Framework for Smart Card Use in the Construction Industry

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Abstract

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The use of Smart Card Technology in the construction industry is untested. This thesis presents the study of framework for using smart card technology as a new means to reduce cost and improve productivity for construction companies. The purpose of this research is to investigate the applicability of smart card in construction sector and explore the potential applications of smart card for timesheet, labor payment, schedule update and job site access control. A smart card questionnaire was conducted to obtain input from construction senior managers and executives regarding the prospect of employing smart card in the industry. In addition, this research identified the potential applications of smart card with the most suitable infrastructure to the construction environment and the capability of card technology to mechanize the current paper-based timesheet and manual labor payment practice. This thesis presents also a proposed implementation process of the Construction Labor Smart Card (CLSC) and its labor payment application along with a cost comparison analysis between paper-based and smart card-based timesheets.

Acknowledgment

All praise is due to God. I would like to express my sincerest gratitude to my professors Dr. S. Alkass and Dr. M. Al-Hussein for their diligent guidance and helpful discussion during the course of this research. Their advice and counseling stimulated my desire to pursue the idea of using the smart card technology in the construction industry.

I would also like to thank Mondex International in the U.S. and Royal Bank of Canada for their support to this research, in particular, Debbie Gamble and Miguel Gonzalez from Mondex and Allan McGale and David Wilson from Royal Bank of Canada.

I would like to express my deepest gratitude to my wife, Noor, for her patience, constant support and encouragement without which it would have been impossible to complete this endeavor.

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

A smart card is a plastic card embedded with an integrated circuit chip (IC Chip) which allows information to be stored, accessed and processed either online or off-line by using a card reader. A smart card stores several hundred times more data than a conventional magnetic stripe card. Using smart cards, project managers, foremen and workers exchange information with each other through a pocket or key-chain card reader. This research investigates the possibility of using the smart card technology in the construction industry as a tool to combine technologies, processes, and management techniques to automate business transactions in construction projects through paperless mechanisms.

1.1 Research Motivation

There is no doubt that IT industry plays an important role in modernizing current practices of different fields, including the construction industry. Technologies such as network computing, internet and telecommunication services have a major impact on the way construction projects are managed and built. Construction companies competing for federal projects are being challenged to modernize their contract procurement and administration processes in order to comply with the government's new requirements.

Smart card technology **cost** is currently less expensive than any other computing technology (such as private networks) of software, equipment and services to company's private operations. The price of a private network has increased from $2.7 billion in 1995 to $20.1 billion in year 2000 according to Killen & Associates report (Brown 1997 & Kaplan 1996). Using the smart card reduces - but does not eliminate - the need for investing in an online network infrastructure, which may not be available to remote construction sites, small projects or environments with limited telecommunication service resources. If the average cost of a smart card is about $20 and the hand-held smart card readers is about $50, the total budget to deploy smart card in a construction project would be $70 times the total number of project personnel carrying cards. Additional costs such as systems integration, consultation, maintenance and online terminals have to be considered when preparing smart card business case.

There has been a tremendous **improvement** in the card technology and its capabilities since the smart card was introduced in late 1970s as shown in Figure 1-1.

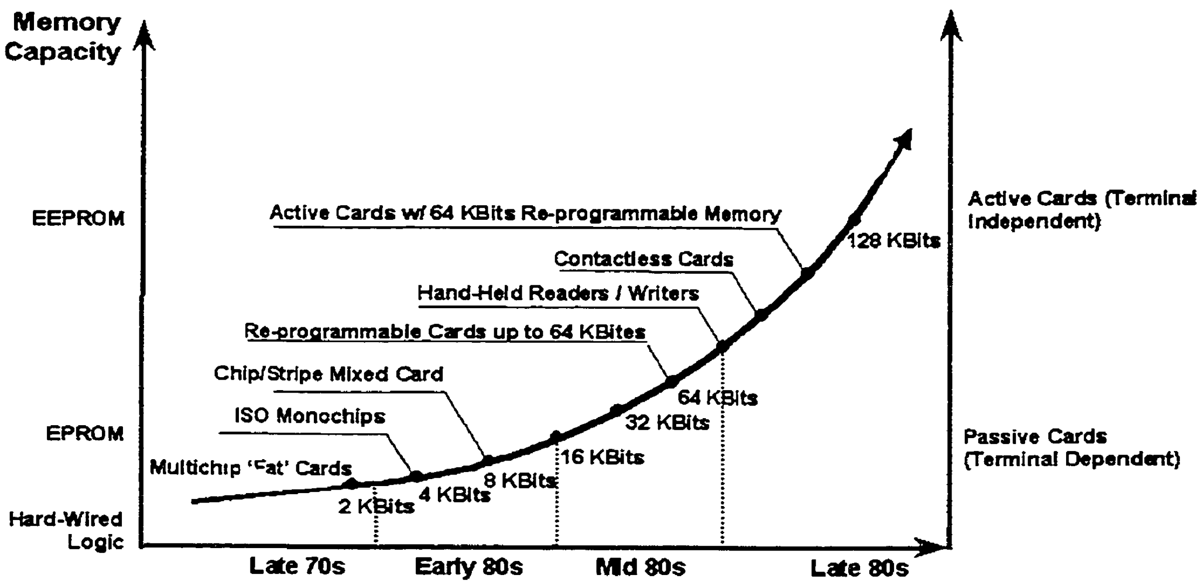


Figure 1-1: Smart Card Technical Evolution

(Source: Bright 1988)

New technologies such as 32-bit chip processors, 32 Kbytes-memory become available in today's applications. Projected growth of smart card EEPROM chip is illustrated in Figure 1-2.

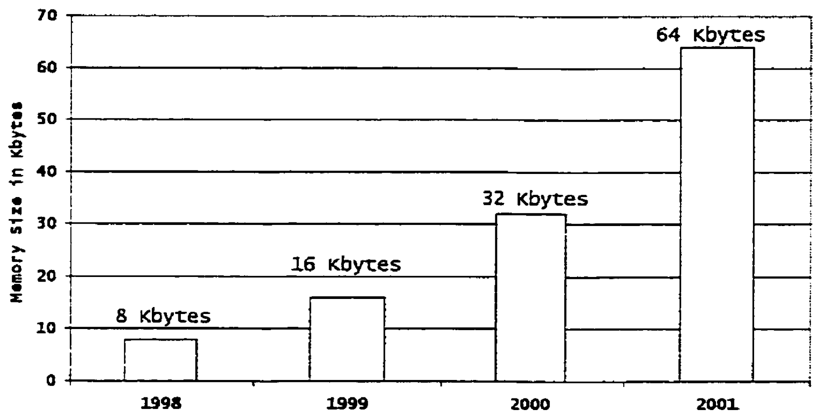


Figure 1-2: Projected Growth of Smart Card EEPROM Chip

(Source: Multos 2000)

New generation of smart cards still in the R&D stage - called super cards technology - use buttons and small displays mounted on the card (similar to today's calculators) and connected to the card integrated circuit. Super card Technology is not part of the scope of this research.

Programmability of the smart card using 32-bit processors and EEPROM memory has made the technology much friendlier. According to Roy Bright's model shown in Figure 1-3, reliability of the smart card in performing financial transactions and data security are major pulling factors towards using the card in industries such as financial, transportation, and healthcare, while other factors are increasing the demand for smart cards.

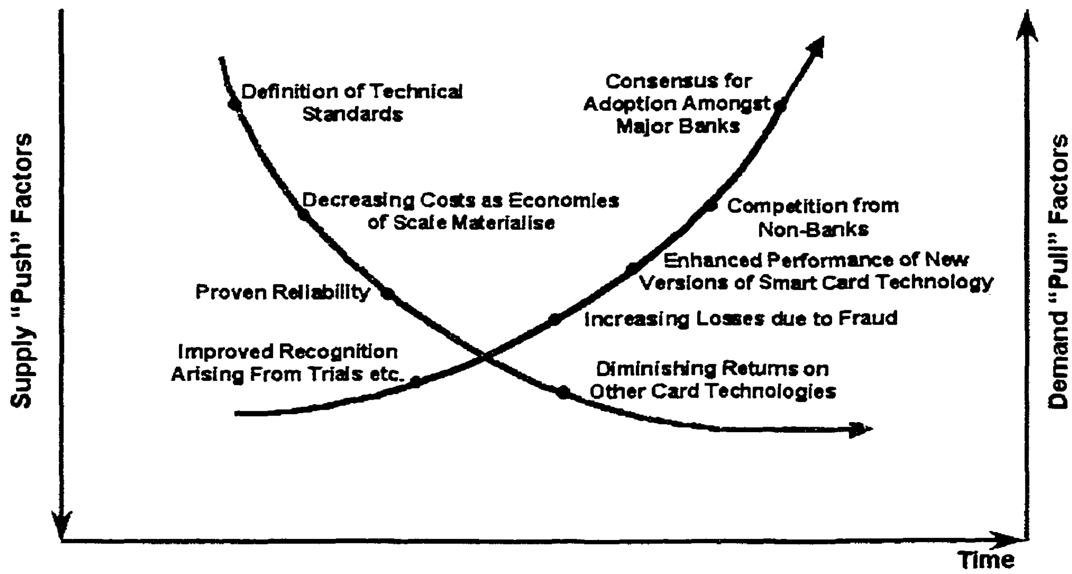


Figure 1-3: Smart Card Supply-Push and Demand-Pull Factors

(Source: Bright 1988)

The Personal Computer / Smart Card (PC/SC) Work Group, International Organization for Standardization (ISO), Open Card Forum, Smart Card Industry Association (SCIA), International Card Manufacturers Association (SCMA), Java Card Forum (JCF), Microsoft Smart Card and other members of card industry groups have made a major **commitment** towards the smart card technology. Microsoft has included smart card features in their products, including Windows and Windows NT. Sun Microsystems released a Java card operating system, which supports multi-application smart cards. A new generation of personal computers and laptops are expected to be available in the market with a built-in smart card reader interface.

Although the **market trend** for each card application is established based on market surveys as shown in Table 1-1 (Web 19), no construction application forecast has been identified during the process of this research.

Smart Card Application	Number of Cards Issued (in Millions)	
	1998 [*]	2003 [**]
Pay Telephones	890	2,804
GSM Cell Phones	120	311
Financial	75	520
Retail / Loyalty	33	236
Health Care	28	189
Electronic Commerce / IT	3	162
Pay TV	29	184
Metering / Vending	16	66
ID / Access	24	267
Transportation	13	165
Other	25	103
Total	1,256	5,007
[*] Actual [**] Projected		

Table 1-1: Global Number of Smart Cards by Application

(Source: Orga 1999)

Some local and federal **governments** currently employ the smart card in their operations and services. In Germany, a healthcare smart card is used nationwide. In France, telephone cards are widely used by the state-owned telecommunication company. In some parts of Argentina, the driver's license smart card has replaced the traditional driver's license. The U.S. General Services Administration (GSA) has set up a 5-year plan to move to a paperless environment by year 2003 (Web 10). According to Card Technology report published by Faulkner & Gray in October 1999 (Web 14), The pay

TV and personal identification and phone smart card applications had the largest market share in the U.S. in 1998 as shown in Table 1-2.

Smart Card Application	Number of Cards Issued (in Millions)	
	1998 [*]	2003 [**]
Pay Telephones	0.3	1.0
GSM Cell Phones	1.2	16.9
Financial	0.1	7.0
Retail / Loyalty	0.1	5.9
Health Care	0.1	2.0
Electronic Commerce / IT	0.1	49.2
Pay TV	5.0	54.8
Metering / Vending	0.3	5.1
ID / Access	0.3	22.8
Transportation	0.0	6.0
Other	0.2	10.0
Total	7.7	180.7
[*] Actual [**] Projected		

Table 1-2: U.S. Number of Smart Cards by Application

(Source: Orga 1999)

The U.S. electronic commerce and pay TV applications are expected to reach 58% of the U.S. smart card market size in 2003 according to Orga's forecast. Many companies have published a 5-year market forecast. Smart card market size is expected to reach 3.4 billion cards by year 2003 as shown in Figure 1-4 (Web 15).

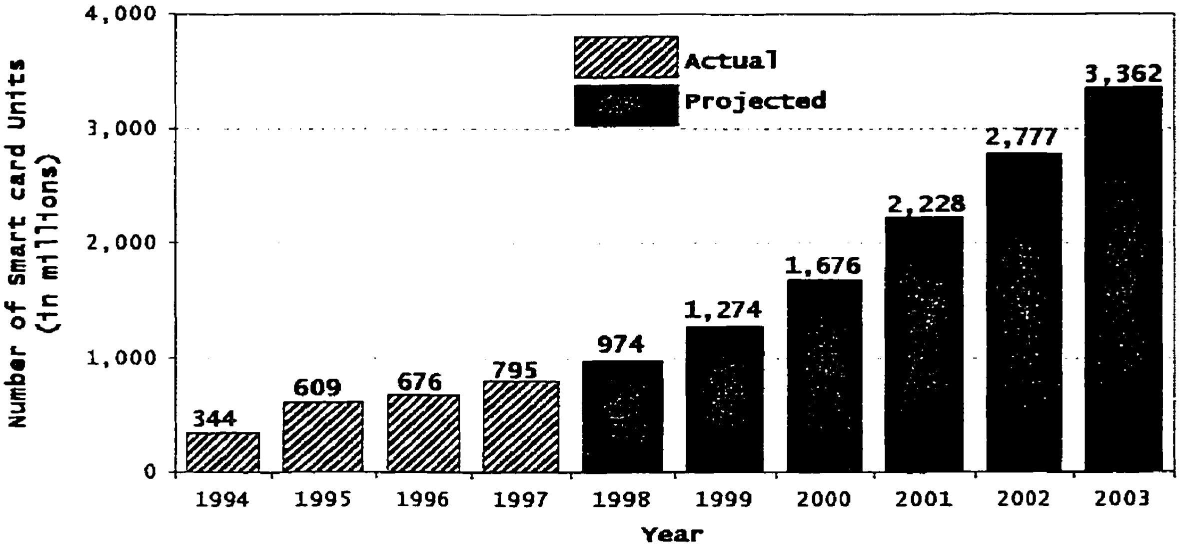
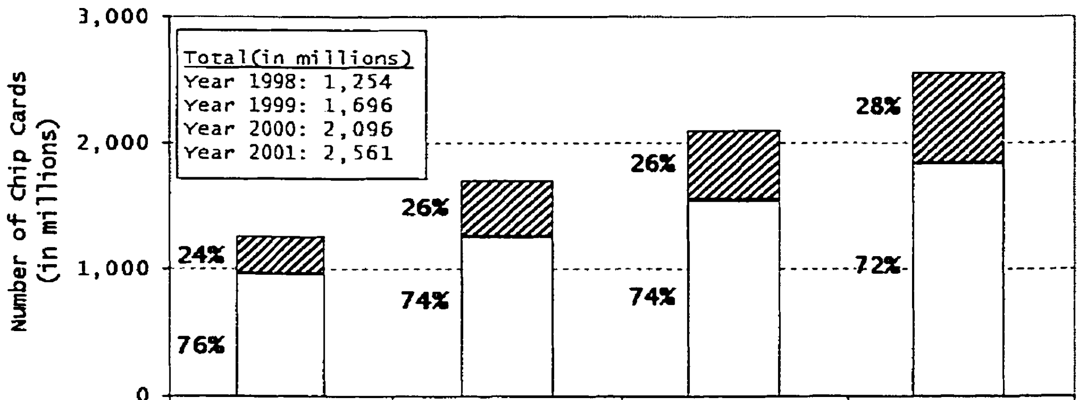


Figure 1-4: Global Smart Card Market Forecast

(Source: Frost & Sullivan 1998)

The smart card growth rate will be higher in the next 5 years, according to Frost and Sullivan forecast. Figure 1-5 illustrates forecast for both smart card and memory card.



	1998	1999	2000	2001
Smart cards	296	439	551	720
Memory cards	958	1,257	1,545	1,841

Figure 1-5: Global Smart Card and Memory Card Forecast

(Source: Dataquest 1998)

Although the smart card trends are not consistent and varying significantly, forecast reports agree that smart card applications are expected to be widely accepted throughout the world. In this research, the use of smart card in construction is studied in an effort to reduce paper work in the field, eliminate redundancy in project reports, enhance data exchange between site and office, mechanize data collection process in the field and avoid re-entering data.

1.2 Research Objectives

The main objectives of this research are:

1) Investigate the applicability of smart card technology in construction projects by examining the technology capabilities that support construction operations.
2) Explore the potential smart card applications, which benefit the construction industry and improve its current practices.

A research objective model is constructed to indicate the inputs to examining the research objectives and outcome of achieving these objectives as shown in Figure 1-6.

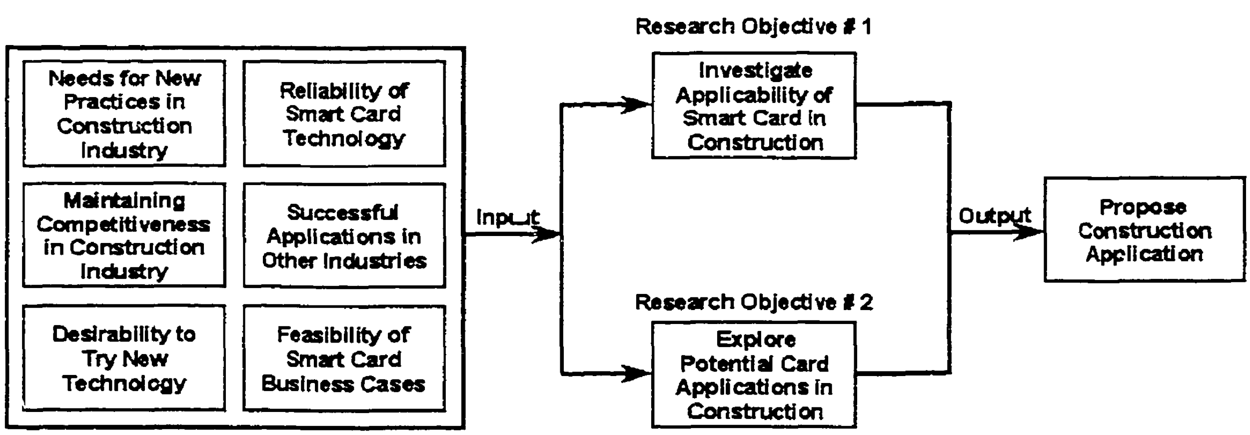


Figure 1-6: Research Objective Model

1.3 Research Plan

The research plan consists of the following five consecutive steps:

1) **Literature Review**: carry out a review of the different smart card applications in the various industries in order to evaluate their main benefits to the intended users and analyze their applicability to construction industry.

2) **Technology Overview**: investigate smart card capabilities, the prospect of card technology, adaptability of such new technology and its feasibility to use in construction projects.

3) **Potential Applications**: explore the potential smart card applications and benefits in construction. Focus on the labor payment application to improve productivity and reduce cost of time keeping and payroll processing.

4) **Smart Card Questionnaire**: conduct a survey to gauge the interest of using smart card technology and the perceived feasibility and adaptability of smart card in the construction industry.

5) **Proposed Application**: propose a Construction Labor Smart Card (CLSC) solution with a labor payment application. Construct an application model and outline a process flow for the proposed application. A method of implementation and deployment for the CLSC solution is adopted from the industry standard Multos platform.

6) **Cost Study**: perform a cost comparison between paper-based and smart card-based timesheets to study the economics of the intended CLSC labor payment solution.

1.4 Thesis Organization

The thesis consists of five chapters. **Chapter 1** (Introduction) covers the research motivation and objectives and discusses the research methodology carried out to construct a framework for smart card use in the construction industry. **Chapter 2** (Literature Review) provides a technology overview including smart card classifications, card operating systems and application programming and card life cycle. The chapter also summarizes the major smart card applications, which are currently used in different industries such as financial, transportation, telecommunications and construction sectors. **Chapter 3** (Framework) discusses the feasibility and adaptability of smart card technology, areas of applications in the construction industry and the potential benefits of these applications. A smart card questionnaire and its results are also covered in this chapter. **Chapter 4** (Labor Payment) addresses the time keeping and labor payment current practices and the proposed smart card labor payment model and its process flow. The Construction Labor Smart Card (CLSC) and its labor payment application development and implementation are also explained in this chapter including a cost comparison between the paper-based and the proposed smart card timesheets. **Chapter 5** summarizes the benefits of using the smart card in construction projects and the value of the proposed CLSC based on the facts discussed in this research. The chapter also encompasses the research contribution and the proposed recommendations for a future research.

Chapter 2 Literature Review

Only one attempt to adopt smart card in the construction industry has been reported in the literature, therefore this chapter summaries the major applications which are mainly used in different industries such as financial, transportation and telecommunications. These applications are used in **Open Environment** such as mass transit and road toll systems or **Closed Environment** applications such as campus, military and government facilities. The smart card technology overview and applications benefits are also discussed.

2.1 Smart Card Technology Overview

The key elements of the smart card technology are classified into 11 categories:

1) Reader Interface
2) Interface Combination
3) Application Functionality
4) Card Dimension
5) Non-Volatile Memory Type
6) Processor Architecture
7) Chip Functionality
8) Operating Systems (OS)
9) Security
10) Processor Clock
11) Memory Size

Figure 2-1 depicts different types of smart cards under each category.

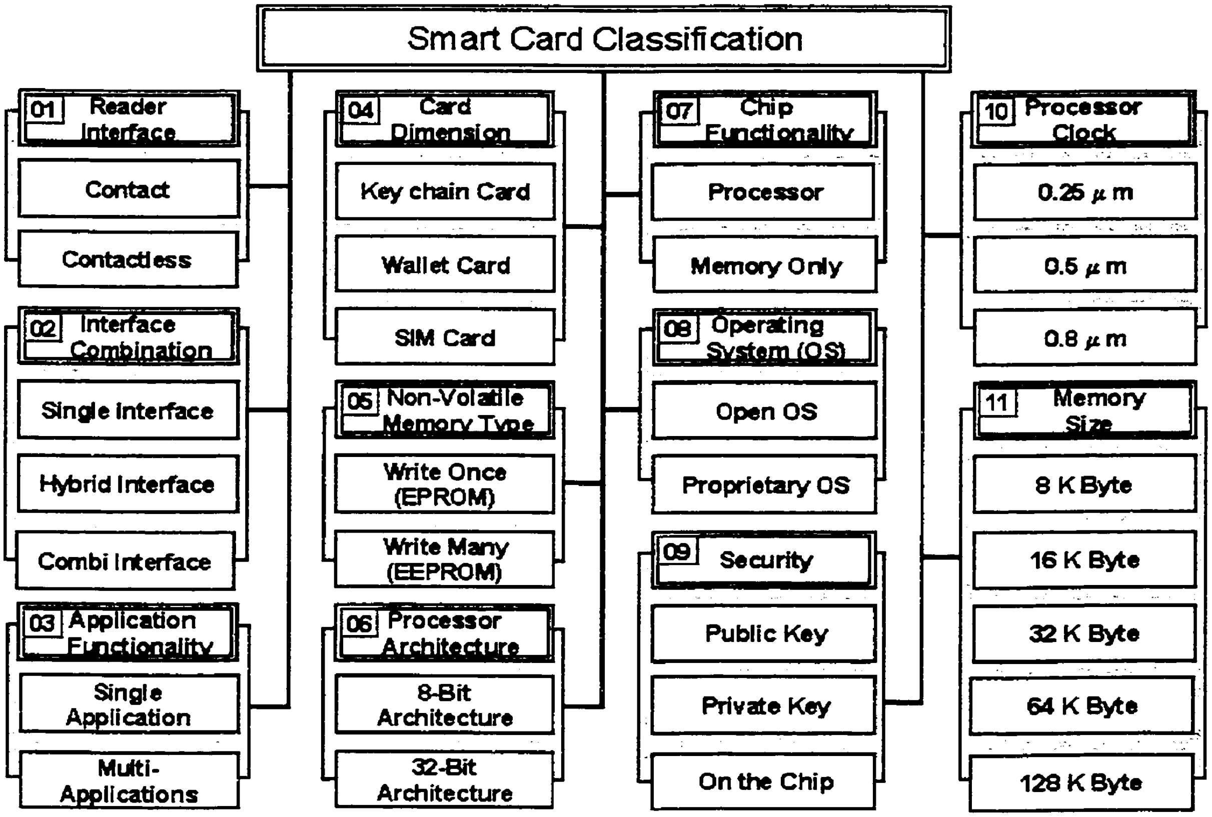
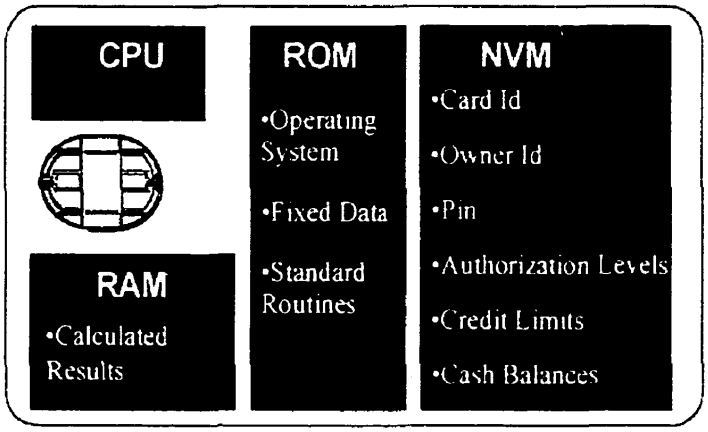


Figure 2-1: Smart Card Classification

This section provides a summary review for smart card's microprocessors, operating systems, standards, card interface, security and life cycle.

2.1.1 Microprocessor

The smart card microprocessor is similar to a computer IC chip produced by semiconductor manufacturers that consists of Central Processing Unit (CPU), Read Only Memory (ROM), Random Access Memory (RAM), Non-Volatile Memory (NVM) as shown in Figure 2-2 (Web 20).



CPU- Central Processing Unit ROM - Read Only Memory
RAM - Read Access Memory NVM - Non-Volatile Memory

Figure 2-2: Smart Card IC Chip Layout

(Source: Philip Andreae & Associates)

The IC Chip is wired to an electronic module, which protects the surface of the chip and works as a conductive interface between the IC chip and the card reader. There are two types of IC Chip cards:

1) **Memory Cards** use memory chip with no computing capability to process information. Memory cards do not have a security feature; therefore they are intended for basic applications such as debiting telephone units.

2) **Microprocessor Cards** have large memory capacity and a microprocessor, enabling them not only to store information but also to carry out complex algorithmic calculations.

2.1.2 Operating System

There are about 20 smart card operating systems (OS) currently available (Bielski 1998). There are three key smart card operating systems:

1) **Microsoft Smart Card** is compatible with Windows and Windows NT operating systems. Windows-based smart-card solutions are inter-operable with products from vendors including Hewlett-Packard, IBM, Schlumberger, and Siemens (Web 17). Microsoft expects cards using its OS to be used for secure network authentication and secure corporate transactions, such as online banking and debit and credit, electronic cash, and customer loyalty programs (Merrill 1998).
2) **Open Standard Java Card** uses Application Programming Interface (API) which enables the smart card application program to access other services such as the operating system, drivers, databases, or middle ware layers. Java card offers a development tool for flexible, multi-platform applications–"Write Once, Run Anywhere"–for devices ranging from Network Computers, Web TV, smart phones and other consumer appliances. Different smart card platform architectures are shown in Figure 2-4 (Web 09). The industry leader Schlumberger, for example, has introduced EasyFlex and FastOS based on Java API (Choi and Whinston 1999).As shown in Figure 2-3, API is the interface driver between the smart card and the card reader (Web 01).

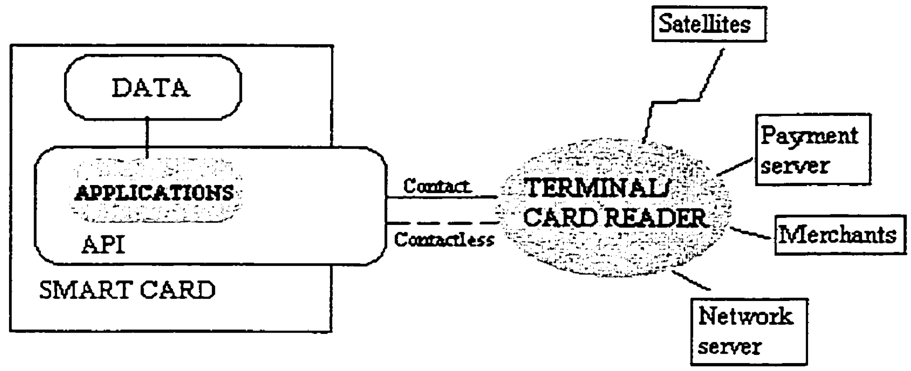


Figure 2-3: Smart Card Application Program Interface

(Source: Choi and Whinston 1999)

3) **Multos**, is a multi-application operating system developed by MAOSCO (a consortium of smart card companies and chip manufacturers). Multos is created to support applications, which are developed independently and run on different platform (Web 08).

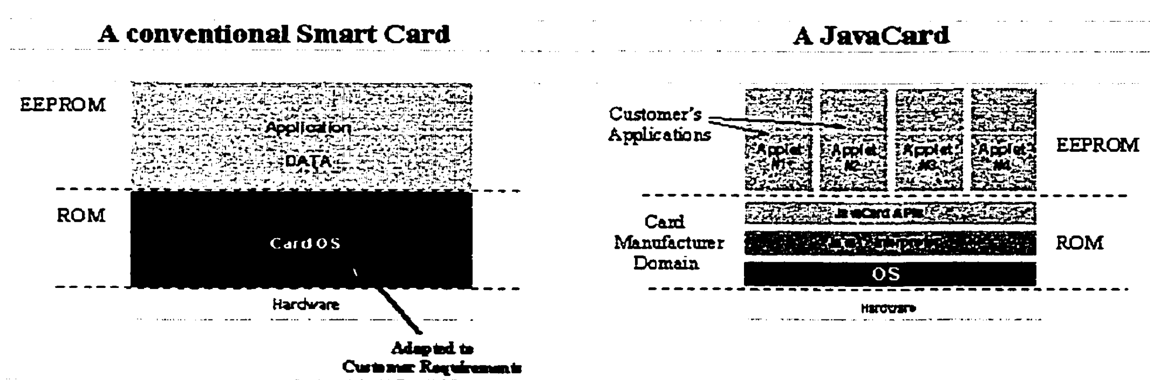


Figure 2-4: Conventional vs. Java Card Operating Systems

(Source: Bull Inc.)

2.1.3 Standards

Smart card standards are classified into two main categories: 1) Application Standards, and 2) IC Card Standards (see Figure 2-5).

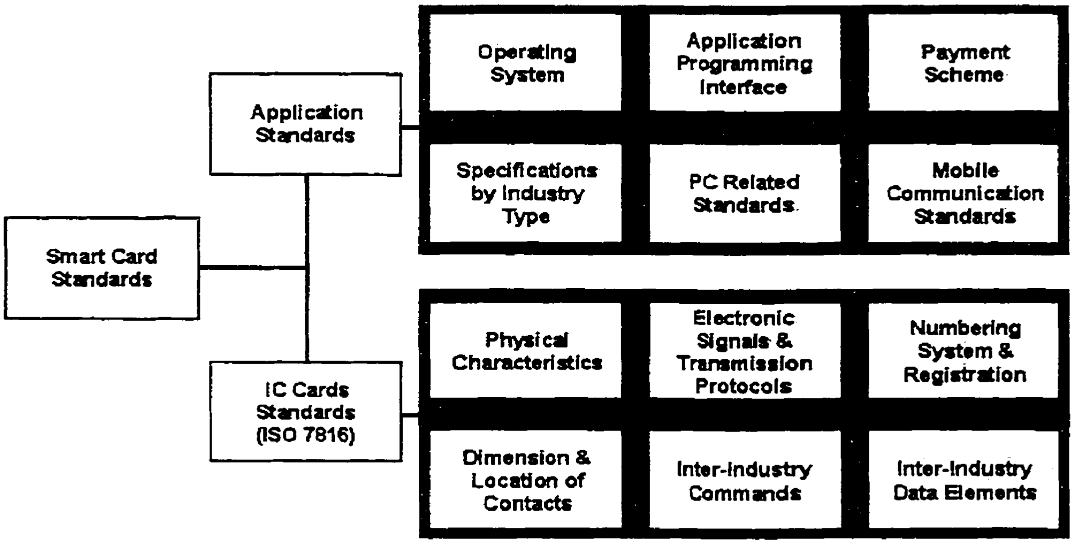


Figure 2-5: Smart Card Standards

The **Application- Standards** govern the interaction between the card and the terminal. For example, the **Global System for Messaging (GSM) Standard** allows a card running on any operating system to operate with any digital mobile phone (Collier 1999). Another example for the applications standards is the **Payment Standard**, which is essential for interoperability- for making sure that a card with a payment application will work in any terminal in the world.

There are two key payment standards (Marlin 1999):

1) EuroPay, MasterCard and Visa (EMV) common standard for selecting a smart card application and for defining how the debit or credit payment function will work.
2) Common Electronic Purse Standard (CEPS) developed by Visa and a number of key domestic stored value programs to define a standard for a) card interaction with a terminal; b) the terminal processing transactions to an acquiring bank; and c) transactions clearance and settlement on a global.

The U.S. General Services Administration (GSA) has published online developmental standards for smart card services related to **Medicare/Medicaid Payments Guidelines** and similar Electronic Benefits Transfer (EBT) programs (Web 10). The basic **IC Card Standards** are specified in details in the International Organization for Standardization (ISO) under ISO 7816 series, which are derived from the financial ID card standards and detail the physical, electrical, mechanical and application programming interface to a contact chip card (Web 11). Currently there are 6 basic sections to ISO 7816 defining the IC card standards as follow (Web 18):

1) Physical characteristics of the card
2) Dimensions and location of contacts on the card
3) Electronic signals and transmission protocols required
4) Commands to read, write and update data
5) Application identifiers
6) Data encoding rules for application purposes

The external dimensions of a smart card resemble a credit card and are determined by the International Organization for Standardization (ISO) as shown in Figure 2-6 (Web 16).

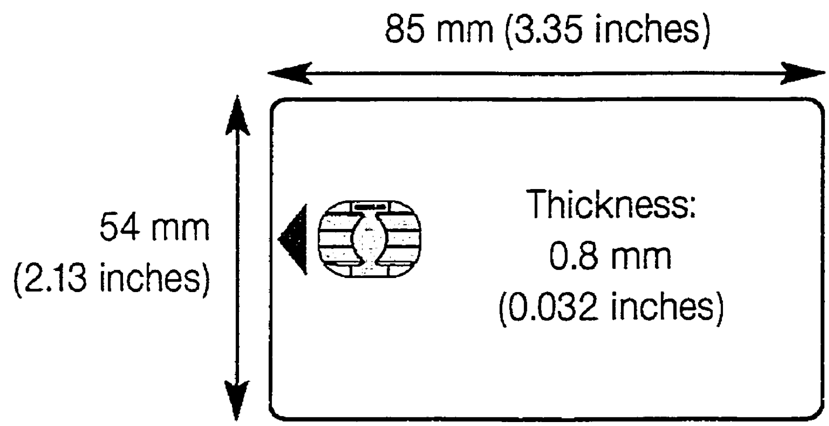


Figure 2-6: Smart Card Standard Dimensions

(Source: Gemplus Company)

ISO 7816 standard also defines the position of the electrical contacts and their function, and how the integrated circuit communicates with the outside world as shown in Figure 2-7 (Web 06).

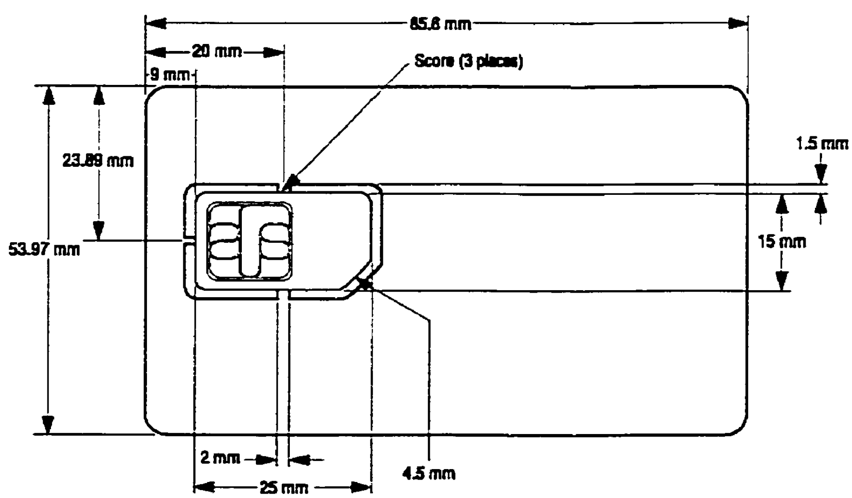


Figure 2-7: Electrical Contact Location on the Smart Card

(Source: Cardlogix Company)

Key-Chain Cards are used when there is no need for other mounted components such as signature panel, magnetic stripe or embossed name or number. The dimensions, set by ISO 7816, for the key-chain size cards are shown in Figure 2-8 (Web 06).

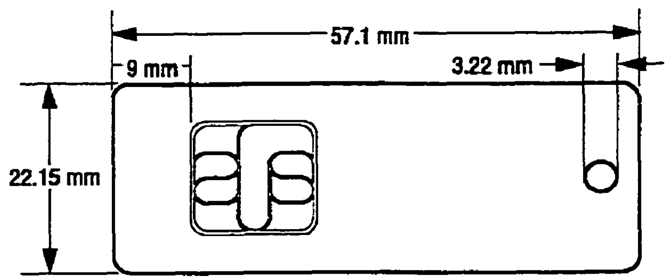


Figure 2-8: Key Chain Smart Card

(Source: Cardlogix Company)

The standard external dimension for the **Global System for Messaging (GSM) Smart Card** (cellular phone smart cards) is different from the one used for payment applications as shown in Figure 2-9 (Web 06).

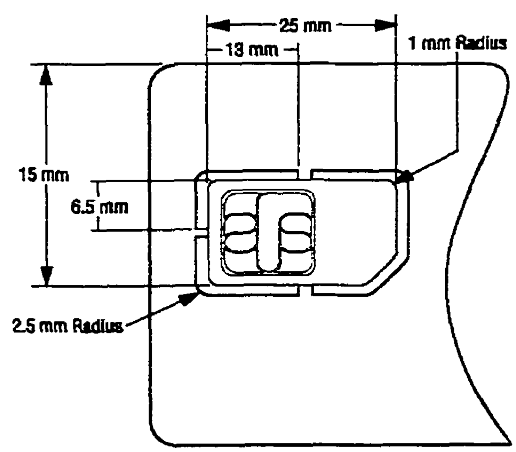


Figure 2-9: Electrical Contact Location on the GSM Smart Card

(Source: Cardlogix Company)

2.1.4 Card Interface

Data stored on the smart cards is read by conventional card readers or by wireless terminals. New devices similar to a floppy disk driver allow smart cards to be read into PC. Computer manufacturers have begun adding smart card readers to some PC models. Based on the smart card interface with the card reader, there are 4 types of cards:

1) **Contact Card**: requires physical contact between card reader and the smart card chip module in order to power the processor and exchange data with the card. The interface module is a gold connector plate of six or eight contacts on the face of the card. Functions that are assigned to each contact vary depending on the card configuration and application but all cards require connections for power, reset, clock and data input and output.
2) **Contactless Card** communicates with the IC Chip through antennas mounted on the card and wired to the module. A matched read/write device provides power and communications to the IC through a Radio Frequency (RF) interface. Contactless cards have a few advantages over contact cards, namely, faster transactions, ease of use, and less wear and tear on the cards and read/write devices, leading to longer lifetimes. ISO standards specify the type of data, which is handled in contact and contactless applications.
3) **Hybrid Card** starts with a contactless card, then adds a second contact chip. The contactless chip is generally used in applications requiring fast transaction time, such as mass transit systems. The contact chip is generally used in applications requiring higher security, such as banking. The hybrid card also provides an interim solution to legacy contact card systems during a transfer to contactless technologies.

4) **Combi Card** has only a single integrated circuit as shown in Figure 2-10. The chip is used for both contact and contactless functions. As in the hybrid card, the contactless interface is typically used in applications requiring fast transaction time, and the contact interface is typically used for higher security applications.

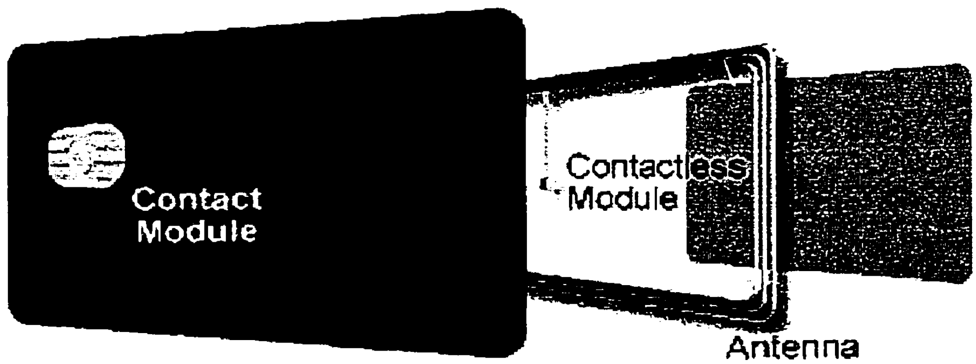


Figure 2-10: Dual Interface Combi Card

(Source: Gemplus)

2.1.5 Card Security

The basic value of smart cards lies in their capability to store personal information with a high degree of security, particularly authentication and data encryption. The portability of the stored private keys, account numbers, passwords, and other forms of personal data provides a much better protective environment for the card itself than the personal computer's hard disk. In addition, smart cards isolate security-critical computations involving authentication, digital signatures, and key exchange from other parts of the system. Five major card security methods are briefly discussed in this section.

1) **Public Key Encryption** messages are encrypted with private key and decrypted with a public key and vice versa. A user's public key is distributed to other users. Smart card with stored private key restricts its use to the card owner.

2) **Digital Signature** is a digitally encoded message verifies the authenticity of both the encoded message and the originator. A digital signature supports non-repudiation, that is, a recipient of a message uses the digital signature to convince the third party as to the identity of the originator (Krishna 1998).

3) **Digital Certificate** is a digitally signed statement by a Certificate Authority (CA) that provides independent confirmation of an attribute claimed by a person offering a digital signature. A certificate is a computer-based record used to verify received documents with digital signature transmitted across the web (Krishna 1998). By using digital certificates, smart cards enhances authentication between parties, control access to intranets and extranets from outside the firewall, and protect the privacy of data, files, and email messages.

4) **Personal Identification Number (PIN)** is another smart card security method which uses a 4 to 12 character alphanumeric code to authenticate a person's identity.

5) **Secure Electronic Transaction (SET)** is a protocol for processing card payments on the internet securely and is designed to replicate the one-to-one consumer-merchant relationship of the physical world. SET protocol uses Digital Certificates (DC) to prove the identity of a cardholder. DC is stored into a smart card chip instead of consumer's PC, which is not a secure device and is actually hooked up to the internet.

Building encryption, firewall, co-processors, digital signatures and certification authority into the smart card chips reduce data and transaction security vulnerabilities.

2.1.6 Smart Card Life Cycle

The smart card life cycle consists of 5 phases as shown in Figure 2-11 (Rankl and Effing 1997).

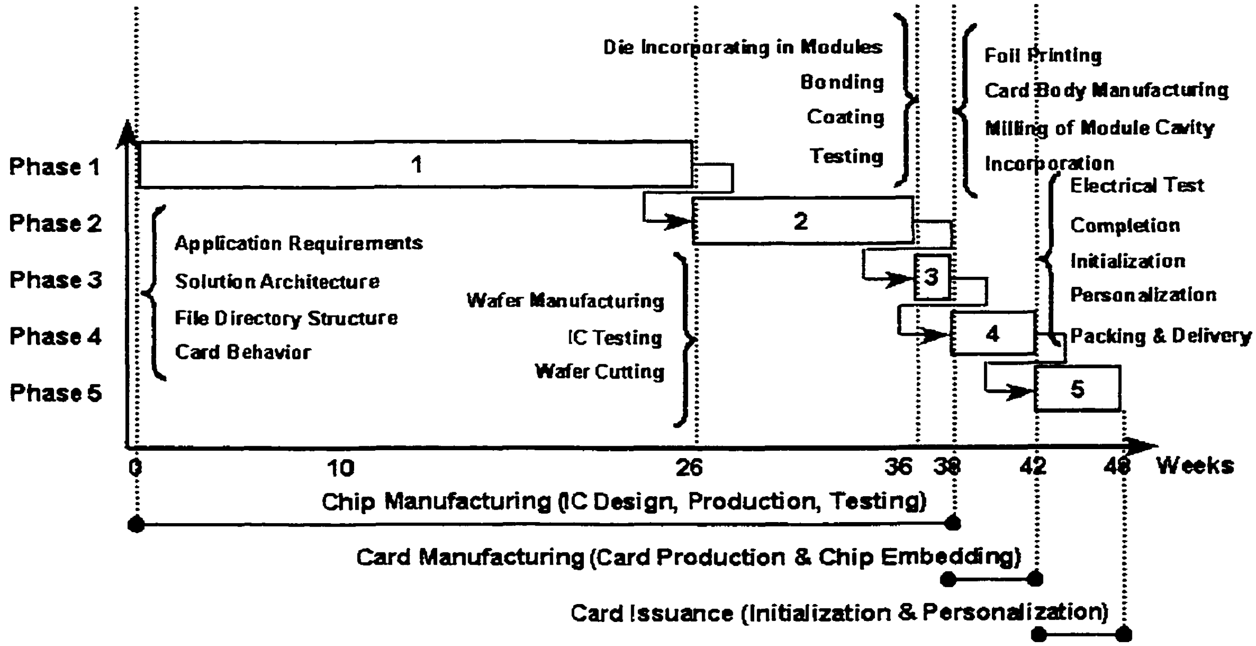


Figure 2-11: Smart Card Life Cycle

(Source: Rankl and Effing 1997)

Phase 1 "Software Engineering": the choice of architecture solution is based on the business requirements of application(s) to be used on the card. Control and Data structure and permanent configuration specifying the file directory structure are determined in this phase.

Phase 2 "Microprocessor Manufacturing": the chip design, production and testing are the responsibility of the chip manufacturers. After this stage, there is no access to card memory addresses except under the control of the card operating system. Tamper-resistant circuitry is activated upon completion of chip testing.

Phase 3 "Chip-Module Manufacturing": the chip is glued and wired to a module, which is considered a conductive medium and a protective cover for the chip. The chip is encapsulated within the module to securely mount the module on the card as shown in Figure 2-12 (Web 20).

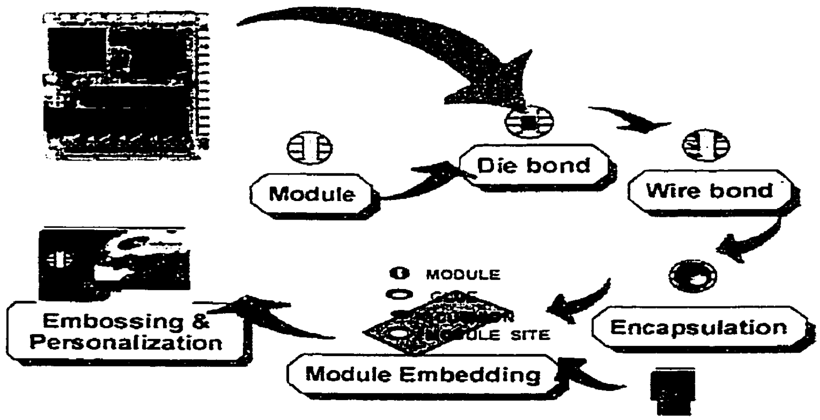


Figure 2-12: Smart Card Manufacturing Process

(Source: Philip Andreae & Associates)

Phase 4 "Plastic Card Manufacturing": independently of chip manufacture, the plastic card is manufactured using high quality plastic materials such as PVC or ABS. During the card manufacturing stage, the chip module is embedded into the plastic.

Phase 5 "Card Issuance": the card issuer prints the logo, determines access privileges, embosses the user's name, account number and sets the protection password according to the customer's file as illustrated in Figure 2-13 (Web 04).

