... 139
4.2.3 Inadequate privacy safeguards ...................................................... 143
4.3 Privacy Protection ............................................................................. 146
4.3.1 International treaties for privacy protection ................................... 146
4.3.2 OECD guidelines for the security of information systems ............. 147
4.3.3 Legal and social consequences of International Privacy Rights (IPRs) ................................................................. 148
4.4 The level of need of the user ............................................................... 150
4.5 Social resistance to change ............................................................... 153
4.6 User acceptance from the point of view of data type ....................... 155
4.7 The concept of an electronic silhouette ............................................. 158
4.8 The growing gap between smart card technology and the creation of new social structures ................................................................. 162
4.9 Defining the relationship between smart card and society ............... 163
4.10 Conclusion ....................................................................................... 165

Chapter Five
Smart Card Innovation as a Sociotechnical Process .............................. 167
5.1 The foundations of sociotechnical theory .......................................... 168
5.1.1 What is sociotechnical theory? ...................................................... 168
5.1.2 Sociotechnical experimentation .................................................... 169
5.1.3 The development of sociotechnical thinking ................................. 176
5.2 Sociotechnical theory as a methodological framework ................. 177
5.3 Sociotechnical thinking and smart card innovation ....................... 180
5.3.1 Public concerns for privacy and the misuse of data ................... 181
5.3.2 Participation and sociotechnical design .................................... 183
5.3.3 A sociotechnical view of smart card innovation .................... 184
5.4 Implications for theory and practice ................................................. 186
5.5 Conclusion ....................................................................................... 188

Chapter Six
Sociotechnical Experimentation: A review of an Australian case study .... 190
6.1 Background to the study .................................................................. 190
6.2 The case study ................................................................................ 192
6.3 Methodology .................................................................................. 194
6.4 Results and Discussion ................................................................... 200
6.4.1 Application of sociotechnical principles .................................. 200
6.4.2 Ranking of key design criteria ................................................... 202
6.4.3 Identified project difficulties ....................................................... 204
6.5 Wider implications for research and practice .................................. 207
6.6 Conclusion ....................................................................................... 211
Contents

Chapter Seven

Smart Card Innovation:
Organisation and execution.........................................................214
7.1 Smart card innovation by design.................................................215
  7.1.1 Innovation paradigms and design concepts.................................215
  7.1.2 Smart card innovation and associated design stages.....................217
  7.1.3 Developing a Comprehensive Analysis for Smart Card
  (CASC) design approach ..................................................................220
  7.1.4 Which evaluation methods can be used?.......................................224
  7.1.5 Limitations of the CASC approach............................................226
  7.1.6 Altering our perceptions of the role of the design function in
  innovation......................................................................................227
7.2 Risk assessment and the development of smart card technology........228
  7.2.1 Why develop RA tools?.............................................................228
  7.2.2 The concept of risk and large scale smart card projects?...............231
  7.2.3 What are the risk factors?.........................................................234
  7.2.4 Smart card risk assessment in practice.......................................236
  7.2.5 Risk assessment using scenario tool GVE.................................238
7.3 The promotion and control of innovation by government.................243
7.4 Conclusion.................................................................................248

Chapter Eight

Towards a Smart Card Innovation Paradigm.......................................249
8.1 Smart card as a major innovation...............................................249
  8.2 MFC/Os: The next generation of smart cards.................................252
    8.2.1 Defining MFC/Os...................................................................253
    8.2.2 Advantages of MFC/Os.........................................................254
    8.2.3 Challenges in migrating to MFC/Os.........................................257
8.3 Innovation in an evolutionary open systems environment................258
8.4 Dealing with evolutionary smart card systems............................263
  8.4.1 A change in engineering focus................................................263
  8.4.2 Managing infostructure............................................................263
  8.4.3 The need for the generalist and specialist....................................264
  8.4.4 Managing a large range of environmental variables......................264
  8.4.5 Future technological convergence............................................265
8.5 The emerging smart card innovation paradigm............................266
8.6 The virtuous cycle of smart card innovation................................269
8.7 The smart card innovation quandary............................................272
8.8 Conclusion....................................................................................273

Chapter Nine

Conclusions and Implications..........................................................275
9.1 Summary of key findings............................................................275
9.2 Limitations of the study..............................................................278
9.3 Suggestions for further research................................................282
9.4 Concluding remarks....................................................................283
Contents

Appendix I: List of factors influencing smart card innovation ........................................287
List of Publications by the Author (1992-1996) ......................................................... 293
References .................................................................................................................. 298
Tables

