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Memory Card Applications For Urban Bus Transit Systems

U.S. Department
of Transportation

**Urban Mass
Transportation
Administration**

Office of Technical Assistance
Office of Bus and Paratransit Systems

Prepared by:
Battelle Columbus Laboratories

ATE Management & Service Co.

November 1984

Technical Assistance — an UMTA Program

UMTA-IT-06-0219-12-1

on

MEMORY CARD APPLICATIONS FOR
URBAN BUS TRANSIT SYSTEMS

to

DEPARTMENT OF TRANSPORTATION/UMTA

Office of Bus and Data Transit Systems

NOVEMBER 1984

Prepared
by

BATTELLE
Columbus Laboratories

With Assistance
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16. Abstract

This report presents a state-of-the-art analysis of smart card/memory card technology and potential applications within transit operations, specifically fare collection and maintenance recordkeeping. Two specific scenarios for the use of smart card/memory card technology are provided for fare collection with a broad spectrum of potential uses described for maintenance recordkeeping.

The conclusions and recommendations presented within the report were developed by Battelle's research staff with technical support on transit operating provided by ATE.

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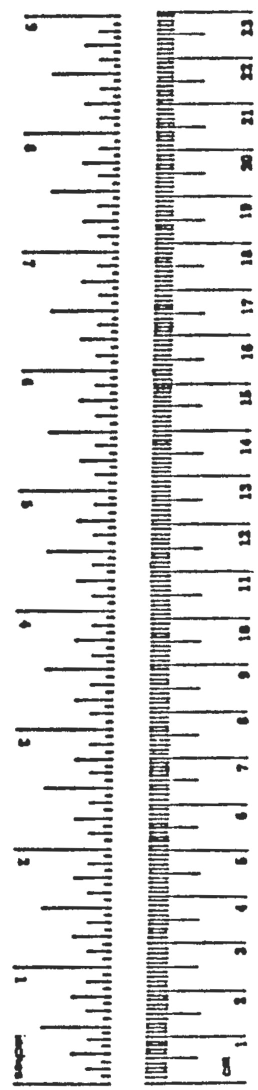
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

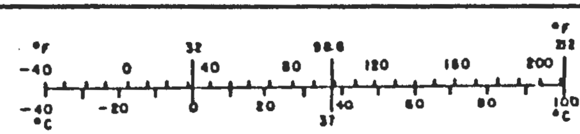
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10.286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

This report follows a six month effort by Battelle's team of MC/SC and payment systems experts, combined with ATE's technical assistance. On-site visits and interviews have been utilized for data collection purposes at two transit properties. Numerous reports on fare collection and the maintenance functions have also been used throughout the study. Finally, ATE has provided valuable information and expertise in the study through detailed documentation and interviews. ATE provides many years of experience in present and future fare collection system configurations and trends.

This report has explored several possibilities for the application of MC/SC technology in the bus transit industry, specifically fare collection and maintenance/recordkeeping. While the design scenarios presented within the body of the report are all deemed to be technically feasible, the conceptual design of these systems cannot be fully and accurately assessed until detailed specifications are developed in conjunction with a specific transit property, and a pilot test conducted. Notwithstanding the need for further study and development work to achieve this end, it appears from the analysis completed during this project that the maintenance and recordkeeping application has a greater initial potential than fare collection to serve as a pilot application.

Despite the favorable characteristics associated with the maintenance and recordkeeping function, it should be recognized that the greatest revenue enhancement opportunity for the transit industry with MC/SC technology ultimately lies within the fare collection process. Data from past studies indicate that the level of fraud and opportunity costs resulting from the inflexibility of existing fare collection systems is indeed significant. Two conceptual designs are presented in Section 3.0 that have the potential to displace a significant proportion of currency and coin from the fare collection process, thus reducing a percentage of the fraud losses. In one of these two conceptual designs, the issue of accomodating rate sensitive fares based upon time and distance parameters is satisfied, thus resulting in a far greater potential payback. Unfortunately, the design of this second system has inordinate hardware and software costs when compared to existing fare collection systems, and is also complex in design.

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FINAL REPORT

on

MEMORY CARD APPLICATIONS FOR URBAN BUS TRANSIT SYSTEMS

for

DEPARTMENT OF TRANSPORTATION

from

BATTELLE

Columbus Laboratories

November 1984

1.0 INTRODUCTION

1.1 Objective and Scope

The objective of this study is to investigate the potential uses of memory cards in the fare collection and maintenance/repair functions for the bus transit industry. The conclusions and recommendations presented in this report are based upon an analysis of the current and expected developments in the memory card field, fare collection and operational procedures in the bus transit industry, and trends in U.S. payment system in general.

The findings contained in the report represent the collective efforts of Battelle staff experienced in digital systems and technology, transportation and financial industry systems. The members of the project team have been involved in memory card research since 1979. Technical assistance on the bus transit fare collection and operations aspect was provided by the ATE Management and Service Company of Cincinnati, Ohio.