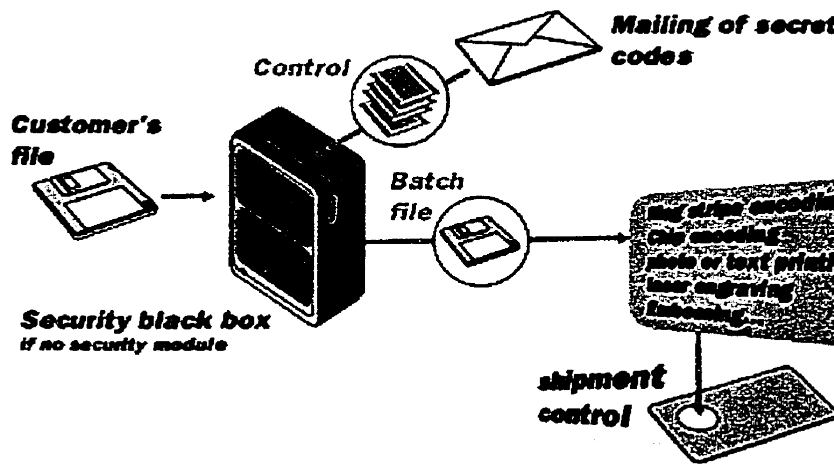


Figure 2-13: Smart Card Issuance Process

(Source: Bull Inc. 1999)

After the card is initialized, personalized and its application is downloaded, the card issuer mails the card and its password separately to the end user for activation.

Phase 6 "Card Use": smart cards are capable of carrying multiple applications, which may, in principle, be modified during this phase. Modifying the card applications is not recommended if internal applications are tied to the exterior appearance of the card.

Phase 7 "Card Invalidation": the invalidation process of lost, stolen, terminated or expired smart cards is used to prevent unauthorized use of any application on the card. Invalid smart cards are encoded with a tracking number, which read by the card terminal each time a transaction is made. Once the card is invalidated, its serial number remains unused in order to avoid any problems in organizational policy that might arise from having two users associated over time with the same card number.

2.2 Smart Card Applications and Benefits in Different Industries

The processing power of smart cards gives them the versatility needed to make payments, configure cell phones and connect to computers via telephone, satellite or the Internet. Smart card applications run off line or forward data to central computers such as payment servers in banks, traffic control centers, mobile phone centers, credit card companies, transit authorities, governments or any other service providers. A list of smart card applications in different industries is shown in Figure 2-14. There are 16 different areas of smart card applications that are discussed in this section.

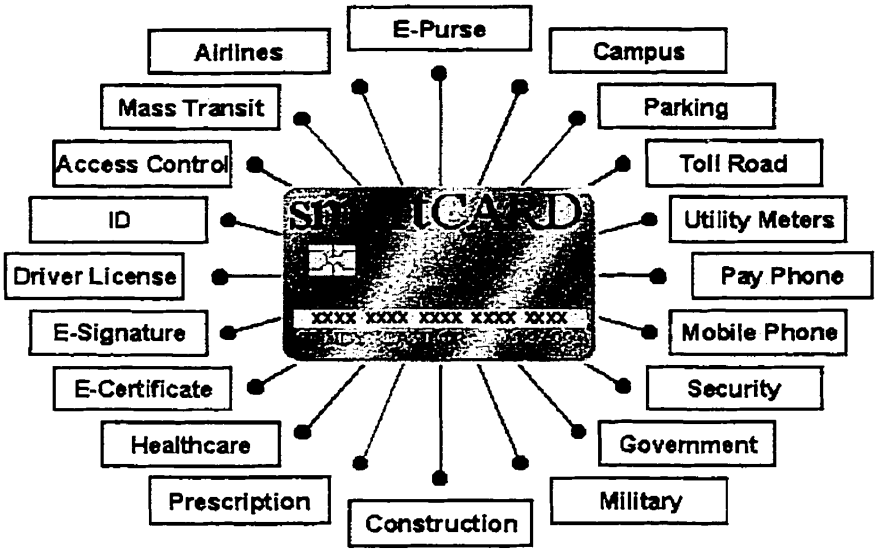


Figure 2-14: Smart Card Applications in Different Industries

2.2.1 Access Control Applications

Smart cards are utilized to restrict individuals from accessing certain areas in a building or proprietary computer network applications. A printed photo ID smart card with matching electronically saved picture and/or a fingerprint are used as an access control card. An off-line contactless card reader authorizes access to a secure area based on the security clearance information stored on the card. The computing capability of the smart card eliminates the need for online-access to centralized or distributed security privilege databases. New access control applications use ID smart cards mounted on Radio Frequency (RF) transmitters, as shown in Figure 2-15, which is detected by wireless card readers within a range of a few feet (Web 21).

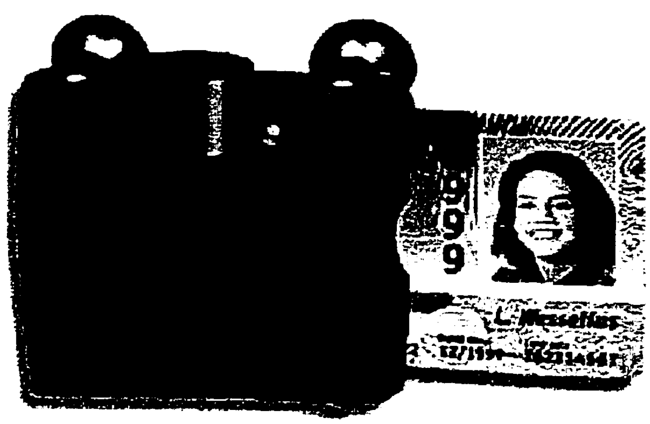


Figure 2-15: ID Smart Card Mounted on Signal Transmitter

(Source: Magna Carta)

2.2.2 Digital Certificate & Signature Applications

A digital signature consists of a small binary object, typically 16 to 20 bytes long, appended to the end of an electronic document. It enables any recipient to determine who actually signed the document and whether it has been altered since it was signed. Baltimore Technologies, a smart card company, provided the first smart card-based digital signature system for a government document signing ceremony between the United States and Ireland (Guyette 1998). In the United Kingdom, self-employed citizens use digital signatures to sign tax returns (Tipton 1999).

Digital signature is used for log-in and authentication. During the log-in session, the user types in an identity and password associated with the user's smart card, along with the identity of the system with which the user wishes to communicate. The smart card uses a signature scheme to check whether or not the log-in is accepted.

2.2.3 Security Applications

Smart cards provide portability for securely exchanging private information between systems in different applications. Smart cards are used to store passwords and employ a different password for every application. New layers of security have appeared, such as smart-card readers that plug into PCs. These readers offer a private-key encryption system that is launched only with a personal identification number (Mayer 1998). Smart cards are used to control mobile PC access, protect hard drives through encryption, generate digital signatures and secure access to e-mail and web sites.

Mondex (a subsidiary smart card company for Master Card) relies on statistical techniques to prevent fraud, claiming that monitoring all e-cash transactions is costly and unnecessary (Marlin 1998). According to Automatic ID News 1999, Gemplus GemSAFE smart card security tools with Veridicom fingerprint capture sensors are used to store fingerprint templates on Gemplus smart cards and compared to live scans captured by Veridicom fingerprint readers attached to the network PCs.

2.2.4 Personal Identification Applications

Identification methods such as keys, tokens, photo ID cards, name, password, or personal identification number (PIN) and fingerprints are commonly used in different applications. Combinations of using the conventional photo ID with an IC card develops a broader usage in smart card applications such as security, access control, healthcare and driver's license. The memory available on the chip allows smart cards to include biometrics attributes that identify users by their unique physical characteristics such as fingerprint and DNA.

Taiwan's government plans to implement a nationwide smart card system. By year 2001, paper ID cards will no longer be in circulation, and about 21.4 million IC cards will have been issued (East Asian Executive Reports 1997). Bank Negara (Malaysian national bank) has indicated that its national government wants a single smart card to serve as a national ID card (Rolfe 1997).

2.2.5 Driver's License Applications

Driver's name, address, license number, blood type and fingerprint data are permanently stored on IC card. Police and authorized entities have permission to read, add or modify driver's records such as traffic violations and fine. Fines are processed auto-matically by a centralized database. In 1995, smart driver's licenses were issued in Mendoza, Argentina (Web 07). Mendoza authorities are now able to keep closer track of driving habits and repeat offenders, and also to control on-the-spot fines and offenses..

2.2.6 Primary and Secondary Educational Facilities Applications

The primary application of smart cards in schools has been as a substitute for cash. The benefit of using the smart card in school is to speed movement through school cafeteria lines and to eliminate the hassle some parents face every morning of having to scramble to find cash to pay for their children's lunches.

2.2.7 University Campus Applications

Campus smart cards are used to access secure areas such as dormitories, computer networks, and parking garages and to pay for photocopies or items in the student bookstore and vending machines. Campus cards are also used as a library card, calling card and mass transit card. Different university campus applications are shown in Figure 2-16.

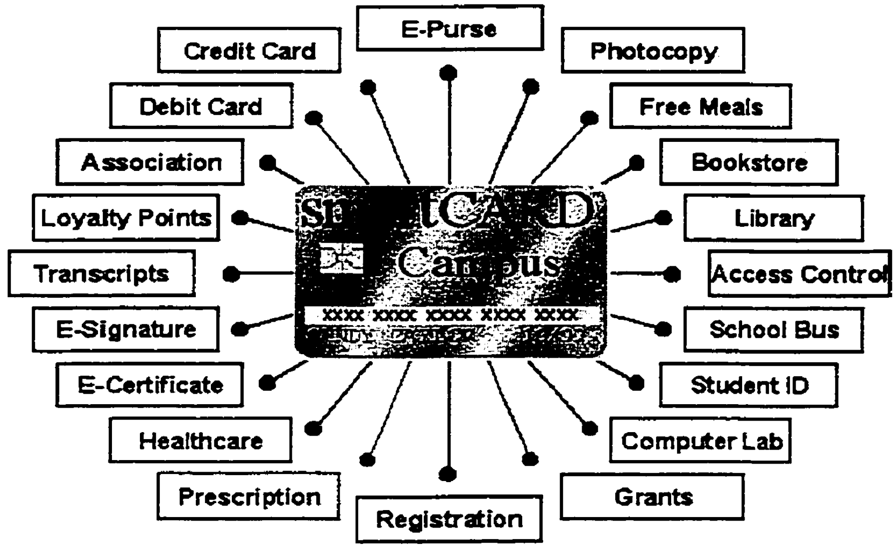


Figure 2-16: University Campus Applications

The total number of university-based smart cards issued in the U.S. and Canada reached 565 millions in 1998 as illustrated in Figure 2-17.

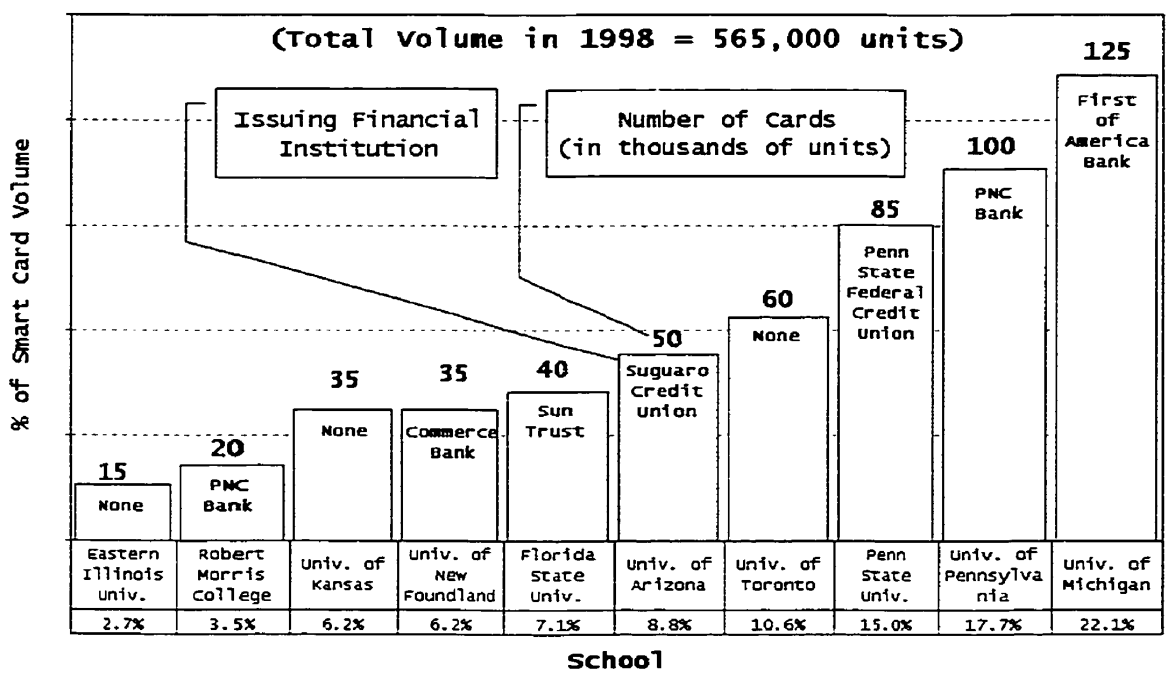


Figure 2-17: North America University-Based Smart Card Programs in 1998

(Source: Debit Card News, March 1998)

According to Credit Card Management (1998), the president of Smart Card Forum reported that university cards are growing at the rate of 100% per year and the number of campuses using the cards grew from 20 to 40 in 1998 and will go to 160 in year 2000. Approximately 20 universities nationwide (including Florida State, University of Michigan, Guilford College and the University of Pennsylvania) have adopted smart cards to provide identification and library access, make vending machine purchases and use laundry machines (Kessler 1998). The Cybermark card, used by more than 40,000 students and staff at Florida State University (FSU), is designed for up to four applications, only one of which is in use right now. In addition to the general stored-value "purse" used at vending machines and the like, FSU is considering adding another "purse" that could be used only to buy books. The book purse could contain up to $2,000 in value, versus the existing chip limit of $100 (O'Sullivan 1999-A). The University of Michigan in Ann Arbor is already beginning to issue smart cards that contain information on students' identification, dorm meal plan, Internet access account, bus pass, and dorm-access codes, as well as cash for the bus or the laundry (Miller 1999). Battelle recently developed a smart card that students at Ohio Dominican College in Columbus are using to pay their tuition, do their banking, access their dorm, download information over the computer, and buy lunch (Olesen 1998).

2.2.8 U.S. Government Applications

The U.S. General Services Administration (GSA), which provides federal agencies with more than $12 billion of goods and services a year, plans to use the technology for its payments cards and for multifunction cards that combine identification and building access with payment services (Williams 1997). Examples of smart card use in the U.S. government are:

1) **SmartPay Program:** the U.S. government is motivated to use the smart card as part of an overall effort to support the federal paperless mandate. A competition in federal card contracts began in 1999 to go all electronic in paying suppliers and recipients of government benefits. More than two million commercial are issued to government agencies under the GSA SmartPay five-year contract program cards (Credit Card Management, January 1999). SmartPay is a contactless card with building access biometrics ID and digital certificate applications. The first phase of SmartPay started in early 1997 when about 2,200 GSA employees were issued smart cards for building access and about 500 employees were issued Electronic Purse (EP) during the pilot program to be used for in-house transactions such as photocopying and checking out library books (McKendrick 1999). Agencies also are benefiting now from electronic payments, which enables them to receive daily invoices, instead of once every 30 days (Credit Card Management, January 1999).

2) **Electronic Benefits Transfer (EBT) Program:** has been supported by the U.S. federal government, in an attempt to improve the processing of the government benefit programs, such as social security, aid to dependent children, food stamps, welfare, Medicaid and Medicare. Year 2002 is the deadline for the large majority of government programs to go electronic (Credit Card Management 1998). EBT system expected to be handled by individual States or groups of States that anticipated to issuing cards protected by PIN numbers. Recipients are planned to access their funds at terminals or from their bank accounts. The Food Stamp Program is the nation's

largest domestic food-assistance program, serving about 1 in 11 Americans each month in 1997. About 40% of all food stamp benefits are now delivered through EBT, already operating in 30 States (Oliveira and Levedahl 1998). The smart card is used to store the recipient's account on the chip and interact with the merchant terminal to authorize the groceries purchased. New monthly-authorized benefits are added using the Point Of Sales (POS) terminal located in retail outlets. POS terminals accumulate the daily transactions and send them in a batch message to a central database where the merchant account is credited. EBT smart cards are operating in parts of Ohio and Wyoming (Oliveira and Levedahl 1998). Use of electronic food stamps stored on smart cards benefits the recipients by reducing periodic visits to the local issuance office, eliminating the risk of coupons being stolen from the mail and reduces illegal "trafficking" in food stamps. In addition the retailer's cost of handling coupons (counting, stamping, and bundling for deposit) is eliminated.

2.2.9 U.S. Military Applications

The Department Of Defense (DOD) program provides about 800,000 personnel with a multi-application smart card loaded with digital certificates (Messmer 1999). The card allows the holder to sign and encrypt documents or purchase orders, and is the means to access networks managed by the Army, Navy, Air Force and Marines. The card reduces paperwork because networked applications uploads the soldier's ID with the military records and download new information related to training or credentials. The card includes an access control application. Examples of the U.S. military include:

1) **The Multi-technology Automated Reader Card (MARC)** program involves all three branches of the military, and more than 100 card applications, including security, travel, legal functions, recruitment and stored value (Hodgson 1997). Michael W. Noll who is the MARC project military coordinator, says the amount of time needed for readiness processing (checking records to make service people deployable) improved from one hour to 15 minutes per person; the time needed to put people on aircraft [improved], from three hours to 40 minutes.

2) **Recruits Program:** the U.S. Army Treasury Department offers recruits smart cards with stored-value and biometrics ID applications. Recruits entering basic training receive cards carrying their fingerprints plus $200 to $260 in pay advances to cover their initial expenses. The recruit smart card aims to cut expenses from cash payments given to recruits to buy goods at the base's post exchanges. Gemplus, the French card supplier, has committed to supply 20,000 cards to the U.S. Army (Orenstein 1998). In March 1998, a $4 million stored-value card program was established with a biometrics security application for issuing salary advances at Ft. Sill, Oklahoma, the nation's main military training center for artillery (Bielski 1998).

3) **Deployment in Bosnia:** the U.S. military deployment in Bosnia used smart cards, long-range Radio Frequency identification (RF/ID) and bar code systems in one program called Operation Joint Endeavor. The program intended to save distribution time and supply costs (Seideman 1997). Deployed items are bar coded and scanned into a centralized database as they are loaded into containers. The information is loaded onto a smart card placed on the outside of each container, which are shipped in air pallets equipped with RF/ID tags.

2.2.10 Healthcare Applications

A health care study by Deloitte & Touche suggests that within five years smart cards will hold a patient's history, home diagnostic tests and medical records which are downloaded on the Internet to allow automated pharmacies to deliver prescription drugs (Theoharides 1997). The objective of using the smart card in the healthcare industry is to simplify data transfer within the health information process, simplify the administrative process and reduce the overhead linked to paper forms. The healthcare smart card serves as a portable database carried in the patient's pocket that assures the medical data is available when it is needed. Patient's information is accessed on the healthcare card without a need for online computers or / and a centralized database. The smart card holds all data, which is useful for medical care, health consultation and management of health care. Data includes, but is not limited to, health check data, medical images with scripts and history of medical services.

The **Versichertenkarte, the German Health Insurance Card,** was implemented by law in 1989 as an administrative card (Schaefer and Sembritzki 1996). All German citizens have a smart card through the national healthcare system (O'Sullivan 1999-A). In France, healthcare smart cards are expected to be nationwide by year 2001 (Allen 1999). In Oklahoma, **MediCard** patient cards are designed to hold identification data as well as details of allergies, diagnoses, medications, insurance, primary physician, and emergency data (Williams 1997). The Health Maintenance Organizations (HMO) managed care **TRICARE** smart cards are expected to be offered in the Colorado Springs region to all Civilian Health and Medical Program Uniformed Service (CHAMPUS) beneficiaries. Three major local HMOs expected to be eligible to enroll at least 54,000 members (Chatfield 1996).

Diabetes Card (DIABCARD) (a project sponsored by the European Union) provides the specification for a Chip Card Based Medical Information System (CCMIS) for the treatment of patients with chronic diseases. While DIABCARD concentrates on diabetes at the moment, the concept of the diabetes chip card is extendible to other chronic diseases. There is a potential important impact on the quality of health care and also contribute to cost reduction of European health care budgets (Engelbrecht et al 1994). Patients, healthcare providers, and health professionals are expected to benefit from the healthcare application. Patients are granted access at all times to their medical history, transfusion and vaccination tracking. Healthcare providers are able to track medical coverage and reimbursements. Health professionals are authorized to save important medical records on the patient's card.

Rite Aid, the United States' largest drugstore chain rolled out 25,000 Verifone smart card terminals (in 1998) and, around midyear, planned to have put 250,000 Gemplus chip cards in the hands of customers under its "**RITE CASH**" stored-value and gift card program, reaching 3,900 stores (Orenstein 1998). Rite Aid has implemented VeriFone's SC 250 modular smart card adapters to extend this new payment method to its customers. Attaching to the current Verifone Everest payment terminals installed at all Rite Aid locations, the SC 250 seamlessly extends smart-card read-and-write capabilities to the POS. The drug store chain now has an integrated system for its Rite Cash gift-card program (Chain Store Age 1998). Pharmacists is able to establish stronger relationships with patients by being the key person to load and update prescriptions, over-the-counter remedies and other related product information for them. Adding these related products to a customer's medical record helps the pharmacist to be more informed as to what medications are being prescribed and identify potential interactions. The pharmacist has also the opportunity to provide tips and suggestions about preventative health measures. Statistics show that the system [smart card] is significantly more reliable and cost effective than the classical client server systems which require complex and costly online connections to complete transactions and keep records current (McGauley 1996).

2.2.11 Utility Meter Applications

Intelligent electricity meters with chip card billing replaces cash via prepaid chip card. Collection of cash is no longer required, servicing is reduced, and safety enhanced, as there is no target for thieves. An integrated chip card reader is used to display card credit balance and download operating data into service terminal. Different tariffs is easily integrated in one device (Web 12).

2.2.12 Mobile Phone Applications

Smart cards are used as a **Subscriber Identification Module (SIM)** with a stored value in the Global System for Messaging (GSM) communications market. The GSM subscriber pays for air time in advance that is represented as stored value on the SIM card, which is plugged into the cellular phone while subscriber placing a telephone call as shown in Figure 2-18.

Figure 2-18: Mobile Phone with Smart Card

(Source: Master Card 2000)

The most substantial market opportunity for GSM pay phones is in rural areas. The installation and maintenance costs associated with GSM pay phones is less than half of those associated with a wired pay phone. Over the next three years, the number of GSM pay phones installed worldwide is expected to reach approximately 30,000 to 40,000 units, representing a market value of some $60 million (Veronik 1998). According to Gemplus report, the number of GSM, PCN and PCS subscribers is estimated to reach 180 million by year 2000 as shown in Figure 2-19 (Web 16).

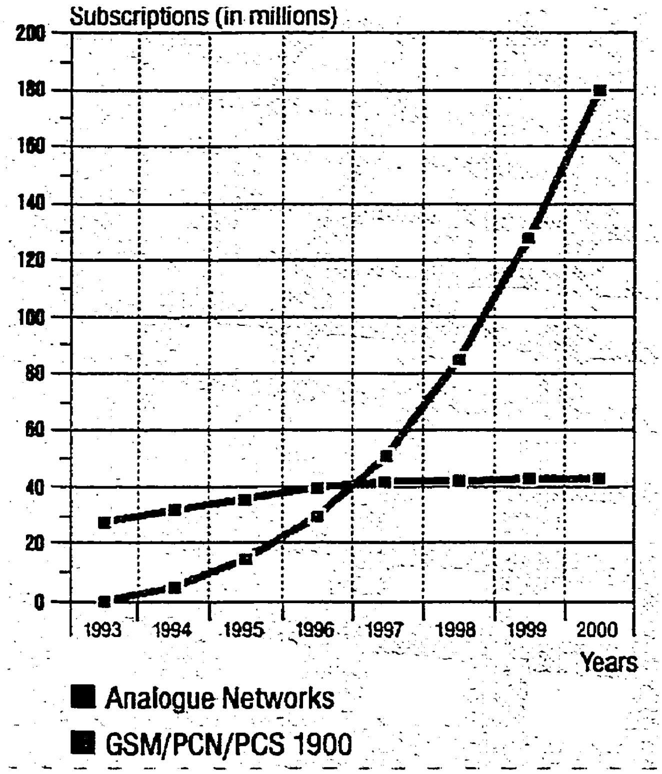


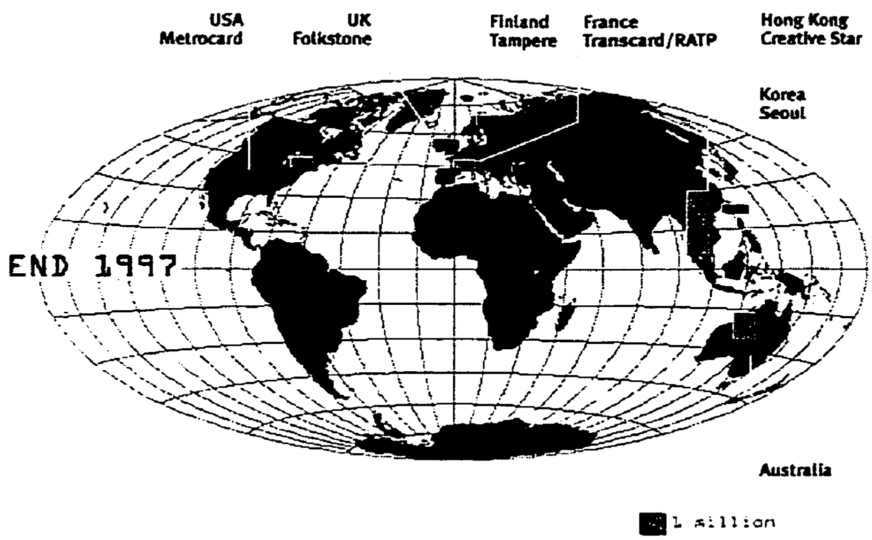
Figure 2-19: The Uptake of GSM in the World

(Source: France Telecom / EMC / EMCI)

The traffic generated by a GSM pay phone is generally much higher than on private cellular phones. Experience in Europe and the United States indicated that GSM pay phone traffic is expected to reach $3000 per month (Veronik 1998).

2.2.13 Mass Transit Applications

The public transit industry has shown a strong interest in the value that smart cards bring to the fare collection process as a way to eliminate bus and subway tokens and to charge different fares for different routes. Contactless smart cards are designed to replace subway, bus and train tickets and improve boarding time and maintain the passenger flow without diminishing fare security. According to IBI Group, a Toronto-based consulting firm, 12% of total transit authorities revenue is spent on handling cash and tokens, in addition to the printing expenses associated with paper passes and transfers. King County Metro (Seattle based transit) figures it costs $4.2 million to $5.1 million to install card readers system wide, according to an agency report. Contactless cards have a price tag of $5 per card (Lucas 1996). The largest mass transit application is Hong Kong's Creative Star system which includes over 4 million cards and handles four million transactions every day (Middleton 1998). According to EuroSmart survey, Hong Kong and Korea had the largest public mass transit smart card applications in 1997 as shown in Figure 2-20 (Web 13).



* Hong Kong Creative Star issued over four million cards in 1997

Figure 2-20: Global Mass Transit Smart Card Market Size in 1997

(Source: EuroSmart 1999)

Smart card vendor Schlumberger now offers Swatch Access in Finland, a contactless smart card in a watch that customers use to pay their bus fares. (O'Sullivan 1999-B). The

Mondex franchise owners in Canada are eyeing the development of a government funded travel card pilot taking place in two small Canadian suburbs and serving 75,000 commuters (according to Allan McGale, vice president of stored value cards at the Royal Bank of Canada). The pilot is implementing unique smart cards, based on contactless technology, that allow for virtually instant ticket payments or transit access with speeds in the range of one or two hundred milliseconds (Web 22).

2.2.14 Airlines Applications

The application is designed to allow the cardholder access to a travel agency's web site, pay for an airline ticket, get a boarding pass and receipt, check bags at the ticket counter, confirm a frequent flier number, make simple flight changes or change or make a seat assignment. Lufthansa has issued 130,000 frequent fliers its Chip Card, which is used as a boarding pass, for frequent traveler lounge access and as a loyalty program card on all German domestic flights and flights from London's Heathrow and Paris' Charles de Gaulle airports (Card Technology, January 1998). Every kind of consumer profile is stored on the card. Checking into a hotel becomes just as easy as loading the room key data from the automatic check-in terminal into the card (Hutton 1998).

2.2.15 Electronic Purse Applications

The stored value cards are designed to replace cash for small, repetitive purchases such as those associated with mass transit, highway tolls, parking, fast food, and vending machines. In Germany, users spend from as little as $0.03 per transaction up to $30.53

(Kruger 1998). Worldwide cash transactions numbered 8.1 trillion in 1993, with 1.8 trillion of these valued at under $10. In the United States, 88% of all transactions are cash or check and 83% of those are for less than $10, according to PSI, Inc. (Allen 1995).

Smart card with stored value is called Electronic Purse (EP) which is loaded by using a cash dispenser (ATM) at the bank or Computer On-line at home. When the consumer buys something from a merchant equipped with a smart card terminal, the amount of the purchase is debited from the consumer's electronic purse and credited to the merchant's terminal. Upon closing the daily sales, the merchant phones the bank to deposit the cash stored in the terminal. Electronic Purse Applications are shown in Figure 2-21 (Web 16).

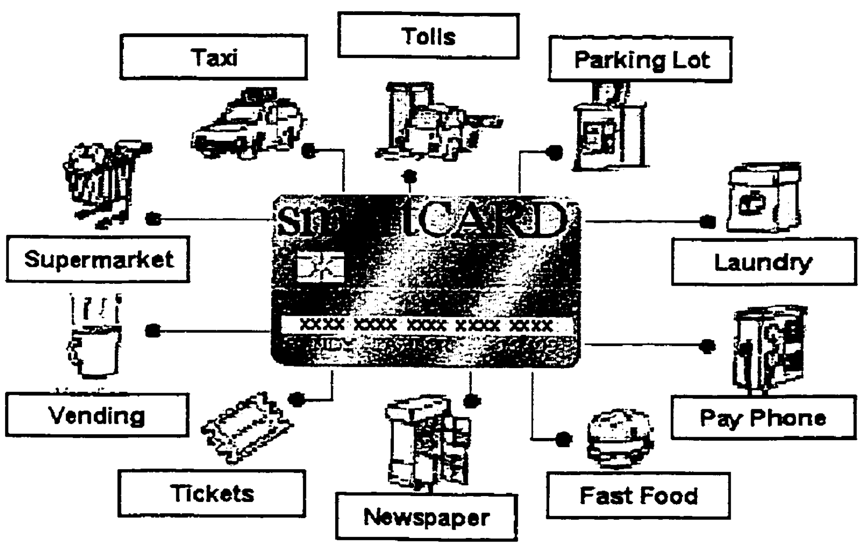


Figure 2-21: Electronic Purse Applications

(Source: Gemplus 2000)

Total EP smart card programs issued in 1999 are illustrated in Figure 2-22.

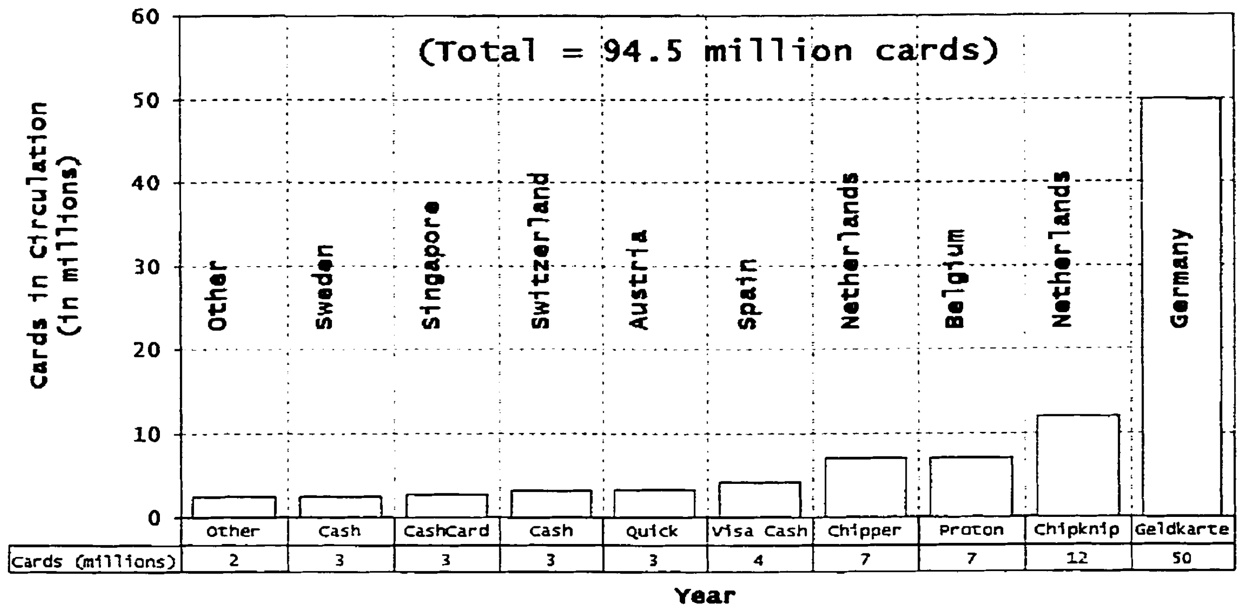


Figure 2-22: Electronic Purse Smart Card Programs in 1999

(Source: Card Technology, January 2000)

Different EP programs are designed to have a combination of cash, credit, and debit applications that is capable to perform other sophisticated functions including account verification and transaction tracking. Datamonitor estimates that bank applications through debit/credit cards, cash alternatives or electronic purses are forecast to grow even more sharply, reaching 450 million in 2001 (Talmor and Timewell 1997).

Merchants pay between 2 percent and 2.5 percent in credit card transaction fees, and those fees usually have a minimum of about 26 cents. These fees are easily wiped out profit margins on low cost items (Patch and Smalley 1998). The real potential of EP lies in providing a cost-effective way to perform secure transactions off-line with an adequate audit trail. In addition, merchants reduce security risks in the handling of cash and are assured of getting real value equivalence (like debit cards but unlike checks).

The issuer of EP will be able to collect "float" on the electronic value until it is redeemed into "real" value, much like issuers of travelers' checks. If the cards are widely used, the float gain may be substantial (Sneddon 1995). The largest European purse program is Germany's GeldKarte, with more than 40 million cards issued (Welch 1999). Smart card vendor Schlumberger now offers a contactless smart card in a watch that customers use to pay their bus fares and which may evolve into Finland's national electronic purse (O'Sullivan 1999-B). Minneapolis-based U.S. Bancorp, working with Visa, has issued nearly 1,500 smart cards to Siemens Corp. employees. The cards a chip carrying a travel application that gives Siemens employees a preferred hotel, car rental or airline rate (Orenstein 1998). In 1993 all French payment cards were smart which reduced the percentage of fraud to 0.028% as shown in Figure 2-23 (Web 16).

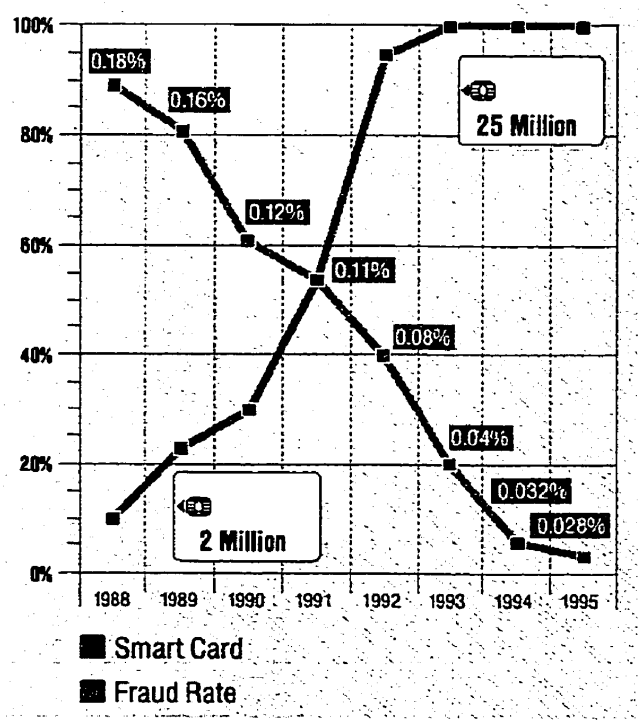


Figure 2-23: Fraud Rate in France

(Source: G.I.E. Cartes Bancaires [French Bank Syndicate])

2.2.16 Construction Industry Application

Smart card technology is new to the construction industry. Only one application has been cited in the marketplace. Smart Card Electronic Solutions, a Canadian firm based in Markham, Ontario, introduced the new application **Skill Data Card Initiative (SDCI)** which construction workers carry as proof of their job-specific qualifications. SDCI stores information regarding labor training, safety certifications, emergency medical data and employment data (Web 03). The SDCI benefits workers, unions, government and companies by reducing paper work, eliminating unnecessary worker safety training, simplifying the worker skill assessment process and improving company safety compliance.

In summary, the mandate by national governments to use smart card applications encouraged adoption of card technology in various industries. The major smart card programs being promoted by governments are the multi-application smart card for U.S. government employees, the recruitment and training applications for U.S. military personnel, the pay phone cards in France, the mass transit cards in Hong Kong, and the mandated healthcare card in Germany. Pilot programs in university-based smart card programs are being successfully implemented on many school campuses such as the Universities of Michigan and Pennsylvania in the U.S. and the University of Toronto in Canada. In financial and network computing applications security, secure applications such as Public Key Infrastructure (PKI), Digital Certificate (DC), and Digital Signature (DS) are being used. Electronic Purse (EP) is currently used extensively in micropayment programs such as Geldkarte in Germany, Chipknip and Chipper in the

Netherlands, and Mondex in Europe and North America. In light of the tremendous potential of smart card technology reported in non-construction industries, this research intended to further investigate the applicability of smart card technology and to explore its potential applications in the construction industry.

Chapter 3 Framework for Smart Card Use in Construction

Using smart card technology as new means to reduce cost and improve productivity for construction operations is studied in this research. This chapter discuss the following 4 main steps:

1) Examining the **feasibility** of using smart card in the construction sector.
2) Investigating the **adaptability** of employing smart card and its infrastructure in construction projects.
3) Identifying areas of **potential applications** and benefits.
4) Analyzing the results of a 20-question **questionnaire** sent to construction company senior managers and executives.

3.1 Feasibility

Feasibility of smart card in construction industry is evaluated according to a set of parameters which are classified into the following five areas of assessment:

1) Vulnerability to construction site conditions such as temperature and damage.
2) Reliability of card security and data protection against tampering, computer virus and chip failure.
3) Services and technology capabilities available.
4) Market requirements in terms of size, affordability and incentive programs.
5) Liabilities associated with implementation such as fraud, data ownership dispute and auditing.

These parameters are summarized in Figure 3-1 and discussed in this section.

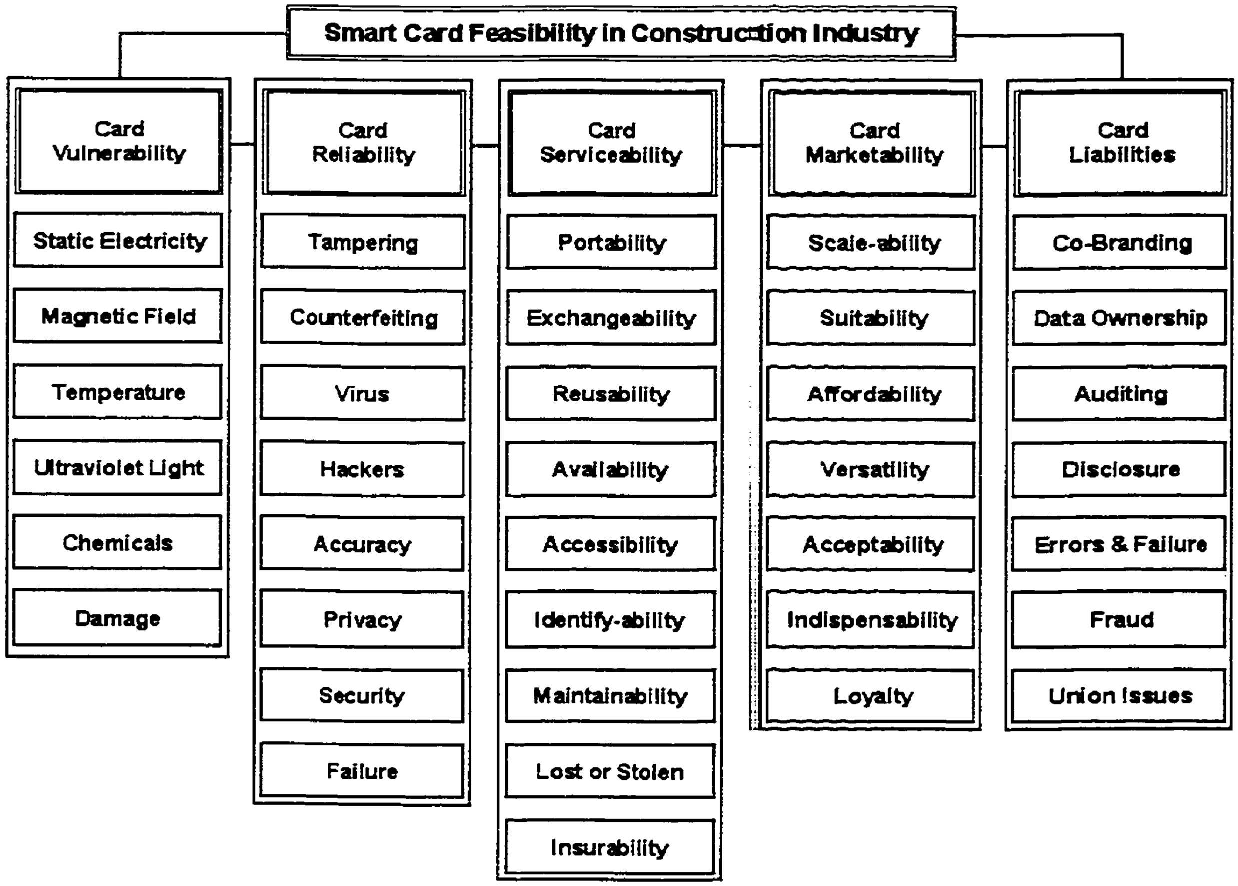


Figure 3-1: Smart Card Feasibility Categories and Parameters

In the **construction environment**, chip cards are more resistant to the types of damage magnetic cards suffer, such as heat and contact with magnetic fields or static electricity. The anticipated working life of a smart card is ten years, compared with three years for a magnetic-stripe card.

The **reliability** of the smart card is demonstrated in its IC chip protection against tampering, counterfeiting, computer virus, hackers, information privacy, operational failure and security of transactions. One immediate advantage of the IC chip is the reduction in the spread of counterfeit cards. There are two types of protection on the card: (1) hardware and (2) software. The hardware protection is added in physical tamper-resistance circuitry, which responds to tampering by inhibiting the output function or generating a code through an algorithm. The software protection is presented in a stored encryption, which scrambles chip memory, digital communications and transactions. Using reverse engineering to counterfeit smart card is almost impossible.

Computer **viruses** damage software applications by causing the computer operating system to overwrite a chip program's instructions. So far no virus attack or hacker incident has been reported since the commercial deployments of smart card in the early 1980s.

Smart card applications are less vulnerable to the attack of computer viruses or computer hackers because of the built-in **security** features, which exceed the security level in computer applications, especially those dealing with electronic payment. At least one third of the code written for a smart card micro-controller program relates to making it secure, that is, fraud-resistant (Babyak 1998). The chip has a secure file system, which computes cryptographic functions and actively detect invalid access attempts. With proper application of file system access rights, a smart card becomes safely used by multiple, independent applications.

Privacy of information held on the card is achievable though procedures are specifically developed for each smart card application. When no longer required, information is purged from the card and associated systems. Project information given for one purpose is not used for any other purpose or passed to any third party, without the subject's informed consent. Technical **failure** of smart card application causes service unavailability and potential disruption to work progress. According to Schlumberger, one of the largest card manufacturers, the main reason for card failures are not because of the chip and are due to other issues such as forgotten PIN or damage to the plastic card as shown in Figure 3-2 (Web 19).

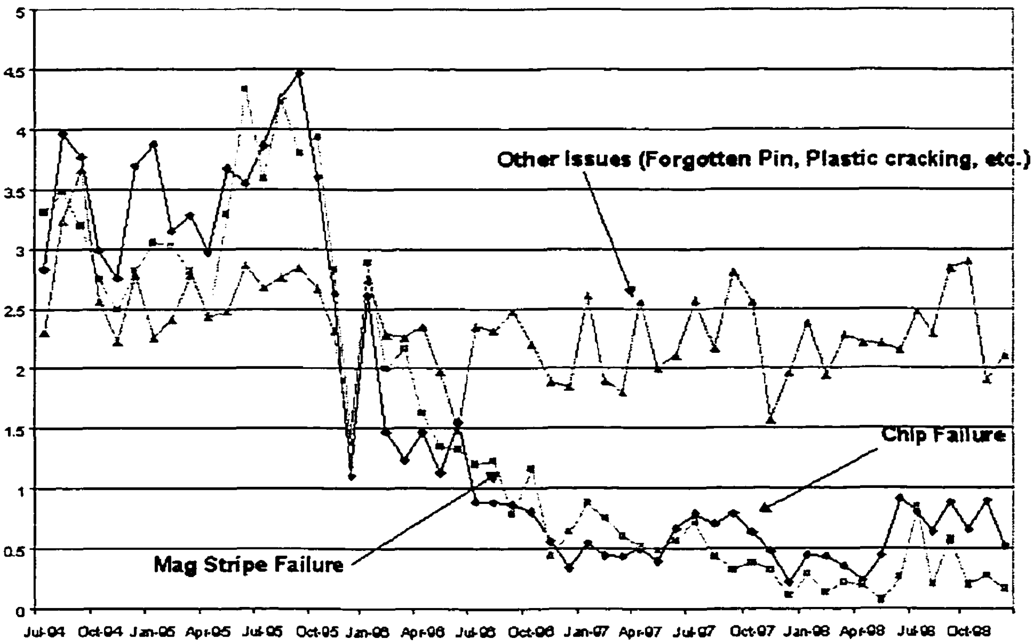


Figure 3-2: Percentage of Card Return over Time

(Source: Schlumberger & GE Carte Bancaire 1999)

There is no doubt that the new development of smart card readers and card interfaces will diminish the risk of smart card failure. However, smart card failure rate is about 0.03% (i.e. 3 failed attempts every 10,000 transactions) according to a France Telecom survey as shown in Table 3-1(Web 19).

Technology	Magnetic Stripe	Optical Card	Smart Card
Failure Rate	2.00%	N/A	0.03%

(Source: France Telecom 1999)

Table 3-1: Failure Rate of Different Card Technologies

Serviceability of smart card encompasses all factors that are related to customer service and product support. Lack of good services increases customer complaints as a result of inability to replace damaged cards, unavailable terminals, or lost or stolen cards. Part of card services is to provide product support to the cardholders such as the possibility to add and delete applications, backup of application data or changed PIN.

Ubiquity of card terminals and good selection of their locations increases convenience to the cardholder. Using pocket card readers increases efficiency in performing peer-to-peer transactions and makes database stored on the card smart card are likely portable. It is believed that smart card chips mounted on a wristwatch or a key-chain would be widely used among construction workers. Development of new mobile phone smart cards with multi-applications is underway.

Increasing the **availability** of these new portable devices will improve card infrastructures, extend the smart card market share and therefore reduce unit cost per user. In closed environments like construction job sites, using PC equipped with smart card interface or employing GSM mobile phone with SIM smart card provides users with alternative methods of **accessing** card data. Off-line terminals installed on the job site are presumably updated during the off hours using a wireless local area network (LAN) connection with a central smart card based-computer. Compared to other card technologies, smart card maintenance is less expensive. Table 3-2 shows a performance comparison of different card technologies (Web 19).

Technology	Magnetic Stripe	Optical Card	IC Card
No. of Intervention	400	400	100
No. of Failures per Year	1,000	800	100
No. of Machines Maintained by One Technician	20	15	100

(Source: France Telecom 1999)

Table 3-2: Performance of Different Card Technologies

Liability insurance is another form of guaranteed high quality customer services that mitigate the risk of any financial losses due to unauthorized transactions, card malfunction or application errors.

Smart card **marketing** in construction sector depends on card economy of scope and scale. It is believed that there will be a substantial market share for smart card in construction sector if trade union labor, management personnel and industry related suppliers are targeted. There are 16.2 million trade union members in the U.S. and 6 million construction workers and more than one million construction management personnel according to Department of Commerce reports (Web 06).

Economy of scope can be realized when two or more applications are jointly produced at a cost lower than that incurred in their separate and independent production. The major argument against smart card is the huge cost incurred in manufacturing hardware and developing software. The unit **cost** of a smart card varies from $8 to $20 depending on the chip size and complexity of the chip design. The cost of the chip is directly proportional to its memory capacity. More sophisticated chips are larger and their costs are higher. Thus, growing card sophistication entails higher unit prices as shown in Figure 3-3 (Web 05).