Table 2-1
A brief smart card chronology (1970-1996) ........................................ 41

Table 2-2
A comparison of different card technologies available at the present time .......... 43

Table 2-3
List of some of the world's first large scale SVC, or true electronic purse projects emerging (1996). ......................................................... 57

Table 2-4
A list of the world's major semiconductor firms capable of supplying card chips (1995) ................................................................. 64

Table 2-5
Comparative cost of alternate technologies *circa* 1995 ................................ 66

Table 2-6
ISO standards have been developed for the essential and now form a basis for some other more developed propriety standards ............................... 87

Table 2-7
Four stages of smart card innovation .................................................... 95

Table 3-1
Health smart card applications ................................................................... 113

Table 3-2
Classification of some health insurance card systems currently in use and their associated objectives .......................................................... 115

Table 4-1
Classification of smart card user acceptance criteria with the associated operational objectives ............................................................. 136

Table 4-2
The likely impact of data type on smart card replacement costs and user acceptance ................................................................. 157

Table 5-1
Stages of the sociotechnical process .......................................................... 179
Tables

**Table 6-1**  
Identified key sociotechnical objectives for the effective development of smart card systems .................................................. 193

**Table 6-2**  
An alphabetical listing of the Australian organisations that participated in the 1993 study (N=26). .................................................. 195

**Table 6-3**  
Profile of the Australian smart card projects surveyed (1993) .......................... 198

**Table 6-4**  
Level of use of sociotechnical principles by Australian firms .......................... 201

**Table 6-5**  
Scale of Australian smart card projects (1993). ........................................... 206

**Table 6-6**  
Some examples of project smart card applications and the key associated organisational goals ........................................... 209

**Table 7-1**  
Smart card innovation stages and the associated conceptual shift occurring at the operational -- or basic design -- level ........................................... 218

**Table 7-2**  
The changing focus of the smart card system's design team .......................... 220

**Table 7-3**  
The comprehensive analysis for smart card (CASC) systems design approach ........................................... 224

**Table 8-1**  
List of the defining innovation features characterising a Multifunction Card operating in an Open system's environment (MFC/O) ........................................... 255

**Table 9-1**  
Summary of main original contributions of thesis ........................................... 280
Figures

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

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

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

Figure 2-2
The ST6XYZ flexible microcomputer for smart card ICs manufactured by SGS-Thomson Microelectronics.

Figure 2-3
Smart card industry by card type (1994-5).

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

Figure 2-5

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.

Figure 2-7
Smart card use by geographic region in 1993 and 1994.

Figure 2-8
Diagram showing the gradual changes in the traditional role of the manufacturer as the smart card industry has developed.

Figure 2-9
Graph showing the use and the level of bank card fraud in France for the period 1988 to 1993.

Figure 2-10
Graph showing the comparative rate of electronic crime incidents reported by Government Departments in the UK for 1990 and 1993.
Figures

Figure 2-11
The defining characteristics of a closed and open operating environment for smart card systems ................................................................. 83

Figure 2-12
A schematic diagram showing the increased exposure of a multiapplication smart card system operating in an open systems environment ........................................ 84

Figure 3-1
Worldwide smart card use by industry in 1994 ................................................ 100

Figure 3-2
A schematic diagram showing how the French health card system (Sesam Vitale) has been implemented ...................................................... 104

Figure 3-3
The evolution in transit payment systems (1970s - 1990s) ...................................... 124

Figure 5-1
Summary overview of the development of sociotechnical theory and its application since its inception in 1951 ................................................................. 171

Figure 5-2
A model of a sociotechnical system ................................................................ 175

Figure 5-3
Model showing the relationships between sociotechnical factors influencing smart card innovation ................................................................. 187

Figure 6-1
User design criteria identified by project staff (N=24). ........................................ 203

Figure 7-1
A schematic diagram of the Comprehensive Analysis of Smart Card (CASC) design framework ................................................................. 223

Figure 7-2
A general Quantitative Reasoning (QR) framework for predicting future smart card project outcomes derived from an identified simple structural description ................................................................. 235

Figure 7-3
Sample semantic net for a simplified model of a large scale SVC project ........ 241
Figures

Figure 8-1
A pictorial representation of smart card stages of development showing the close relationship between the product and process view of innovation ............268

Figure 8-2
The smart card development virtuous cycle showing the interrelatedness between organisational, technical and social changes during the smart card innovation process ...............................................................271
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 Telecommunication 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

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