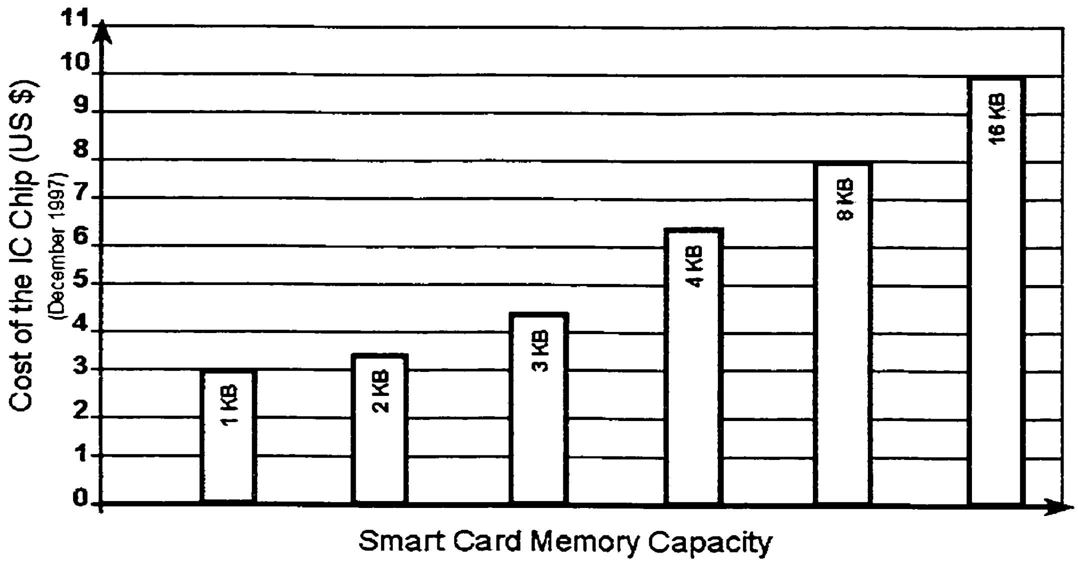


Figure 3-3: Card Memory Capacity Cost Comparison

(Source: Gemplus & EuroPay 1997)

Smart card lifetime is about 10 years. The cost of a personal card reader ranges between $40 to $50. According to Svigals Inc., a card technology consulting firm, the estimated cost of Point of Sales (POS) terminal is about $400 per unit per every 150 cards per every 5 years (Demery 1998). Smart card prices drop considerably. The cell phone smart card (SIM card) unit cost dropped 50% from 1995 to 1998 as shown in Figure 3-4 (Web 05)

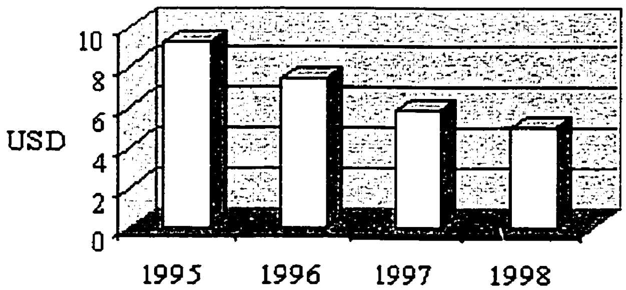


Figure 3-4: SIM Smart Card Unit Cost

(Source: Gemplus 1999)

The application cost changes depending on the application's functionality, security features and environment type (open or closed). According to a Svigals Inc. report (Demery 1998), it costs about 23 cents per month to issue three applications [non-construction] on a single smart card. In another report, Ahjua's business case, the total cost of ownership for a PKI/smart card solution is about $150 per user for four years including card, reader and application. Estimates indicate that in a large company it costs approximately $36 to circulate and process a single hard-copy expense report. That cost drops to around $4 per report with the use of electronic signatures (Ahuja 1998). The business case of the future will come from the ability to have debit, credit, Electronic Fund Transfer (EFT), Electronic Benefits Transfer (EBT), ID, drivers license, etc., all resident in one versatile card. The growing use of the Internet and the rapid rise of electronic commerce will contribute to the public's desire for smart cards. Widespread use by the government will also help push adoption of card technology. With the U.S. General Services Administration's (GSA) goal to migrate federal employees to a paperless environment by year 2003 (Web 10), smart cards will become indispensable.

According to Silicon Valley Round Table News report (Web 02), the economics of smart cards are attractive today. An economic comparison of smart card versus magnetic stripe card reveals that smart cards cost $0.17 per transaction while magnetic cards are $0.29 per transaction. The comparison includes the total out of pocket costs such as card stock, PIN validation, transaction authorization and the useful life of the card. Moreover, multiple applications provide more revenues than standard cards.

Smart card liability is defined as accountability of stakeholders in terms of co-branding, ownership of card data, auditing, disclosure cardholder information, error / failure recovery, and risk exposure due to fraud. Smart card stakeholders including chip manufacturer, card manufacturer, card issuer, card operator, and terminal / card reader manufacturer and others (see Figure 3-5) play different roles in the card life cycle. Every stakeholder has a different level of liability according to industry agreements.

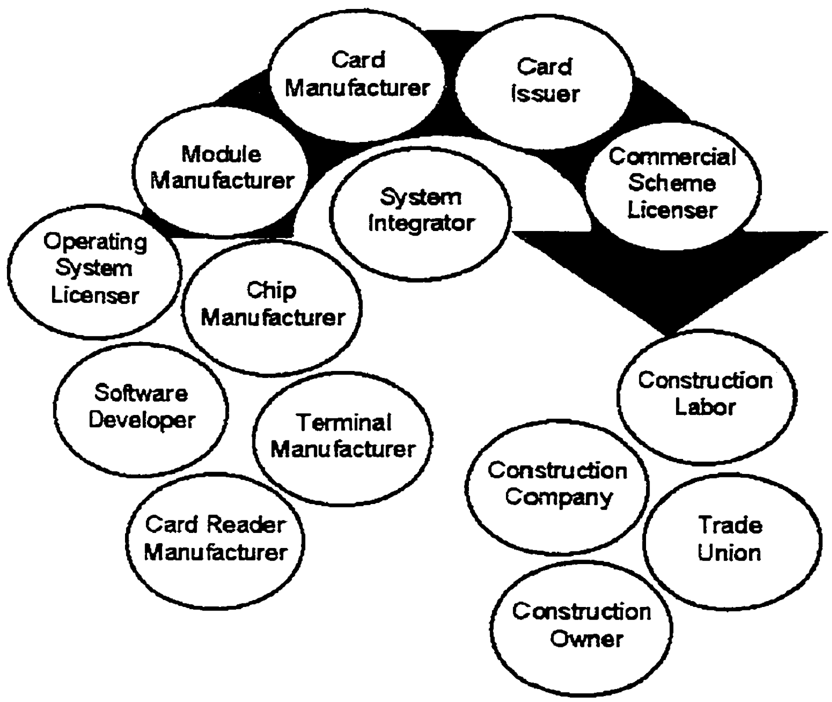


Figure 3-5: Construction Labor Smart Card Stakeholders

Liability of smart cards in construction projects is a complex issue due to the nature of the construction industry where the cardholder can be a contractor or project owner or supplier or a trade union member. Currently, there is no liability agreement for using smart card in construction that addresses issues such as privacy of labor, confidentiality of contractor's data and owner and union rights to access card data.

Co-branding is an issue of sharing the memory in the chip and possibly the logo on the card. Co-branded smart card carries the name of a particular company as well as the issuing financial institution. Ownership of data and authority to access intellectual property, including source code, is arranged through a written agreement and partnership between card stakeholders.

Card auditing is classified into three levels. The first auditing level occurs before card deployment to ensure that card application is in compliance with the company guidelines and industry standards. Systems development and software code are carefully tested and approved by the auditing company. The second level of auditing is during the card usage phase where card transactions and authorization records need to be compared. It is normal for transaction data to be accessed on occasions by an auditing party, in order to test the performance of the system, and to ensure that contingent risks are being appropriately addressed. The third level of auditing is to collect and distribute appropriate funds such as personnel payment, government taxes, trade union fees, progress payments and performance bond.

3.2 Adaptability

The successfulness of applying smart card technology in construction industry depends on the industry's willingness to adapt its current practices to the card technology and the capability of such technology to accommodate the construction needs. Contributing factors for the adaptation of both the smart card technology and construction industry are shown in Figure 3-6.

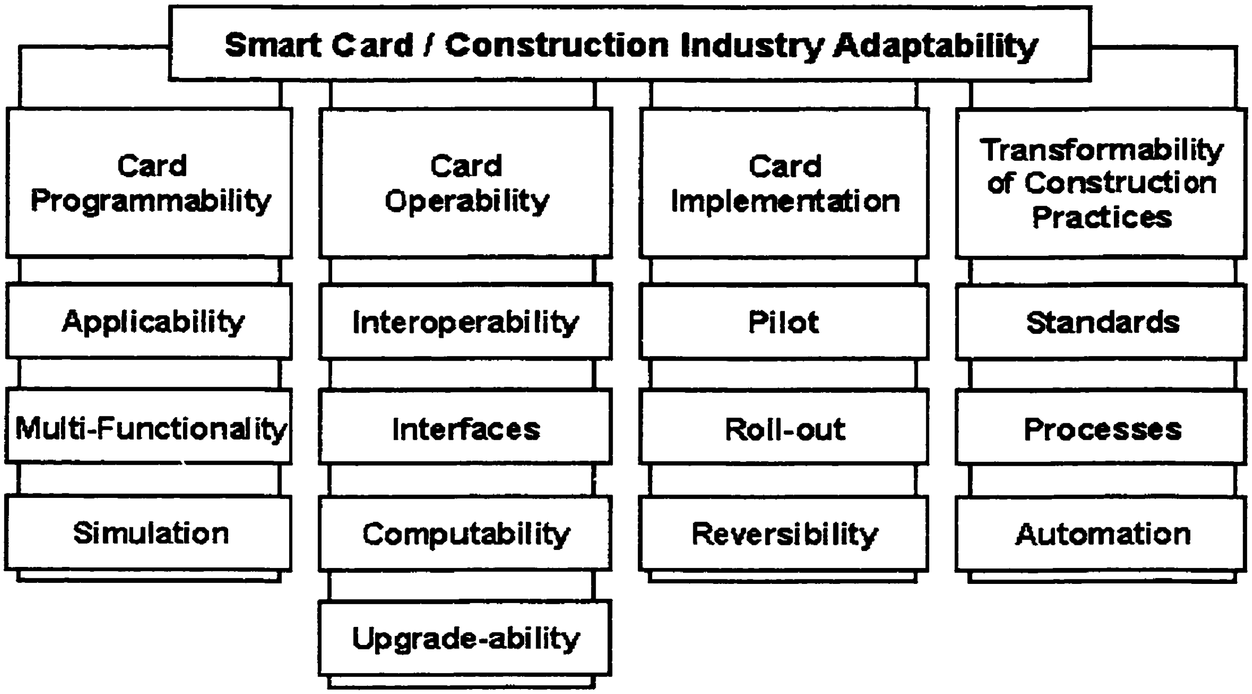


Figure 3-6: Adaptability Factors of the Smart Card and the Construction Industry

The adaptability of the IC chip to the construction business environment is discussed in terms of the card programmability, operability and implementations. In addition, transformability of construction processes and current practices to accommodate the new technology is also covered.

Programmability of the card depends on performance of the IC chip, flexibility of the programming language and applicability, which is defined as the ability to fit applications on a limited memory smart card. Access control and personal identification technologies are easy to apply in construction. Cellular phone with smart card is a good application for remote job sites where construction personnel and workers use the card to make telephone calls, place electronic material order to the warehouse and receive email or paging messages. Applications are bundled together in a multifunctional smart card reducing the need to carry multiple cards on site. The drawback of loading many applications on a single card is the need for a larger silicon chip, which increases the initial cost of the card.

The ability of smart card applications to operate on different card readers while maintaining the identical user interface and functionality is a critical issue which likely affects smart card deployment in the construction sector. Standards are essential for **interoperability**- for making sure that a card with an application works in any terminal anywhere. Interoperability is mistakenly used when there is no common operating systems in place for smart card. Lack of interoperability between smart card readers is a major roadblock in the smart card implementation. The development of PC/SC open specifications is underway to ensure interoperability among smart cards, smart card readers, and computers made by different manufacturers. It is believed that the PC/SC open specifications will make the smart card more adaptable to the construction industry where operating systems, smart card readers and smart cards themselves are developed independently and yet still inter-operate.

The **interface** between smart card readers and existing technologies is essential for immediate deployment of smart cards in the construction industry. New card reader interfaces have been developed and are currently used, such as PC smart card reader, smart card cellular phone adapter and infrared card reader interface and Radio Frequency (RF) smart card transmitter. Synergy between wireless and smart card technology provides a powerful telecommunication tool to the construction industry. In addition, it is believed there is a great need for developing smart card interfaces to other existing technologies such as Radio Frequency (RF) material bar code scanners, closed circuit security camera systems, automatic on-off switches, and wide range electronic sensors. Such existing technologies are already tested in many projects and widely accepted by construction companies.

Many construction project managers are reluctant to utilize a new technology unless it has been successfully tested. It is proposed to start **implementation** of smart card in the construction industry with small **pilot programs** ranging from access control to digital signature applications. The purpose of the smart card pilots is to try construction applications in a small, isolated environment where any glitches in the system are easy to iron out without jeopardizing the workflow of the construction activities. The pilot program is expected to shed light on the costs and benefits of smart card use and determine its acceptance to construction personnel. A good overall pilot plan lays the groundwork for successful large-scale deployment and reduces risk of losing corporate funds in bad investment. A proposed break down for pilot planning is illustrated in Figure 3-7 that includes pilot objectives, pilot scope, pilot size / scale, location, testing preparation, managerial / administrative functions, timing / scheduling and funding / budgeting. However, timing, scope and location are the critical success factors in smart card pilot programs.

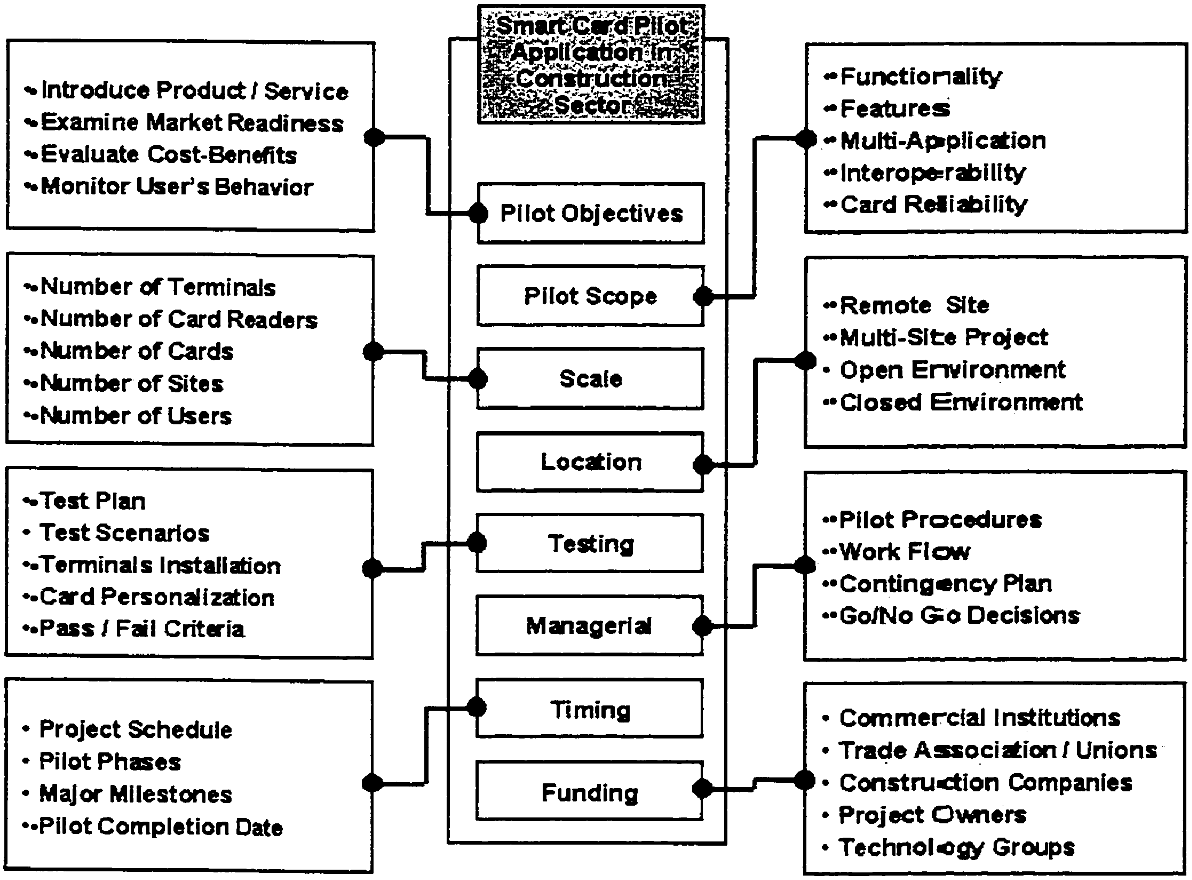


Figure 3-7: Smart Card Pilot Application Planning

Several current large-scale pilot programs are aimed at testing the future acceptance of smart cards. Most of these pilot schemes fall into 3 broad categories: (1) Electronic purse schemes; (2) Plans to replace the older magnetic authorization method; and (3) Loyalty schemes. Successful pilots have already been carried out in closed environments such as military bases, college campuses and hospitals where a captive audience has a limited number of places to spend money.

Transformability of construction current practices to smart card based-solutions is achievable through establishing common standards for using smart cards in the construction industry. Currently, there are no standards to address issues such as transferring field data between applications, synergy between construction applications and other commercial schemes such as Mondex electronic purse. The benefits of developing local standards for construction applications are:

1) Reducing the risk in investing in proprietary applications that may not be compatible with future generation technologies.
2) Eliminating the need for expensive system integration.
3) Assuring synergy between card applications and other technology applications, which are currently adopted in construction.

It is believed that introducing smart card-based methodologies to adapt the requisite changes to the existing construction practices and manual processes will benefit the construction industry. There is also a need for new provisions in construction contracts and labor collective agreements to address issues regarding employing smart card technology. These issues include techniques such as Electronic Benefits Transfer (EBT) for labor and management personnel, Public Key Infrastructure (PKI) in confidential project communications, Electronic Signature (ES) in contract procurement / administration and Electronic Purse (EP) in expense voucher.

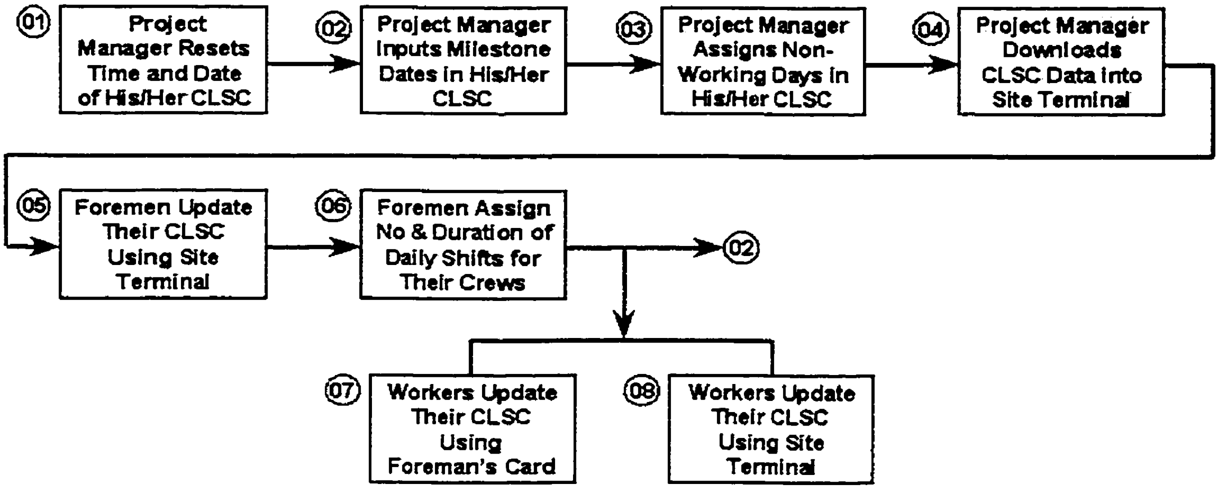
Tracking labor hours and expense vouchers in heavy construction projects requires a lot of administrative effort, which can be reduced by using the smart card and its audit trail mechanism. However construction contracts remain silent about whether EBT, PKI, ES and EP smart card applications are acceptable in construction projects.

3.3 Potential Applications

Carrying or wearing a smart card on the job site with a portable database and processor opens the door for many field applications, which require a small PC. Potential applications in construction are classified into three categories: (1) Software Applications, (2) Hardware Applications, and (3) Customized Applications. Software application category includes any written construction programs, which can be downloaded and run using any typical contactless or contact smart card. ID card, Electronic Purse and Electronic-Signature are examples of the first category. The hardware application category refers to the use of smart cards as electronic smart devices in construction equipment or systems such as automatic on/off switches and gates, cellular phone interface and Radio Frequency (RF) bar code scanners. The third category, which is the customized applications, encompasses areas where special hardware and software design are developed according to specific needs, for example, using smart cards in remote crane or robot operations.

3.3.1 Date and Time Stamp

In the construction industry, there is no consistent on-site audit trail mechanism in place to stamp each event with the correct date and time. Using closed circuit TV cameras and sometimes a wristwatch to record site events result in different time stamps. The purpose of the proposed smart card application is to establish an exclusive date and time stamp tool to record time and synchronize events such as automatic on/off switches and gates. A process flow diagram for the operational steps is illustrated in Figure 3-8.



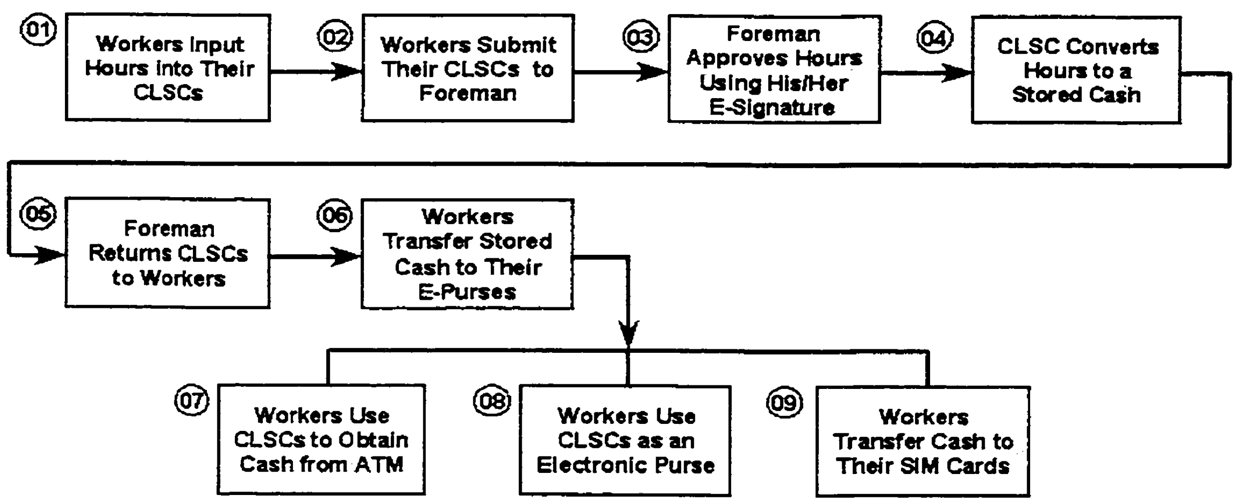
CLSC: Construction Labor Smart Card

Figure 3-8: Date and Time Stamp Application Process Flow Diagram

The Project manager uses his/her Construction Labor Smart Card (CLSC) as a master key to synchronize date and time among project personnel. The master CLSC is updated with the accurate clock, project calendar, holiday schedules and overtime regulations. When information is uploaded to the off-line site terminals, foremen modify terminal information according to their crew structures, number of shifts and the need for overtime. Workers use site terminal to automatically update their CLSC, which becomes synchronized with the information store on the master CLSC. It is possible to use any synchronized CLSC to control On/Off Switches and gates, feed other applications with working/non working days, measure equipment operation time, record site events or card transaction with a consistent date and time stamp. Using synchronized CLSC with digital signature increases accuracy of tracking any electronically signed documents.

3.3.2 Labor Payment

In the construction industry, foremen spend part of their time updating timesheets of their crews whose paychecks are based on the total number of hours and type of hours spent on the job site. Using smart card with double-slot reader to record hours and process labor payments reduces paper work and administrative time. A proposed process flow diagram for the operational steps is illustrated in Figure 3-9.



CLSCs: Construction Labor Smart Cards
SIM: Subscriber Identification Member
E-Signature: Electronic Signature
E-Purses: Electronic Purses
ATM: Automatic Teller Machine

Figure 3-9: Labor Payment Application Process Flow Diagram

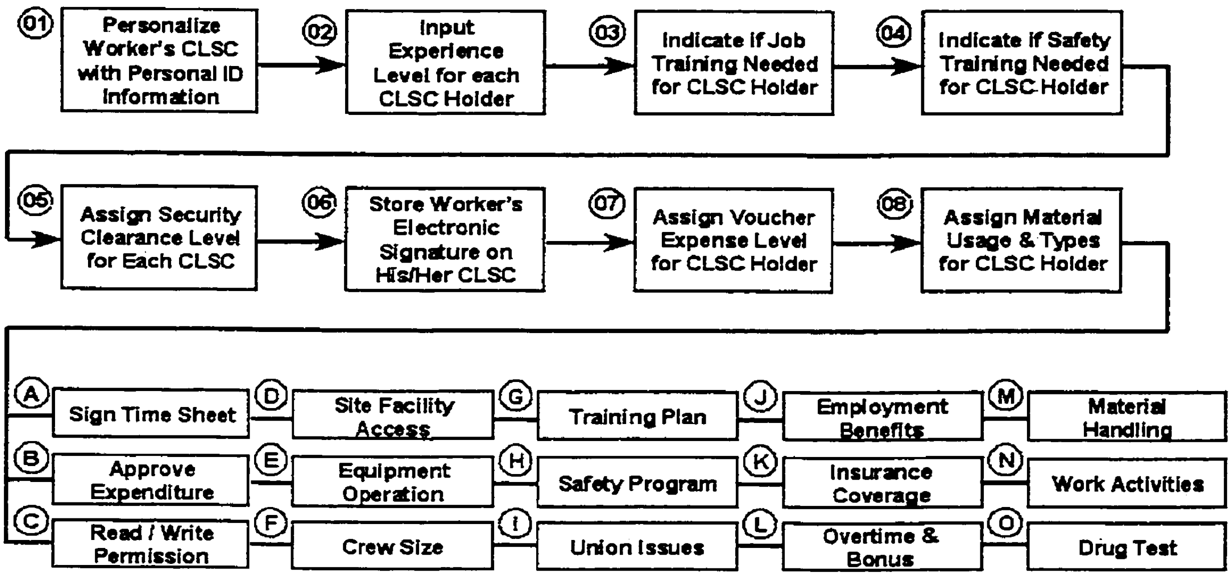
Every worker uses his/her CLSC to sign in prior to starting any work activity and sign out upon completion. CLSC stores the total hours spent broken down by activity type on an electronic timesheet. When the foreman reviews electronic timesheets received from his/her crew member, he/she electronically signs them using a double slot card reader to transfer the approval from the foreman's card to the worker's card. Once the stored timesheet is approved, the worker converts saved hours into a stored cash value. Every

CLSC uses a different hour rate schedule to calculate the equivalent monetary value for earned hours. The hour rate schedule for each worker is predetermined according to worker's experience, skill and training level. Other factors such as benefits, premiums and compensation are also included in the hourly rate schedule.

Integrating the labor payment with a commercial application such as Mondex Electronic Purse (EP) allows workers to transfer electronic payment to their EP. Workers have the option to transfer payment to their bank account by using the CLSC and an online terminal available on site or via a personal computer.

3.3.3 ID and Access Control

Photo ID cards are used in the construction industry as part of the clearance process to allow authorized personnel access to the construction job site. Carrying ID is usually mandatory in high-security construction sites such as military bases, power plant facilities, embassies and airports. Qualified workers' fingerprints, personal information, including training level, years of experience and salary are kept in a personnel file, which are manually updated. The purpose of this application is to use the smart card as an ID and access control on the job site. A process flow diagram for the operational steps is shown in Figure 3-10.



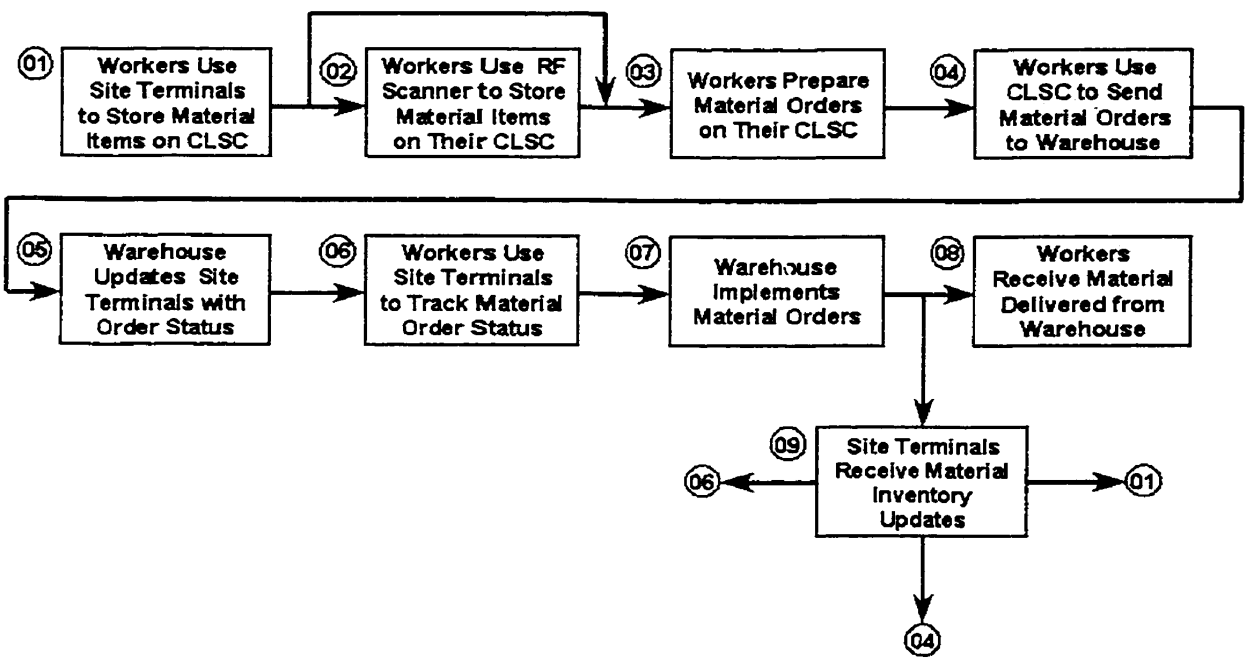
CLSC: Construction Labor Smart Card

Figure 3-10: ID Smart Card Application Process Flow Diagram

It is proposed to store the worker's profile on a CLSC, which is used to obtain access to the job site and restricted facilities, detect hazardous material, activate operation of heavy equipment, procure and purchase material, place orders to the warehouse and receive electronic cash. Contactless and Radio Frequency (RF) interfaces are the most suitable technology to provide yes / no access permission or on/off switch function based on a received electromagnetic or transmitted infrared signal from the CLSC. Adding digital signature application to IDs and access control cards enables cardholder to electronically sign timesheets, vouchers, purchase orders or legal documents.

3.3.4 Material Order

In the construction industry, workers commonly spend part of their time at the warehouse to obtain the material and tools they need to perform their jobs. Using bar code and inventory database has not eliminated the early morning congestion at the warehouse nor reduced the amount of paper work required and time spent away from their work activity. The purpose of the proposed CLSC with material order application is to place electronic material orders to the warehouse. A process flow diagram for the operational steps is illustrated in Figure 3-11.



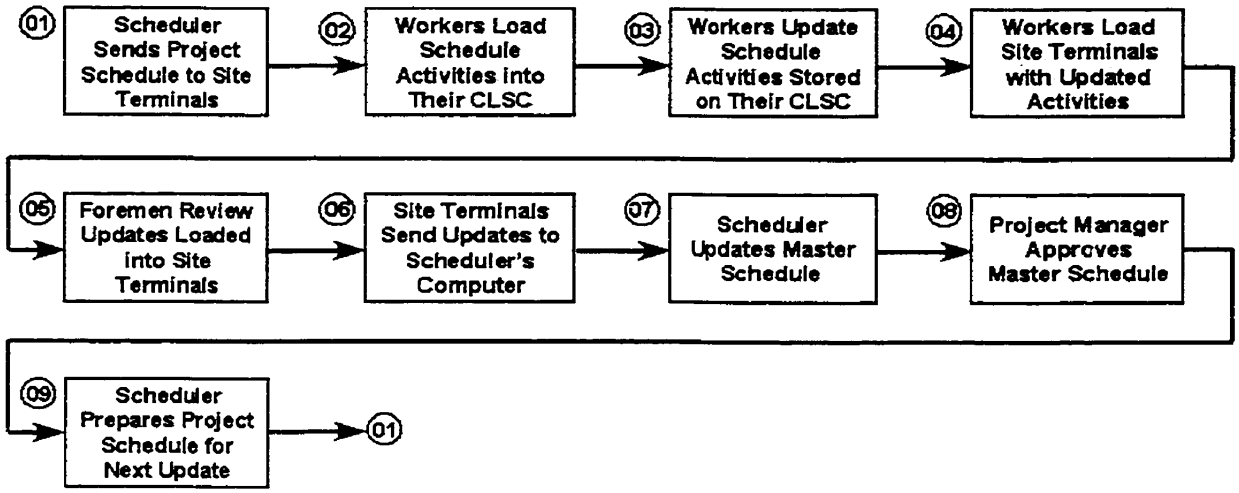
CLSC: Construction Labor Smart Card
RF: Radio Frequency

Figure 3-11: Material Order Application Process Flow Diagram

An electronic material order form stored on the CLSC ready to be populated with list of material items needed for the job. Cardholder completes the electronic form by using any of the following methods: (1) Manual inputs using the card reader key pad; (2) Download from material database stored into site terminals; or (3) Radio Frequency (RF) bar code scanner. Once the material order is complete, worker electronically forwards the order to the warehouse via site terminals. Site terminal smart modem connects the terminal with the warehouse system at prescribed periods in order to transfer and receive data to and from the warehouse. Workers have the capability to track status of their material order using the site terminal, track orders delivered from the warehouse, remotely place material orders using cellular phone.

3.3.5 Construction Schedule

The construction schedule is a primary tool in project control, progress payment and status reporting. The process of calculating schedule dates, critical path and floats is fully computerized but the process to gather the progress update information remains manual. Schedule engineers spend much of their time updating percentages of work completed and revising start and finish dates. Progress update information is found in daily site reports, meeting minutes and verbal or written messages, which typically come from people working in the field. The purpose of the proposed construction schedule application is to use smart card technology to electronically collect data from the field to update construction schedules. A process flow diagram for the operational steps is illustrated in Figure 3-12.



CLSC: Construction Labor Smart Card

Figure 3-12: Construction Schedule Application Process Flow Diagram

The scheduling engineer sends the project schedule to the site terminal. Authorized personnel such as site superintendents and foremen use site terminals to download activities to update their CLSC(s). Schedule updates are exchanged between different smart cards and uploaded into site terminals. Once the site manager approves a progress update stored into the site terminal, information is sent to a remote computer into which the master schedule is saved. The scheduling engineer uses his/her CLSC to integrate the master schedules and regenerate the progress status reports. The authority to alter project schedule information using CLSC depends on read-write permissions and application access privileges granted to the CLSC user.

3.4 Smart Card Questionnaire

The construction industry smart card questionnaire was conducted in summer of 2000 and was sent to 105 companies specializing in different sectors such as energy, telecommunications, and residential and commercial construction projects in the U.S. and Canada. The response rate was 20% representing the views of 21 different construction company senior managers and vice presidents about the prospect of employing smart card in the industry. The questionnaire comprised of 20 questions and its objectives are:

1) Measure awareness, perception and interest of construction industry senior managers and executives towards using smart card technology.
2) Obtain industry representative opinions regarding the feasibility of smart card considering its vulnerability to site conditions, reliability of card security and serviceability of card infrastructure, acceptable cost ranges and appropriate card data ownership.
3) Validate the adaptability of smart card including applicability to various construction project functions, multi-functionality of cards in different industries and interface-ability between card hardware and various construction tools.

The questionnaire results are compiled in Table 3-3.

Construction Industry Smart Card Questionnaire			
General			
1 Cardholder's Awareness			
Y = 14%	N = 86%	N/A = 0%	Have you ever used a Smart Card?
2 User's Perception			
			Smart Cards can be used as a payment vehicle. Do the following payment applications support your needs?
Y = 48%	N = 33%	N/A = 19%	- Supplier invoices (cash out)
Y = 38%	N = 48%	N/A = 14%	- Customer invoices (cash in)
Y = 38%	N = 48%	N/A = 14%	- Labor payment (payroll)
Y = 48%	N = 38%	N/A = 14%	- Expense vouchers
Y = 33%	N = 43%	N/A = 24%	- Tax, insurance, union dues
Y = 19%	N = 0%	N/A = 81%	- Other: Rent & Office Expenses, Miscellaneous Purchases (3 Responses)
3 User's Interest			
Y = 52%	N = 24%	N/A = 24%	Would you be interested in using Smart Cards as a tool to exchange information between project stakeholders?
4 Motivation			
			Indicate whether the following would motivate you to obtain a Smart Card
Y = 57%	N = 33%	N/A = 10%	- Reduce number of plastic cards in your wallet
Y = 48%	N = 43%	N/A = 10%	- Possess an alternative personal identification method
Y = 48%	N = 38%	N/A = 14%	- Use electronic signature
Y = 52%	N = 29%	N/A = 19%	- Eliminate the needs to memorize many passwords
Y = 52%	N = 29%	N/A = 19%	- Access job site facility
Y = 62%	N = 24%	N/A = 14%	- Store your personal profile and medical records
Y = 52%	N = 38%	N/A = 10%	- Receive electronic cash instead of printed check
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
Feasibility			
5 Card Vulnerability			
			Of the following work conditions which ones would construction Smart Cards be exposed to during work?
Y = 67%	N = 14%	N/A = 19%	- Static electricity
Y = 67%	N = 19%	N/A = 14%	- Magnetic field
Y = 71%	N = 14%	N/A = 14%	- Temperature
Y = 52%	N = 29%	N/A = 19%	- Ultraviolet light
Y = 57%	N = 33%	N/A = 10%	- Chemicals
Y = 86%	N = 5%	N/A = 10%	- Damage
6 Card Reliability			
			Would any of the following risk factors prevent you from using a Smart Card in your project?
Y = 67%	N = 24%	N/A = 10%	- Tampering
Y = 62%	N = 24%	N/A = 14%	- Counterfeiting
Y = 48%	N = 38%	N/A = 14%	- Virus
Y = 48%	N = 33%	N/A = 19%	- Hackers
Y = 52%	N = 33%	N/A = 14%	- Accuracy
Y = 62%	N = 24%	N/A = 14%	- Privacy
Y = 71%	N = 24%	N/A = 5%	- Security
Y = 52%	N = 29%	N/A = 19%	- Failure

Legend

Y: Yes
N: No
N/A: Not Applicable, Undecided, Not Answered
% Y: Percentage of Total Y-Responses
% N: Percentage of Total N-Responses
% N/A: Percentage of Total N/A

Table 3-3: Smart Card Questionnaire

Construction Industry Smart Card Questionnaire

7 Serviceability			
			Would any of the following features encourage you to employ Smart Cards in your project?
Y = 81%	N = 14%	N/A = 5%	- Portability of database stored on the card
Y = 81%	N = 10%	N/A = 10%	- Exchangeability of information with others
Y = 67%	N = 19%	N/A = 14%	- Reusability of card with new applications
Y = 48%	N = 14%	N/A = 38%	- Ubiquity of card readers and terminals
Y = 67%	N = 19%	N/A = 14%	- Accessibility to card readers and terminals on site
Y = 76%	N = 10%	N/A = 14%	- Identify-ability of cardholder
Y = 62%	N = 29%	N/A = 10%	- Replaceability of lost, damaged or stolen cards
Y = 57%	N = 19%	N/A = 24%	- Insurability to protect cardholder
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
8 Scale-ability			
			Which of the following projects do you feel needs Smart Card Applications (labor payment, access control, ..etc.)?
Y = 62%	N = 19%	N/A = 19%	- Remote site
Y = 52%	N = 19%	N/A = 29%	- Multi-site project
Y = 52%	N = 10%	N/A = 38%	- Power plant project
Y = 43%	N = 19%	N/A = 38%	- Housing project
Y = 43%	N = 19%	N/A = 38%	- Highway project
Y = 52%	N = 10%	N/A = 38%	- Off-shore project
Y = 48%	N = 14%	N/A = 38%	- Project in a developed country
Y = 29%	N = 24%	N/A = 48%	- Project in an underdeveloped country
Y = 10%	N = 0%	N/A = 90%	- Other: Overhead Labor Charges (in the Yard), Rehabilitation Project
9 Target User			
			Which of the following project stakeholders do you think benefits from employing Smart Card Technology in construction sector?
Y = 57%	N = 24%	N/A = 19%	- Owner representative
Y = 95%	N = 0%	N/A = 5%	- Project manager
Y = 71%	N = 10%	N/A = 19%	- Foreman
Y = 52%	N = 33%	N/A = 14%	- Worker
Y = 48%	N = 33%	N/A = 19%	- Subcontractor
Y = 62%	N = 24%	N/A = 14%	- Supplier
Y = 62%	N = 29%	N/A = 10%	- Project engineer
Y = 76%	N = 10%	N/A = 14%	- Project control
Y = 62%	N = 24%	N/A = 14%	- Human resources
Y = 76%	N = 10%	N/A = 14%	- Payroll department
Y = 52%	N = 29%	N/A = 19%	- Quality control
Y = 71%	N = 14%	N/A = 14%	- Safety
Y = 10%	N = 0%	N/A = 90%	- Other: Superintendent, Litigation (ease of ability to prove cost)

Legend

Y: Yes
N: No
N/A: Not Applicable, Undecided, Not Answered
% Y: Percentage of Total Y-Responses
% N: Percentage of Total N-Responses
% N/A: Percentage of Total N/A

Table 3-3: Smart Card Questionnaire (Continue)

Construction Industry Smart Card Questionnaire

Y	N	N/A	Question
10 Affordability			
			Assuming each laborer is issued a Smart Card, which of the following average unit cost ranges would be considered cost effective?
Y = 62%	N = 10%	N/A = 29%	- Less than $20
Y = 29%	N = 38%	N/A = 33%	- $20-$30
Y = 19%	N = 52%	N/A = 29%	- $30-$40
Y = 10%	N = 62%	N/A = 29%	- $40-$50
Y = 10%	N = 62%	N/A = 29%	- Greater than $50
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
11 Data Ownership			
			Of the following data ownership agreements which is likely to be acceptable to your company?
Y = 19%	N = 67%	N/A = 14%	- Card issuer owns and maintains data on the card
Y = 76%	N = 10%	N/A = 14%	- Your company owns and maintains data on the card
Y = 29%	N = 52%	N/A = 19%	- Third party maintains the card databases
Y = 24%	N = 57%	N/A = 19%	- Data co-ownership between your company and bank
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
12 Audit-ability			
			Of the following audit trail methods which best meets your company policy guidelines?
Y = 86%	N = 5%	N/A = 10%	- Audit trail all Smart Card transactions
Y = 29%	N = 48%	N/A = 24%	- Anonymous audit trail on a project level
Y = 0%	N = 67%	N/A = 33%	- No audit trail
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
Adaptability			
13 Applicability			
			Which of these project functions do you feel is suitable for Smart Card?
Y = 52%	N = 29%	N/A = 19%	- Schedule update
Y = 62%	N = 24%	N/A = 14%	- Material ordering
Y = 38%	N = 38%	N/A = 24%	- Quantity takeoff
Y = 43%	N = 24%	N/A = 33%	- Meter readings
Y = 57%	N = 29%	N/A = 14%	- Billing
Y = 52%	N = 24%	N/A = 24%	- Labor payment
Y = 33%	N = 48%	N/A = 19%	- Subcontractor payment
Y = 24%	N = 57%	N/A = 19%	- Contract signing
Y = 71%	N = 10%	N/A = 19%	- Time Sheet
Y = 5%	N = 0%	N/A = 95%	- Other: Change order generation
14 Multi-Functionality			
			Of the following functions which best describes those you would employ or like to see made available on a Smart Card?
Y = 43%	N = 29%	N/A = 29%	- Electronic cash
Y = 62%	N = 14%	N/A = 24%	- Personal identification
Y = 67%	N = 14%	N/A = 19%	- Log on password
Y = 67%	N = 10%	N/A = 24%	- Credit or debit card
Y = 52%	N = 24%	N/A = 24%	- Medical insurance card
Y = 48%	N = 29%	N/A = 24%	- Driver license
Y = 29%	N = 33%	N/A = 38%	- Training profile
Y = 38%	N = 29%	N/A = 33%	- Work experience and skills
Y = 5%	N = 0%	N/A = 95%	- Other: Subcontractor last performance (on time, on budget, etc.)

Legend
Y: Yes
N: No
N/A: Not Applicable, Undecided, Not Answered
% Y: Percentage of Total Y-Responses
% N: Percentage of Total N-Responses
% N/A: Percentage of Total N/A

Table 3-3: Smart Card Questionnaire (Continue)

Construction Industry Smart Card Questionnaire

Y	N	N/A	Question
15 Interface-ability			
			Which of the following interface requirements would you like to see made available on a Smart Card?
Y = 81%	N = 5%	N/A = 14%	- PC Computer interface
Y = 14%	N = 57%	N/A = 29%	- Radio Frequency Scanner
Y = 24%	N = 57%	N/A = 19%	- Closed Circuit TV
Y = 48%	N = 19%	N/A = 33%	- Equipment Control
Y = 48%	N = 29%	N/A = 24%	- Remote Control On/Off Devices
Y = 38%	N = 29%	N/A = 33%	- CAD Systems
Y = 48%	N = 24%	N/A = 29%	- Survey Instruments
Y = 19%	N = 48%	N/A = 33%	- Meters (Utility, Weather..etc.)
Y = 5%	N = 0%	N/A = 95%	- Other (please specify) G.P.S.
16 Piloting			
Y = 43%	N = 38%	N/A = 19%	Would you like to participate in one of the Smart Card future pilot programs?
17 Roll-out			
Y = 62%	N = 14%	N/A = 24%	If Smart Cards pilot were successful, would you promote using Smart Cards in your project?
18 Technology Infrastructure			
			Smart Cards in the construction industry may utilize new techniques. Which of the following techniques would you employ?
Y = 48%	N = 33%	N/A = 19%	- Electronic signature to sign documents
Y = 48%	N = 29%	N/A = 24%	- Electronic cash instead of checks
Y = 62%	N = 14%	N/A = 24%	- Cell phone with a Smart Card to communicate with others
Y = 76%	N = 5%	N/A = 19%	- PC with card reader to do business on the Internet
Y = 71%	N = 0%	N/A = 29%	- Double-slot card reader to exchange data with others
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
19 Transformability of Current Processes			
			Migrating construction projects to paperless environment may require the development of new processes. Which of the following current practices would you recommend to be modified?
Y = 71%	N = 10%	N/A = 19%	- Updating schedule
Y = 29%	N = 57%	N/A = 14%	- Signing contractual forms
Y = 76%	N = 10%	N/A = 14%	- Tracking cost
Y = 81%	N = 5%	N/A = 14%	- Time keeping
Y = 76%	N = 14%	N/A = 10%	- Monitoring Equipment utilization
Y = 62%	N = 14%	N/A = 24%	- Tracking warehousing inventory level
Y = 71%	N = 19%	N/A = 10%	- Managing material procurement orders
Y = 67%	N = 14%	N/A = 19%	- Exchanging information
Y = 48%	N = 24%	N/A = 29%	- Hiring screening process
Y = 57%	N = 24%	N/A = 19%	- Reviewing safety compliance
Y = 57%	N = 19%	N/A = 24%	- Taking off material quantity
Y = 62%	N = 19%	N/A = 19%	- Tracking quality control submittals
Y = 0%	N = 0%	N/A = 100%	- Other (please specify)
20 Questionnaire Results			
Y = 43%	N = 29%	N/A = 29%	Would you like to receive the results of this questionnaire?
Y = 48%	N = 24%	N/A = 28%	% Total

Legend

Y: Yes
N: No
N/A: Not Applicable, Undecided, Not Answered
% Y: Percentage of Total Y-Responses
% N: Percentage of Total N-Responses
% N/A: Percentage of Total N/A

Table 3-3: Smart Card Questionnaire (Continue)

The **key findings** of the questionnaire results are:

Question # 1: as illustrated in Figure 3-13, only 14% of the respondents have smart cards which indicates that the respondents are generally not embracing the smart card technology.

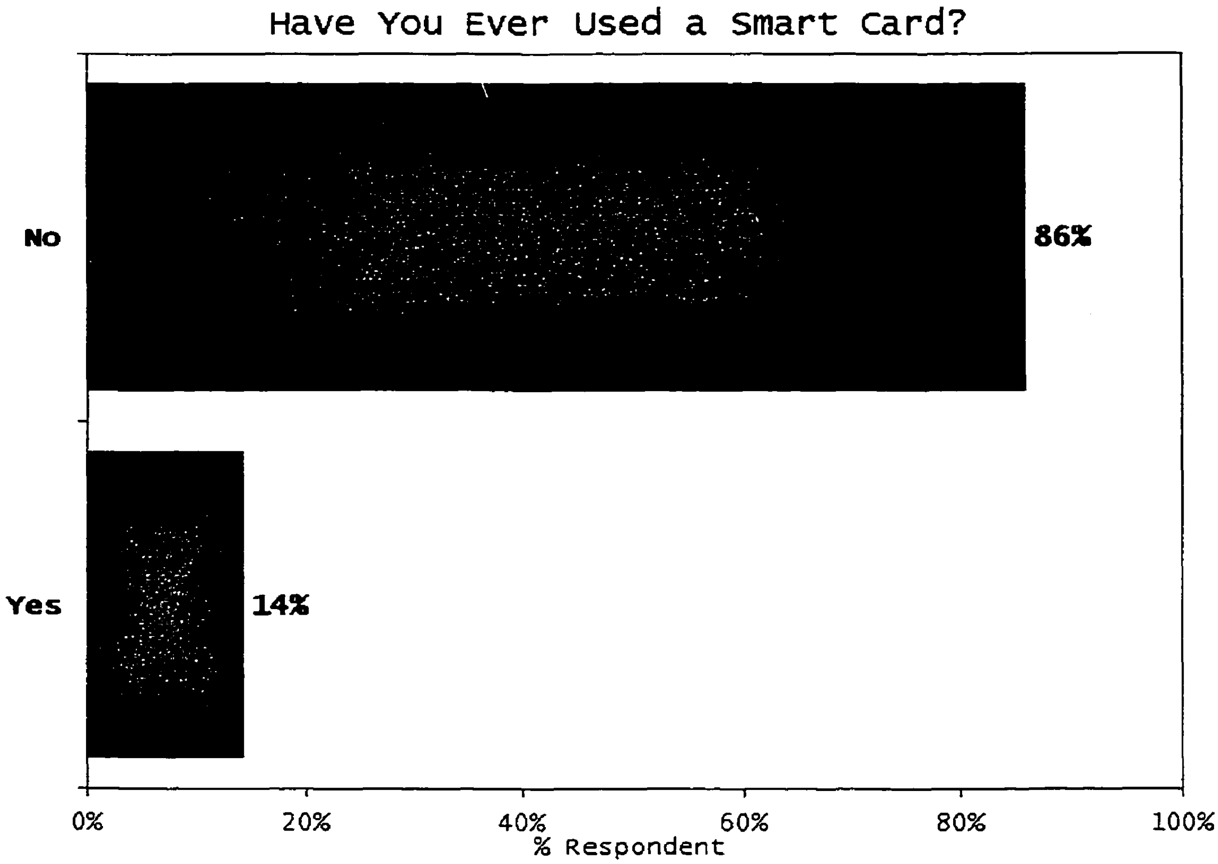


Figure 3-13: Smart Card Questionnaire Response of Question # 1

Question #2: responses are illustrates in Figure 3-14. Forty-eight (48%) of the respondents agreed that using smart card in expense voucher or supplier invoicing would support their needs. Only 38% of the respondents favor applying smart card in labor payment (payroll) and billing systems. One third chose to use smart card in tax, insurance and invoicing applications. Other respondents requested to include more applications such as 1) personalized programmable operators card, 2) rent / office expenses, 3) miscellaneous purchases (small tools), 4) buying office supplies, 5) miscellaneous expenses and supplies procurement.

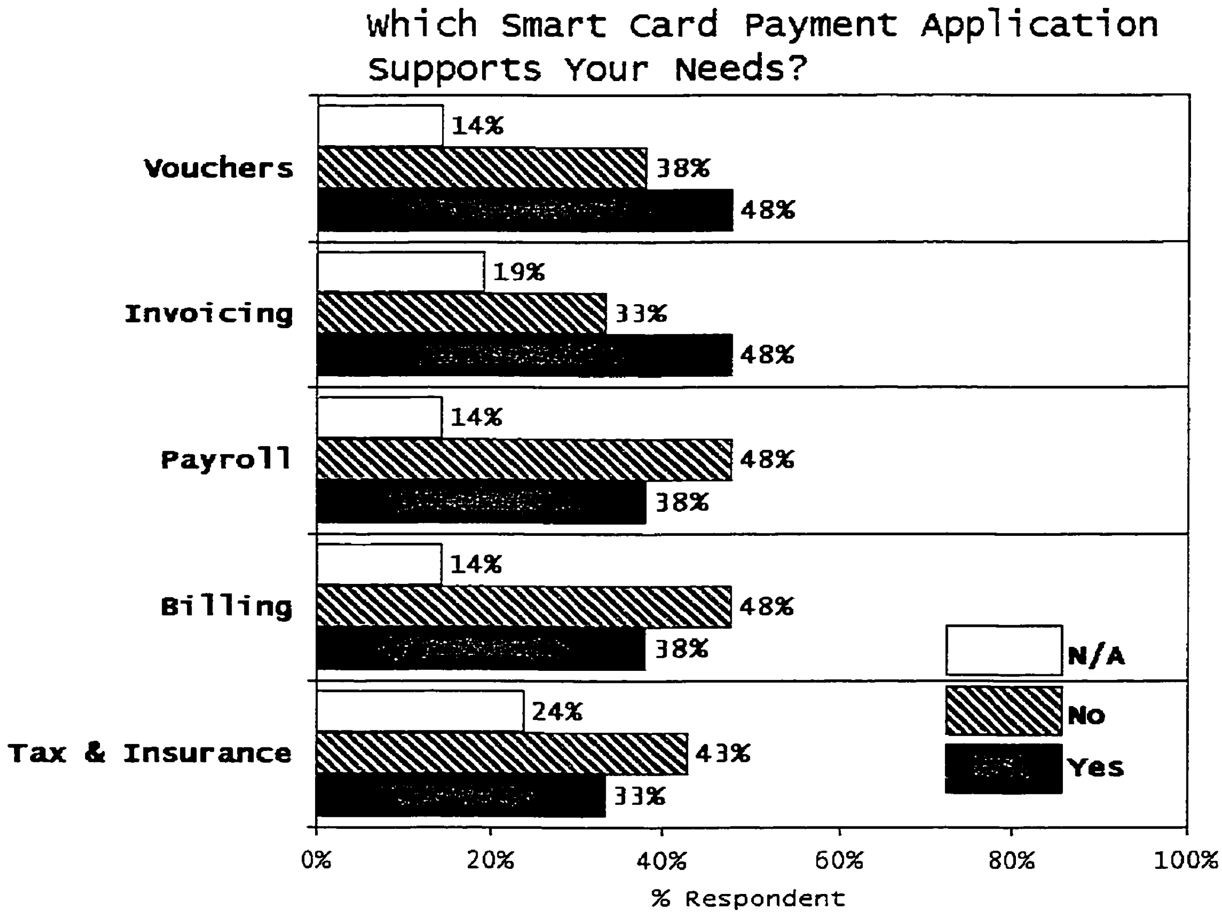


Figure 3-14: Smart Card Questionnaire Response of Question # 2

Question #3: as illustrated in Figure 3-15, fifty-two percent (52%) of the respondents showed interest in using smart card as a tool to exchange information between project stakeholders. Twenty-four percent (24%) of respondents are not in favor and 24% are undecided, uninterested or unfamiliar with the smart card technology.

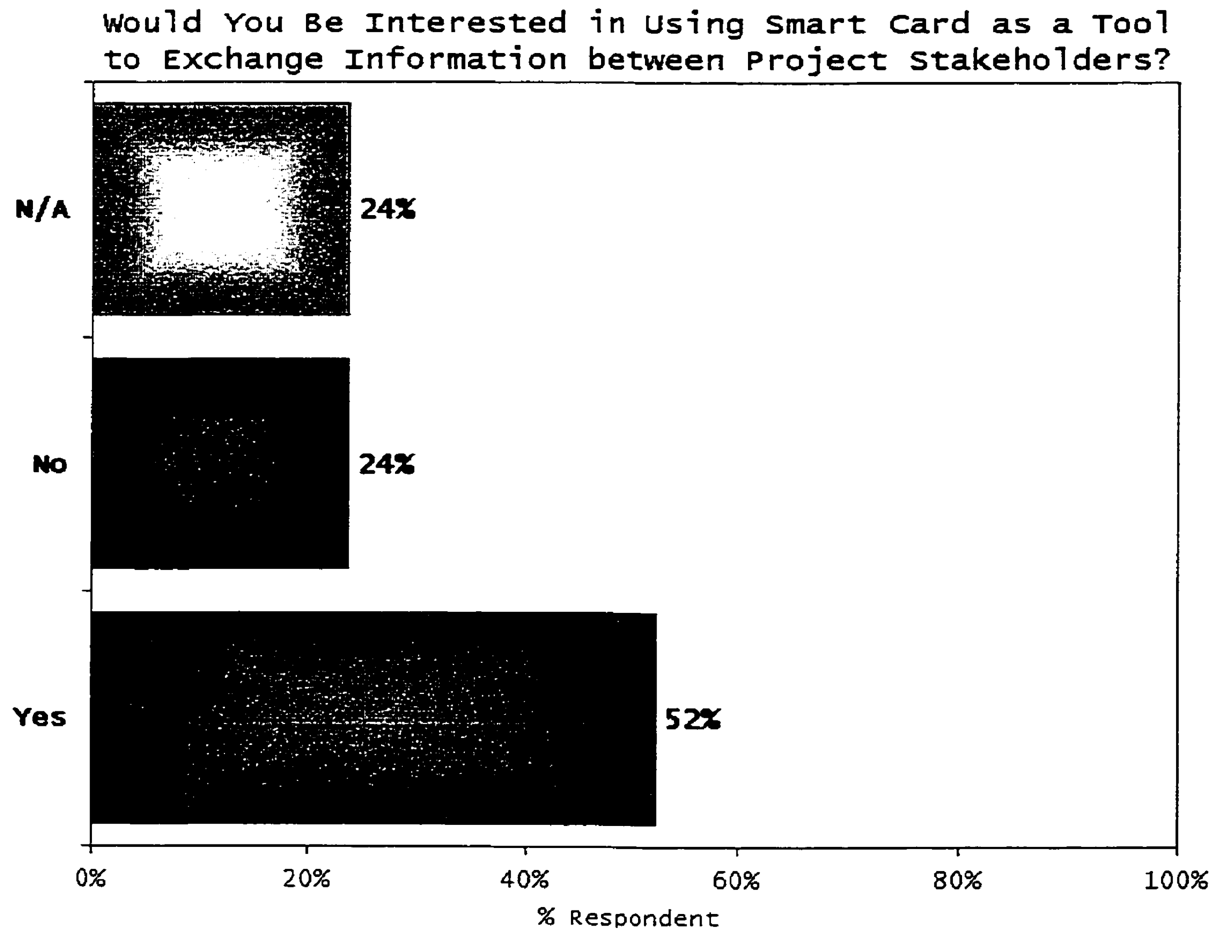


Figure 3-15: Smart Card Questionnaire Response of Question # 3

Question #4: the responses indicate that 62% of the respondents are motivated to use smart card for medical profiles as illustrated in Figure 3-16. Fifty-two percent (52%) chose accessing control, security password or electronic cash applications, while 48% selected electronic signature or personal identification.

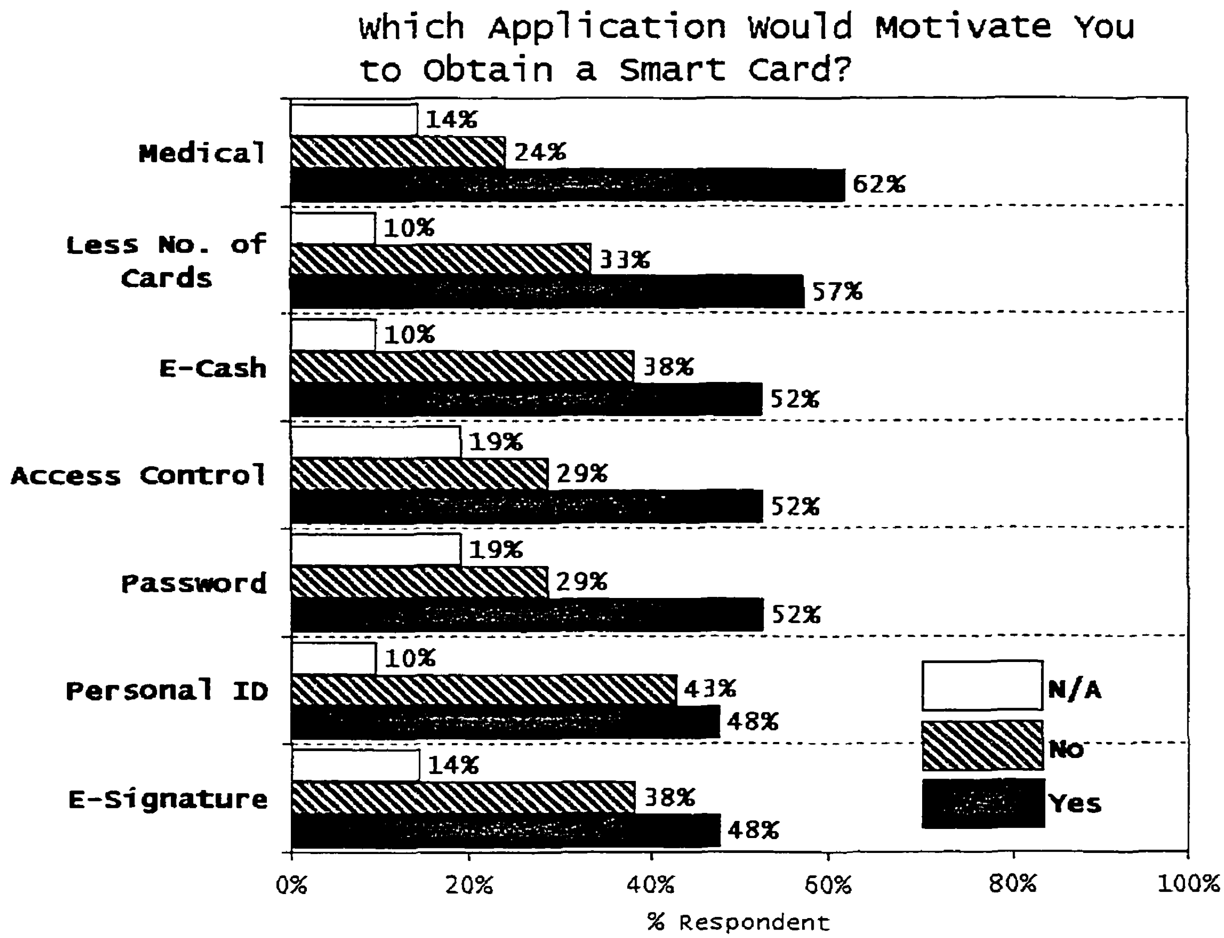


Figure 3-16: Smart Card Questionnaire Response of Question # 4

Question #5: the responses indicate that 86% of the respondents believe that smart card would be exposed to damage from construction work conditions. Card vulnerability to temperature and magnetic or static field comes in the second and third orders with approval rates (%Yes) of 71% and 67% respectively as illustrated in Figure 3-17.

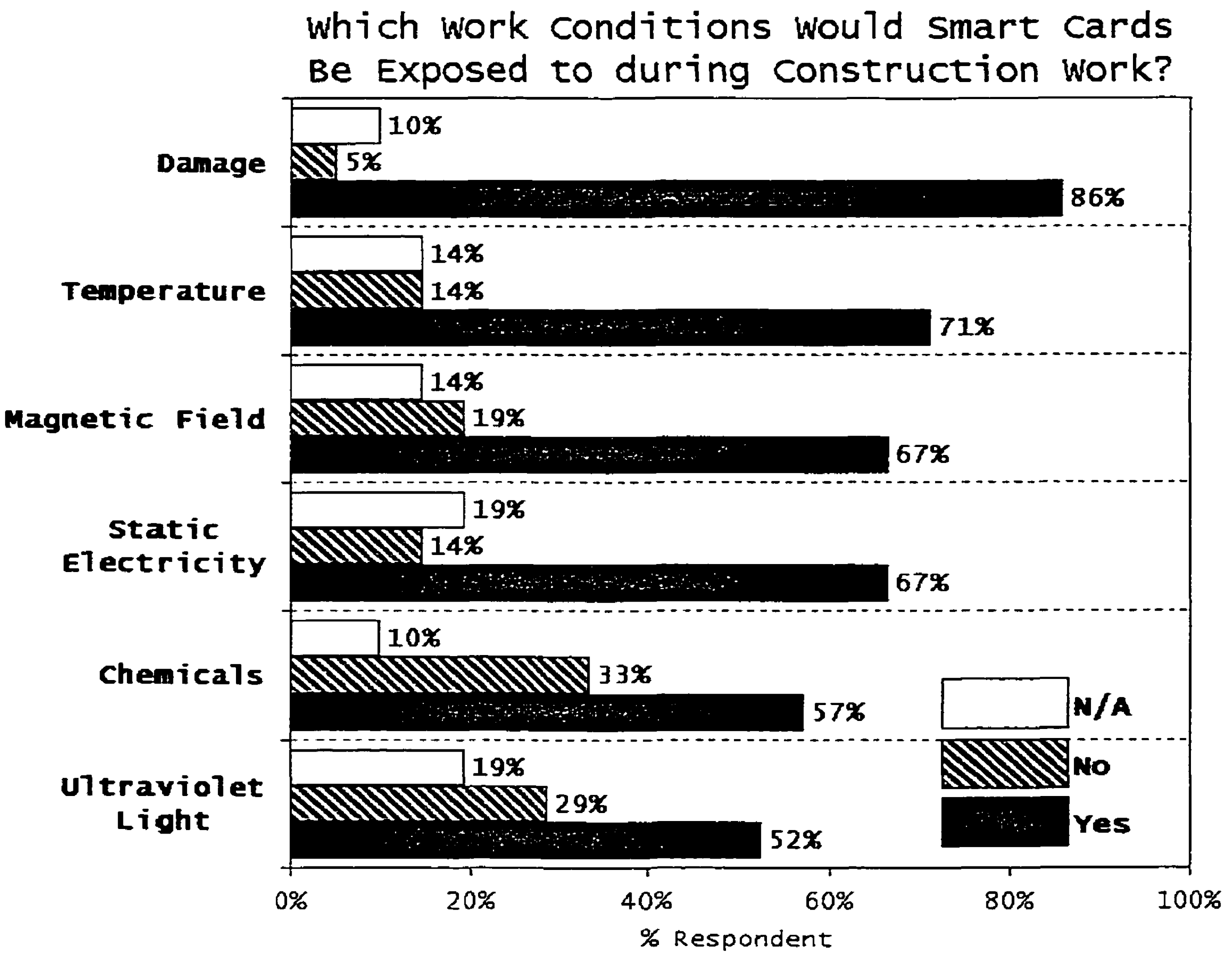


Figure 3-17: Smart Card Questionnaire Response of Question # 5

Question #6: according to the responses, the top three risk factor ranked by the approval rate (%Yes), which would prevent construction managers from using smart cards in their projects, are 1) security (71%), 2) tampering (67%), and 3) privacy or counterfeiting (62%) as illustrated in Figure 3-18. Fifty-two percent (52%) are concerned about data accuracy or card failure, while 48% viewed hackers and viruses as potential risks to smart card. In one response comment, respondent was unsure of level of security provided with the smart card, therefore, respondent was unable to respond to the question.

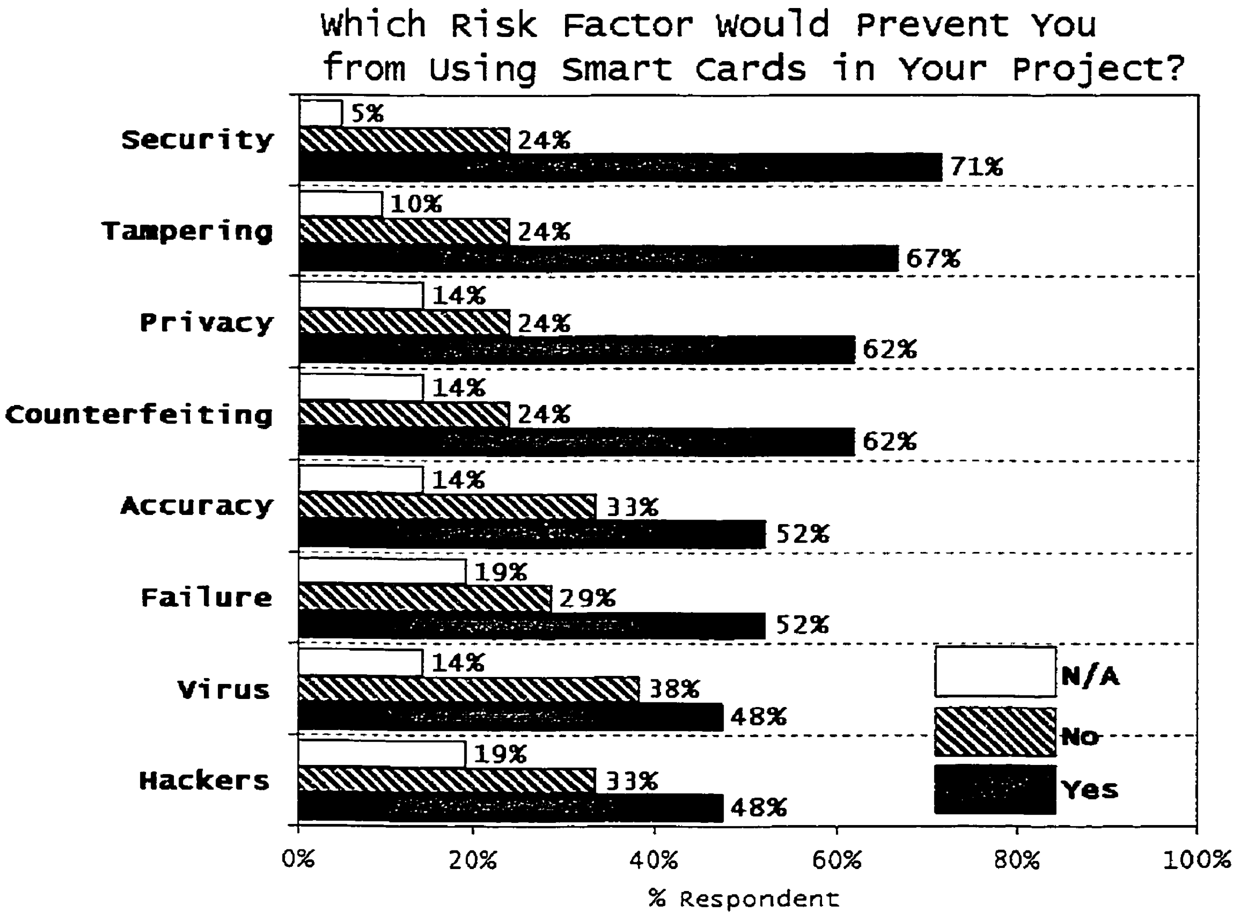


Figure 3-18: Smart Card Questionnaire Response of Question # 6

Question #7: the responses indicate that 81% of the respondents are in favor of employing smart cards, which have the capability of storing and exchanging information between project personnel. Between 62-76% are in favor of card features such as personal identification and access control. Services such as card replacing, insurance and ubiquity of infrastructure have the lowest approval rate, which ranges from 62% to 48% as illustrated in Figure 3-19.

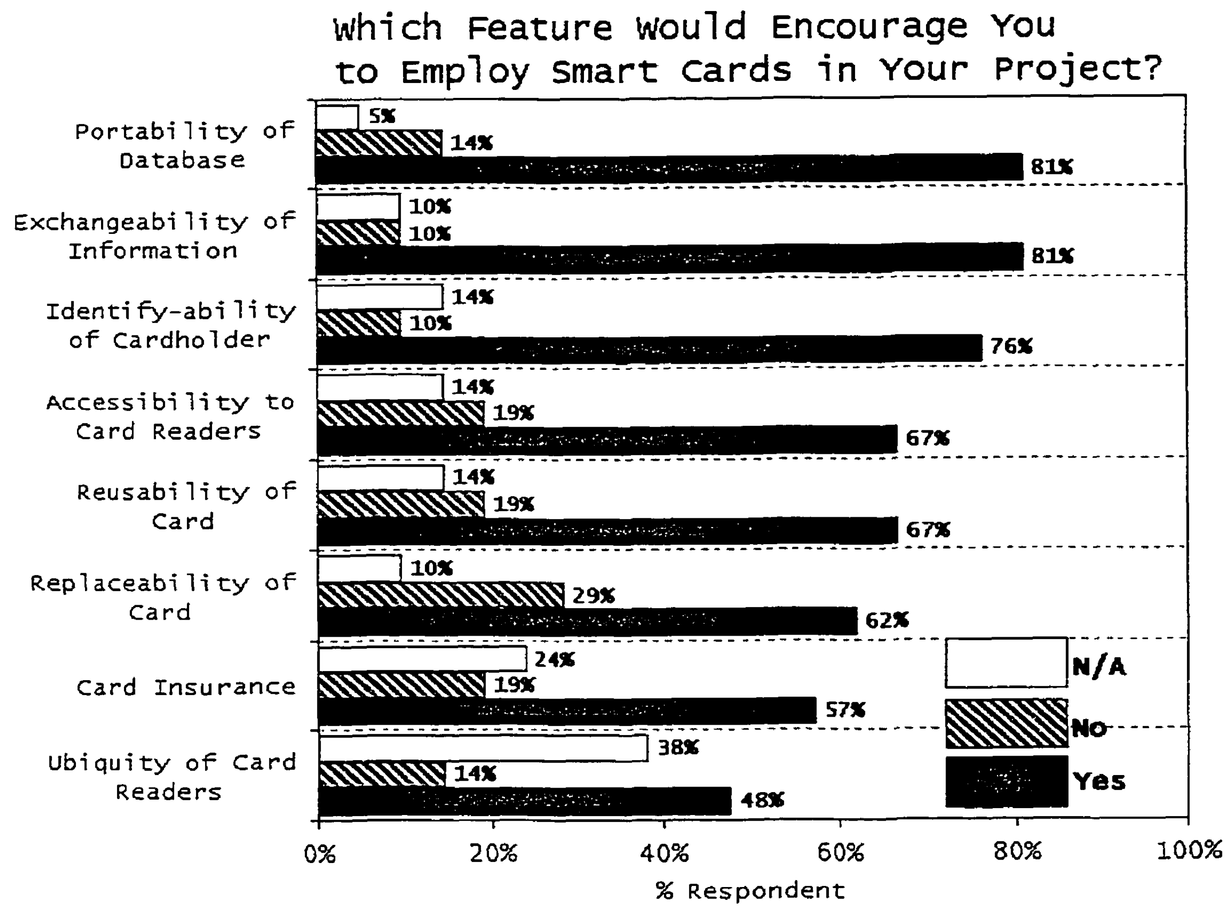


Figure 3-19: Smart Card Questionnaire Response of Question # 7

Question #8: the responses show 62% of the answers are in favor of using smart card in remote sites, while 52% selected off-shore sites, multi-sites and power plant projects as illustrated in Figure 3-20. Less than half of the respondents (43%) agreed that construction highway and housing projects would need smart card applications. In two responses, the respondents recommended including 1) overhead labor charges "In the Yard", and 2) rehabilitation projects.

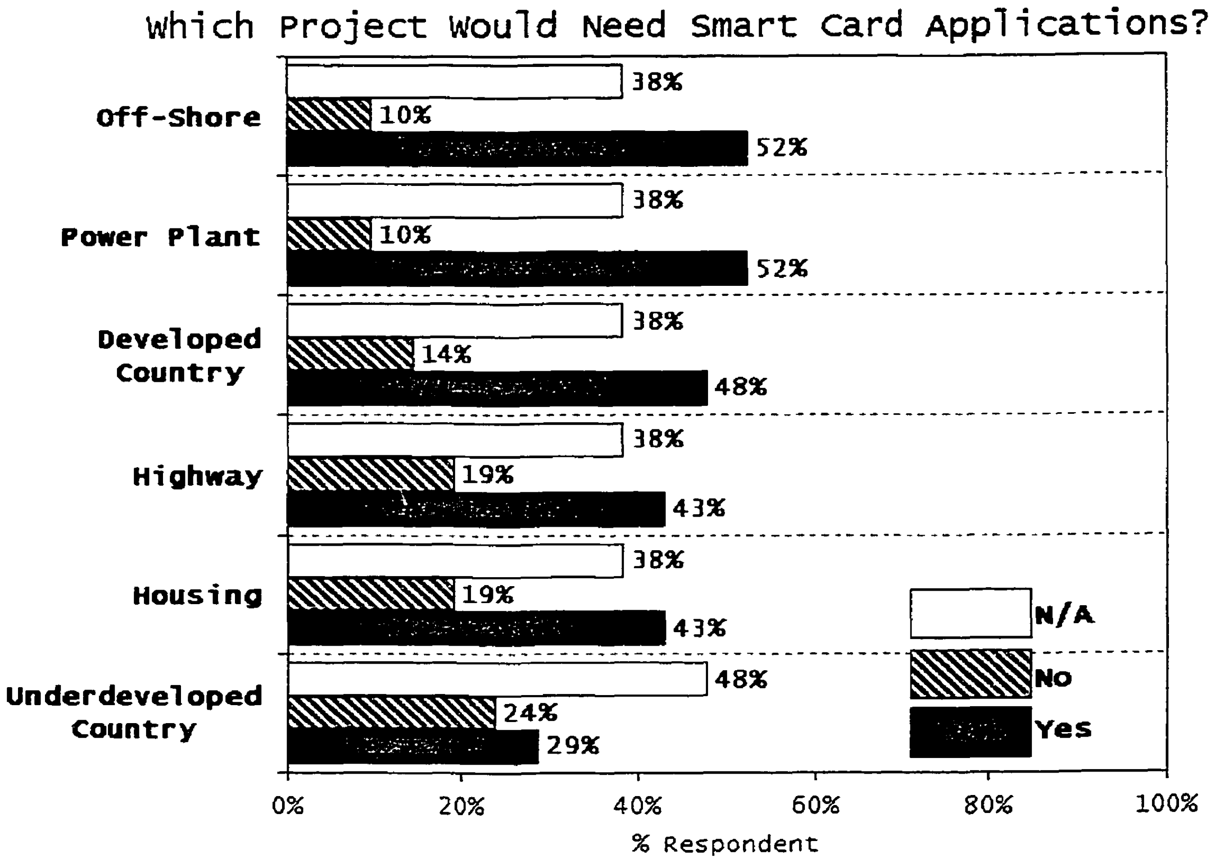


Figure 3-20: Smart Card Questionnaire Response of Question # 8

Question #9: according to the responses of, project stakeholders are grouped into three ranges (High, Medium and Low) ranked by the approval rate (%Yes) as illustrated in Figure 3-21. The **high range** includes 71-95% of respondents who believe that project managers, payroll department, project control, safety and foremen would benefit from employing smart card technology in construction. The **medium range** includes 57-62% of respondents who would assign smart card to project engineers, suppliers, human resources and project owner representatives. The **low range** includes 48-52% of the respondents who felt that smart card would benefit workers, quality control engineers and subcontractors. Two of the respondents requested that litigation specialists and site superintendents be considered potential smart card users as well.

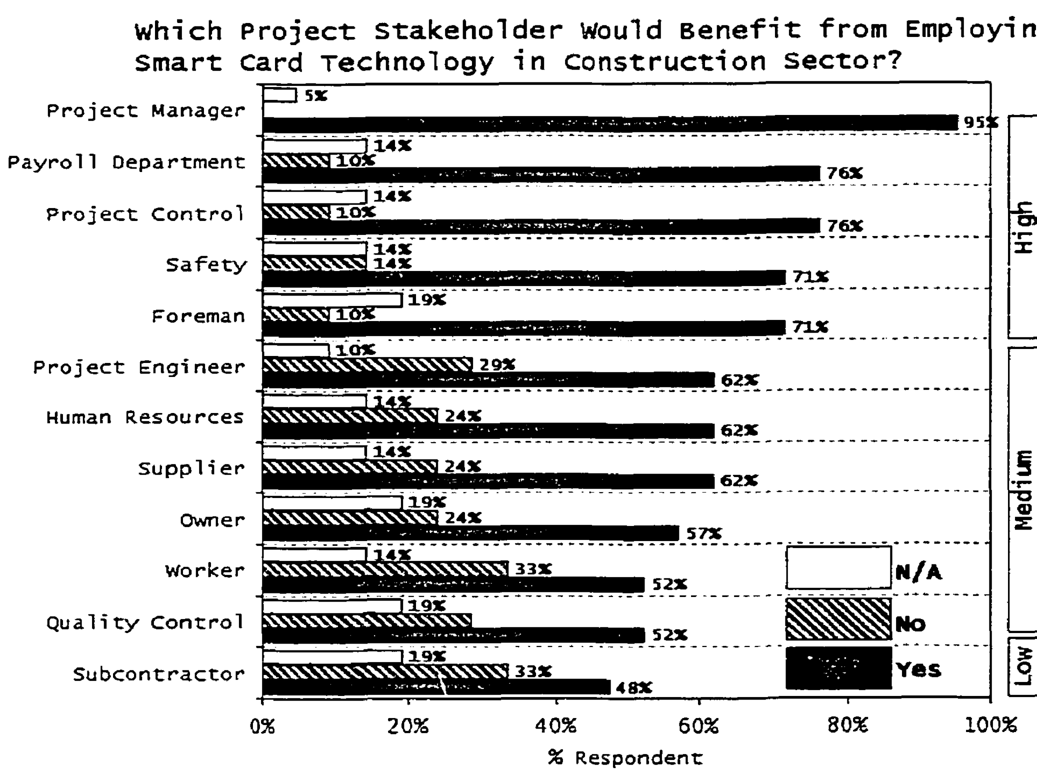


Figure 3-21: Smart Card Questionnaire Response of Question # 9

Question #10: the responses are illustrated in Figure 3-22. Where up to 62% of the respondents believe that smart card would be cost effective if the card price is below $20 per unit. Only 10% of the respondents felt that smart card might still be financially feasible if the card price is higher than $40 per unit. About 29% of the respondents are undecided, unfamiliar with the card applications or not in favor of using smart card technology.

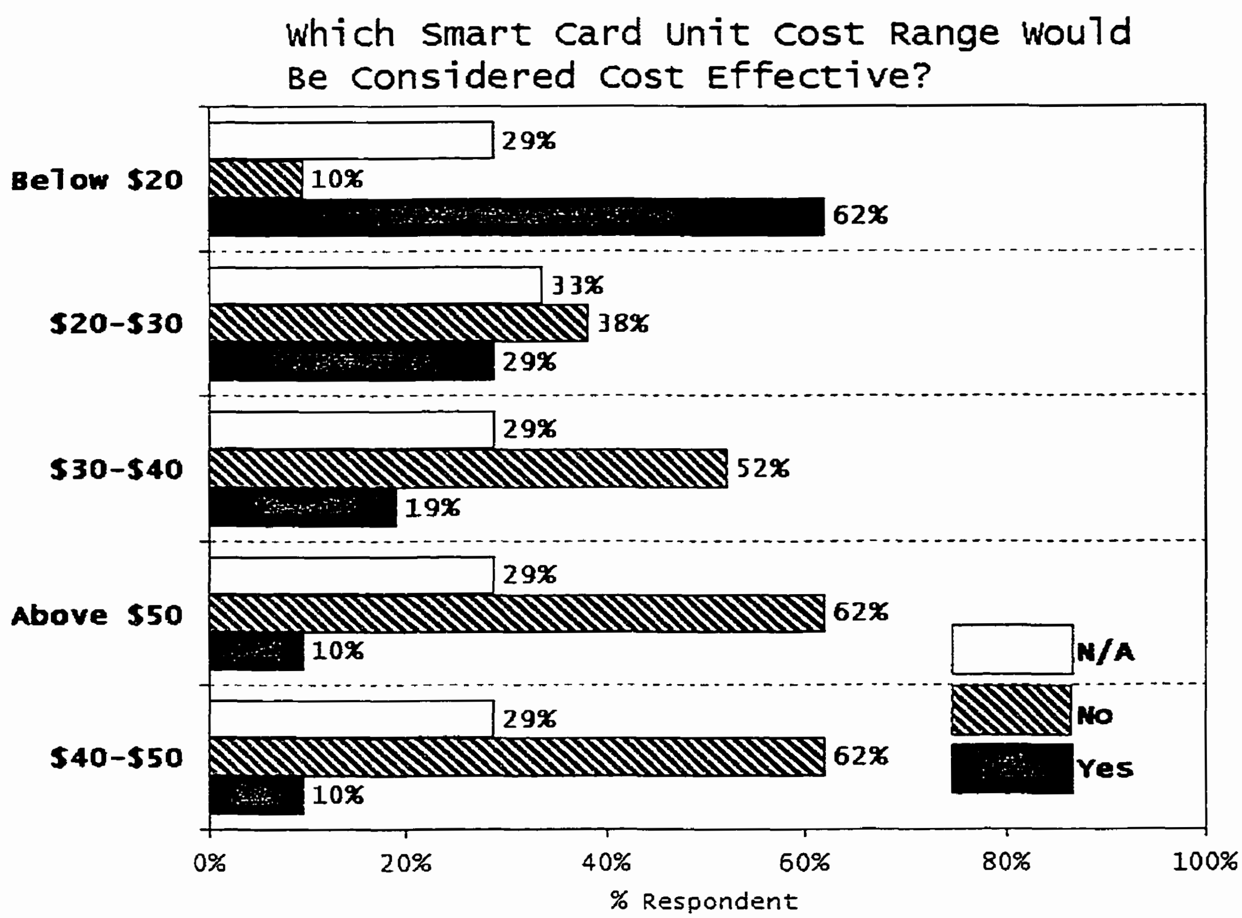


Figure 3-22: Smart Card Questionnaire Response of Question # 10

Question #11: seventy-six percent (76%) of the responses of indicate that the respondents would select their companies to own and maintain the database of the card. Only 29% of the respondents are in favor of a third party managing database of the card, while 19% are in favor of the card issuer as illustrated in Figure 3-23.

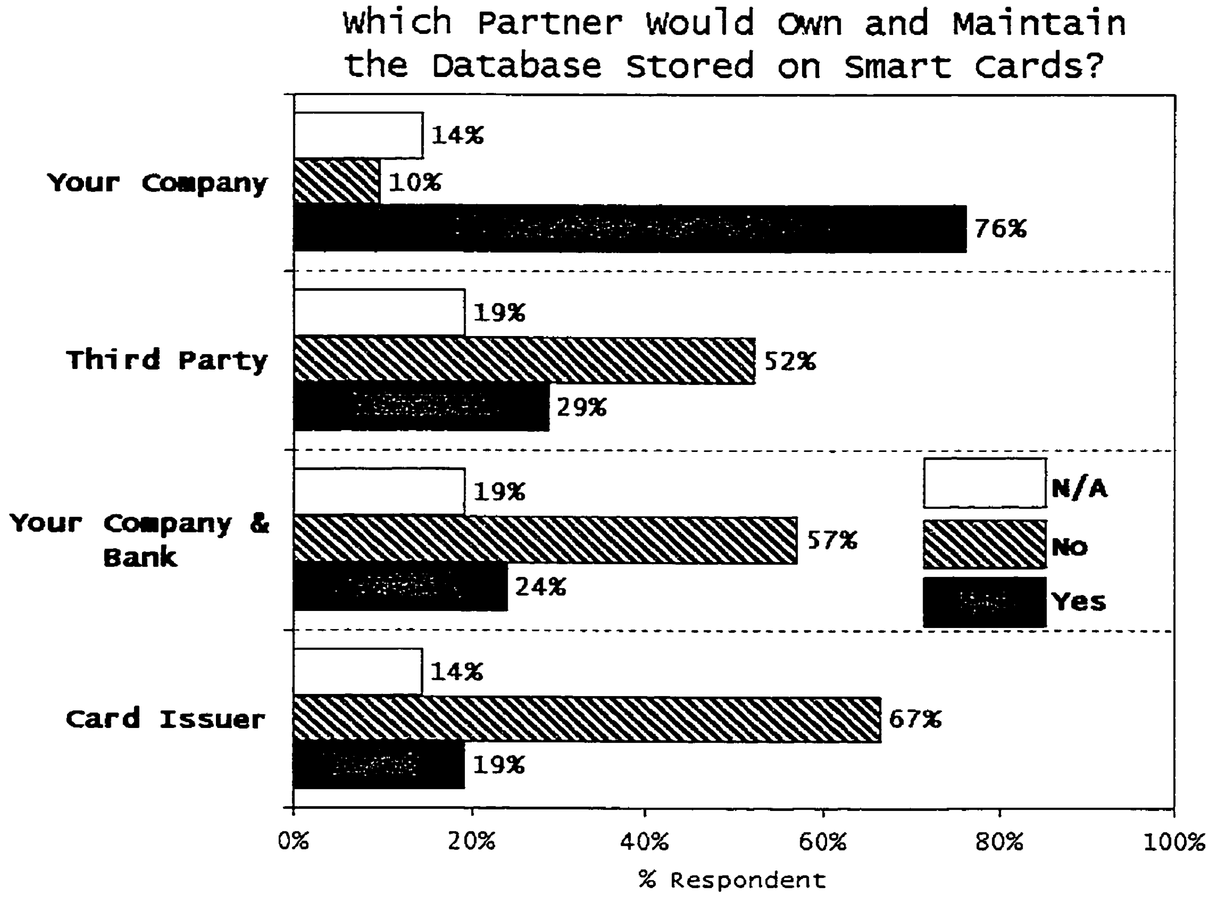


Figure 3-23: Smart Card Questionnaire Response of Question # 11

Question #12: hundred percent (100%) of the respondents expressed the need to establish some sort of audit trail mechanism, with 86% agreeing to perform a full audit trail for all smart card transactions. Only 29% of the answers are in favor of anonymous audit trail on the project level as illustrated in Figure 3-24.

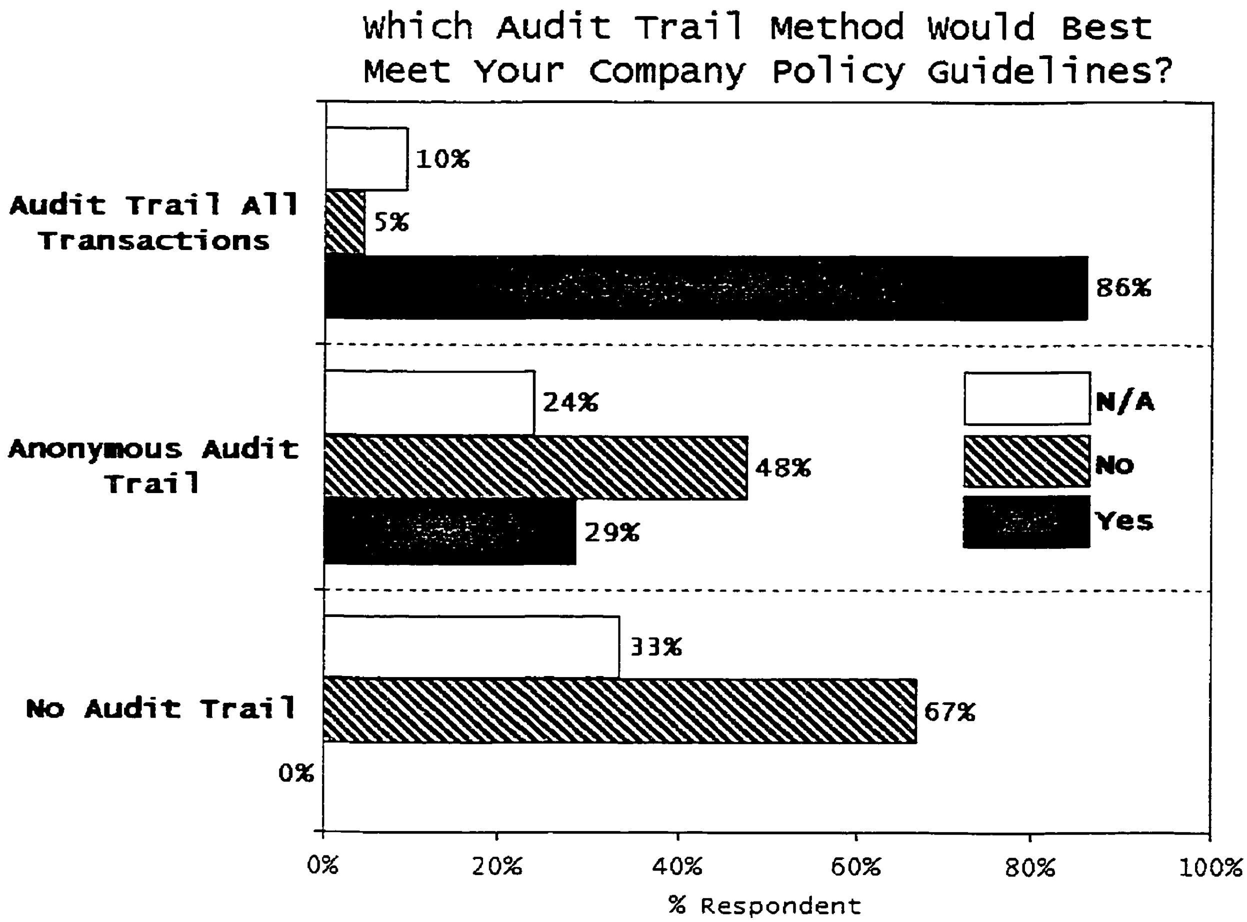


Figure 3-24: Smart Card Questionnaire Response of Question # 12

Question #13: according to the responses, the top four construction project functions, ranked by the highest approval rate (%Yes), suitable for smart card are 1) time keeping (71%), 2) material ordering (62%), 3) billing (57%), and 4) labor payment and schedule update (52% each). Other project functions are within the medium range of 33-43% such as meter reading (43%), quantity take off (38%), and subcontractor payment (33%). The least favorite smart card application is contract signing with approval rate (%Yes) of 24% level as illustrated in Figure 3-25. One respondent recommended change order generation as a potential smart card application.

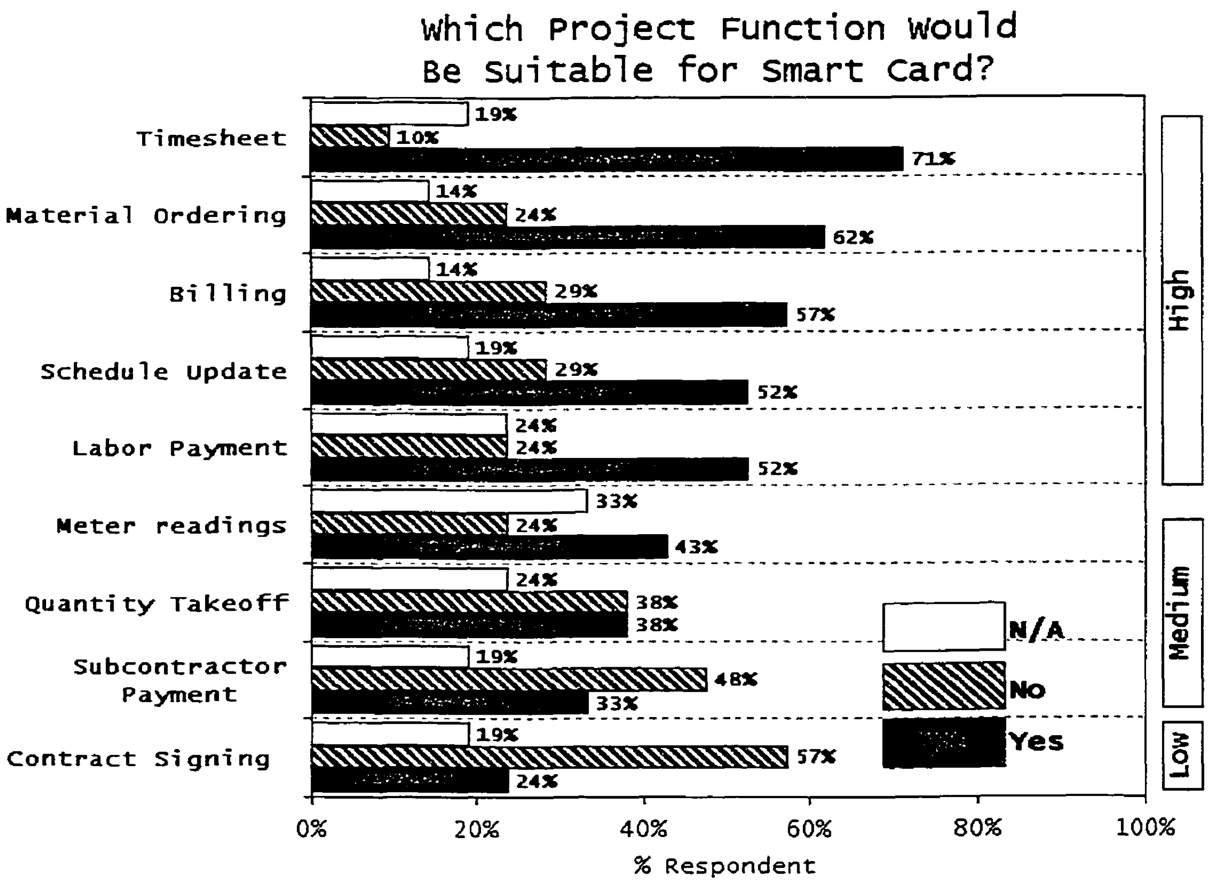


Figure 3-25: Smart Card Questionnaire Response of Question # 13

Question #14: is intended to gauge the construction industry decision-maker's interest in non-construction smart card applications. As illustrated in Figure 3-26, credit and debit card, log on password, and personal identification are in the highest favorable approval (%Yes) range 62-67%. Medical record, driver license, and electronic cash are in the medium favorable approval (%Yes) range 52-43%. Only 29-38%% of the respondents would like to use smart card in tracking training and work experience. One respondent recommended including subcontractors last performance.

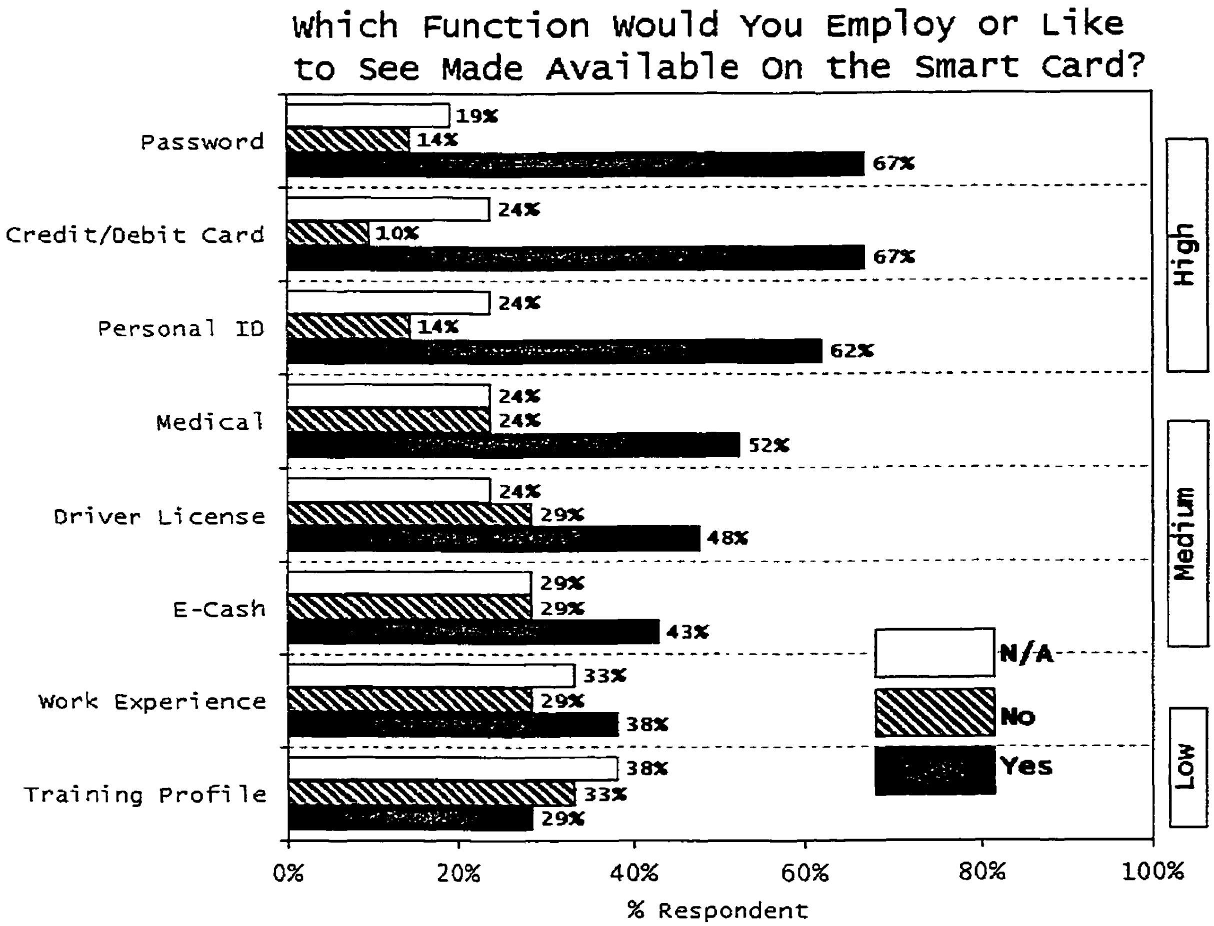


Figure 3-26: Smart Card Questionnaire Response of Question # 14

Question #15: is intended to measure the interest of the respondents in employing smart card interfaces or developing new ones. Card interfaces are considered part of the necessary infrastructure for construction applications. As illustrated in Figure 3-27, 81% of the respondents are in favor of seeing smart card PC interface made available. Proposed interfaces such as remote control, survey instrument, equipment automation, and CAD system had the next highest approval rate (%Yes) range 48-38%. Closed circuit TV, measuring meters, and radio frequency scanner are in the low approval rate range of 14-24%. One respondent recommended including the Global Positioning System (GPS).

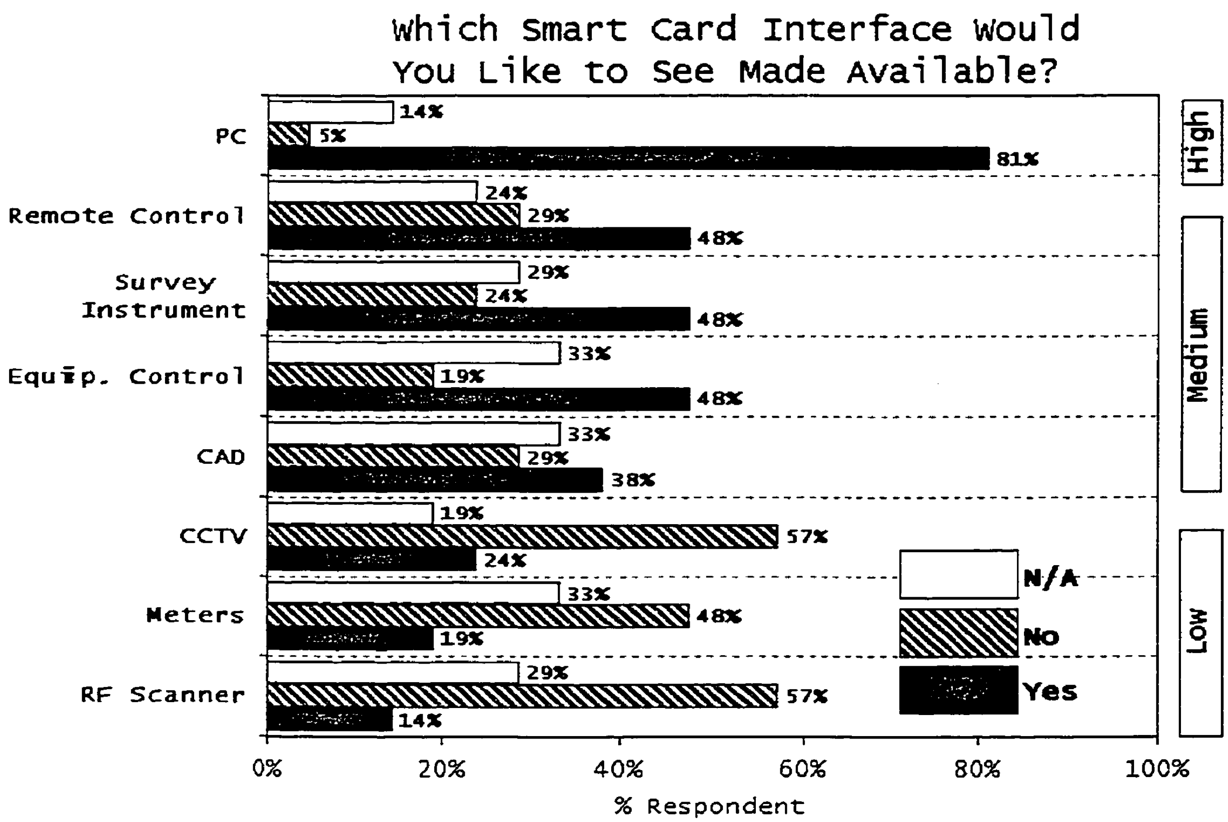


Figure 3-27: Smart Card Questionnaire Response of Question # 15

Question #16: the responses of are illustrated in Figure 3-28. Although unfamiliar with card technology, 43% of the respondents welcomed an opportunity to participate in a future smart card pilot program. Only 19% of the respondents are undecided. Two conservative respondents reserved their approval to participate in any pilots until they receive more information.

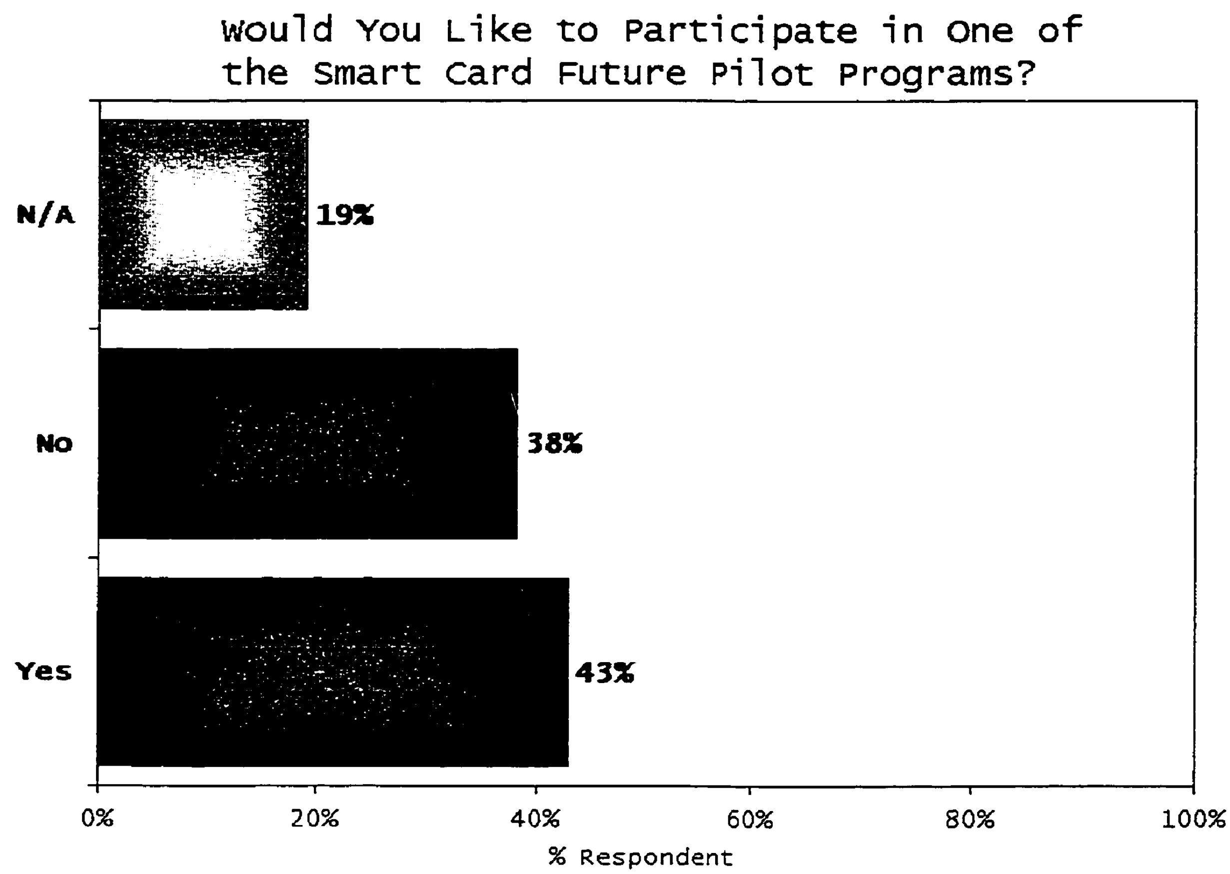


Figure 3-28: Smart Card Questionnaire Response of Question # 16

Question #17: the percentage of respondents likely to promote using smart card in their projects is 62%, if the pilot were successful as illustrated in Figure 3-29. The percentage of respondents who would not participate in any programs decreases from 38% before the pilot to 14% after the pilot. One respondent expressed the willingness to participate if more information is provided.

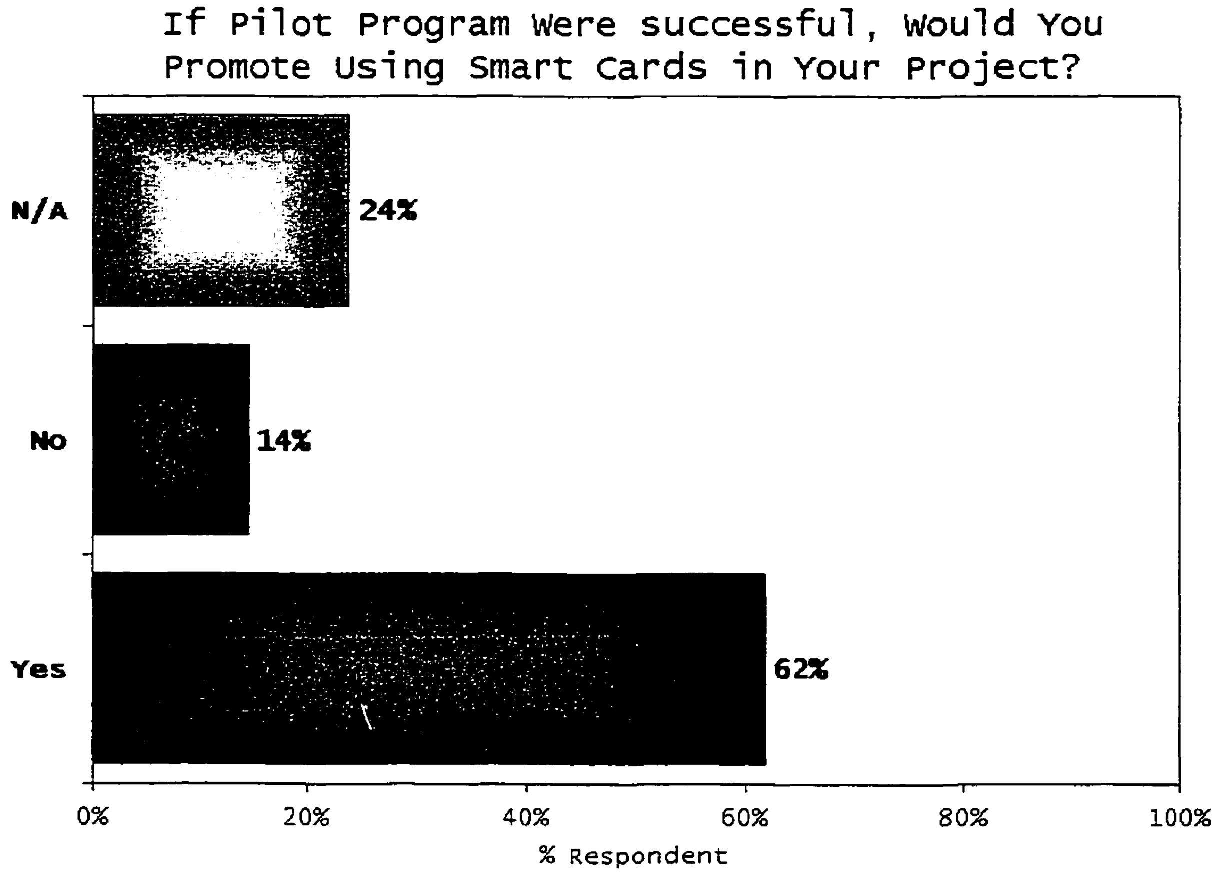


Figure 3-29: Smart Card Questionnaire Response of Question # 17

Question #18: the percentage of respondents in favor of using smart card in performing electronic commerce is 76%, and 62% would like to use smart card with mobile phone communications as illustrated in Figure 3-30. Percentage of respondents in favor of using electronic signature remains 48% which is consistent with the results in question # 4. Although 52% of respondents are in favor of using electronic cash application (see question #4) only 48% would use this application in construction industry.

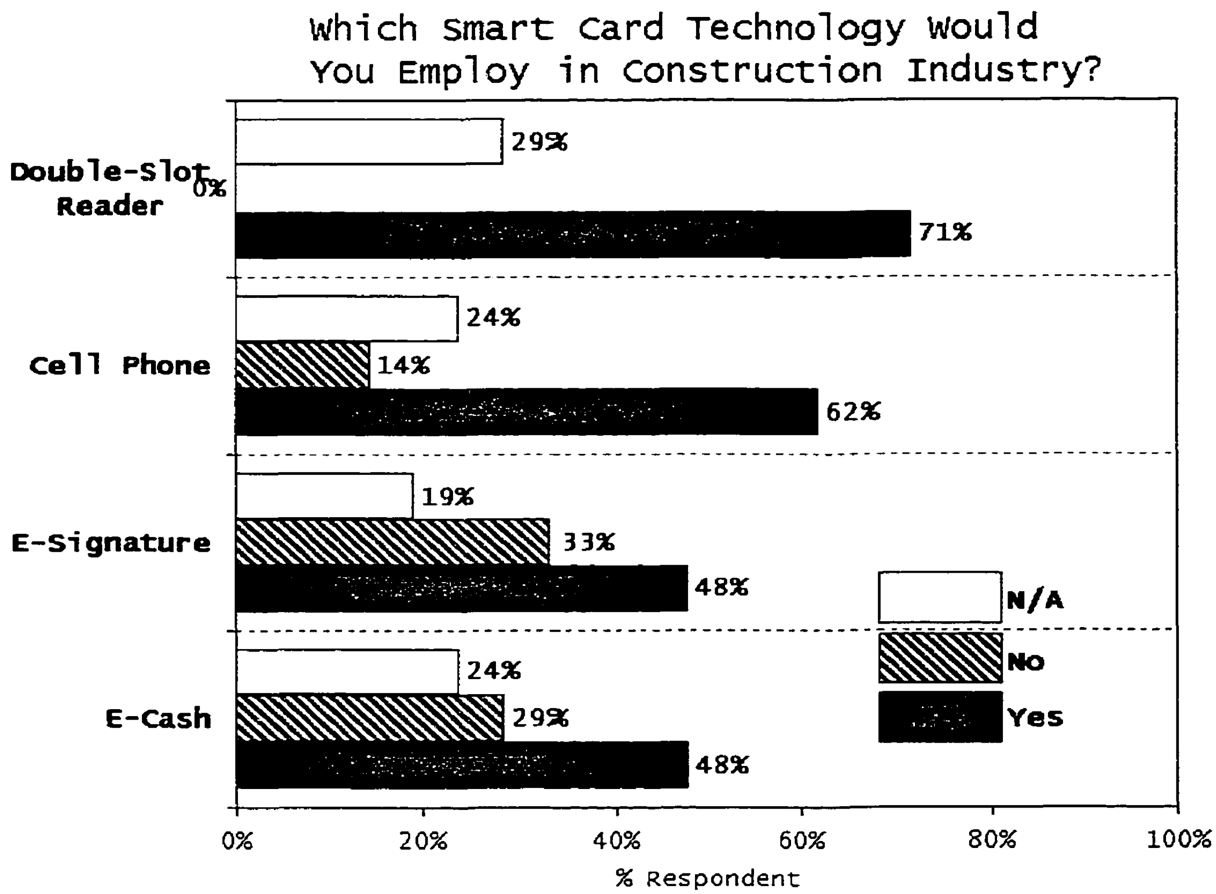


Figure 3-30: Smart Card Questionnaire Response of Question # 18

Question #19: is intended to determine the order in which the respondents rank 12 manual construction processes for migration to a paperless environment. The proposed processes are sorted by percentage of approval rate (%Yes) and grouped into three ranges (High, Medium and Low) as illustrated in Figure 3-31. The **High** range: 71-81% of respondents agreed to modify the following processes: time keeping, monitoring equipment utilization, tracking cost, material ordering, and updating schedule. The **Medium** range: 57-67% includes the following processes: exchanging information, tracking submittal, tracking inventory, material take off, and safety review. The **Low** range: 29-48% includes hiring and screening, and signing forms.

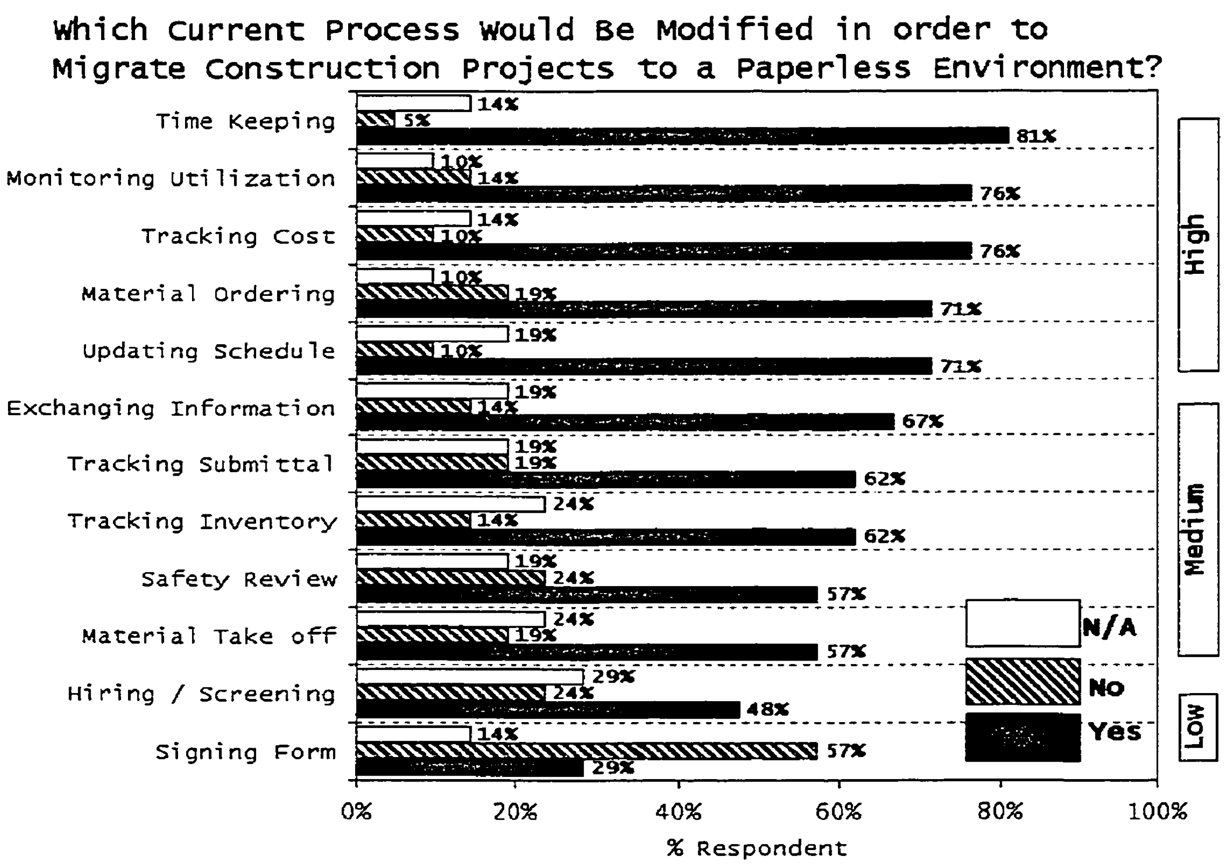


Figure 3-31: Smart Card Questionnaire Response of Question # 19

Question #20: the responses indicate that the percentage of the respondents who would like to receive the questionnaire results is 43% as illustrated in Figure 3-32. Twenty nine percent are currently not interested and another 29% are undecided or did not respond to the question.

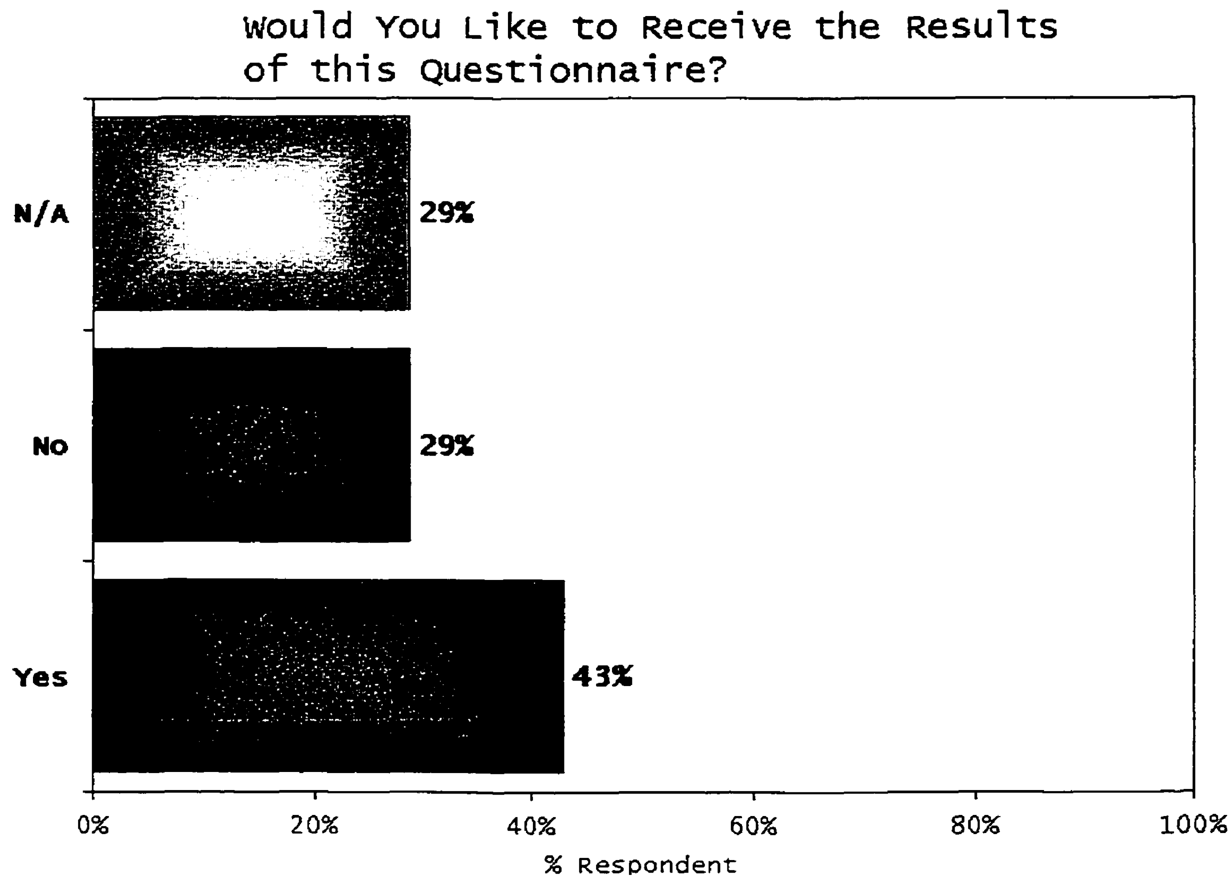


Figure 3-32: Smart Card Questionnaire Response of Question # 20

In summary, the survey showed the following:

1) Almost 2/3 of the responses would promote using smart card in construction although only 14% of the respondents own or use smart cards in non-construction applications.

2) Of the respondents, 71% see smart card is suitable for time keeping function and more than 1/2 of the respondents are in favor of using smart card in labor payment, schedule update, billing and material ordering.

3) More than 3/4 of the responses agreed that construction operations such as time keeping, cost tracking, material ordering and schedule updating need to be modified in order to migrate current construction practices to a paperless environment.

4) More than 70% of the respondents are in favor of assigning smart cards to the project manager, paymaster, cost controller, safety inspectors and site foremen.

5) The most approved hardware pieces in construction projects are double-slot card readers (71%) and smart card cell phones (62%). Meanwhile, smart card-PC interface has the highest acceptable rate (81%) followed by remote access, survey instrument and equipment on/off switch interfaces which obtained only 48%.

6) Respondents are concerned with the security of data on the card and the vulnerability of the computer chips to damage during the construction works.

7) All respondents agreed to have an audit trail for smart card construction applications, while 76% are in favor of owning the database stored on the smart cards.

The questionnaire reinforced the belief that using smart cards to replace paper timesheets and manual labor payment methods is a worthwhile endeavor. In addition, the questionnaire results indicate that there is tremendous potential to successfully penetrate the construction market by educating the construction managers about the financial benefits, ease of use and other advantages of using smart cards among construction labors.

Chapter 4 Proposed Labor Payment Application

This chapter presents the proposed Construction Labor Smart Card (CLSC) application for preparing worker's timesheet and processing labor payment. The proposed payment process is explained based on the assumptions that each worker is issued a smart card. The CLSC implementation, card issuer registration and labor payment application registration processes are discussed in light of the multi-application guidelines provided by MOASCO, the smart card worldwide industry groups consortium.

4.1 Current Practice

Tracking timesheets is critical to any construction project. Timesheets can be incomplete, based on estimates rather than actual hours or submitted late or even lost. In manual systems, each worker is issued a brass tag with a number on it. The brass tag is picked up from the timekeeper as the worker arrives on site each day and replaced as worker leaves. The timekeeper's tracking of the worker's brass tag is considered the basis for timesheet inputs and payroll administration. The manual labor payment model is illustrated in Figure 4-1 and summarized in Table 4-1.

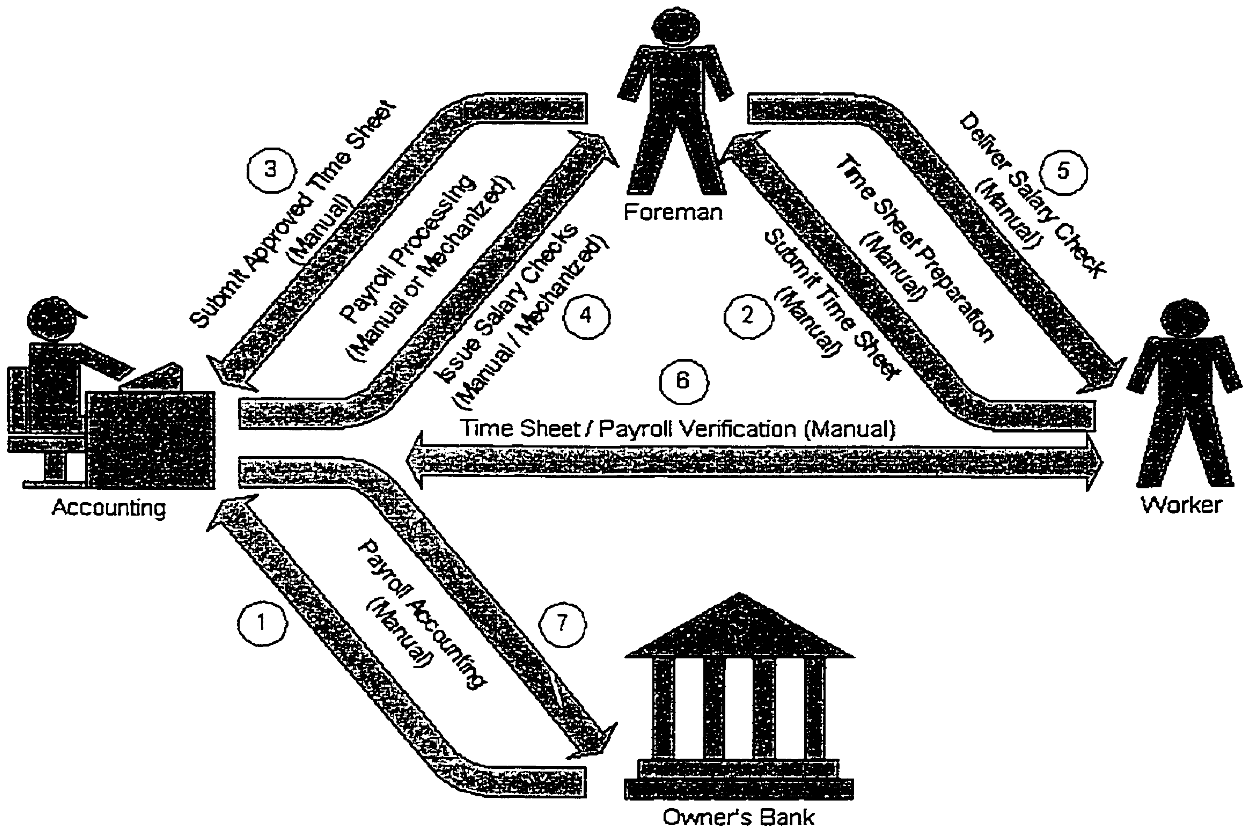


Figure 4-1: Labor Payment Model in Current Practice

Step (1) the payroll department establishes a payroll account with the bank and obtains the necessary payroll checkbook.

Step (2) workers complete their timesheet according to the timekeeper's records. Complete timesheet contains worker's name, worker's ID, worker's signature, date, number of straight hours spent, overtime hours, activity codes and cost account. Worker submits his or her timesheet to the foreman for approval.

Step (3) foreman collects timesheets and reviews them for missing information and validates hours according to the timekeeper's report. The foreman then authorizes work premium and other exceptions and delivers timesheets to the payroll department. Foreman and worker usually keep a hard copy for their records.

Step (4) payroll department inputs labor hours into a payroll application or processes the payroll manually according to method adopted for the project. In major construction projects, computerized payroll systems and pre-printed timesheet forms are used in order to reduce timesheet errors, omissions and creative writing. There are many time keeping and payroll applications available to make the time entry logical and easy by using entry screens designed to simulate a paper timesheet. Automated timesheet features such as single entry and automatic updating and electronic archiving reduce errors and increase security. Most of these computer applications have the capability to generate labor payment checks, which are manually delivered to the foreman for distribution.

Step (5) foreman distributes payment checks to his / her crew.

Step (6) workers reconcile their payment with the payroll department in case of timesheet or payroll errors.

Step (7) payroll department performs book-closing process and starts new payroll cycle.

Step	Function	Responsibility
1	Set up a payroll bank account and obtain a payroll checkbook	Payroll Department
2	Prepare and submit time sheet to the foreman	Worker
3	Review and submit time sheet to the payroll department	Foreman
4	Issue and deliver worker pay checks to foreman	Payroll Department
5	Deliver pay check to workers	Foreman
6	Verify payment against approved time sheet	Worker
7	Perform book closing and prepare for a new payroll cycle	Payroll Department

Table 4-1: Summary of Labor Payment Model in Current Practice

Timesheet validation in a paper-based system is the most time-consuming function of the entire process. Accurate time keeping allows construction companies to control payroll costs and provide accurate information to other functions such as project scheduling, cost control, invoicing, and human resources. Project departments create multiple versions of the same timesheet to extract information according to their needs. For example: the paymaster uses rates to determine overtime payments, the human resources department counts number of vacation sick days, the cost estimator uses labor hours with different rates in preparing a change order, the cost controller measures labor productivity and budget labor cost versus actual. Although project departments operate differently, they independently update their databases using copies of the daily timesheet.

According to studies conducted by the American Payroll Association, the benefits of using automated time keeping systems are:

1) Eliminating up to 80% of payroll preparation time
2) Improving payroll accuracy
3) Consistently applying payroll policies and work rules
4) Helping to control labor costs by providing powerful real-time management reports

It is believed that converting paper checks into electronic payment debits reduces the processing cost by 60% as shown in Figure 4-2.

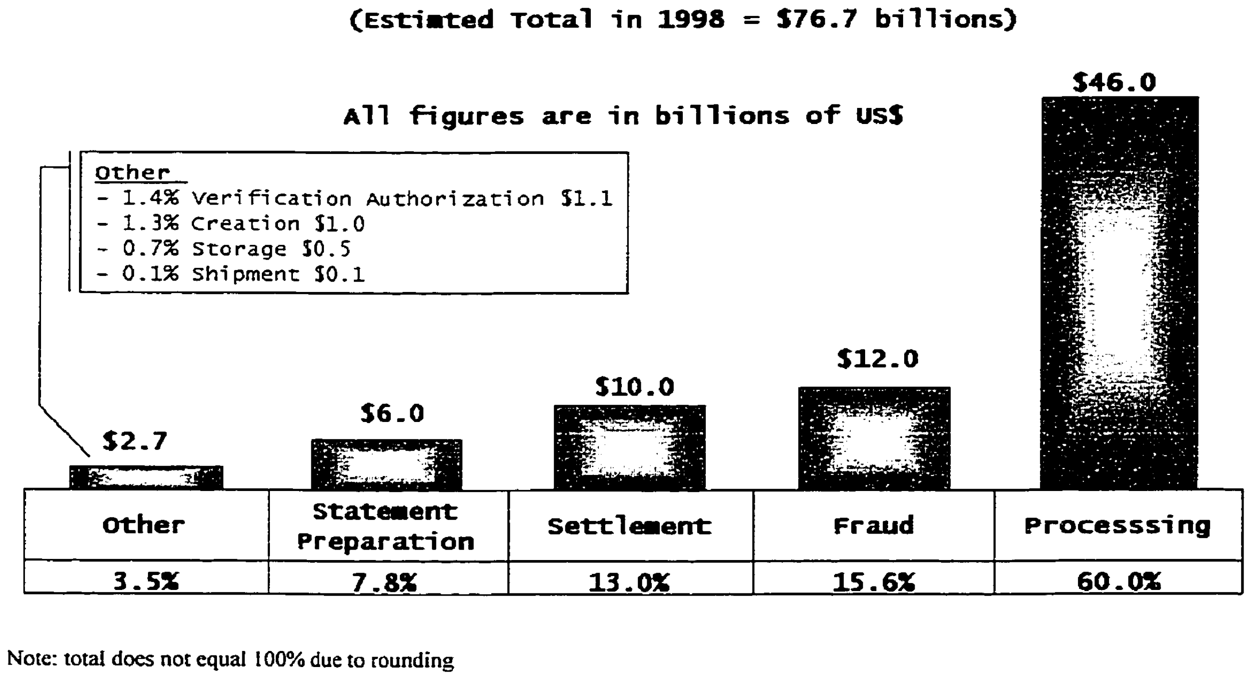


Figure 4-2: U.S. Cost Reduction of Converting Paper Checks into Electronic Debits

(Source: American Banker, July 1998)

4.2 Proposed Model

The proposed labor payment process is based on using the Construction Labor Smart Card (CLSC) to record time, measure hours per activity and cost code, administer the approval process for timesheet, and calculate wage payment. Figure 4-3 illustrates the proposed model, which is inline with the manual practice and consists of the following 7 consecutive steps:

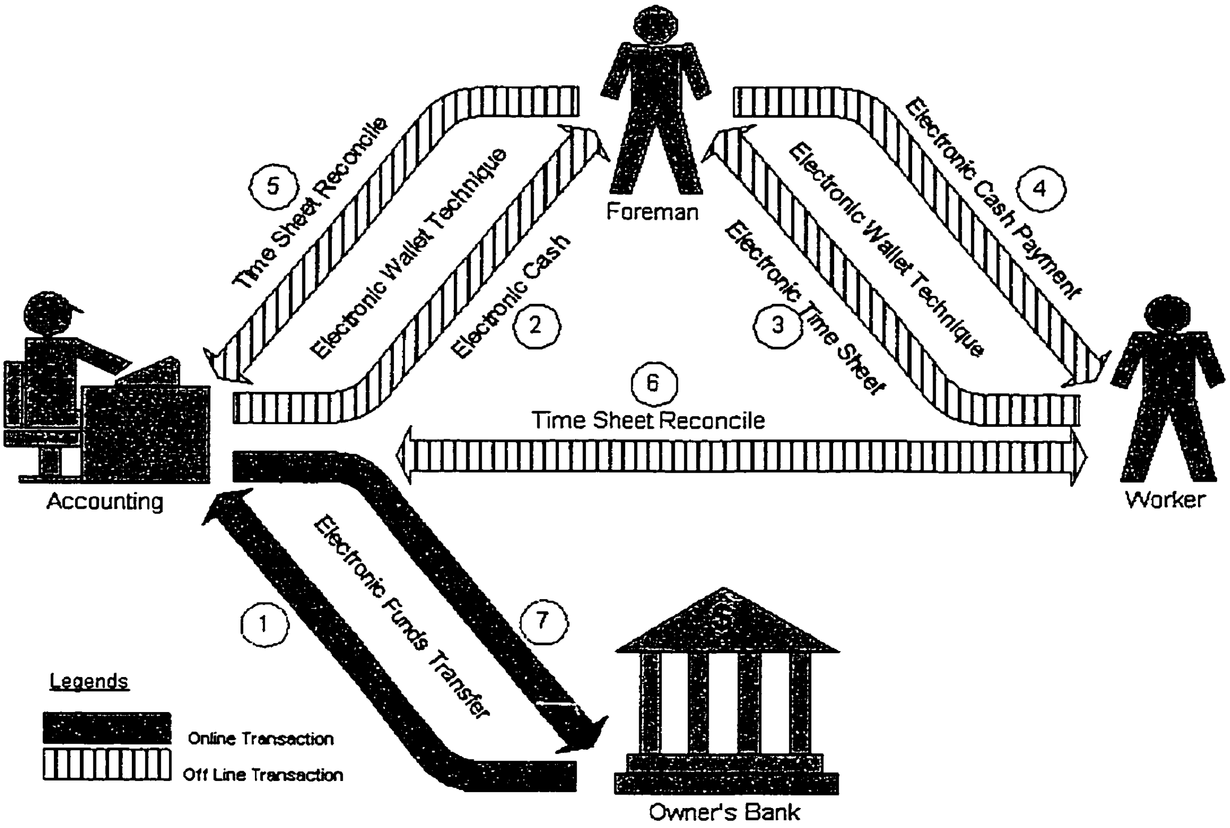


Figure 4-3: Proposed Labor Payment Model

Step (1) the payroll department establishes a payroll account with the bank using smart card and electronic purse scheme. Sufficient funds are downloaded into paymaster's smart card to cover the payroll budget, which is either weekly or biweekly.

Step (2) foreman downloads sufficient cash from the paymaster's card into foreman's card using double-slot card reader.

Step (3) each worker has a card with an electronic timesheet stored on it. Workers input hours earned into their cards, complete the electronic timesheet with number of straight hours spent, overtime hours, activity codes and cost account. Forman extracts electronic timesheets from his or her crew for approval.

Step (4) foreman reviews timesheets and authorizes work premium. Foreman converts the approved timesheet hours into cash according to an hourly rate schedule. Workers download the converted cash from their foreman's card into their card using double-slot card reader.

Step (5) a copy of all cash transactions on the foreman's card is sent to the payroll department for audit trails.

Step (6) a copy of all transactions are collected from workers cards when workers sign in or out using the time keeping terminals. The payroll department reconciles foreman and workers transactions before starting new payroll cycle.

Step (7) the payroll department sends a new request to the bank to recharge the paymaster's card with new cash and starts a new payroll cycle.

The proposed labor payment model steps are summarized in Table 4-2.

Step	Function	Responsibility	Status
1	Set up a payroll bank account and obtain electronic cash using Electronic Funds Transfer (EFT) and smart card Scheme	Payroll Department	Online
2	Download cash from the payroll department into Foreman's card using double-slot card reader	Foreman	Off-line
3	Prepare and submit to foreman an electronic time sheet using smart card and smart card reader / writer	Worker	Off-line
3	Review and convert electronic time sheet into electronic cash and transfer cash into worker's card	Foreman	Off-line
5	Send a copy of transferring transaction (in step 3) to the payroll department	Worker	Off-line
6	Verify received electronic cash against approved electronic time sheet and send a copy of receiving transaction to the payroll	Worker	Off-line
7	Provide bank with audit trail transaction before obtain new cash via EFT.	Payroll Department	Online

Table 4-2: Summary of Proposed Labor Payment Model

The detailed labor payment process consists of eight different entities exchanging 16 transactions. These entities are a) worker's electronic timesheet, b) benefits / premium schedule, c) cost / activity code table, d) hourly rate schedule, e) worker's card, f) foreman's card, g) labor cost database, h) paymaster's card, and i) bank. As shown in Figure 4-4, vertical sight lines present entities and horizontal sight lines present transaction the directions of which are indicated using arrows. Solid and hollow arrows mean online and off-line transactions respectively. Using one of the following card infrastructures performs a transaction: 1) personal card reader/writer, 2) double slot card reader / writer, 3) personal Automatic Teller Machine (ATM), 4) PC card reader/writer, 5) on-site card terminal.

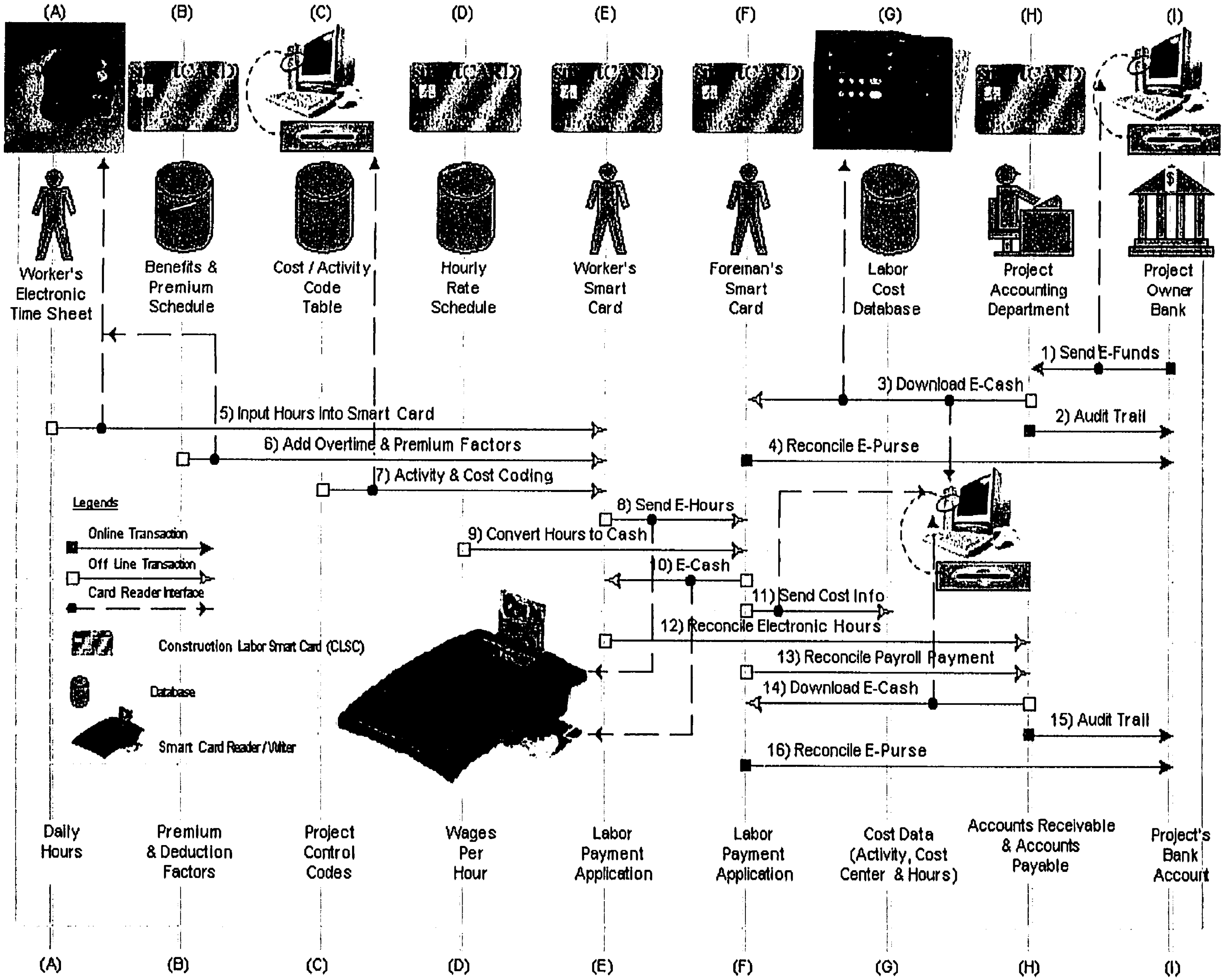


Figure 4-4: Detailed Labor Payment Process

(A) **Electronic Timesheet**: every worker carrying a Construction Labor Smart Card (CLSC) has an electronic timesheet integrated with the labor payment application stored on his or her card. Workers uses a pocket card reader / writer to electronically populate their timesheet with number of straight and overtime hours, activity and cost code and worker' signature. Workers use their CLSC to sign in and sign out at the beginning and end of every shift. CLSC records elapsed time and validates hours recorded against the ones populated in the timesheet. Worker is supposed to sign in and out before and after each new activity in order to allocate hours spent to the right activity and cost codes. Electronic signature technique is used if there is a need to use the timesheet as a legal document. A double-slot card reader is used to exchange timesheet information between worker and foreman's card.

(B) **Benefits and Premium Schedule:** every worker has personalized benefits and premiums, which depend on the level of training, skills, experience, type of work, union agreement and payment under adverse weather conditions. It is possible that worker's benefit schedule varies from one hiring contract to another depending on the negotiated terms between the worker and hiring company. Benefits and premium schedule are securely stored on a worker's card as a separate file or part of the customized portion of the labor payment application. Only the human resources department alters worker's benefits and premium schedule information stored on the card. Foreman's authorization to change timesheet information is limited to number of hours and its associated activity and cost codes.

(C) **Activity and Cost Code**: a table of all project activity and cost codes is stored on a site terminal or on a separate smart card. Worker browses through the table to choose the appropriate activity and cost codes according to the type of work performed. Codes are either manually entered using card reader keypad or retrieved from another card using double-slot card reader. Worker has an option to save a sub-table of activity and cost codes, which is frequently used.

(D) **Hourly Rate Schedule**: hourly rates are stored in a separate schedule, which is maintained by the payroll department. There is only one hourly rate schedule set up for all workers that is built based on project estimates and labor market rates. Any changes to the hourly rate schedule require a prior approval from the project manager in order to keep the project budget on target and avoid any cost over run.

(E) **Worker's Card**: workers carry CLSC loaded with a different set of smart card applications according to individual's role and functions. CLSC applications are expected to include, but are not limited to, personal identification, job site access control, time keeping and labor payment. Each CLSC application uses separate databases or an integrated database stored on the card. Cardholder's information and CLSC applications are securely protected any changes without special security keys. Workers use their card as a vehicle to prepare their daily timesheet and receive payment in the form of electronic cash. Once CLSC is charged with cash it behaves as an electronic wallet. Workers are given the option to keep the cash on their CLSC or transfer the cash to their bank account. Electronic cash are transferred from card to another using the double slot-card reader, site terminal or PC computer. However, all labor payment transactions are recorded, stored either on the card chip or the site terminal and subsequently consolidated into an audit trail database for the payroll department.

(F) **Foreman's Card:** all project personnel including project manager, site superintendents, foremen carry CLSCs similar to the workers cards. Forman's card has a higher security access to transfer electronic funds from payroll account to worker's card.

(G) **Labor Cost Database:** in the proposed labor payment process, labor cost data is collected from the foreman's card and sent to the project control department where tracking and status reports are generated. Labor cost database includes worker's productivity information such as labor hours by activity code and cost center, labor cost by activity code and cost center and quantity installed by individual. Details of sick leaves, vacation days, and personal time are not captured in the labor cost database but are found in the human resources database.

(H) **Payroll Department**: paymaster is the sole person responsible for the payroll accounting, which is a key entity in the proposed labor payment process. Paymaster's card has more functionality than any other CLSC with labor payment application because of the card's capability to interface with the bank, foreman and worker at any stage during the payroll cycle. Paymaster manages the payroll account using smart card to electronically transfer funds from the project bank account to his or her card, download cash into foreman's card, reconcile payment transactions with foreman and workers and update payroll database with the necessary information for accounts payable and receivable. Transactions between the bank and the paymaster are performed using online telecommunication services (via PC, telephone, or cellular phone). Transactions between foreman, worker and paymaster are completed either online via computer or off-line via site terminal or card reader.

(I) **Project's Bank**: in the proposed labor payment process, electronic cash stored on a smart card is the exclusive method of payment for worker's wages. The electronic cash is transferred from the bank to the paymaster's card. The bank's responsibility is to maintain the payroll account for the project and to provide a period statement to the payroll department with all processed transactions. Project accountants views status of the bank account via online services such as home banking or using a smart card to download a copy of the bank audit trail report. Project manager, human resources, project control and foremen have different access to the bank account that is established with the bank.

A summary of transaction flow between different entities of the labor payment process is shown in Table 4-3.

Performed Transaction			Process Entity		Type of Card Infrastructure Used
No.	Function	Status	From	To	
1	Download E-Cash into Paymaster's card using	Online	(I) Bank	(H) Paymaster	PC Card Reader / Writer
2	Send a Copy of Transaction Audit Trail	Online	(H) Paymaster	(I) Bank	PC Card Reader / Writer
3	Download E-Cash into Foreman's Card	Off Line	(H) Paymaster	(F) Foreman's Card	Personal ATM
4	Send a Copy of Transaction Audit Trail	Online	(F) Foreman's Card	(I) Bank	PC Card Reader / Writer
5	Input Daily Hours into E-Time Sheet stored on Worker's Card	Off Line	(A) E-Time Sheet	(E) Worker's Card	Personal Card Reader / Writer
6	Download Premium & Overtime Factors into Worker's Card	Off Line	(B) Premium Schedule	(E) Worker's Card	Double Slot Card Reader / Writer
7	Download Activity and Cost Codes into Worker's Card	Off Line	(C) Coding Table	(E) Worker's Card	Double Slot Card Reader / Writer
8	Transfer Worker's E-Time Sheet to Foreman's card	Off Line	(E) Worker's Card	(F) Foreman's Card	Double Slot Card Reader / Writer
9	Convert E-Time Sheet into E-Cash on Foreman's Card	Off Line	Hour Rate Schedule	(F) Foreman's Card	Personal Card Reader / Writer
10	Transfer E-Cash to Worker's Card	Off Line	(F) Foreman's Card	(E) Worker's Card	Double Slot Card Reader / Writer
11	Update Cost Database with Foreman's & Worker's Card	Off Line	(F) Foreman's Card	(G) Cost Database	PC Card Reader / Writer
12	Send a Copy Worker's Transaction Audit Trail	Off Line	(E) Worker's Card	(H) Paymaster	On-Site Card Terminal
13	Send a Copy of Foreman's Transaction Audit Trail	Off Line	(F) Foreman's Card	(H) Paymaster	On-Site Card Terminal
14	Download E-Cash using ATM into Foreman's Card	Off Line	(H) Paymaster	(F) Foreman's Card	Personal ATM
15	Send a Copy of Paymaster's Transaction Audit Trail	Online	(H) Paymaster	(I) Bank	PC Card Reader / Writer
16	Send a Copy of Foreman's Transaction Audit Trail	Online	(F) Foreman's Card	(I) Bank	PC Card Reader / Writer

E-Time sheet: Electronic Time Sheet, ATM: Automatic Teller Machine, EFT: Electronic Funds Transfer

Table 4-3: Summary of Detailed Labor Payment Process

4.3 Implementation

The implementation of Construction Labor Smart Card (CLSC) and its labor payment application is discussed in this section in the following order: 1) card implementation, 2) application development and 3) application implementation. CLSC implementation is based on the multi-operation system (Multos) which is selected as a platform for the proposed payment application.

4.3.1 Card Implementation

The CLSC implementation process is adopted from MAOSCO documentation. The proposed process consists of four consecutive paths representing the process flow and connecting nine different parties as shown in Figure 4-5. The process parties are 1) MAOSCO, 2) Multos Implementer, 3) Multos Certification Authority (MCA), 4) IC Manufacturer, 5) Card Manufacturer, 6) Card Issuer, 7) Application Provider, 8) Construction Company and 9) Workers.

Each path on the process flow consolidates the process steps to accomplish a certain function or unique process output. For example: the IC chip is the output of Path A, the plastic card is the output of Path B, the labor payment application development and implementation is the output of Path C, and CLSC as a smart card loaded with the labor payment application is output of path D.

The key process party, **MAOSCO,** was formed in May 1997 by eight companies including Dai Nippon Printing, Gemplus, Hitachi, Keycorp, MasterCard International, Mondex International, Motorola and Siemens (Web 22). MAOSCO develops / maintains

Multos specifications and licenses the platform specifications to Multos implementers and application developers (see steps A-1 and A-2).

Multos implementers write the code for the silicon device provided by the IC manufacturer (see step A-3). The responsibility of **Multos Certification Authority (MCA)** is to provide the security keys for the IC chip during the manufacturing, transporting and downloading application (see steps A-4, C-3 and C-6). Card issuer and application are registered by MCA. Registration process will be discussed in further detail later in this chapter.

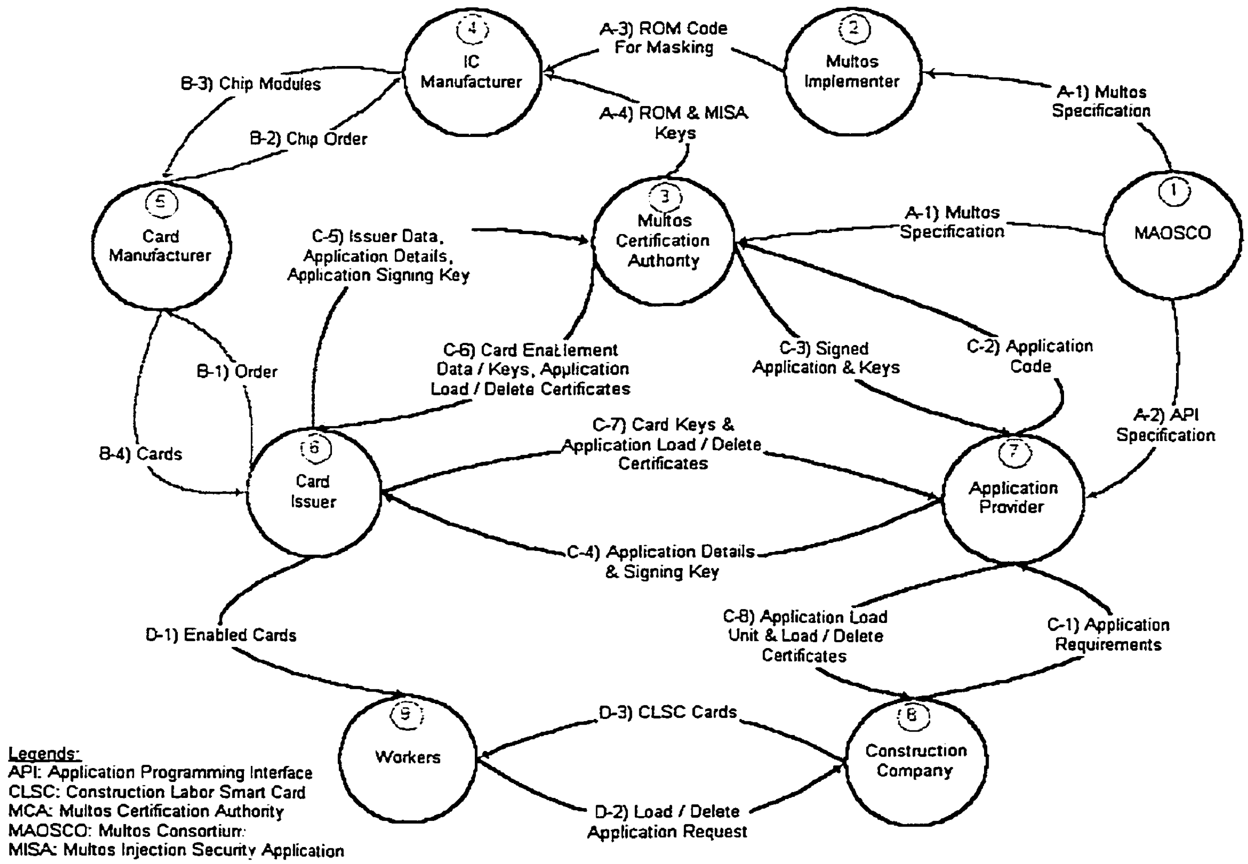


Figure 4-5: Construction Labor Smart Card Implementation

(Adopted from MAOSCO Documentation 2000)

The **IC manufacturer** obtains a card order from the card manufacturer to produce the silicon chips and securely delivered to the **Card Manufacturer** (see steps B-2 and B-3) which produces the plastic cards and embed the IC chip into the card. The card manufacturer deliver the finished product (card with IC chip) to the **Card Issuer** (see step B-4) who is responsible for 1) card registration with **Multos Certification Authority** (MCA, 2) card design, 3) card inventory, 4) card delivery to the worker, and 5) card validation.

The **Application Provider** obtains labor payment application requirements, designs the application, writes code, performs application tests, obtains application registration from MCA, obtains application load and delete certificates from the card issuer and delivers application and its certificates to the construction company (see steps C-1 through C-8 in Figure 4-4). Steps C-8 and D-1 are two independent steps, which take place simultaneously. In step C-8, the application provider delivers the labor payment application to the Construction Company in a Multos Executable Language (MEL) compiled code which is known as an Application Load Unit (ALU). In step D-1, the card issuer delivers enabled personalized cards (with no application loaded) to the newly hired workers. The Construction Company loads the ALU into worker's card using application load certificates, which are issued by MCA.

Summary of the CLSC implementation process is shown in Table 4-4.

Step	From	To	Function	
A-1	MAOSCO Consortium	Multos Implementer/Certification	Issue Multos Specification	Path (A)
A-2	MAOSCO Consortium	Application Provider	Send Application Programming Interface API specification	
A-3	Multos Implementer	Chip Manufacturer	Send ROM code for masking	
A-4	Multos Certification	Chip Manufacturer	Send ROM keys and Multos Injection Security Application	
B-1	Card Issuer	Card Manufacturer	Place Smart Card Order	Path (B)
B-2	Card Manufacturer	Chip Manufacturer	Place Chip Order	
B-3	Chip Manufacturer	Card Manufacturer	Deliver Chip Module	
B-4	Card Manufacturer	Card Issuer	Deliver Plastic Card with Embedded Chip	
C-1	Construction Company	Application Provider	Provide Application Requirements and Business Rules	Path (C)
C-2	Application Provider	Multos Certification	Apply for Application Signature and Encryption Keys	
C-3	Multos Certification	Application Provider	Provide Application Signature and Encryption Keys	
C-4	Application Provider	Card Issuer	Apply for Application Load / Delete Certificates	
C-5	Card Issuer	Multos Certification	Apply for Application Certificates & Card Enabling	
C-6	Multos Certification	Card Issuer	Provide Application Certificates and Card Enabling Data	
C-7	Card Issuer	Application Provider	Provide Application Load / Delete Certificates	
C-8	Application Provider	Construction Company	Provide Application Load Unit & Load / Delete Certificates	
D-1	Card Issuer	Worker	Send Enabled Card with no Application Loaded	Path (D)
D-2	Worker	Construction Company	Apply for Load / Delete Application	
D-3	Construction Company	Worker	Return Card with Loaded / Deleted Application	

Table 4-4: Summary of Construction Labor Smart Card Implementation

Application Load Unit (ALU) consists of issuer / application registration IDs, worker's name / ID, labor payment source code / databases, application directory structure / file control information, and application integrity / secrecy protection. CLSC is customized with worker's information, or protected with application signature and encryption before or after loading ALU. Therefore, the Construction Company as an application loader has the option to compile the card customization, protection and encryption with ALU. Figure 4-6 illustrates the data structure loaded on the CLSC chip (adopted from Web 22). Data structure is broken down into 13 data sections. Table 4-5 summarizes the content of each data section.

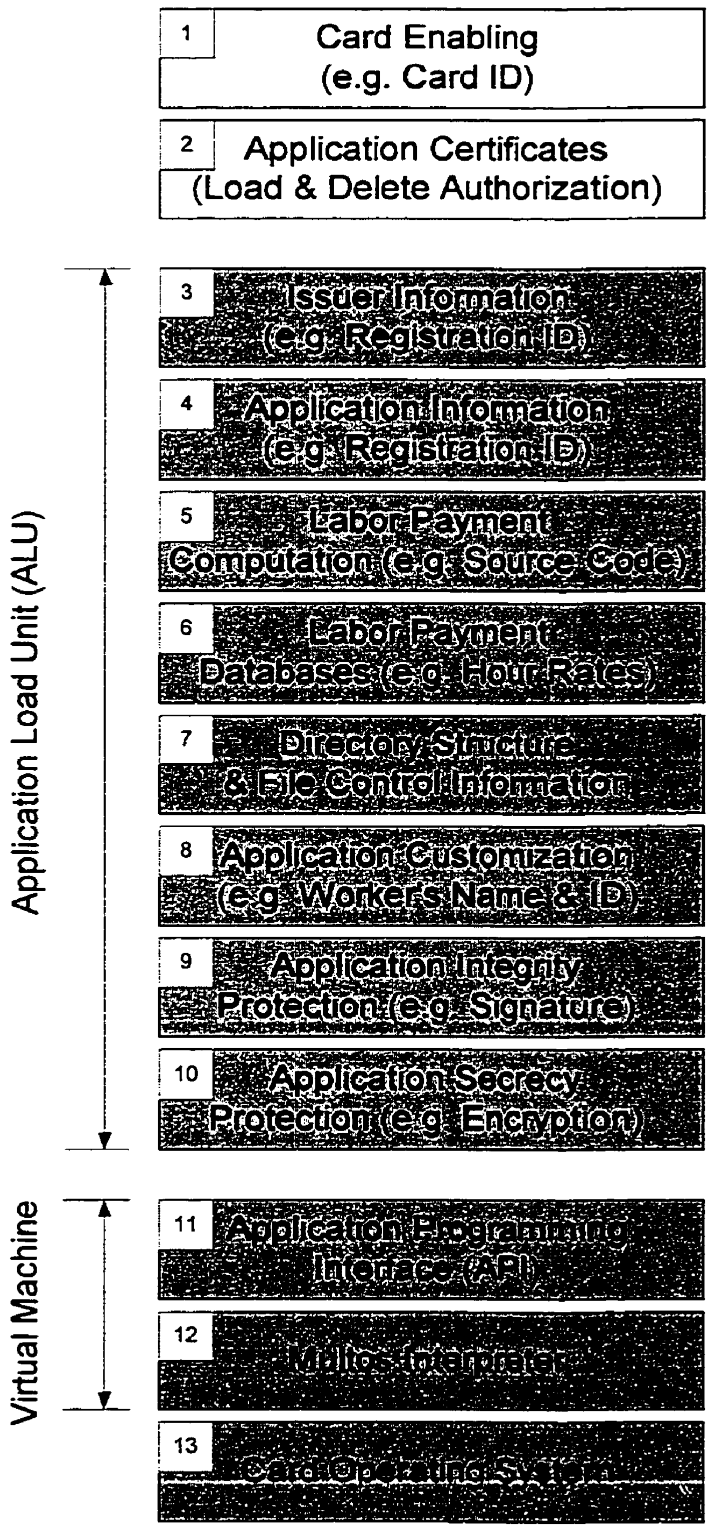


Figure 4-6: Construction Labor Smart Card Data Structure

(Adopted from MAOSCO Documentation 2000)

Unit	Title	Type of Data	
1	Card Enabling	Multos Carrier Device (MCD) Number, Product ID, Multos Security Manager (MSM) Information	
2	Application Certification	Application ID, MCD Number, Issuer ID, Product IDs, MSM Information	
3	Issuer Information	Issuer ID.	Labor Payment Application Load Unit (ALU)
4	Application Information	Application ID.	
5	Labor Payment Computation	Application Code compiled into Multos Executable Language (MEL).	
6	Labor Payment Databases	Hourly Rate Schedule and Activity / Cost Codes Databases.	
7	Directory Structure & File Control Information	Data Structure such as Master (Root Directory), Dedicated (Sub-Directories) and Elementary (Data) Files. File Control Information such as File Identifier, File Name, Specifications of Record or Data Lengths in the file.	
8	Application Customization	Worker's Account Name and Number.	
9	Application Integrity Protection	Key Transformation Unit (Signature Keys) to prevent making any changes to Application Source Codes	
10	Application Secrecy Protection	Encryption Keys to prevent viewing the Application Source Code	
11	Application Programming Interface	Messages Exchanged between Card Reader, Application and IC Chip	Virtual Machine
12	MEL Interpreter	Multos Executable Language(MEL) Commands	
13	Card Operating System	Input /Output Manager, File Manager, Security Manager	

Table 4-5: Summary of Construction Labor Smart Card Data Structure

4.3.2 Application Development

The process to develop a labor payment application includes systems requirements collection, system design, system coding and testing. A proposed labor payment computation flowchart is shown in Figure 4-7. The flowchart indicates the basic subroutine functions such as read timesheet and compute gross salary, overtime, allowance, and tax. For simplicity, overtime is calculated on the total number of hours per week exceeding 40 hours. The daily electronic timesheet stored on the card is designed to accommodate 24 different overtime hour rates, 10 different work premium / allowance conditions and three alphanumeric four-character codes for worker, activity and cost codes respectively (see Table 4-6: Timesheet Codification). Alternatively, a backup paper timesheet is used should the worker fails to input his or her timesheet. Worker's name, ID and signature with date are automatically populated in the electronic timesheet. Repetitive activity and cost codes are automatically input using short keys or macros. The payment calculation subroutine is performed on the foreman's card using the timesheet information stored on the worker's card. Worker has the option to view an estimated payment value prior to submitting his or her timesheet to the foreman. The actual payment is deducted from the stored electronic funds on the foreman's card and transferred to the worker's card. Although all CLSC are loaded with one labor payment application, CLSC behaves differently according to both the customized cardholder's information stored on the chip and the customized application according to the project need.

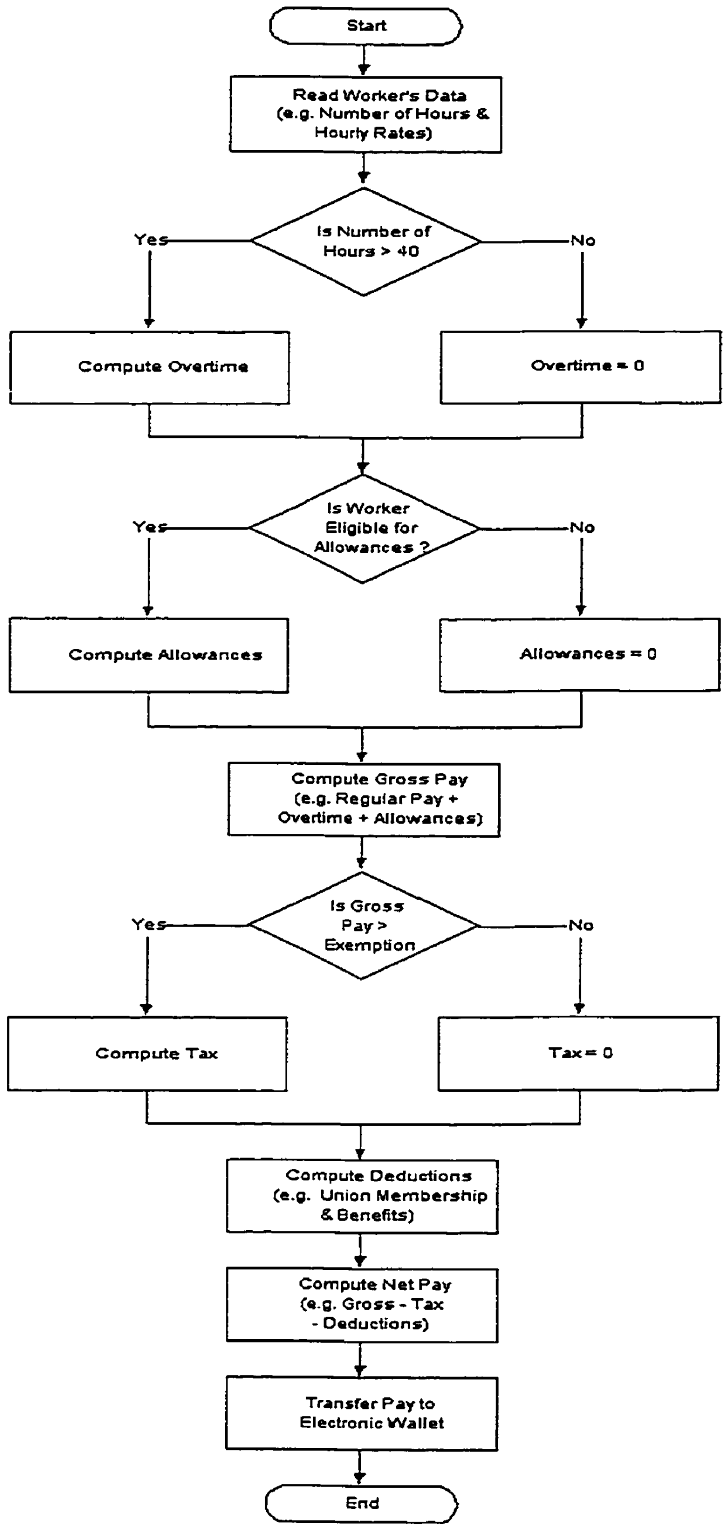


Figure 4-7: Labor Payment Computation

Worker's ID	Cell (1)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (2)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (3)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (4)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
Activity Code	Cell (1)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (2)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (3)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (4)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
Cost Code	Cell (1)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (2)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (3)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
	Cell (4)	0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	J
		K	L	M	N	O	P	Q	R	S	T
		U	V	W	X	Y	Z				
Date Code	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
		Nov	Dec								
	Day	01st	02nd	03rd	04th	05th	06th	07th	08th	09th	10th
		11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
		21st	22nd	23rd	24th	25th	26th	27th	28th	29th	30th
		31st									
		Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.			
Hour Code	Straight	08AM	09AM	10AM	11AM	12PM	01PM	02PM	03PM	04PM	05PM
	Overtime	01AM	02AM	03AM	04AM	05AM	06AM	07AM	08AM	09AM	10AM
		11AM	Noon	01PM	02PM	03PM	04PM	05PM	06PM	07PM	08PM
		11AM	Midnight								
	Premium	1	2	3	4	5	6	7	8	9	10

Table 4-6: Timesheet Codification

4.3.3 Application Implementation

The labor payment application implementation is a subset of CLSC implementation that encompasses the card issuer registration process, application development, application registration process, application customization and application loading. Figure 4-8 shows the execution order of the application implementation steps. Some of these steps like application development, card manufacturing and enabling were already covered earlier in this chapter.

After the application is developed, it is compiled into a Multos Executable Language (MEL). MEL is segmented into Application Load Units (ALU) using special programming tools provided by Multos. ALU is loaded into enabled cards using the Multos application load certificate obtained from Multos Certification Authority (MCA) during the registration process. Loading an application on the card is not permitted unless the security code loaded on the enabled card matches the same code embedded in the registered application and the load certificate.

Adding a worker's name and ID to the application is called application customization, which occurs either during the ALU (pre-customization) or after the ALU (post-customization). Only an Application Delete Certificate (ADC) with matching security code provides user with a key to delete a loaded application. The payment application registration process is implemented after the card issuer registration is complete. The Multos-registered application are loaded into the smart card with the Application Load Certificates (ALC).

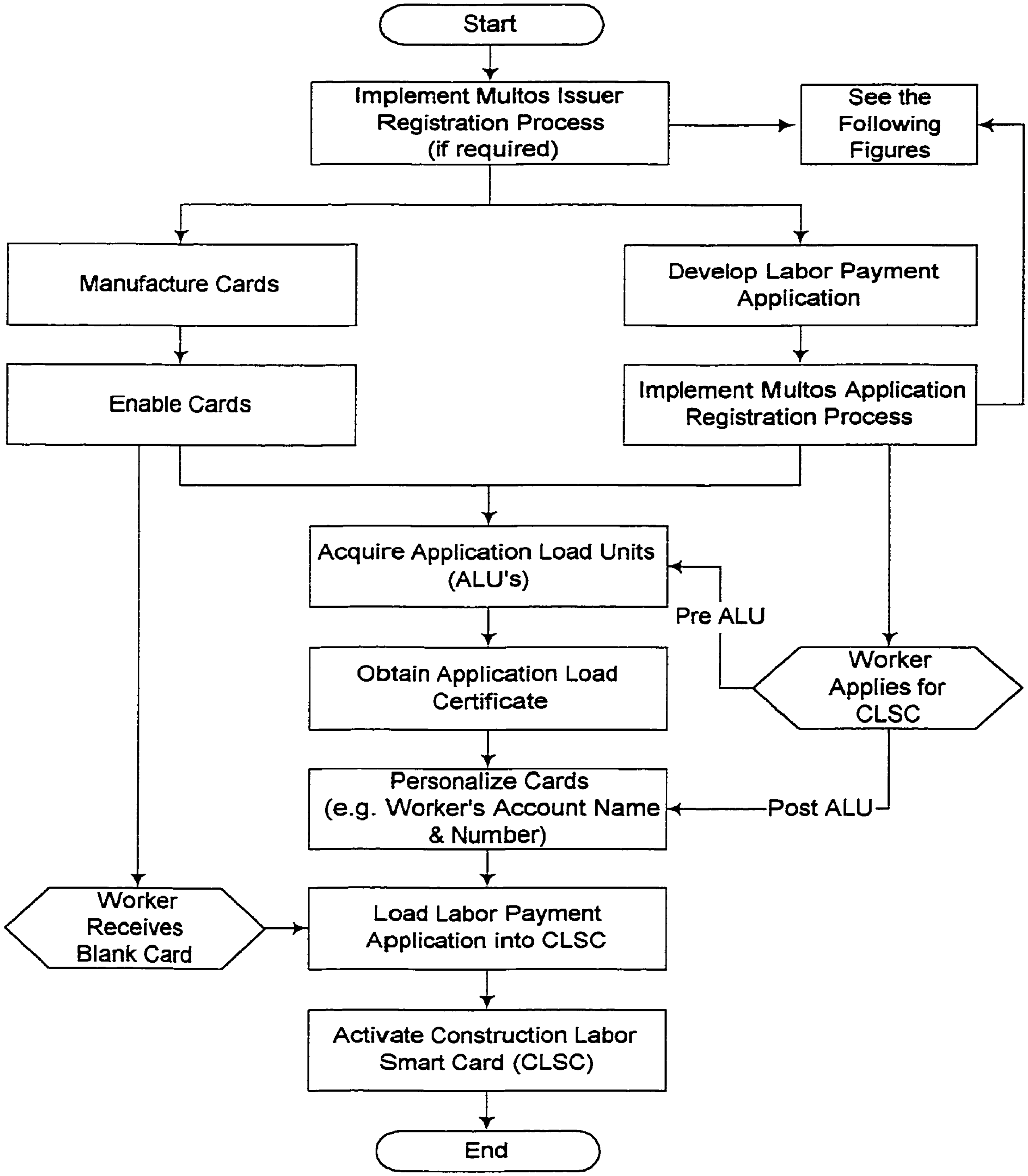


Figure 4-8: Labor Payment Application Implementation

(Adopted from MAOSCO Documentation 2000)

4.4 Timesheet Cost Comparison

This timesheet cost analysis is intended to compare the cost between paper-based (manual method) and smart card-based (electronic method) timesheets. The cost estimates of both manual and electronic methods are explained in Appendices A and B respectively. The calculations of both estimates are based on a set of assumptions and variables discussed in Appendix C. In both cost estimate, there are six key variables: Hourly Labor Rate, Number of Crews, Crew Size, Interest Rate and Inflation Rate. Each variable has an initial value (baseline) and a testing domain. The timesheet cost estimates and cash flows for both the manual and electronic methods are based on the baseline values. The testing domain is described as a range with minimum and maximum limits within which the baseline varies. The testing domains are intended to study the impact on the estimated cost as a result of incremental changes to the baseline values. The six key variables with their baseline values and the testing domain limits and incremental values are listed in Table 4-7.

Key Variable	Baseline	Testing Domain		
		Minimum	Maximum	Increment
Hourly Labor Rate	$16.56	$8.00	$48.00	$8.00
Number of Crews	10 Crew	1 Crew	10 Crews	1 Crew
Crew Size	10 Workers	10 Workers	100 Workers	10 & 50 Workers
Interest Rate	5%	2%	16%	2%
Inflation Rate	5%	1%	12%	1%
Project Duration	5 Years	1 Year	5 Years	1 Year

Table 4-7: The Timesheet Cost Estimate Key Variables

The manual method cost estimate is based on three cost categories:

1) **Labor Cost**, which includes five cost elements (C_{11}, C_{21}, C_{31}, C_{41} and C_{51}) and are incurred at the beginning of the first, second, third, fourth and fifth years respectively.
2) **Material Cost**, which includes five cost elements (C_{12}, C_{22}, C_{32}, C_{42} and C_{52}) and are incurred at the beginning of the first, second, third, fourth and fifth years respectively.
3) **Paycheck Issuance Fee**, which includes five cost elements (C_{13}, C_{23}, C_{33}, C_{43} and C_{53}) and are incurred at the beginning of the first, second, third, fourth and fifth years respectively.

The manual method cost elements ($C_{ij\ Manual}$) are calculated in Appendix A. The values of $C_{ij\ Manual}$ are listed in Equation 1.

$$\underset{Manual}{C_{ij}} = \left\{ \begin{array}{c|c|c} \underline{\underline{Labor\_\$}} & \underline{\underline{Material\_\$}} & \underline{\underline{Fees\_\$}} \\ C_{11} = \$121.7 & C_{12} = \$19.5 & C_{13} = \$10.4 \\ \hline C_{21} = \$127.8 & C_{22} = \$20.5 & C_{23} = \$10.9 \\ \hline C_{31} = \$134.2 & C_{32} = \$21.5 & C_{33} = \$11.5 \\ \hline C_{41} = \$140.8 & C_{42} = \$22.6 & C_{43} = \$12.0 \\ \hline C_{51} = \$147.9 & C_{52} = \$23.7 & C_{53} = \$12.6 \end{array} \right\}$$

(Figures are in thousands of $)

Equation 1

Where:

i is the matrix row number which refers to the year i.

j is the matrix column number which refers to the cost category number j.

The present values ($PV_{ij\ Manual}$) of the cost elements ($C_{ij\ Manual}$) and the total present value ($PV_{t\ Manual}$) are calculated in Equations 2 and 3 respectively.

$$PV_{ij\,Manual} = \sum_{\substack{j=1 \xrightarrow{m} 3 \\ i=1 \xrightarrow{n} 5}} \left(C_{ij\,Manual} \times \frac{(1+B)^{i-1}}{(1+A)^{i-1}} \right)$$

Equation 2

$$PV_{t\,Manual} = \sum_{\substack{j=1 \xrightarrow{m} 3 \\ i=1 \xrightarrow{n} 5}} PV_{ij\,Manual}$$

Equation 3

Where:

$PV_{t\,Manual}$ is the present value of the total timesheet cost using the manual method.

$PV_{ij\,Manual}$ is the present value of cost category $C_{ij\,Manual}$.

B is the inflation rate (5%).

A is the combined interest rate (10.25%) according to the Then-Current Cash Flow Analysis formula ($A = B + C + B * C$) where C is the interest rate (5%). For simplicity, the factor A used in Equation 2 is rounded to be 10%.

n and m are the numbers of cost elements and cost categories respectively.

The present values ($PV_{ij\,Manual}$) of the 15 cost elements ($C_{ij\,Manual}$) are listed in Equation 4.

$$\underset{Manual}{PV_{ij}} = \left\{ \begin{array}{c|c|c} \underline{Labor\_\$} & \underline{Material\_\$} & \underline{Fees\_\$} \\ PV_{11} = \$121.7 & PV_{12} = \$19.5 & PV_{13} = \$10.4 \\ \hline PV_{21} = \$116.2 & PV_{22} = \$18.6 & PV_{23} = \$9.9 \\ \hline PV_{31} = \$110.9 & PV_{32} = \$17.7 & PV_{33} = \$9.5 \\ \hline PV_{41} = \$105.9 & PV_{42} = \$17.0 & PV_{43} = \$9.1 \\ \hline PV_{51} = \$101.0 & PV_{52} = \$16.2 & PV_{53} = \$8.6 \end{array} \right\}$$

(Figures are in thousands of $)

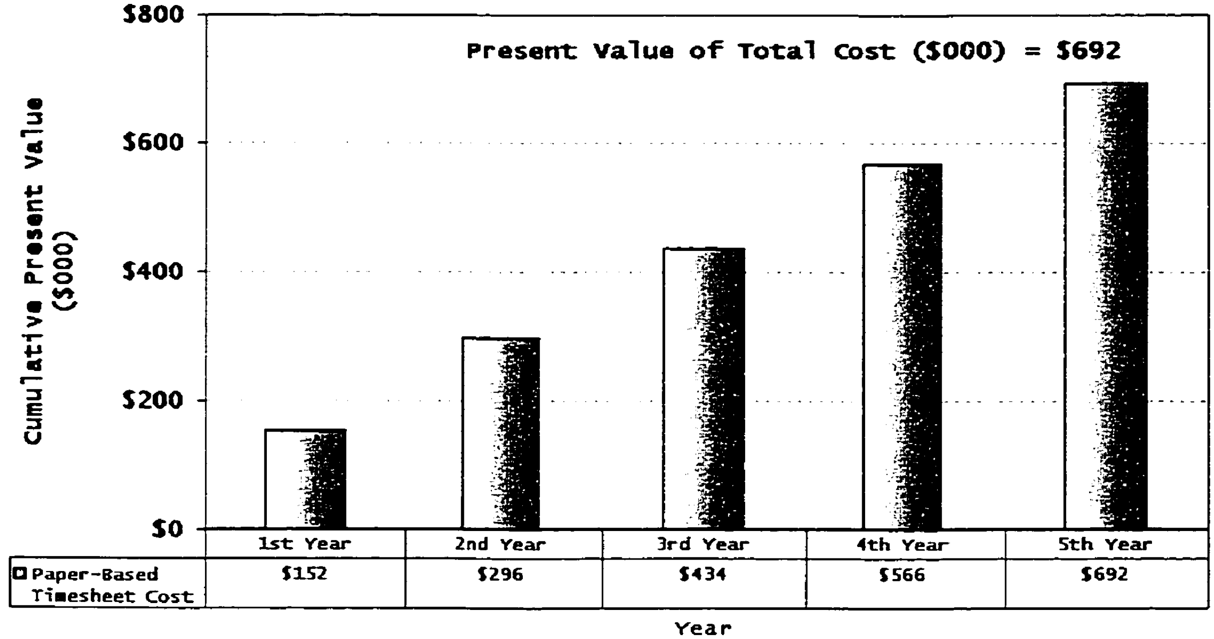
Equation 4

The paper-based timesheet (manual method) cost cash flow analysis is summarized in Table 4-8.

Cost Estimate [*]		1st Year	2nd Year	3rd Year	4^{th} Year	5th Year	Total
1	Labor Cost	$121,704.96	$127,790.21	$134,179.72	$140,888.70	$147,933.14	
2	Material Cost	$19,500.00	$20,475.00	$21,498.75	$22,573.69	$23,702.37	
3	Paycheck Issuance Fee	$10,400.00	$10,920.00	$11,466.00	$12,039.30	$12,641.27	
Total Cost (Items 1, 2 & 3)		$151,604.96	$159,185.21	$167,144.47	$175,501.69	$184,276.78	
PV of Total Annual Cost		$151,604.96	$144,713.83	$138,135.92	$131,857.02	$125,863.52	$692,175.25
[*] The cost estimate of the paper-based timesheet (manual method) is explained in Appendix A							

Table 4-8: Paper-Based Timesheet Cost Cash Flow

The manual method cost cash flow diagram is illustrated in Figure 4-9.



(Figures are in thousands of $)

Figure 4-9: Paper-Based Timesheet Cost Cash Flow Analysis

The cost of using the manual method to track timesheets and process payroll for 100 workers during a 5-year project is estimated to be $692,175.25.

The electronic method cost estimate is based on five cost categories:

1) **Labor Cost**, which includes five cost elements (C_{11}, C_{21}, C_{31}, C_{41} and C_{51}) and are incurred at the beginning of the first, second, third, fourth and fifth years respectively.
2) **Hardware Cost**, which includes four cost elements (C_{12}, C_{32}, C_{42} and C_{52}) and are incurred at the beginning of the first, third, fourth and fifth years respectively.
3) **Software Cost**, which includes one cost element (C_{13}) and is incurred at the beginning of the first year.
4) **Membership Fee**, which includes five cost elements (C_{14}, C_{24}, C_{34}, C_{44} and C_{54}) and are incurred at the beginning of the first, second, third, fourth and fifth years respectively.
5) **Data Archiving Cost**, which includes five cost elements (C_{15}, C_{25}, C_{35}, C_{45} and C_{55}) and are incurred at the beginning of the first, second, third, fourth and fifth years respectively.

The electronic method cost elements ($C_{ij\ Electronic}$) are calculated in Appendix B. The values of $C_{ij\ Electronic}$ are listed in Equation 5.

$$
\underset{Electronic}{C_{ij}} = \left\{
\begin{array}{c|c|c|c|c}
\underline{\underline{Labor\_\$}} & \underline{\underline{Hardware\_\$}} & \underline{\underline{Software\_\$}} & \underline{\underline{Fees\_\$}} & \underline{\underline{Archiving\_\$}} \\
C_{11} = \$46.3 & C_{12} = \$33.4 & C_{13} = \$45.3 & C_{14} = \$36.0 & C_{15} = \$5.2 \\
\hline
C_{21} = \$48.6 & C_{22} = \$0.0 & C_{23} = \$0.0 & C_{24} = \$37.8 & C_{25} = \$5.5 \\
\hline
C_{31} = \$51.0 & C_{32} = \$5.1 & C_{33} = \$0.0 & C_{34} = \$39.7 & C_{35} = \$5.7 \\
\hline
C_{41} = \$53.6 & C_{42} = \$8.0 & C_{43} = \$0.0 & C_{44} = \$41.7 & C_{45} = \$6.0 \\
\hline
C_{51} = \$56.3 & C_{52} = \$6.0 & C_{53} = \$0.0 & C_{54} = \$43.8 & C_{55} = \$6.3
\end{array}
\right\}
$$

(Figures are in thousands of \$)

Equation 5

Where:

i is the matrix row number which refers to the year i.

j is the matrix column number which refers to the cost category number j.

The present values ($PV_{ij\ Electronic}$) of the cost elements ($C_{ij\ Electronic}$) and the total present value ($PV_{t\ Electronic}$) are calculated in Equations 6 and 7 respectively.

$$
PV_{ij\ Electronic} = \sum_{i=1 \xrightarrow{n} 5}^{j=1 \xrightarrow{m} 5} \left(C_{ij\ Electronic} \times \frac{(1+B)^{i-1}}{(1+A)^{i-1}} \right)
$$

Equation 6

$$
PV_{t\ Electronic} = \sum_{i=1 \xrightarrow{n} 5}^{j=1 \xrightarrow{m} 5} PV_{ij\ Electronic}
$$

Equation 7

Where:

$PV_{t\ Electronic}$ is the present value of the total timesheet cost using the electronic method.

$PV_{ij\ Electronic}$ is the present value of cost category $C_{ij\ Electronic}$.

B is the inflation rate (5%).

A is the combined interest rate (10.25%) according to the Then-Current Cash Flow Analysis formula ($A = B + C + B * C$) where C is the interest rate (5%). For simplicity, the factor A used in Equation 2 is rounded to be 10%.

n and m are the numbers of cost elements and cost categories respectively.

The values of $PV_{ij\ Electronic}$ are listed in Equation 8.

$$\underset{Electronic}{PV_{ij}} = \left\{ \begin{array}{c|c|c|c|c} \underline{\underline{Labor\_\$}} & \underline{\underline{Hardware\_\$}} & \underline{\underline{Software\_\$}} & \underline{\underline{Fees\_\$}} & \underline{\underline{Archiving\_\$}} \\ PV_{11} = \$46.3 & PV_{12} = \$33.4 & PV_{13} = \$45.3 & PV_{14} = \$36.0 & PV_{15} = \$5.2 \\ \hline PV_{21} = \$44.2 & PV_{22} = \$0.0 & PV_{23} = \$0.0 & PV_{24} = \$34.4 & PV_{25} = \$5.0 \\ \hline PV_{31} = \$42.2 & PV_{32} = \$4.2 & PV_{33} = \$0.0 & PV_{34} = \$32.8 & PV_{35} = \$4.7 \\ \hline PV_{41} = \$40.3 & PV_{42} = \$6.0 & PV_{43} = \$0.0 & PV_{44} = \$31.3 & PV_{45} = \$4.5 \\ \hline PV_{51} = \$38.4 & PV_{52} = \$3.9 & PV_{53} = \$0.0 & PV_{54} = \$29.9 & PV_{55} = \$4.3 \end{array} \right\}$$

(Figures are in thousands of $)

Equation 8

The smart card-based timesheet (electronic method) cost cash flow analysis is summarized in Table 4-9.

	Cost Estimate [*]	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
1	Labor Cost	$46,285.20	$48,599.46	$51,029.43	$53,580.90	$56,259.95	
2	Hardware Cost						
	Smart Cards with IC Chip	$2,000.00	$0.00	$0.00	$0.00	$0.00	
	Card Readers	$6,000.00	$0.00	$0.00	$6,945.75	$0.00	
	Double-Slot Card Readers	$1,000.00	$0.00	$1,102.50	$0.00	$1,215.51	
	Site Terminals	$3,000.00	$0.00	$3,307.50	$0.00	$3,646.52	
	Smart Phones	$2,000.00	$0.00	$0.00	$0.00	$0.00	
	Smart PCs	$15,000.00	$0.00	$0.00	$0.00	$0.00	
	Testing and Installation	$2,900.00	$0.00	$441.00	$694.58	$486.20	
	Damage	$1,450.00	$0.00	$220.50	$347.29	$243.10	
	Total Hardware Cost	$33,350.00	$0.00	$5,071.50	$7,987.61	$5,591.33	
	[*] The cost estimate of the smart card-based timesheet (electronic method) is explained in Appendix B						

Table 4-9: Smart Card-Based Timesheet Cost Cash Flow

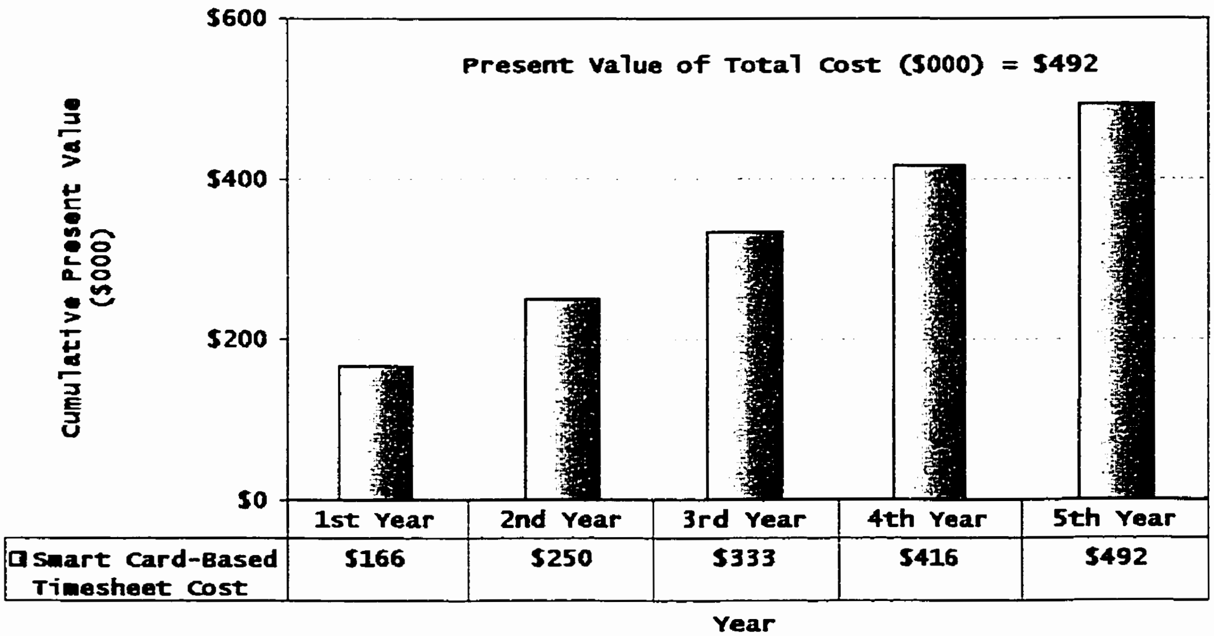
Cost Estimate [*]		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
3	Software Cost						
	System Integration	$20,000.00	$0.00	$0.00	$0.00	$0.00	
	Application Development	$2,000.00	$0.00	$0.00	$0.00	$0.00	
	Registration	$5,000.00	$0.00	$0.00	$0.00	$0.00	
	Training	$13,248.00	$0.00	$0.00	$0.00	$0.00	
	Implementation	$5,000.00	$0.00	$0.00	$0.00	$0.00	
	Total Software Cost	$45,248.00	$0.00	$0.00	$0.00	$0.00	
[*] The cost estimate of the smart card-based timesheet (electronic method) is explained in Appendix B							

Table 4-9: Smart Card-Based Timesheet Cost Cash Flow (Continued)

Cost Estimate [*]		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
4	Membership	$36,000.00	$37,800.00	$39,690.00	$41,674.50	$43,758.23	
5	Data Archiving Cost	$5,200.00	$5,460.00	$5,733.00	$6,019.65	$6,320.63	
Subtotal Cost (Items 4 & 5)		$41,200.00	$43,260.00	$45,423.00	$47,694.15	$50,078.86	
Total Cost (Items 1, 2, 3, 4 & 5)		$166,083.20	$91,859.46	$101,523.93	$109,262.67	$111,930.14	
PV of Total Cost		$166,083.20	$83,508.60	$83,904.08	$82,090.66	$76,449.79	$492,036.32
[*] The cost estimate of the smart card-based timesheet (electronic method) is explained in Appendix B							

Table 4-9: Smart Card-Based Timesheet Cost Cash Flow (Continued)

The electronic method cost cash flow diagram is illustrated in Figure 4-10.



(Figures in are in thousands of $)

Figure 4-10: Smart Card-Based Timesheet Cost Cash Flow Analysis

The cost of using the electronic method to track timesheets and process payroll for 100 workers during a 5-year project is estimated to be $492,036.32.

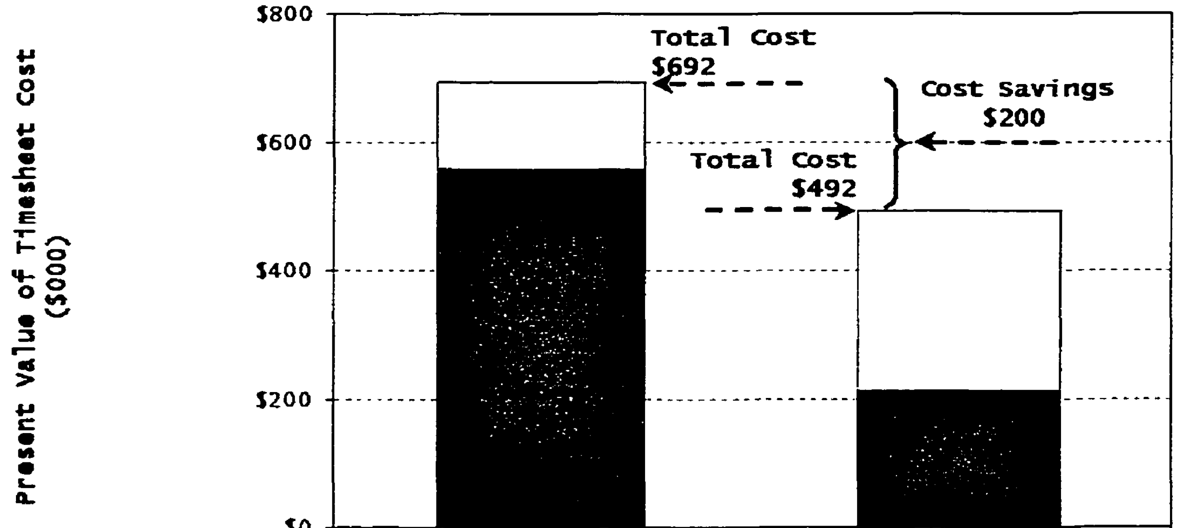
The cost variance (*$PV_{t\ var}$*) between the electronic method (*$PV_{t\ Electronic}$*) and manual method (*$PV_{t\ Manual}$*) is estimated to be $200,138.92 according to Equation 9.

$$\left\{\begin{matrix}\textit{Cost}\\ \textit{Savings}\\ PVt_{\mathrm{var}}\\ \$200.1\end{matrix}\right\} = \left\{\begin{matrix}\textit{Manual}\\ \textit{Method}\\ PVt_{Manual}\\ \$692.2\end{matrix}\right\} - \left\{\begin{matrix}\textit{Electronic}\\ \textit{Method}\\ PVt_{Electronic}\\ \$492.0\end{matrix}\right\}$$

(Figures are in thousands of $)

Equation 9

The $PV_{t\,var}$ represents a 29% savings of the electronic method over the manual method as shown in Figure 4-11.



	Paper-Based Timesheet Cost	Smart Card-Based Timesheet Cost
□ Miscellaneous ($000)	$137	$281
■ Labor ($000)	$556	$211

Cost Category

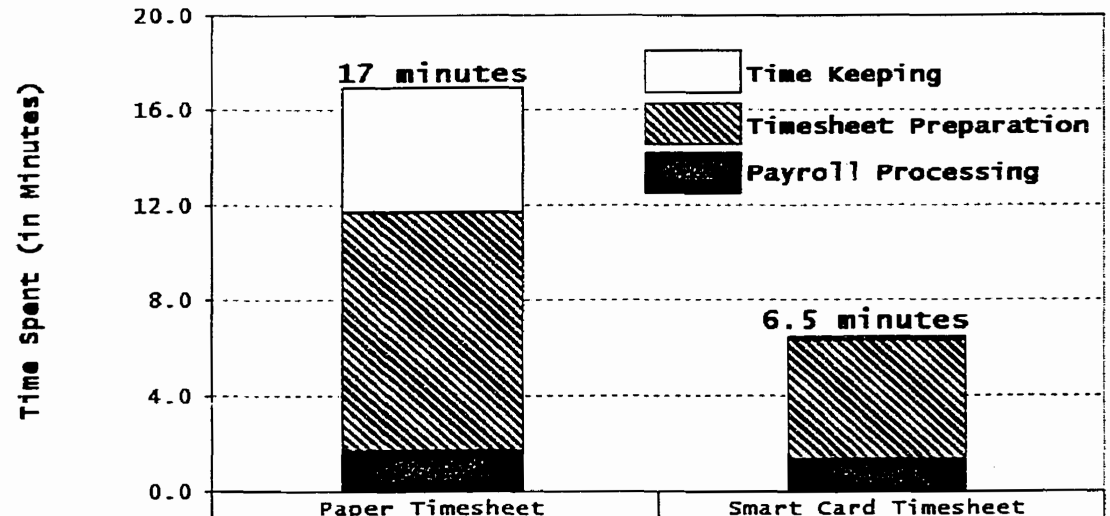
(Figures are in thousands of $)

Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-11: Present Value Timesheet Cost Comparison

The present value of the labor cost variance between the manual and electronic methods is estimated to be $343,740.26, which represents a 62% savings in the labor cost of the electronic method over the manual method. It is estimated that the non-labor cost (e.g. material cost and bank fees) of the electronic method is higher than the manual method by $144,201.33.

The labor payment cycle time of the electronic method is estimated to be shorter than the manual method by10.5 minutes per day for each worker. The cycle time for both the manual and electronic methods are as illustrated in Figure 4-12.



	Paper Timesheet	Smart Card Timesheet
Time Keeping	5.3	0.2
Timesheet Preparation	10.0	5.0
Payroll Processing	1.7	1.3

October 25, 2000

Labor Payment Method

Figure 4-12: Timesheet Labor Payment Cycle Time

The cycle time results indicated that the time spent to prepare a worker's timesheet in the electronic method is estimated to be 50% shorter than manual method. In addition, the electronic method is expected to reduce the time to process payroll by 24% and the project headcount by one, which is the timekeeper's position.

The estimated cost savings (***$PV_{1\,var}$, $PV_{2\,var}$, $PV_{3\,var}$, $PV_{4\,var}$*** and ***$PV_{5\,var}$***) for the first, second, third, fourth, and fifth years respectively are calculated using Equation 10.

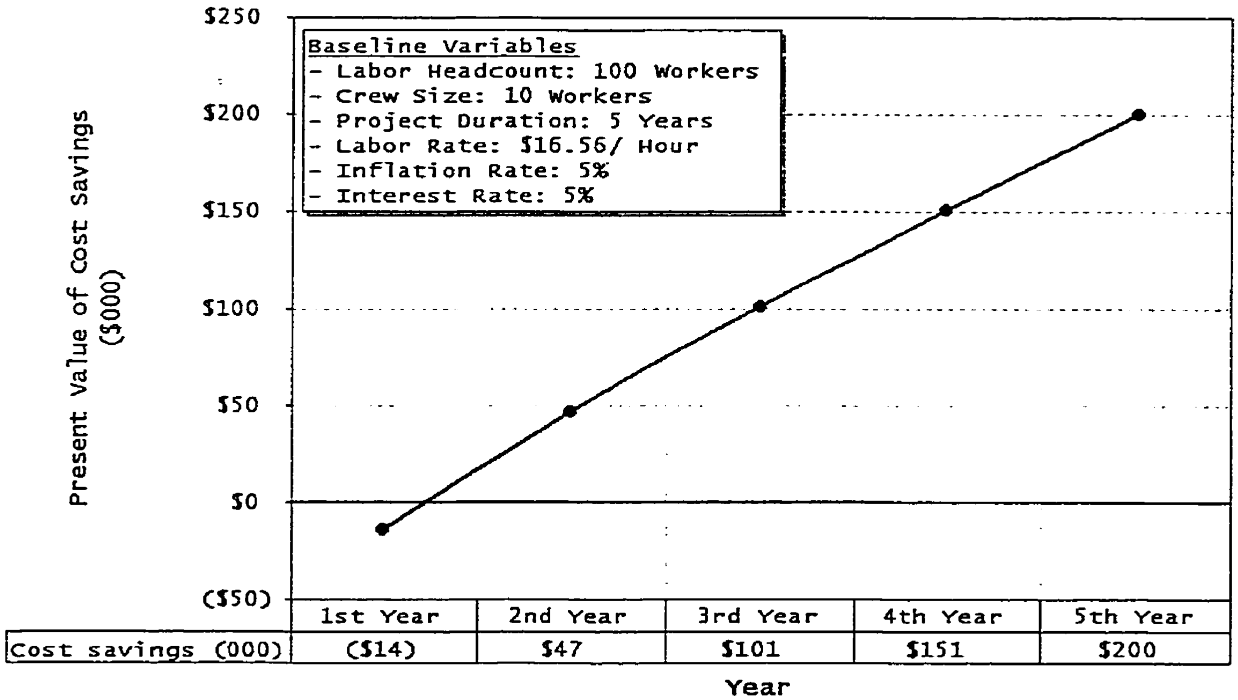
$$\left\{\begin{array}{c}\textit{Cost}\\ \textit{Savings}\\ PV_{1var} = (\$14.5)\\ \hdashline PV_{2var} = \$61.2\\ \hdashline PV_{3var} = \$54.2\\ \hdashline PV_{4var} = \$49.8\\ \hdashline PV_{5var} = \$49.4\end{array}\right\} = \left\{\begin{array}{c}\textit{Manual}\\ \textit{Method}\\ PV_{1\,Manual} = \$151.6\\ \hdashline PV_{2\,Manual} = \$144.7\\ \hdashline PV_{3\,Manual} = \$138.1\\ \hdashline PV_{4\,Manual} = \$131.9\\ \hdashline PV_{5\,Manual} = \$125.9\end{array}\right\} - \left\{\begin{array}{c}\textit{Electronic}\\ \textit{Method}\\ PV_{1\,Electronic} = \$166.1\\ \hdashline PV_{2\,Electronic} = \$83.5\\ \hdashline PV_{3\,Electronic} = \$83.9\\ \hdashline PV_{4\,Electronic} = \$82.1\\ \hdashline PV_{5\,Electronic} = \$76.4\end{array}\right\}$$

(Figures are in thousands of \$)

Equation 10

The ***$PV_{1\,var}$, $PV_{2\,var}$, $PV_{3\,var}$, $PV_{4\,var}$*** and ***$PV_{5\,var}$*** are estimated to be -\$14,478.24 in the first year (the variance is negative in first year) and \$61,205.23, \$54,231.84, \$49,766.36 and \$49,413.73 for second, third, fourth and fifth years respectively.

The cost variance between the manual and the electronic methods is estimated to break even during the first year of the project as illustrated in Figure 4-13.



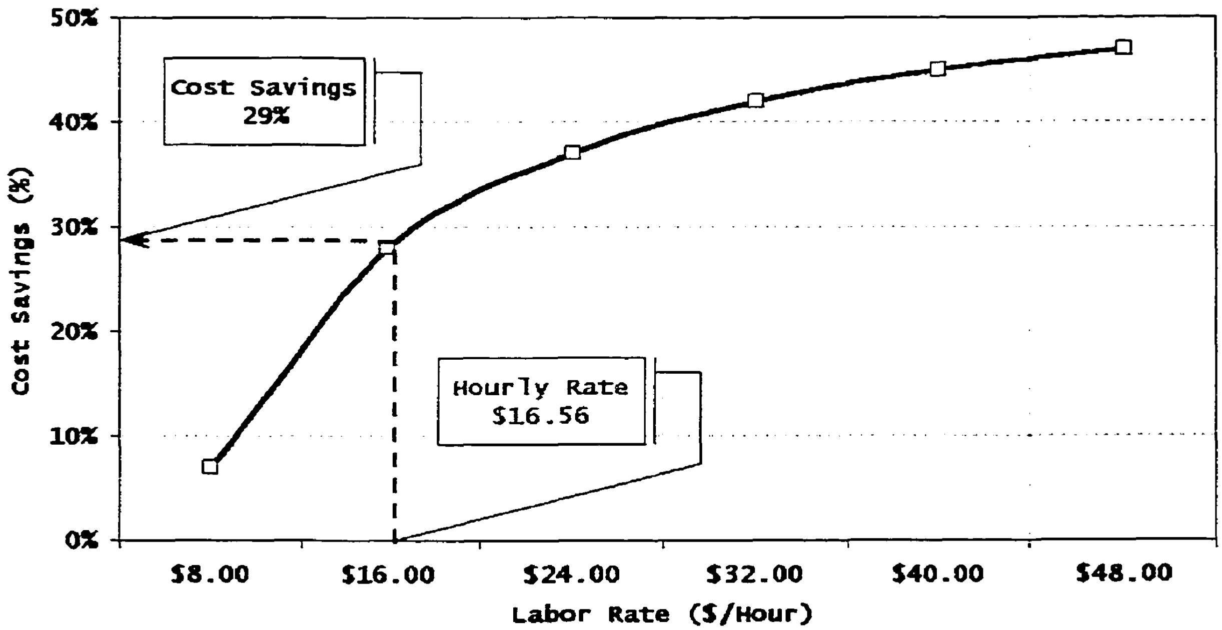
(Figures are in thousands of $)

Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-13: Annual Cost Savings of Smart Card Timesheet

The electronic method annual cost is estimated to be 9.5% higher than the manual method's in the first year because of the hardware acquisition and software development costs. The average cost savings per year is estimated to be $40.027.79 upon adopting the electronic method.

The cost savings of using the electronic method proportionally increased from 7% to 47% when hourly labor rate increased from $8.00 to $48.00 as shown in Figure 4-14.



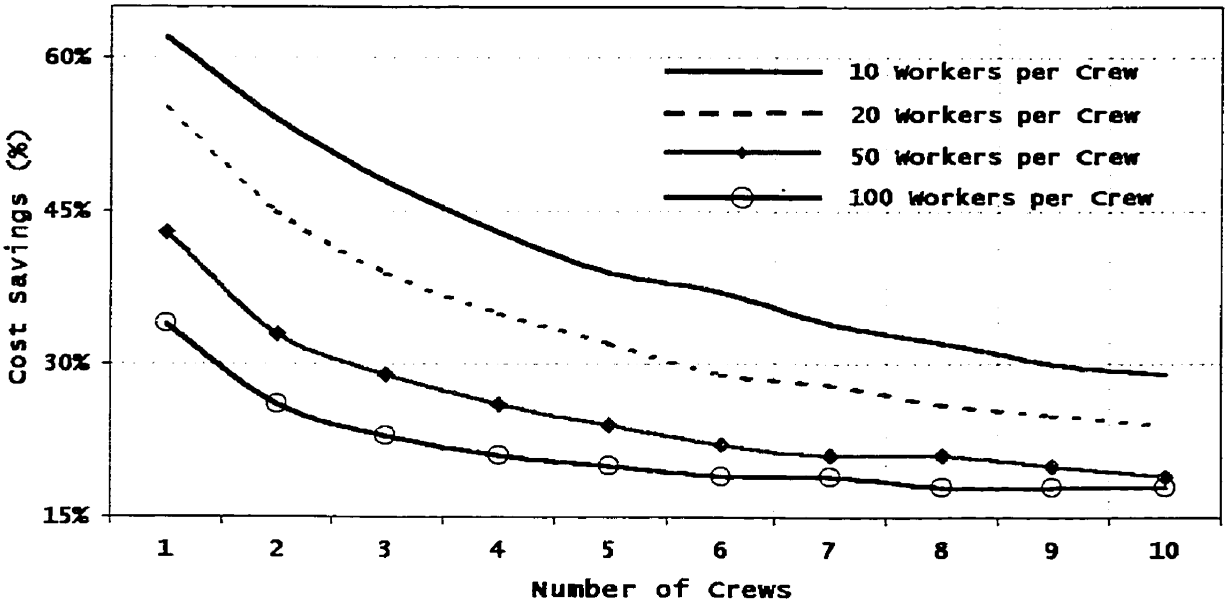
(Figures are in thousands of $)

Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-14: Hourly Rate Impact on Smart Card Timesheet Cost Savings

The cost savings rate is expected to decline as the hourly labor rate exceeds $20.00, as the number of crews and the crew size remain unchanged and equal to 10 crews per project and 10 workers per crew respectively.

Studying the impact of the crew size on the cost of using the electronic method, results indicated that the cost savings for a 10-worker crew decreased from 62% to 29% by increasing the number of crews from 1 to 10 crews as shown in Figure 4-15.

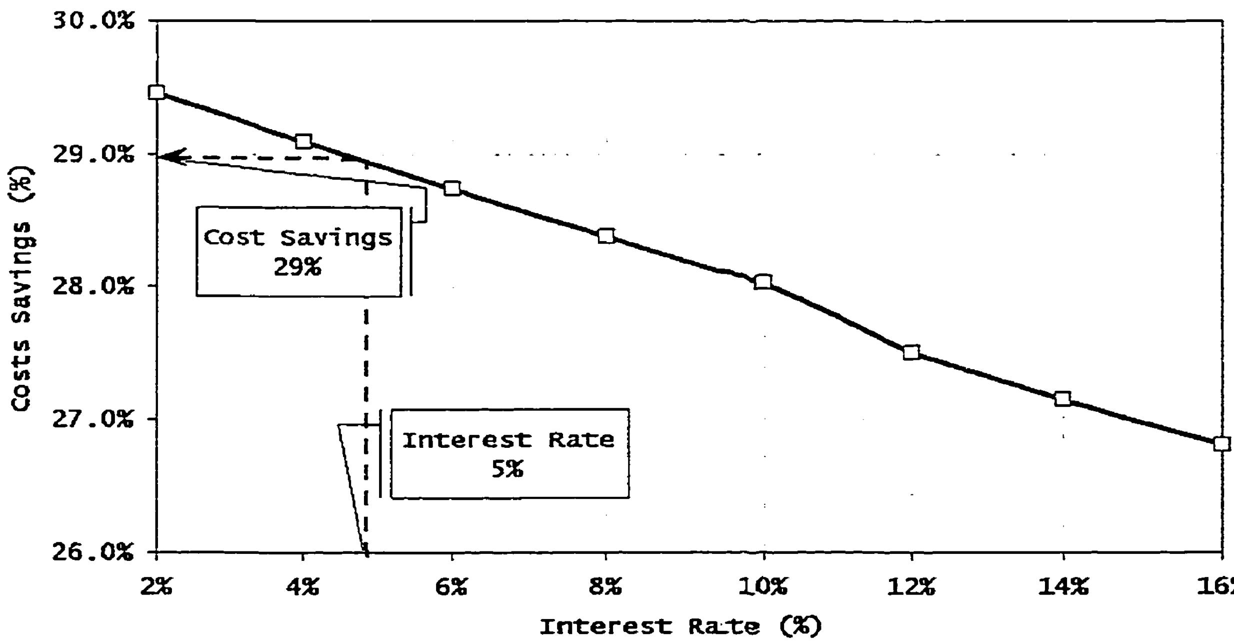


Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-15: Crew Size Impact on Smart Card Timesheet Cost Savings

The cost of using the electronic method does not exceed the cost of the manual method as a result of changing the crew size baseline from 10 to 100 workers per crew using any number of crews between 1 and 10.

Studying the impact of the interest rate on the cost of using the electronic method, the results indicated that the cost savings inversely decreased from 30% to 27% by raising the interest rate from 2% to 16% as shown in Figure 4-16.

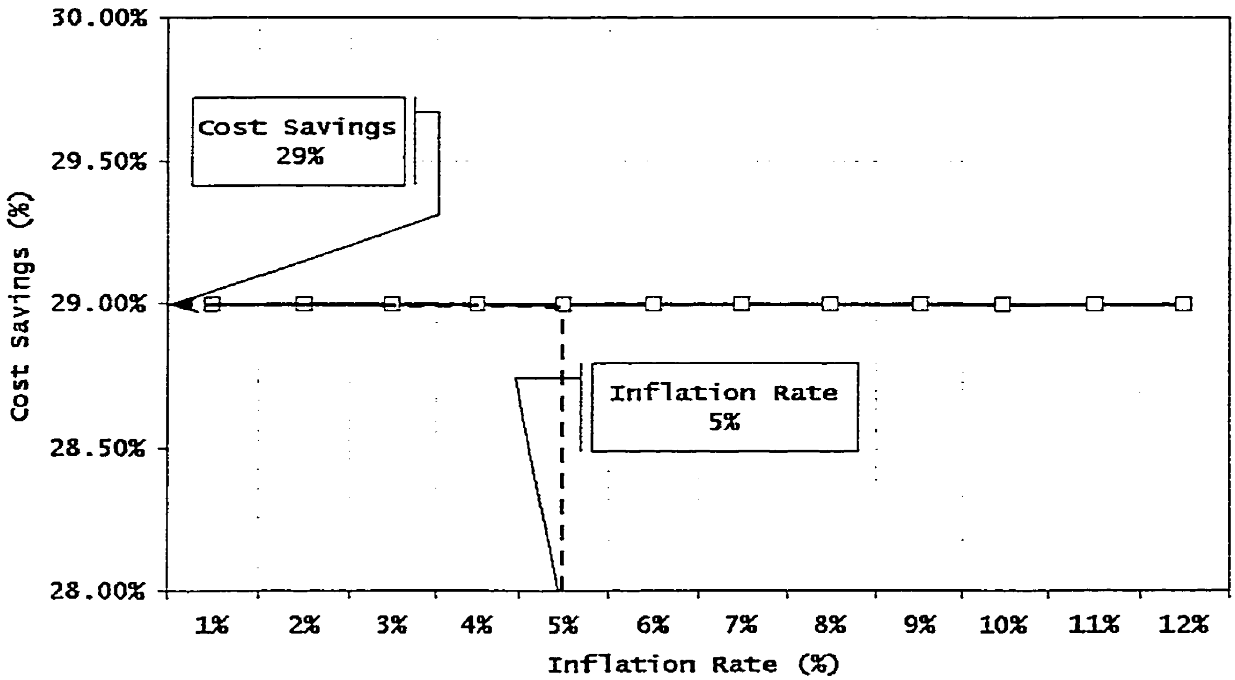


Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-16: Interest Rate Impact on Smart Card Timesheet Cost Savings

The cost of using the electronic method does not exceed the cost of the manual method as a result of changing the interest rate baseline value (5%) from 2% to 16%.

Studying the impact of the inflation rate on the cost of using the electronic method, the results indicated that the inflation rate has not effect on the cost savings as shown in Figure 4-17.

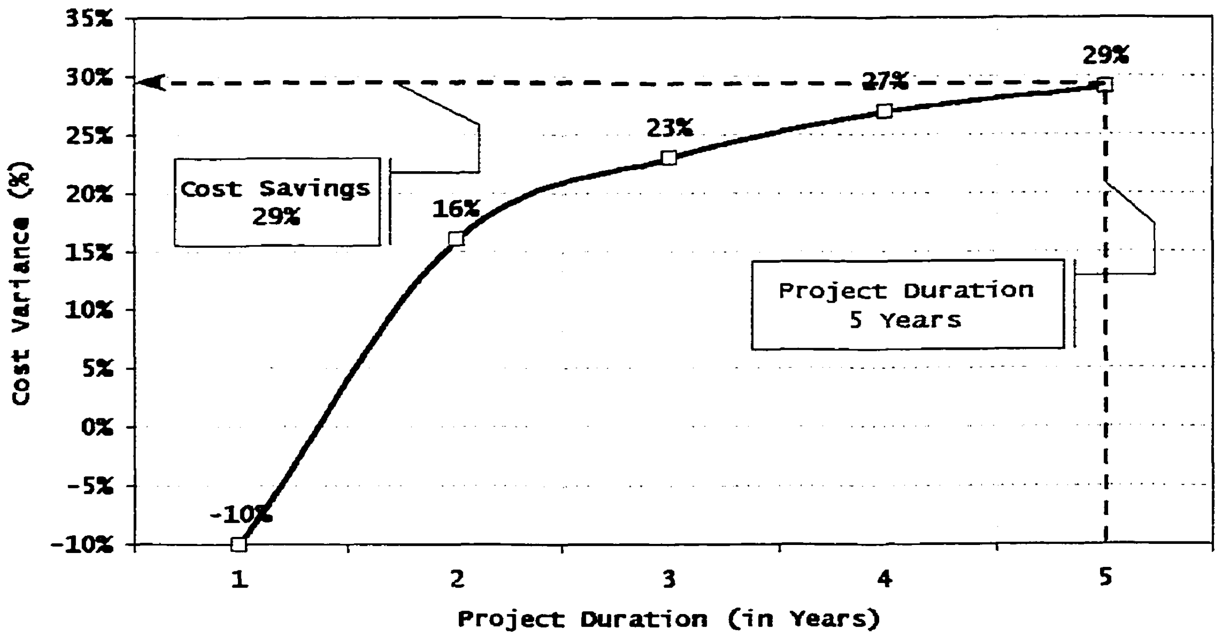


Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-17: Inflation Rate Impact on Smart Card Timesheet Cost Savings

The cost of using the electronic method does not exceed the cost of the manual method as a result of changing the inflation rate baseline (5%) from 1% to 12%.

Studying the impact of the project duration on the cost of using the electronic method, the results indicated that the cost savings decreased from 29% to 16% when the project duration decreased from 5 years to 2 years as shown in Figure 4-17. In a one-year project, the cost of using the manual method is 10% less than cost of using the electronic method.



Cost Savings = Paper-Based Timesheet Cost - Smart Card-Based Timesheet Cost

Figure 4-18: Project Duration Impact on Smart Card Timesheet Cost Savings

In summary, this cost study quantified the potential cost savings of using smart card technology to replace the manual method of time keeping, timesheet preparation and payroll processing in construction projects. The cost comparison indicates that the cost savings range is expected to be 10-60% depending on the cost estimate assumptions. This cost study is intended for demonstration purposes only.

Chapter 5 Conclusion and Recommendations

5.1 Conclusion

This thesis presented a framework for smart card use in the construction industry. The framework was intended to investigate the applicability of smart card technology and to explore its potential applications in the construction industry. Key research findings are:

1) Construction Labor Smart Cards (CLSC) have computing capability to run applications, store results and exchange information at low cost. The financial feasibility of CLSC is proven if smart card economies of both scale and scope are materialized. Economy of scale is achieved when cards and IC chips are manufactured in high volume. Economy of scope is achieved when two or more applications are jointly produced at a cost lower than that incurred in their separate and independent production. However, bundling construction applications together in a multifunctional smart card reduces the need to carry multiple cards on site but increases the cost of producing large-memory IC chips. The application implementation (card reader / site terminal infrastructure, etc.) entails high fixed costs, of which distribution among CLSC participants (project stakeholders) is problematic.

2) Among questionnaire participants, the most commonly approved smart card infrastructure hardware in construction projects are double-slot card readers, smart mobile or cell phones, and personal computers with smart card interfaces. Smart cards with dual interface (hybrid or combi smart cards) suit the needs of construction applications in terms of accuracy and speed. Smart card selections of both type and

application are restricted by the need to balance between privacy with security protections and other interests such as convenience and ability to audit trail transactions. Because of the versatility of the smart card, it is difficult to define generally applicable selection criteria as the focus of selection shifts between technology and business requirements.

3) Lack of interoperability between card readers, incompatible card operating systems and inadequate card infrastructures are major roadblocks for implementing smart card in construction projects. Currently, there is no widely accepted standard to support implementing construction applications in an open environment using a standard platform.

5.2 Research Contribution

The research framework emphasized: 1) the effectiveness of smart card in mechanizing current manual practices in construction operations, and 2) the potential of the smart card successfulness to gravitate the construction industry toward a cashless and paperless environment. The framework also proposed the Construction Labor Smart Card (CLSC) focusing primarily on implementation of the electronic timesheet and labor payment application. The research intended to propose the following CLSC implementation building blocks:

1) **Transformation Model**: explains the process to mechanize paper timesheet and manual labor payment operation into a smart card-based solution. The smart card labor payment process is discussed in detail in this research.

2) **Implementation Methodology**: encompasses CLSC life cycle and the roles and responsibilities of each party involved in the implementation process.

3) **Infrastructure Layout**: illustrates the various elements and functions of CLSC hardware elements including card readers, site terminals and smart card PC and telephone sets.

4) **Coding Template**: is intended to support the transition from a manual paper-based to a mechanized smart card-based timesheet. The coding template is also used as a backup timesheet for workers who do not use smart card or do not have access to the CLSC infrastructure.

To illustrate the analysis of the study, a cost comparison between paper and smart card timesheet has been presented showing the potential cost savings of the proposed CLSC application. The thesis also presented the results of a questionnaire designed to gauge the interest of using smart card technology and the perceived feasibility and adaptability of smart card in the construction industry. The participants of the study supported the use of smart cards to replace paper timesheets and manual labor payment methods. In addition, the questionnaire results indicate that there is tremendous potential to successfully penetrate the construction market if construction managers are educated about the financial benefits, ease of use and other advantages of using smart cards among construction laborers.

5.3 Recommendations for Future Studies

There is a need to form a construction industry body to study smart card issues such as:

1) Managing the ownership of information held on the smart card and on any associated data processing or storage system.
2) Tracking modifications to the card applications or the worker's personalized profile.
3) Ensuring the synergy between construction applications and other non-construction schemes or applications.
4) Developing new methodologies to adopt the requisite changes to the existing construction practices and manual processes.
5) Provide risk management strategies to construction companies migrating to smart card environment.
6) Establishing new provisions in construction contracts and labor collective agreements to address issues related to employing applications such as Electronic Benefits Transfer (EBT) for labor and management personnel, Public Key Infrastructure (PKI) in confidential project communications, Electronic Signature (ES) in contract procurement and administration and Electronic Purse (EP) in expense voucher.
7) Providing smart card audit trail mechanisms without violating the privacy of workers.
8) Governing permanent and shared smart card data and user's data to be personalized.

In future studies, it is also recommended to include the following:

1) Developing an electronic payment scheme for construction laborers using electronic cash and electronic purse applications on smart cards. The objective would be the integration of smart card financial schemes in construction invoicing, billing and payroll operations.
2) Proposing new smart card hardware interfaces with smart card readers and other technologies that are commonly used in construction such as Radio Frequency (RF) bar code scanners, Closed Circuit TV (CCTV) cameras, automatic on-off switches, wireless devices and wide range electronic sensors.

References

Ahuja, Vijay (1998), "**Certified Security: Making PKI Pay for Itself**" Data Communications, November 1998, 27(16): 25-26, Publisher: CMP Media Inc. Manhasset, NY, USA.

Allen, Catherine (1995), "**Is There a Smart Card in Your Future?**" The Bankers Magazine, January /February 1995, 178(1): 38-40, Publisher: Warren Gorham Lamont, Boston, MA, USA.

Allen, Catherine (1995), "**Get Smart (Smart Cards and Virtual Banking)**" Journal: Bank Management, March / April 1995, Volume 71, Issue 2, Page 58-60 & 62-3, Publisher: Bank Administration Institute, Chicago, IL, USA.

Automatic ID News (1999), "**Soccer Players Get a Kick out of Smart Cards**" Automatic ID News; January 1999; Anonymous; Volume 15, Issue 1, Page 34, Advanstar Communications, Inc., Duluth, MN, USA.

Arnaud, Denis (1997), "**Appendix 7: Smart Card Technology**" Web Site http://ecwww.eurecom.fr

Babyak, Richard (1998), "**The Electronic wallet**" Appliance Manufacturer, March 1998, 46(3): 63-64, Publisher: Business News Publishing Company, Solon, OH, USA.

Bielski, Lauren (1998), "**Small Cards, Coming up to Bat**" American Bankers Association, ABA Banking Journal, November1998, Volume 90, Issue 1, Page 57-62, Publisher: Simmons-Boardman Publishing Corporation, New York, NY, USA.

Bliss, Jeff (1998), "**GemSafe Smart-Card Bundle Guards Online Identities**" Computer Reseller News; June 1998; Issue 794, Page 154, CMP Media Inc., Manhasset, New York, NY, USA.

Bright, Roy (1988), "**Smart Cards: Principles, Practice, Applications**", Publisher: Chichester: Ellis Horwood ; New York, Halsted Press, 1988.

Brown, Patricia (1997), "**Extranets: Next step in Networking**" Communications Week; June 1997; Issue 669, Publisher: CMP Media Inc., Manhasset, NY, USA.

Chatfield, J.N. (1996), "**Marketing an HMO by 'Smart' ID Cards with Patient History on an Electronic Medical Record**" Proceedings: Toward an Electronic Patient Record, 13-18 May 1996. Twelfth International Symposium on the Creation of Electronic Health Record System and Global Conference on Patient Cards, p. 608-20, volume1, Publisher: Medical Records Inst. - Newton, MA, USA.

Chaum, David (1994), "**Prepaid Smart Card Techniques: a Brief Introduction and Comparison**" Web Site http://ganges.cs.tcd.ie/mepeirce/Project/Chaum/cardcom.html

Cherneff, Ruth et al (1996), "**Smart Card Paper**" Web Site http://www1.shore.net/~bauster/cap/s-card

Choi, Soon-Yong et al (1999), "**Smart Cards Enabling Smart Commerce in the Digital Age**" Web Site http://www.AmericanPacific.net

Collier, Alan (1999), "**Framework for Smart Card Use in Government**" Web Site http://www.ftp.cl.cam.ac.uk/ftp/users/rja14/cardnonsense.txt

Demery, Paul (1998), "**An Easy Fix for Fraud?**" Credit Card Management; New York; May 1998; Volume 11, Issue 2, Page 72-76, Publisher: Faulkner & Gray, Inc., Chicago, IL, USA.

Engelbrecht, R. et al (1994), "**A Chip Card for Patients with Diabetes**" Journal: Computer Methods and Programs in Biomedicine, October 1994, Volume 45, Issue 1-2, Page 33-5.

Flaherty, Nick (1999), "**Case Study: Putting the "Smart" in Smart Cards**" Web Site http://www.s2mag.com/Editorial

Goldfinger, Charles (1999), "**Economics of Financial Applications of the Smart Card: a Summary Overview**" Web Site http://www.ispo.cec.be/fiwg/fasc.html

Guyette, James (1998), "**A New 'John Hancock' for Electronic Commerce**" Automatic ID News; November 1998; Volume 14, Issue 12, Page 22, Publisher: Advanstar Communications, Inc., Duluth, MN, USA.

Hodgson, Karyn (1997), "**Smart Security**" Security, March 1997, Volume 34, Issue 3, Page 14-15+, Publisher: Cahners Business Information, a division of Reed Elsevier, Inc., Englewood, CO, USA.

Hutton, David (1998), "**Attack of the Smart Cards**" Bank Marketing, February 1998, Volume 30, Issue 2, Page 40-46, Publisher: Bank Marketing Association, Washington, DC, USA.

Kaplan, Marcia (1996), "**Scrutinizing Switches**" Business Communications Review; November 1996; Volume 27, Issue 1, Page 59-62, Publisher: Business Communications Review, Elmhurst, IL, USA.

Kessler, Ann (1998), "**College Students: a Market Worth Pursuing**" Bank Marketing, July 1998, Volume 30, Issue 7, Page 14-17, Publisher: Bank Marketing Association, Washington, DC, USA.

Krishna, Arvind (1998), "**Protect Yourself**" Inform, November 1998, Volume 12, Issue 10, Page 26-29, Publisher: Association for Information and Image Management, Silver Spring, MD, USA.

Kruger, Peter (1998), "**Trading Places**" Communications International, November 1998, Volume 25, Issue 11, Page 47-50, Publisher: EMAP Business Publishing, London, England.

Lucas, Allison (1996), "**What in the World Is Electronic Commerce?**" Sales and Marketing Management (SMT Supplement), June 1996, Page 24-29, Publisher: Bill Communications, Riverton, NJ, USA.

Lucas, Peter (1996), "**All Aboard for Smart Cards**" Credit Card Management, June 1996, Volume 9, Issue 3, Page 100-103, Publisher: Faulkner & Gray, Inc., Chicago, IL, USA.

Marlin, Steven (1998), "**Digital Patrol: Banks Move to Lock out Electronic Attackers**" Bank Systems & Technology, October 1998, Volume 35, Issue 10, Page 40-44, Publisher: Miller Freeman Inc., New York, NY, USA.

Marlin, Steven (1999), "**Q&A Executive: Market building**" Bank Systems & Technology, February 1999, Volume 36, Issue 2, Page 36-37, Publisher: Miller Freeman Inc., New York, NY, USA.

McGauley, J.L. (1996), "**A Smart Card Based Medical Information System that Works**" Proceedings: Toward an Electronic Patient Record '96. Twelfth International Symposium on the Creation of Electronic Health Record System and Global Conference on Patient Cards, Volume 1, Page 630-4.

McKendrick, Joseph (1999), "**Inch by Inch for Smart Cards**" Credit Card Management, May 1999, Volume 12, Issue 2, Page 44-50, Publisher: Faulkner & Gray, Inc., Chicago, IL, USA.

Merrill, Kevin (1998), "**Oui! to Smart Cards**" Computer Reseller News, November 1998, Issue 815, Page 225, Publisher: CMP Media Inc., New York, NY, USA.

Messmer, Ellen (1999), "**Pentagon Gets 'Smart'**" Network World, September 1999, Volume 16, Issue 38, Page 1,77, Publisher: Network World Inc., Framingham, MA, USA.

Middleton, William D (1998), "**Riders Respond to a Fare Deal**" Railway Age, May 1998, Volume 199, Issue 5, Page 55-58, Publisher: Simmons-Boardman Publishing Corporation, New York, NY, USA.

Miller, Annetta (1999), "**The Millennial Mind-Set**" American Demographics, January 1999, Volume 21, Issue 1, Page 60-65, Publisher: PRIMEDIA Intertec, Overland Park, KS, USA.

O'Sullivan, Orla (1999-A), "**Cash it ain 't, but that's not All**" United States Banker, March 1999, Volume 109, Issue 3, Page 42-51+, Publisher: American Banker-Bond Buyer, a Division of Thomson Publishing Corporation, New York, NY, USA.

O'Sullivan, Orla (1999-B), "**Swatch this Space**" United States Banker, March 1999, Volume 109, Issue 3, Page 24, Publisher: American Banker-Bond Buyer, a Division of Thomson Publishing Corporation, New York, NY, USA.

Olesen, Douglas (1999), "**Technology Breakthroughs for the Next Decade**" Executive Speeches, January 1999, Volume 13, Issue 3, Page 1-5, Publisher: The Executive Speaker, Dayton, OH, USA.

Oliveira, Victor and Levedahl, J. William (1998), "**All Food Stamp Benefits to be Issued Electronically**" Food Review, January / April 1998, Volume 21, Issue 1, Page 35-39, Publisher: Superintendent of Documents, Washington, DC, USA.

Orenstein, Alison (1998), "**Smart Cards: U.S. Banks Ponder the Business Case**" Bank Systems & Technology, Volume 35, Issue 6, Page 34-40, Publisher: Miller Freeman Inc., New York, NY, USA.

Patch, Kimberly and Smalley, Eric (1998), "**Drop a Dime Online**" InfoWorld, November 1998, Volume 20, Issue 48, Page 71-72, InfoWorld Publications, Inc. Publisher: San Mateo, CA, USA.

Railway Age (1999),"**Washington, San Francisco Move to Smart Cards**" July 1999; Volume 200, Issue 7, Page 24, Publisher: Simmons-Boardman Publishing Corporation, New York, NY, USA.

Rankl, Wolfgang and Effing, Wolfgang (1997), "**Smart Card Handbook**", Publisher: Chichester, New York : Wiley, 1997.

Rolfe, Richard (1997), "**The Smart Card Proving Ground**" Credit Card Management, September 1997, Volume 10, Issue 6, Page 159-162, Publisher: Faulkner & Gray, Inc., Chicago, IL, USA.

Schaefer, O.P. and Sembritzki, J. (1996), "**German Patient Cards and the Impact on Interoperability**" Proceedings: Toward an Electronic Patient Record, Twelfth International Symposium on the Creation of Electronic Health Record System and Global Conference on Patient Cards. 3-18 May 1996, Volume 2, Page 137-9, Publisher: Medical Records Institute, Newton, MA, USA.

Seideman, Tony (1997), "**U.S. Military Deploys Auto. ID to Track Goods in Bosnia**" Automatic ID News, March 1997, Volume 13, Issue 3, Page 37, Publisher: Advanstar Communications, Inc., Duluth, MN, USA.

Talmor, Sharona and Timewell, Stephen (1997), "**Get Smart**" The Banker, October 1997, Volume 147, Issue 860, Page 26-28, Publisher: Pearson Professional Limited, London, England.

Theoharides, Chris (1997), "**The Smart Card: It's Smart, it's Flexible and it's the Next Wave**" Credit World; St. Louis; May/June 1997, Volume 85, Issue 5, Page 15-17, Publisher: International Credit Association, St Louis, MO, USA.

Tipton, Anne (1999), "**New Windows Smart Card OS May Strengthen, Streamline Market**" Credit Card Management, January 1999, Volume 8, Issue 3, Page 58-63, Publisher: Advanstar Communications Inc.

Veronik, Bostjan (1998), "**Smart Cards in Payphones: the Wireless Dimension**" Telecommunications (International Edition), May 1998, Volume 32,Issue 5, Page 91-94, Publisher: Horizon House Publications, Inc., Braintree, MA, USA.

Web 01 (2000), "**American Pacific**" Web Site http://www.AmericanPacific.net

Web 02 (2000), "**Silicon Valley Roundtable News**" Web Site http://www.marcar.com/svrt/

Web 03 (1999), "**BIT Inc.**" Web Site http://www.bit-inc.com

Web 04 (2000), "**Bull**" Web Site http://www.cp8.bull.net

Web 05 (2000), "**Economics of Financial Applications of the Smart Card: a Summary Overview by Charles Goldfinger**" Web Site http://www.ispo.cec.be/fiwg/fasc.htm

Web 06 (2000), "**U. S. Department of Commerce, Bureau of Labor Statistics**" Web Site http://stats.bls.gov/oco/cg/cgs003.htm

Web 07 (2000), "**Card Europe**" Web Site http://www.cardshow.com

Web 08 (2000), "**MAOSCO, Multos Mondex Documentation**" Web Site http://www.mondex.com

Web 09 (2000), "**CoinCard**" Web Site http://coincard.com

Web 10 (2000), "**U.S. General Services Administration (GSA)**" Web Site http://smart.gov

Web 11 (2000), “**Smart Card International Association (SCIA)**” Web Site http://www.scia.org

Web 12 (2000), “**Basic Card**” Web Site http://www.basiccard.com

Web 13 (2000), “**EuroSmart**” Web Site http://www.eurosmart.com

Web 14 (1999), “**Faulkner & Gray**” Web Site http://www.cardtech.faulknergray.com

Web 15 (2000), “**Frost & Sullivan**” Web Site http://www.frost.com

Web 16 (2000), “**Gemplus**” Web Site http://www.gemplus.com

Web 17 (2000), “**Smart Card for Microsoft Windows**” Web Site http://www.microsoft.com/windowsce/smartcard

Web 18 (2000), “**Purdue University, Automatic ID & Data Capture (AIDC) Center**” Web Site http://www.tech.purdue.edu/it/resources/aidc/smcard.htm

Web 19 (2000), “**International Card Manufacturer Association (ICMA)**” Web Site http://www.icma.com

Web 20 (2000), “**Philip Andreae & Associates**” Web Site http://www.andreae.com

Web 21 (2000), “**MagnaCarta**” Web Site http://www.magnacarta.nl

Welch, Peter (1999), “**Facing up to Change**” Credit Card Management, February 1999, Volume 11, Issue 11, Page 86-90, Publisher: Faulkner & Gray, Inc., Chicago, IL, USA.

Williams, Kathy (1997), “**U.S. Lags in Smart Card Use**” Management Accounting, December 1997, Volume 79, Issue 6, Page 14, Publisher: Institute of Management Accountants, Montvale, NJ, USA.

Williams, Tish (1997), “**Netscape Takes a Licking--and Keeps on Ticking”** Upside, October 1997, Volume 9, Issue 9, Page 36-37, Publisher: Upside Publishing Company, San Mateo, CA, USA.

Appendix A

The Cost Estimate of the Paper-Based Timesheet

The cost estimate of **the paper-based timesheet (manual method)** is prepared in 6 steps:

1) The time spent to prepare a worker's timesheet is estimated to be 16.96 minutes per day (see Table A-1).
2) The labor cost of timesheet preparation is estimated to be $121,704.96, $127,790.21, $134,179.72, $140,888.70 and $147,933.14 in the first, second, third, fourth and fifth years respectively (see Table A-2).
3) The material cost of timesheet preparation is estimated to be $19,500.00, $20,475.00, $21,498.75, $22,573.69 and $23,702.37 in the first, second, third, fourth and fifth years respectively (see Table A-3).
4) The cost of issuing paper paychecks is estimated to be $10,400.00, $10,920.00, $11,466.00, $12,039.30 and $12,641.27 in the first, second, third, fourth and fifth years respectively (see Table A-4).
5) For a 5-year project with 100 workers, the total cost of paper-based timesheet is estimated to be $151,604.96, $159,185.21, $167,144.47, $175,501.69 and $184,277.78 in the first, second, third, fourth and fifth years respectively (see Table A-5).
6) The Present Value (PV) of the paper-based timesheet cost is estimated to be $692,175.25 (see Table A-6).

Step #1: Estimated Daily Time Spent in Preparing Worker's Timesheet				Assumption No*
	N_{06}	6.00	Minutes Spent to Populate Paper Timesheet Form	#06: Preparation Time
	N_{07}	0.30	Minutes Spent to Review and Approve Timesheet	#07: Approval Time
	N_{08}	2.50	Minutes Spent to Handle Timesheet	#08: Handling Timesheet
	N_{091}	0.50	Minutes Spent to Sign in and out at the Gate	
	N_{10}	0.70	Minutes Spent to Prepare and Handle Paycheck	#10: Handling Check
	N_{09}	4.80	Minutes Spent to Track Worker's Attendance	#09: Timekeeper
	N_{12}	0.96	Minutes Spent to Process Timesheet and Payroll	#12: Payroll Time
	N_{18}	1.20	Minutes Spent to Archive Worker's Paper Timesheet	#18: Archiving Time
		=========		
	N_{01}	16.96	Total Minutes Spent per Worker $(N_{01} = N_{06} + N_{07} + N_{08} + N_{091} + N_{10} + N_{09} + N_{12} + N_{18})$	

(Figures are in minutes)

Table A-1: Estimated Time Spent to Prepare Paper-Based Timesheet

*All assumptions are explained in Appendix C

Step #2: Estimated Timesheet Labor Cost				Assumption No *
Annual Cost	U_{011}	\$4.68	Daily Labor Cost of Preparing a Worker's Timesheet (U_{011} =Hourly Rate U_{01} * Hours Spent to Complete Worker's Timesheet N_{01})	#01: Hourly Rate
	C_{11}	\$121,704.96	Labor Cost of Preparing Timesheet in Year 1 (All Workers) (C_{11} = Daily Cost U_{011} * No. of Working Days per Year N_{02} * N_{04} * C_{05})	#02: Project Calendar #03: Project Duration
	C_{21}	\$127,790.21	Labor Cost of Preparing Timesheet in Year 2 (All Workers) (C_{21} = Labor Cost of Timesheets in Year 1 C_{11} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{31}	\$134,179.72	Labor Cost of Preparing Timesheet in Year 3 (All Workers) (C_{31} = Labor Cost of Timesheets in Year 2 C_{21} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{41}	\$140,888.70	Labor Cost of Preparing Timesheet in Year 4 (All Workers) (C_{41} = Labor Cost of Timesheets in Year 3 C_{31} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{51}	\$147,933.14	Labor Cost of Preparing Timesheet in Year 5 (All Workers) (C_{51} = Labor Cost of Timesheets in Year 4 C_{41} * (1+ Inflation Rate B))	#33: Inflation Rate
Present Value	PV_{11}	\$121,704.96	PV of Timesheet Labor Cost in Year 1 (All Workers) ($PV_{11} = C_{11}$)	
	PV_{21}	\$116,172.92	PV of Timesheet Labor Cost in Year 2 C_{21} (All Workers) (PV_{21} =Labor Cost in Year 2 C_{21} / (1+ Combined interest Rate A)^1)	#34: Interest Rate
	PV_{31}	\$110,892.33	PV of Timesheet Labor Cost in Year 3 C_{31} (All Workers) (PV_{31} =Labor Cost in Year 3 C_{31} / (1+ Combined interest Rate A)^2)	#34: Interest Rate
	PV_{41}	\$105,851.77	PV of Timesheet Labor Cost in Year 4 C_{41} (All Workers) (PV_{41} =Labor Cost in Year 4 C_{41} / (1+ Combined interest Rate A)^3)	#34: Interest Rate
	PV_{51}	\$101,040.32	PV of Timesheet Labor Cost in Year 5 C_{51} (All Workers) (PV_{51} =Labor Cost in Year 5 C_{51} / (1+ Combined interest Rate A)^4)	#34: Interest Rate
		==========		
	PV_{t1}	\$555,662.30	Total PV of Timesheet Labor Cost ($PV_{t1} = PV_{11} + PV_{21} + PV_{31} + PV_{41} + PV_{51}$)	

Table A-2: Estimated Labor Cost of Preparing Paper-Based Timesheet

*All assumptions are explained in Appendix C

Step #3: Estimated Timesheet Material Cost				Assumption No [*]
Annual Cost	U_{11}	\$0.75	Daily Material Cost of a Worker's Timesheet (U_{11} = Printing, Photocopying, Filing Costs)	#11: Material $
	C_{12}	\$19,500.00	Material Cost of Timesheet in Year 1 (All Workers) (C_{12} = Daily Cost U_{11} * No. of Working Days per Year)	
	C_{22}	\$20,475.00	Material Cost of Timesheet in Year 2 (All Workers) (C_{22}= Material Cost of Timesheets in Year 1 C_{12} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{32}	\$21,498.75	Material Cost of Timesheet in Year 3 (All Workers) (C_{32}= Material Cost of Timesheets in Year 2 C_{22} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{42}	\$22,573.69	Material Cost of Timesheet in Year 4 (All Workers) (C_{42}= Material Cost of Timesheets in Year 3 C_{32} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{52}	\$23,702.37	Material Cost of Timesheet in Year 5 (All Workers) (C_{52}= Material Cost of Timesheets in Year 4 C_{42} * (1+ Inflation Rate B))	#33: Inflation Rate
Present Value	PV_{12}	\$19,500.00	PV of Timesheet Material Cost in Year 1 (All Workers) ($PV_{12} = C_{12}$)	
	PV_{22}	\$18,613.64	PV of Timesheet Material Cost in Year 2 (All Workers) (PV_{22} =Material Cost in Year 2 C_{22} / (1+ Combined interest Rate A)^1)	#34: Interest Rate
	PV_{32}	\$17,767.56	PV of Timesheet Material Cost in Year 3 (All Workers) (PV_{32} =Material Cost in Year 3 C_{32} / (1+ Combined interest Rate A)^2)	#34: Interest Rate
	PV_{42}	\$16,959.95	PV of Timesheet Material Cost in Year 4 (All Workers) (PV_{42} =Material Cost in Year 4 C_{42} / (1+ Combined interest Rate A)^3)	#34: Interest Rate
	PV_{52}	\$16,189.04	PV of Timesheet Material Cost in Year 5 (All Workers) (PV_{52} =Material Cost in Year 5 C_{52} / (1+ Combined interest Rate A)^4)	#34: Interest Rate
		=========		
	PV_{t2}	\$89,030.18	Total PV of Timesheet Material Cost ($PV_{t2} = PV_{22} + PV_{22} + PV_{32} + PV_{42} + PV_{52}$)	

Table A-3: Estimated Material Cost of Paper-Based Timesheet

[*] All assumptions are explained in Appendix C

Step #4: Estimated Cost of Issuing Printed Paycheck				Assumption No *
Annual Cost	U_{13}	$0.40	Daily Paycheck Issuance Cost per Worker (U_{13} = Check Printing Cost and Bank Fees)	#13: Paper Check $
	C_{13}	$10,400.00	Paycheck Issuance Cost of Timesheets in Year 1 (All Workers) (C_{13} = Daily Cost U_{13} * No. of Working Days per Year N_{02})	
	C_{23}	$10,920.00	Paycheck Issuance Cost of Timesheets in Year 2 (All Workers) (C_{23} = Paycheck Issuance Cost in Year 1 C_{13} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{33}	$11,466.00	Paycheck Issuance Cost of Timesheets in Year 3 (All Workers) (C_{33} = Paycheck Issuance Cost in Year 2 C_{23} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{43}	$12,039.30	Paycheck Issuance Cost of Timesheets in Year 4 (All Workers) (C_{43} = Paycheck Issuance Cost in Year 3 C_{33} * (1+ Inflation Rate B))	#33: Inflation Rate
	C_{53}	$12,641.27	Paycheck Issuance Cost of Timesheets in Year 5 (All Workers) (C_{53} = Paycheck Issuance Cost in Year 4 C_{43} * (1+ Inflation Rate B))	#33: Inflation Rate
Present Value	PV_{13}	$10,400.00	PV of Timesheet Paycheck Issuance Cost in Year 1 (All Workers) ($PV_{13} = C_{13}$)	
	PV_{23}	$9,927.27	PV of Timesheet Paycheck Issuance Cost in Year 2 (All Workers) (PV_{23} =Paycheck Issuance Cost in Year 2 C_{23} / (1+ Combined interest Rate $A)^1$)	#34: Interest Rate
	PV_{33}	$9,024.79	PV of Timesheet Paycheck Issuance Cost in Year 3 (All Workers) (PV_{33} =Paycheck Issuance Cost in Year 3 C_{33} / (1+ Combined interest Rate $A)^2$)	#34: Interest Rate
	PV_{43}	$9,045.30	PV of Timesheet Paycheck Issuance Cost in Year 4 (All Workers) (PV_{43} =Paycheck Issuance Cost in Year 4 C_{43} / (1+ Combined interest Rate $A)^3$)	#34: Interest Rate
	PV_{53}	$8,634.15	PV of Timesheet Paycheck Issuance Cost in Year 5 (All Workers) (PV_{53} =Paycheck Issuance Cost in Year 5 C_{53} / (1+ Combined interest Rate $A)^4$)	#34: Interest Rate
		=========		
	PV_{t3}	$47,031.52	Total PV of Paycheck Issuance Cost ($PV_{t3} = PV_{33} + PV_{23} + PV_{33} + PV_{43} + PV_{53}$)	

Table A-4: Estimated Cost of Issuing Paper Paychecks

*All assumptions are explained in Appendix C

Step #5: Annual Cost of Timesheets (All Workers)				**Assumption No** *
Annual Cost	C_{1t}	\$151,604.96	Cost of Timesheets in Year 1 (All Workers) (C_{1t} = Labor Cost C_{11} + Material Cost C_{12} + Fees C_{13})	
	C_{2t}	\$159,185.21	Cost of Timesheets in Year 2 (All Workers) (C_{2t} = Labor Cost C_{21} + Material Cost C_{22} + Fees C_{23})	
	C_{3t}	\$167,144.47	Cost of Timesheets in Year 3 (All Workers) (C_{3t} = Labor Cost C_{31} + Material Cost C_{32} + Fees C_{33})	
	C_{4t}	\$175,501.69	Cost of Timesheets in Year 4 (All Workers) (C_{4t} = Labor Cost C_{41} + Material Cost C_{42} + Fees C_{43})	
	C_{5t}	\$184,276.78	Cost of Timesheets in Year 5 (All Workers) (C_{5t} = Labor Cost C_{51} + Material Cost C_{52} + Fees C_{53})	

Table A-5: Total Estimated Cost of Paper-Based Timesheet

*All assumptions are explained in Appendix C

Step #6: Present Value (PV) of Timesheet Costs (All Workers)				Assumption No *
Present Value	PV_{1t}	$151,604.96	PV of Timesheet Cost in Year 1 (All Workers) ($PV_{1t} = C_{1t}$)	
	PV_{2t}	$144,713.83	PV of Timesheet Cost in Year 2 (All Workers) (PV_{2t} =Cost in Year 2 C_{2t} / (1+ Combined interest Rate $A)^1$)	#34: Interest Rate
	PV_{3t}	$138,135.92	PV of Timesheet Cost in Year 3 (All Workers) (PV_{3t} =Cost in Year 3 C_{3t} / (1+ Combined interest Rate $A)^2$)	#34: Interest Rate
	PV_{4t}	$131,857.02	PV of Timesheet Cost in Year 4 (All Workers) (PV_{4t} =Cost in Year 4 C_{4t} / (1+ Combined interest Rate $A)^3$)	#34: Interest Rate
	PV_{5t}	$125,863.52	PV of Timesheet Cost in Year 5 (All Workers) (PV_{5t} =Cost in Year 5 C_{5t} / (1+ Combined interest Rate $A)^4$)	#34: Interest Rate
		==========		
	PV_t	$692,175.25	Total PV of Timesheet Cost ($PV_t = PV_{1t} + PV_{2t} + PV_{3t} + PV_{4t} + PV_{5t}$)	

Table A-6: Present Value of Paper-Based Timesheet Cost

*All assumptions are explained in Appendix C

Appendix B

The Cost Estimate of the Smart Card –Based Timesheet

The cost estimate of **the smart card-based timesheet (electronic method)** is prepared in 9 steps:

1) The time spent to prepare a worker's timesheet is estimated to be 6.45 minutes per day (see Table B-1).
2) The labor cost of timesheet preparation is estimated to be \$46,285.20, \$48,599.46, \$51,029.43, \$53,580.90 and \$56,259.95 in the first, second, third, fourth and fifth years respectively (see Table B-2).
3) The timesheet hardware cost is estimated to be \$33,350.00, \$5,071.50, \$7,987.61, and \$5,591.33 in the first, third, fourth and fifth years respectively (see Table B-3).
4) The timesheet software cost is estimated to be \$45,248.00 in the first year (see Table B-4).
5) The membership fee is estimated to be \$36,000.00, \$37,800.00, \$39,690.00, \$41,674.50 and \$43,758.23 in the first, second, third, fourth and fifth years respectively (see Table B-5).
6) The data archiving cost is estimated to be \$5,200.00, \$5,460.00, \$5,733.00, \$6,019.65 and \$6,320.63 in the first, second, third, fourth and fifth years respectively (see Table B-6).
7) For a 5-year project with 100 workers, the total cost of smart card-based timesheet is estimated to be \$166,083.20, \$91,859.46, \$101,523.93, \$109,262.67 and \$111,930.14 in the fifth years respectively (see Table B-7).

8) The Present Value (PV) of the smart card-based timesheet cost is estimated to be $492,036.32 (see Table B-8).

9) The cost savings of using the smart card-based timesheet is estimated to be $200,138.92 (see Table B-0).

Step #1: Estimated Daily Time Spent in Preparing Worker's Timesheet				**Assumption No [1]**
	N_{011}	4.00	Minutes Spent to Populate Electronic Timesheet	
	N_{012}	0.50	Minutes Spent to Review and Approve Timesheet	
	N_{20}	0.30	Minutes Spent to Update Financial System	#20: Financial System
	N_{013}	0.50	Minutes Spent to Handle Timesheet (Exchanging Cards)	
	N_{014}	0.15	Minutes Spent to Sign in and out at the Gate	
	N_{14}	0.50	Minutes Spent to Download Cash into Worker's Smart Card	#14: Loading Cash
	N_{15}	0.30	Minutes Spent to Reconcile with Payroll Department	#15: Reconcile
	N_{16}	0.10	Minutes Spent to Update Cost Database	#16: Update Database
	N_{17}	0.10	Minutes Spent to Download Cost and Activity Codes	#17: Coding Time
		=========		
	N_{01}	6.45	Total Minutes Spent per Worker $(N_{01} = N_{011} + N_{012} + N_{20} + N_{013} + N_{014} + N_{14} + N_{15} + N_{16} + N_{17})$	

(Figures are in minutes)

Table B-1: Estimated Time Spent to Prepare Smart Card-Based Timesheet

[1] All assumptions are explained in Appendix C

Step #2: Estimated Daily Time Spent in Preparing Worker's Timesheet				Assumption No *
Annual Cost	C_{11}	\$46,285.20	Labor Cost of Timesheets in Year 1 (All Workers) (C_{11} = Total Minutes N_{01} / 60* Hourly Rate U_{01} * No. of Crews N_{05} * Crew Size N_{04} * No. of Working Days per Year N_{02})	#01: Hourly Rate
	C_{21}	\$48,599.46	Labor Cost of Timesheets in Year 2 (All Workers) (C_{21} = Labor Cost in Year 1 C_{11} * (1+Inflation Rate $B)^1$)	#33: Inflation Rate
	C_{31}	\$51,029.43	Labor Cost of Timesheets in Year 3 (All Workers) (C_{31} = Labor Cost in Year 1 C_{11} * (1+Inflation Rate $B)^2$)	#33: Inflation Rate
	C_{41}	\$53,580.90	Labor Cost of Timesheets in Year 4 (All Workers) (C_{41} = Labor Cost in Year 1 C_{11} * (1+Inflation Rate $B)^3$)	#33: Inflation Rate
	C_{51}	\$56,259.95	Labor Cost of Timesheets in Year 5 (All Workers) (C_{51}= Labor Cost in Year 1 C_{11} * (1+Inflation Rate $B)^4$)	#33: Inflation Rate
	PV_{t1}	\$211,322.04	Present Value of Labor Cost (All Workers) (PV_{t1} = PV of Labor Costs for Years 1, 2, 3, 4, and 5)	#34: Interest Rate

Table B-2: Estimated Labor Cost to Prepare Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Step #3: Total Hardware Cost (All Workers)				Assumption No *
	$\boldsymbol{H_{11}}$	\$2,000.00	Cost of IC Chip Cards in Year 1 ($\boldsymbol{H_{11}}$ = Smart Card Unit Cost $\boldsymbol{U_{21}}$ * Crew Size $\boldsymbol{N_{04}}$ *No. of Crews $\boldsymbol{N_{05}}$)	#21: IC Chip Card \$
	$\boldsymbol{H_{12}}$	\$6,000.00	Cost of Card Readers in Year 1 ($\boldsymbol{H_{12}}$ = Card Reader Unit Cost $\boldsymbol{U_{26}}$ * Crew Size $\boldsymbol{N_{04}}$ *No. of Crews $\boldsymbol{N_{05}}$)	#26: Pocket Reader \$
	$\boldsymbol{H_{42}}$	\$6,945.75	Replacement Cost of Card Readers in Year 4 ($\boldsymbol{H_{42}}$ = Cost of Card Reader in Year 1 $\boldsymbol{H_{12}}$ * $(1+\text{Inflation Rate } \boldsymbol{B})^3$)	#26: Pocket Reader \$
	$\boldsymbol{H_{13}}$	\$1,000.00	Cost of Double-Slot Card Readers in Year 1 ($\boldsymbol{H_{13}}$ = Double-Slot Reader Unit Cost $\boldsymbol{U_{25}}$ * No. of Crews $\boldsymbol{N_{05}}$)	#25: Double-Slot Card Reader \$
	$\boldsymbol{H_{33}}$	\$1,102.50	Replacement Cost of Double-Slot Card Readers in Year 3 ($\boldsymbol{H_{33}}$ = Cost of Double-Slot Readers in Year 1 $\boldsymbol{H_{13}}$ * $(1+\text{Inflation Rate } \boldsymbol{B})^2$)	#25: Double-Slot Card Reader \$
	$\boldsymbol{H_{53}}$	\$1,215.51	Replacement Cost of Double-Slot Readers in Year 5 ($\boldsymbol{H_{53}}$ = Cost of Double-Slot Readers in Year 1 $\boldsymbol{H_{13}}$ * $(1+\text{Inflation Rate } \boldsymbol{B})^4$)	#25: Double-Slot Card Reader \$
	$\boldsymbol{H_{14}}$	\$3,000.00	Cost of Site Terminals in Year 1 ($\boldsymbol{H_{14}}$ = Site Terminal Unit Cost $\boldsymbol{U_{24}}$ * No. of Crews $\boldsymbol{N_{05}}$)	#24: Terminal \$
	$\boldsymbol{H_{34}}$	\$3,307.50	Replacement Cost of Site Terminals in Year 3 ($\boldsymbol{H_{34}}$ = Cost of Site Terminals in Year 1 $\boldsymbol{H_{14}}$ * $(1+\text{Inflation Rate } \boldsymbol{B})^2$)	#24: Terminal \$
	$\boldsymbol{H_{54}}$	\$3,646.52	Replacement Cost of Site Terminals in Year 5 ($\boldsymbol{H_{54}}$ = Cost of Site Terminals in Year 1 $\boldsymbol{H_{14}}$ * $(1+\text{Inflation Rate } \boldsymbol{B})^4$)	#24: Terminal \$
	$\boldsymbol{H_{15}}$	\$2,000.00	Cost of Smart Phones in Year 1 ($\boldsymbol{H_{15}}$ = Smart Phone Unit Cost $\boldsymbol{U_{23}}$ * No. of Crews $\boldsymbol{N_{05}}$)	#23: Phone \$
	$\boldsymbol{H_{16}}$	\$15,000.00	Cost of Smart PCs in Year 1 ($\boldsymbol{H_{16}}$ = Smart PC Unit Cost $\boldsymbol{U_{22}}$ * No. of Crews $\boldsymbol{N_{05}}$)	#22: PC \$

Table B-3: Estimated Hardware Cost of Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Step #3: Total Hardware Cost (All Workers)				**Assumption No***
	H_{17}	\$2,900.00	Testing and Installation Cost in Year 1 (= 10% of Cost of Hardware in Year 1) ($H_{17} = 0.10 * (H_{11}+H_{12}+H_{13}+H_{14}+H_{15}+H_{16})$)	
	H_{37}	\$441.00	Testing and Installation Cost in Year 3 (= 10% of Cost of Hardware in Year 3) ($H_{37} = 0.10 * (H_{33}+H_{34})$)	
	H_{47}	\$694.58	Testing and Installation Cost in Year 4 (= 10% of Cost of Hardware in Year 4) ($H_{47} = 0.10 * H_{42}$)	
	H_{57}	\$486.20	Testing and Installation Cost in Year 5 (= 10% of Cost of Hardware in Year 5) ($H_{57} = 0.10 * (H_{53}+H_{54})$)	
	H_{18}	\$1,450.00	Cost of Hardware Damage in Year 1 (= 5% of Cost of Hardware in Year 1) ($H_{16} = 0.05 * (H_{11}+H_{12}+H_{13}+H_{14}+H_{15}+H_{16})$)	
	H_{38}	\$220.50	Cost of Hardware Damage in Year 3 (= 5% of Cost of Hardware in Year 3) ($H_{38} = 0.05 * (H_{33}+H_{34})$)	
	H_{48}	\$347.29	Cost of Hardware Damage in Year 4 (= 5% of Cost of Hardware in Year 4) ($H_{48} = 0.05 * H_{42}$)	
	H_{58}	\$243.10	Cost of Hardware Damage in Year 5 (= 5% of Cost of Hardware in Year 5) ($H_{58} = 0.05 * (H_{53}+H_{54})$)	

Table B-3: Estimated Hardware Cost of Smart Card-Based Timesheet (Continued)

* All assumptions are explained in Appendix C

Step #3: Total Hardware Cost (All Workers)				Assumption No*
Annual Cost	C_{12}	$33,350.00	Total Hardware Cost in Year 1 (= Total Hardware, Installation and Damage Costs in Year 1) ($C_{12} = H_{11}+H_{12}+H_{13}+H_{14}+H_{15}+H_{16}+H_{17}+H_{18}$)	
	C_{32}	$5,071.50	Total Hardware Cost in Year 3 (= Total Hardware, Installation and Damage Costs in Year 3) ($C_{32} = H_{33}+H_{34}+H_{37}+H_{38}$)	
	C_{42}	$7,987.61	Total Hardware Cost in Year 4 (= Total Hardware, Installation and Damage Costs in Year 4) ($C_{42} = H_{42}+H_{47}+H_{48}$)	
	C_{52}	$5,591.33	Total Hardware Cost in Year 5 (= Total Hardware, Installation and Damage Costs in Year 5) ($C_{52} = H_{53}+H_{54}+H_{57}+H_{58}$)	
	PV_{t2}	$47,361.49	Present Value of Total Hardware Costs (PV_{t2} = PV of Hardware Costs for Years 1, 3, 4, and 5)	#34: Interest Rate

Table B-3: Estimated Hardware Cost of Smart Card-Based Timesheet (Continued)

* All assumptions are explained in Appendix C

Step #4: Total Software Cost (All Workers)				**Assumption No** *
Annual Cost	S_{11}	$20,000.00	Systems Integration and Solution Architecture Cost in Year 1	#27: System Integration
	S_{12}	$2,000.00	Timesheet Application Development Cost in Year 1	#28: Application $
	S_{13}	$5,000.00	Registration, License and Certificate Fees in Year 1	#29: Initial Fee
	S_{14}	$13,248.00	Smart Card Program Training Cost in Year 1	#30: Training $
	S_{15}	$5,000.00	Implementation and Deployment Cost in Year 1	#32: Deployment $
		=========		
	C_{13}	$45,248.00	Total Software Cost in Year 1 (C_{13} = System Integration S_{11} + Application S_{12} + Fees S_{13} + Training S_{14} + Implementation S_{15})	
	PV_{13}	$45,248.00	Present Value of Total Software Cost (PV_{13} =Software Cost in Year 1 C_{13})	#34: Interest Rate

Table B-4: Estimated Software Cost of Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Step #5: Total Membership Fees (All Workers)				Assumption No*
Annual Cost	C_{14}	$36,000.00	Membership Fee in Year 1 (C_{14} = Monthly Fee U_{31} * 12 months * Crew Size N_{04} *No. of Crews N_{05})	#31: Membership $
	C_{24}	$37,800.00	Membership Fee in Year 2 (C_{24} = Membership Fee in Year 1 C_{14} * (1+Inflation Rate $B)^1$)	#33: Inflation Rate
	C_{34}	$39,690.00	Membership Fee in Year 3 (C_{34} = Membership Fee in Year 1 C_{14} * (1+Inflation Rate $B)^2$)	#33: Inflation Rate
	C_{44}	$41,674.50	Membership Fee in Year 4 (C_{44} = Membership Fee in Year 1 C_{14} * (1+Inflation Rate $B)^3$)	#33: Inflation Rate
	C_{54}	$43,758.23	Membership Fee in Year 5 (C_{54} = Membership Fee in Year 1 C_{14} * (1+Inflation Rate $B)^4$)	#33: Inflation Rate
	PV_{14}	$164,363.41	Present Value of Total Membership Fee (PV_{14} = PV of Membership Fee for Years 1, 2, 3, 4, and 5)	#34: Interest Rate

Table B-5: Estimated Membership Fee of Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Step #6: Total Cost of Data Archiving (All Workers)				Assumption No *
Annual Cost	C_{1S}	$5,200.00	Cost of Data Archiving in Year 1 (C_{1S} = Daily Data Archiving Cost U_{19} * No. of Working Days per Year N_{02})	#19: Electronic Archive $
	C_{2S}	$5,460.00	Cost of Data Archiving in Year 2 (C_{2S} = Cost of Data Archiving in Year 1 C_{1S}* (1+Inflation Rate B)^1)	#33: Inflation Rate
	C_{3S}	$5,733.00	Cost of Data Archiving in Year 3 (C_{3S} = Cost of Data Archiving in Year 1 C_{1S}* (1+Inflation Rate B)^2)	#33: Inflation Rate
	C_{4S}	$6,019.65	Cost of Data Archiving in Year 4 (C_{4S} = Cost of Data Archiving in Year 1 C_{1S}* (1+Inflation Rate B)^3)	#33: Inflation Rate
	C_{5S}	$6,320.63	Cost of Data Archiving in Year 5 (C_{5S} = Cost of Data Archiving in Year 1 C_{1S}* (1+Inflation Rate B)^4)	#33: Inflation Rate
	PV_{tS}	$23,741.38	Present Value of Total Data Archiving Cost (5 Years) (PV_{tS} = PV of Data Archiving Costs for Years 1, 2, 3, 4, and 5)	#34: Interest Rate

Table B-6: Estimated Data Archiving Cost of Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Step #7: Annual Cost of Timesheets (All Workers)				Assumption No *
Annual Cost	C_{1t}	$166,083.20	Total Cost of Timesheets in Year 1 (All Workers) (C_{1t} = Labor C_{11}+ Hardware C_{12}+ Software C_{13}+ Membership C_{14}+ Archiving C_{15})	
	C_{2t}	$91,859.46	Total Cost of Timesheets in Year 2 (All Workers) (C_{2t} = Labor C_{21}+ Hardware C_{22}+ Software C_{23}+ Membership C_{24}+ Archiving C_{25})	
	C_{3t}	$101,523.93	Total Cost of Timesheets in Year 3 (All Workers) (C_{3t} = Labor C_{31}+ Hardware C_{32}+ Software C_{33}+ Membership C_{34}+ Archiving C_{35})	
	C_{4t}	$109,262.67	Total Cost of Timesheets in Year 4 (All Workers) (C_{4t} = Labor C_{41}+ Hardware C_{42}+ Software C_{43}+ Membership C_{44}+ Archiving C_{45})	
	C_{5t}	$111,930.14	Total Cost of Timesheets in Year 5 (All Workers) (C_{5t} = Labor C_{51}+ Hardware C_{52}+ Software C_{53}+ Membership C_{54}+ Archiving C_{55})	

Table B-7: Estimated Total Cost of Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Step #8: Present Value (PV) of Timesheet Costs (All Workers)				Assumption No *
Present Value	PV_{1t}	$166,083.20	PV of Timesheet Cost in Year 1 (All Workers) (PV_{1t} = Timesheet Cost in Year 1 C_{1t} (All Workers))	#34: Interest Rate
	PV_{2t}	$83,508.60	PV of Timesheet Cost in Year 2 (All Workers) (PV_{2t} =Total Cost in Year 2 C_{2t} / (1+ Combined Interest Rate $A)^1$)	#34: Interest Rate
	PV_{3t}	$83,904.08	PV of Timesheet Cost in Year 3 (All Workers) (PV_{3t} =Total Cost in Year 3 C_{3t} / (1+ Combined Interest Rate $A)^2$)	#34: Interest Rate
	PV_{4t}	$82,090.66	PV of Timesheet Cost in Year 4 (All Workers) (PV_{4t} =Total Cost in Year 4 C_{4t} / (1+ Combined Interest Rate $A)^3$)	#34: Interest Rate
	PV_{5t}	$76,449.79	PV of Timesheet Cost in Year 5 (All Workers) (PV_{5t} =Total Cost in Year 5 C_{5t} / (1+ Combined Interest Rate $A)^4$)	#34: Interest Rate
		==========		
	PV_t	$492,036.32	Total Present Value of the Smart Card-Based Timesheet Cost ($PV_t = PV_{1t} + PV_{2t} + PV_{3t} + PV_{4t} + PV_{5t}$)	

Table B-8: Present Value of Smart Card-Based Timesheet Cost

* All assumptions are explained in Appendix C

Step #1: Cost Savings of Using the Smart Card-Based Timesheet (Electronic Method)				Assumption No*
	PV_{var}	\$200,138.92	Cost Variance between Manual and Electronic Methods ($PV_{var} = PV_t$ *Manual* - PV_t *Electronic*)	
	PV_{Ratio}	71%	Cost Ratio between Manual and Electronic Methods ($PV_{Ratio} = PV_t$ *Electronic* / PV_t *Manual*)	
	$\%PV_{var}$	29%	Percentage of Cost Savings of Using the Electronic Method ($\%PV_{var} = (PV_t$ *Manual* - PV_t *Electronic*)/ PV_t *Manual*)	

Table B-9: Cost Savings of Using the Smart Card-Based Timesheet

* All assumptions are explained in Appendix C

Appendix C

The Calculation Notes of the Timesheet Cost Estimates

Assumption #1: According to the U.S. Bureau of Labor Statistics, the average hourly earnings of U.S. non-government construction workers in 1998 is $16.56 which represents the hourly rate (U_{01}) in estimating the timesheet labor cost C_{i1} as shown in Equation C.1.

$$\underset{i=1 \xrightarrow{n} 5}{C_{i1}} = \frac{N_{01}}{60} \times N_{04} \times N_{05} \times N_{02} \times U_{01} \times (1+B)^{i-1}$$

Equation C.1

Where:

C_{i1} is the labor cost in year i.

n is the number of years of the project duration (see assumption #3).

N_{01} is the number of minutes spent to prepare and complete a worker's timesheet.

N_{02} is the number working days per year (see assumption #2).

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

U_{01} is the hourly labor rate, which is assumed to be $16.56.

B is the inflation rate (see assumption #33).

Assumption #2: the number of working days per week is 5 days. The estimated number of working days per month is 21.7 days, which equals 52 weeks multiplied by 5 days per week divided by 12 months. The estimated number of working days per year (N_{02}) is 260 days, which equals 5 days per week multiplied by 52 weeks. The number of working weeks per year is assumed to be 52 weeks and the estimated number of working weeks per month is 4.33 weeks, which equals 52 weeks divided by 12 months.

Assumption #3: The project duration (***n***) is assumed to be 5 years. Therefore, the total number of working weeks per project is assumed to be 260weeks, which equals the project duration in years multiplied by 52 weeks. The total number of working days per project is 1,300 working days, which equals project duration in years multiplied by 52 weeks multiplied by 5 working days per week.

Assumption #4: the total number of workers per crew (N_{04}) is assumed to be 10 workers including the foreman of the crew.

Assumption #5: the total number of crews (N_{05}) per project or site is assumed to be 10 crews. The estimated number of workers per project or site is 100 workers which equals number of workers per crew multiplied by number of crews per project or site.

Assumption #6: the estimated time spent (N_{06}) the foreman to complete a worker's timesheet is 6 minutes per day, or one hour per crew per day, according Equation C.2.

$$N_{06} = \sum_{i=1 \longrightarrow 6} N_{06i} = \left[\begin{array}{c:c:c:c:c:c} N061 & N062 & N063 & N064 & N065 & N066 \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ 20 & 15 & 10 & 5 & 5 & 5 \end{array} \right]_{(1x6)}$$

(Figures are in minutes)

Equation C.2

Where:

N_{061} is the time spent to populate a crew's timesheets (20 minutes).

N_{062} is the time spent to verify crew's timesheets with the timekeeper (15 minutes).

N_{063} is the time spent to code crew's timesheets with activity and cost codes (10 minutes).

N_{064} is the time spent to report crew status (e.g. absence and dismissals) (5 minutes).

N_{065} is the time spent to prepare crew overtime reports (if required) (5 minutes).

N_{066} is the time spent to add remarks (e.g. penalty, bonus, illness, or injury) (5 minutes).

Assumption #7: foremen submitted daily timesheets of their crews to the site superintendent for approval. The estimated time spent by site superintendent to review and approve daily timesheets for all crews is 30 minutes. The estimated time spent (N_{07}) to review and approve a worker's timesheet is 0.3 minute which equals the time spent by superintendent to approve timesheets divided by the number of project workers.

Assumption #8: the estimated time spent by a foreman to handle timesheets is 25 minutes per crew, which includes 5 minutes to prepare blank forms, 15 minutes to photocopy completed timesheets, and 5 minutes to distribute and submit timesheets to payroll department. The estimated time spent (N_{08}) to handle a worker's timesheet is 2.5 minutes which equals the time spent to handle a crew's timesheets divided by the number of workers per crew.

Assumption #9: each project has a fulltime timekeeper to track worker's time spent on the job site using the brass tags as basis for the daily attendance report. The estimated time spent (N_{09}) by timekeeper to track a worker's attendance per day is 4.8 minutes which equals 8 working hours spent by the timekeeper divided by the number of project workers.

Assumption #10: the payroll cycle is assumed to be a weekly cycle. The estimated time spent to handle weekly paychecks is 35 minutes, which includes 30 minutes spent by payroll department to print and verify paychecks and 5 minutes spent by foreman to pickup and deliver paychecks to workers. The estimated time spent (N_{10}) to handle a worker's paycheck is 0.7 minutes per day which equals the total minutes spent weekly to prepare and handle a crew's paychecks divided by the number of days per week divided by the number of workers per crew.

Assumption #11: production and reproduction cost of timesheet depends on the administrative requirements outlined by the company's guidelines or the project manager. In this cost model, it is assumed that foreman uses official form of timesheets with serial numbers. The estimated paper cost of a single sheet is assumed to be $0.25 per original form and $0.10 per photocopied form. Daily timesheet photocopies are distributed to foreman, timekeeper, payroll department, cost controller and human resources. The total paper cost (U_{11}) of a worker's timesheet is estimated to be $0.75 per day which equals the cost of an original form added to the cost of 5 photocopied sheets.

Assumption #12: the estimated time spent by the payroll department to process a weekly payroll cycle is 8 hours, which includes inputting timesheets into the payroll system, and processing and validating paychecks. The number of minutes spent (N_{12}) to process payroll per worker is 0.96 minutes per day, which equals 8 hours multiplied by 60 minutes divided by the total number of project workers divided by the number of days per week.

Assumption #13: cost of printing a worker's paycheck including the bank fee is assumed to be $2.00 per week. The estimated cost (U_{13}) of issuing a worker's paycheck is $0.40 per day, which equals the cost per week divided by 5 days.

Assumption #14: time spent by a foreman to download electronic cash into workers' smart cards is assumed to be 5.00 minutes per week. The time spent (N_{14}) to download electronic cash per worker is 0.5 minutes per day, which equals 0.5 minutes per crew divided by 5 working days per week divided by the number of workers per crew.

Assumption #15: time spent to transfer transactions on the foreman's card to the payroll database is assumed to be 3 minutes per day. The estimated number of minutes spent (N_{15}) to reconcile a foreman's card per worker is 0.3 minutes per day which equals the time spent to reconcile foreman's card per day divided by the number of workers per crew.

Assumption #16: time spent to exchange data between the foreman's card and the cost database is assumed to be 1 minute per day. The number of minutes spent (N_{16}) to update the cost database per worker is 0.10 minutes per day, which equals the time spent to update the cost database per day divided by the number of workers per crew.

Assumption #17: time spent by foreman to download activity and cost codes table into a smart card is assumed to be 1 minute per day. The number of minutes spent (N_{17}) to download codes per worker is 0.10 minutes per day, which equals the time spent to download codes per day divided by number of workers per crew.

Assumption #18: the estimated time (N_{18}) to archive paper timesheets is assumed to be 2 hours per day. The estimated value of N_{18} is 1.2 minutes per day, which equals the time spent to archive paper timesheets divided by total number of workers per project as shown in Equations C.3 and C.4.

$$N_{18} = \left(\sum_{i=1 \xrightarrow{n} 5} N_{18i} \right)_{(1x5)} \times \left(\frac{N_{02}}{(N_{04} \times N_{05})} \right)$$

Equation C.3

$$\sum_{i=1 \xrightarrow{n} 5} N_{18i} = \left[\begin{array}{c:c:c:c:c} N_{181} & N_{182} & N_{183} & N_{184} & N_{185} \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ 50 & 15 & 25 & 15 & 15 \end{array}\right]_{(1x5)}$$

(Figures are in minutes)

Equation C.4

Where:

N_{181} is the time spent by foreman to archive timesheet reports (5 minutes).

N_{182} is the time spent by timekeeper to archive attendance report is15 minutes).

N_{183} is the time spent by payroll department to archive payroll printouts (25 minutes).

N_{184} is the time spent by HR department to archive time off report (15 minutes).

N_{185} is the time spent by cost controller to archive labor cost reports (15 minutes).

N_{02} is the number of working days per year (see assumption #2).

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

n is the number of years of the project duration (see assumption #3).

Assumption #19: the size of project data generated by smart card transactions is assumed to be 1000 Mbytes per day. The estimated cost to archive 1000 Mbytes of data is \$20.00. The estimated cost (U_{19}) to archive data generated by a worker's card is \$0.20 per day. U_{19} equals the daily cost of archiving project data divided by number of workers per project. The annual cost (C_{i5}) to archive data generated by all workers is calculated using Equation C.5.

$$\underset{i=1 \xrightarrow{n} 5}{C_{i5}} = N_{04} \times N_{05} \times U_{19} \times N_{02} \times (1+B)^{i-1}$$

Equation C.5

Where:

C_{i5} is the data archiving cost in year i.

N_{02} is the number of working days per year (see assumption #2).

U_{19} is the estimated cost to archive data generated by worker's card.

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Assumption #20: time spent to retrieve terminal-stored transactions and consolidate the data into the project financial database is assumed to be 30 minutes per day. The total number of minutes spent (N_{20}) to update the financial database per worker is 0.30 minutes per day which equals the time spent to retrieve data from terminals divided by the number of workers per project.

Assumption #21: the estimated cost (U_{21}) of a smart card with IC chip and contactless interface is $20.00. The number ($N_{21}$) of smart cards assigned to each worker is assumed to be one. The smart card lifetime is assumed to be 10 years, therefore, there is no smart card replacement cost during the project. The total number of smart cards required for the project is 100 units. The annual smart card cost (H_{i1}) for the project is calculated using Equation C.6.

$$\underset{i=1 \xrightarrow{n} 5}{H_{i1}} = N_{21} \times U_{21} \times N_{04} \times N_{05} \times R_{21i} \times (1+B)^{i-1}$$

Equation C.6

Where:

H_{i1} is the smart card cost in year i.

N_{21} is the number of smart cards assigned to each worker.

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

U_{21} is the smart card unit cost. U_{21} is assumed to be \$20.00.

R_{21i} is the smart card replacement factor for year i where R_{211}, R_{212}, R_{213}, R_{214}, R_{215} are assumed to be 1, 0, 0, 0 and 0 for the first, second, third, fourth and fifth year respectively.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

The card damage and testing costs are assumed to be 5.0% and 10.0% of the smart card cost.

Assumption #22: the estimated cost (U_{22}) of a personal computer with smart card reader is \$1,500.00. The number (N_{22}) of personal computers assigned to each crew is assumed to be one. The personal computer lifetime is assumed to be 5 years, therefore, there is no personal computer replacement cost during the project. The total number of personal computer sets required for the project is 10 sets. The personal computer cost (H_{i6}) for the project is calculated using Equation C.7.

$$\underset{i=1 \xrightarrow{n} 5}{H_{i6}} = N_{22} \times U_{22} \times N_{05} \times R_{22i} \times (1+B)^{i-1}$$

Equation C.7

Where:

H_{i6} is the personal computer cost in year i.

N_{22} is the number of personal computers assigned to each crew.

N_{05} is the number of crews per project (see assumption #5).

U_{22} is the personal computer unit cost, which is assumed to be \$1,500.00.

R_{22i} is the personal computer replacement factor for year i where R_{221}, R_{222}, R_{223}, R_{224}, R_{225} are assumed to be 1, 0, 0, 0 and 0 for the first, second, third, fourth and fifth year respectively.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Some of the personal computer hardware parts would be replaced due to wear and tear or upgrade requirements. The damage and testing-installation costs are assumed to be 5.0% and 10.0% of the personal computer hardware cost.

Assumption #23: the estimated cost (U_{23}) of a phone with smart card reader is \$200.00. The number (N_{23}) of smart phones assigned to each crew is assumed to be one. The smart phone lifetime is assumed to be 5 years, therefore, there is no smart phone replacement cost during the project. The total number of smart phone sets required is 10 sets. The smart phone cost (H_{i5}) for the project is calculated using Equation C.8.

$$\underset{i=1 \xrightarrow{n} 5}{H_{i5}} = N_{23} \times U_{23} \times N_{05} \times R_{23i} \times (1+B)^{i-1}$$

Equation C.8

Where:

H_{i5} is the smart phone cost in year i.

N_{23} is the number of smart phones assigned to each crew.

N_{05} is the number of crews per project (see assumption #5).

U_{23} is the smart phone unit cost, which is assumed to be \$200.00.

R_{23i} is the smart phone replacement factor for year i where R_{231}, R_{232}, R_{233}, R_{234}, R_{235} are assumed to be 1, 0, 0, 0 and 0 for the first, second, third, fourth and fifth year respectively.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Some of the smart phone hardware parts would be replaced due to wear and tear or upgrade requirements. The damage and testing-installation costs are assumed to be 5.0% and 10.0% of the smart phone hardware cost.

Assumption #24: the estimated cost (U_{24}) of a site terminal with smart card reader is \$300.00. The number (N_{24}) of site terminals assigned to each crew is assumed to be one. The site terminal lifetime is assumed to be 2 years, therefore, the number of site terminals required are 10, 0, 10, 0 and 10 units for the first, second, third, fourth and fifth year respectively. The site terminal cost (H_{i4}) for the project is calculated using Equation C.9.

$$\underset{i=1 \xrightarrow{n} 5}{H_{i4}} = N_{24} \times U_{24} \times N_{05} \times R_{24i} \times (1+B)^{i-1}$$

Equation C.9

Where:

H_{i4} is the site terminal cost in year i.

N_{24} is the number of site terminals assigned to each crew.

N_{05} is the number of crews per project (see assumption #5).

U_{24} is the site terminal unit cost, which is assumed to be \$300.00.

R_{24i} is the site terminal replacement factor for year i where R_{241}, R_{242}, R_{243}, R_{244}, R_{245} are assumed to be 1, 0, 1, 0 and 1 for the first, second, third, fourth and fifth year respectively.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Some of the site terminal hardware parts would be replaced due to wear and tear or upgrade requirements. The damage and testing-installation costs are assumed to be 5.0% and 10.0% of the site terminal hardware cost.

Assumption #25: the estimated cost (U_{25}) of a double-slot smart card reader is $100.00. The number ($N_{25}$) of double-slot smart card readers assigned to each crew is assumed to be one. The double-slot card reader lifetime is assumed to be 2 years, therefore, the number of double-slot card readers required are 10, 0, 10, 0 and 10 units for the first, second, third, fourth and fifth year respectively. The double-slot card reader cost (H_{i3}) for the project is calculated using Equation C.10.

$$\underset{i=1 \xrightarrow{n} 5}{H_{i3}} = N_{25} \times U_{25} \times N_{05} \times R_{25i} \times (1+B)^{i-1}$$

Equation C.10

Where:

H_{i3} is the double-slot card reader cost in year i.

N_{25} is the number of double-slot card readers assigned to each crew.

N_{05} is the number of crews per project (see assumption #5).

U_{25} is the double-slot reader unit cost, which is assumed to be $100.00.

R_{25i} is the double-slot card reader replacement factor for year i where R_{251}, R_{252}, R_{253}, R_{254}, R_{255} are assumed to be 1, 0, 1, 0 and 1 for the first, second, third, fourth and fifth year respectively.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Some of the double-slot reader hardware parts would be replaced due to wear and tear or upgrade requirements. The damage and testing-installation costs are assumed to be 5.0% and 10.0% of the double-slot card reader hardware cost.

Assumption #26: the estimated cost (U_{26}) of a smart card reader is $60.00. The number ($N_{26}$) of card readers assigned to each worker is assumed to be one. The card reader lifetime is assumed to be 3 years, therefore, the number of card readers required are 10, 0, 0, 10 and 0 units for the first, second, third, fourth and fifth year respectively. The card reader cost (H_{i2}) for the project is calculated using Equation C.11.

$$\underset{i=1 \xrightarrow{n} 5}{H_{i2}} = N_{26} \times U_{26} \times N_{04} \times N_{05} \times R_{26i} \times (1+B)^{i-1}$$

Equation C.11

Where:

H_{i2} is the card reader cost in year i.

N_{26} is the number of card readers assigned to each worker.

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

U_{26} is the card reader unit cost, which is assumed to be $60.00.

R_{26i} is the smart card replacement factor for year i where R_{261}, R_{262}, R_{263}, R_{264}, R_{265} are assumed to be 1, 0, 0, 1 and 0 for the first, second, third, fourth and fifth year respectively.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Some of the card reader hardware parts would be replaced due to wear and tear or upgrade requirements. The damage and testing-installation costs are assumed to be 5.0% and 10.0% of the card reader hardware cost.

Assumption #27: smart card systems integration cost (S_{i1}) is assumed to be $20,000.00 for the entire project. The (S_{i1}) is assumed to be paid at the beginning of the project as shown in Equation C.12.

$$\underset{1 \xrightarrow{n} 5}{S_{i1}} = \begin{bmatrix} S_{11} & S_{21} & S_{31} & S_{41} & S_{51} \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ \$20.0 & \$0.0 & \$0.0 & \$0.0 & \$0.0 \end{bmatrix}_{(1x5)}$$

Equation C.12

(Figures are in thousands of $)

Where

S_{11}, S_{21}, S_{31}, S_{41}, S_{51} are the system integration costs for the first, second, third, fourth and fifth years respectively.

n is the number of years of the project duration (see assumption #3).

Assumption #28: smart card timesheet and labor payment application development cost (S_{i2}) is assumed to be $2,000.00 for the entire project. The S_{i2} is to be paid during the first year of the project as shown in Equation C.13.

$$\underset{1 \xrightarrow{n} 5}{S_{i2}} = \left[\begin{array}{c:c:c:c:c} S_{12} & S_{22} & S_{32} & S_{42} & S_{52} \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ \$2.0 & \$0.0 & \$0.0 & \$0.0 & \$0.0 \end{array} \right]_{(1x5)}$$

Equation C.13

(Figures are in thousands of $)

Where

S_{12}, S_{22}, S_{32}, S_{42}, S_{52} are the application development costs for the first, second, third, fourth and fifth years respectively.

n is the number of years of the project duration (see assumption #3).

Assumption #29: The initial fee (U_{29}) per worker is assumed to be $50.00 (including registration, license and certificate charges). The initial fee (S_{13}) for all workers is to be paid during the first year of the project. S_{13} is calculated using Equation C.14.

$$S_{13} = U_{29} \times N_{04} \times N_{05} \times N_{21}$$

Equation C.14

Where:

S_{13} is the initial fee in the first year.

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

N_{21} is the number of smart cards assigned to each worker.

U_{29} is the initial fee per worker, which is assumed to be $50.00.

Assumption #30: time spent (N_{30}) by workers in training is assumed to be 8 hours which includes 4 hours for learning smart card applications and 4 hours for on-hand practice with smart card hardware. The estimated training cost (S_{14}) for all workers is to be paid during the first year of the project. S_{14} is calculated using Equation C.15.

$$S_{14} = N_{30} \times U_{01} \times N_{04} \times N_{05}$$

Equation C.15

Where:

S_{14} is the training cost during the first year.

N_{30} is the number of training hours per worker.

N_{04} is the number workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

U_{01} is the labor hourly rate (see assumption #1).

Workers who are already received smart card training do not incur new training costs when they are transferred to a different site.

Assumption #31: smart card monthly membership fee (U_{31}) is assumed to be \$30.00 per worker. The total fee (C_{i4}) for the project is calculated using Equation C.16.

$$\underset{i=1 \xrightarrow{n} 5}{C_{i4}} = U_{31} \times N_{04} \times N_{05} \times 12 \times (1+B)^{i-1}$$

Equation C.16

Where:

C_{i4} is the membership fee in year i where C_{14}, C_{24}, C_{34}, C_{44}, C_{54} are the annual membership fee for the first, second, third, fourth and fifth year respectively.

N_{04} is the number of workers per crew (see assumption #4).

N_{05} is the number of crews per project (see assumption #5).

U_{31} is the monthly membership fee per worker, which is assumed to be $30.00.

B is the inflation rate (see assumption #33).

n is the number of years of the project duration (see assumption #3).

Assumption #32: the estimated implementation and deployment cost S_{15} is $15,000.00 based on the following assumptions:

- Three smart card consultants are hired to launch the application on construction site.
- Smart card consultants spend 5 days on site to facilitate the program implementation.
- The smart card consultant labor rate is $1,000.00 per day.

The implementation and deployment cost (S_{15}) is to be paid during the first year of the project.

Assumption #33: the inflation rate (B) is assumed to be 5.0%.

Assumption #34: The combined interest rated (A) is assumed to be 10% which represents the discount rate for time value of money factor. The value of A is calculated using Equation C.17.

$$A = B + C + B \times C$$

Equation C.17

Where:

B is the inflation rate (5%)

C is the real interest rate, which is assumed to be 5%.