1.2 Memory Card Definition

In the latter 1970's, driven by a need in the European financial industry, microprocessor technology was merged with the plastic bank card to form what has been termed the "smart card". It is "smart" because it contains on-board intelligence and decision making capabilities, allowing it to perform a certain level of local data processing without the need for access to an external computer system.

While the smart card has continued to evolve in parallel with advancements in the microelectronics industry, other portable storage devices have also emerged. Enhanced storage magnetic stripes, laser storage media, and erasable electronic memory, all embedded in cards and other portable packages, are available today. Unlike the smart card, these devices contain no on-board microprocessor. All of these technologies may find application in the bus transit industry.

Although a variety of portable data storage device technologies are available, a common element to all is their ability to store large amounts of data. For this reason, Battelle has chosen to adopt the term "memory card" to refer to the category of portable data storage devices referred to above. Throughout this report, the reader will find reference to two terms, which are defined for purposes of this report as follows:

- **"memory card"** - a portable data carrying device capable of storing large amounts of information using non-volatile memory techniques. That is, no on-board power source is required in order for memory to retain its contents. The package is designed for human handling, but need not be in the shape of a credit card.
- **"smart card"** - a portable data carrier which contains on-board intelligence in addition to non-volatile data storage capabilities. While it may also resemble a credit card in appearance, it can be packaged in a number of ways.

The acronym **MC/SC** is adopted to refer to devices which follow under either of the two definitions. As elaborated upon in the next section, magnetic stripe cards are not considered within the scope of this definition and are therefore not addressed within this report.

1.3 Report Organization

The report is organized into six sections with four appendices. Following the Introduction, Section 2.0 marks the first technical discussion of emerging MC/SC technology. The purpose of this discussion is to survey the various types of MC/SC products that are being developed or are planned, the principle companies that are involved, commercial applications in which the memory card will first be used, system costs, experimental programs in France and the U.S., the results of those tests, and a long range forecast for the technology.

Against the backdrop of the technical discussion, Section 3.0 explores two alternate scenarios for the use of the MC/SC in the fare collection application. The scenarios encompass both a high level design of the system, as well as a discourse on the benefits to be gained, possible problem areas, and system costs. The purpose of describing two scenarios is to provide a perspective of a fairly simple MC/SC fare collection system as contrasted with a more complex and highly integrated version.

Section 4.0 profiles the maintenance and operational aspects of bus transit properties. The purpose of this discussion is to examine the current environment to determine where and how the MC/SC may be adapted to solve existing problems. The main thrust of the section is to describe information flows and activities.

Section 5.0 then explores MC/SC system scenarios within the context of performance, repair history, on-board diagnostics, and resource access applications. A high level design is provided as well as the advantages of the system, its weak points, and the anticipated implementation and operational costs.

The study's conclusions and recommendations are presented in Section 6.0.

Appendix A analyzes the United States payment system. The purpose of this section is to profile the different forms of payment utilized by consumers for goods and services. Particular emphasis is placed upon fast developing EFT (electronic funds transfer) forms of payment.

Following a description of today's overall payment system, Appendix B describes the likely evolution of each form of payment based upon Battelle's interpretation of current trends and the results of consumer surveys. This discussion serves as a bellwether to what types of innovative payment devices that consumers may be willing to accept and use. The important point here is that the technological feasibility of a system does not guarantee its acceptability. Lack of consumer acceptance can undermine a technically sound system if the system is not easy to use, convenient, or similar to other types of payment mechanisms used at the retail level.

Appendix C concentrates on the problems and costs which typify existing farebox systems. For the most part, the data presented here has been obtained from previous Urban Mass Transportation Administration (UMTA) funded projects. The problems and costs inherent to current fare collection procedures are referenced later in the report as design objectives for a MC/SC fare collection system.

Finally Appendix D contains a sampling of reports that are generated from the information captured by today's more sophisticated electronic fare collection system.

2.0 TECHNOLOGY SURVEY

2.1 Introduction

Advances in the field of microelectronics have made possible the ability to store and process large amounts of information on a single silicon integrated circuit at very low costs. For example, single-chip microcomputers are commercially available for under $5 which are more powerful than desktop computers of five years ago. These advances have made possible entirely new capabilities in the field of distributed information processing.

Perhaps one of the most dramatic exploitations of the microchip has been its implantation into a plastic credit card, creating what has been termed a "memory card" or "smart card". To date, the most publicized use of this technology has been in the financial sector as a secure, off-line alternative for electronic funds transfer operations. Other packages are also in use, including cartridges, keys, and military dog tags.

2.1.1 Memory Card Definition

It has been given many names since its inception, including smart card, memory card, chip card, integrated circuit card, and computer card. However, the distinguishing attribute of each of these systems is determined by the extent of data processing that is available within the portable package structure. For example, a **smart** card refers to a device which contains **on-board intelligence**, such as a microprocessor. More generally, the industry has adopted the term **memory card** to refer to any portable package which contains **non-volatile memory** within its structure. Even the term "card" is somewhat misleading, because available products are in card form as well as other form factors, such as keys or tags.

Because of the precedence of the words "smart card" and "memory card" in industry, this report makes no attempt to change the terminology, but rather notes that "card" is a misnomer. The term results from the packaging convention used by the pioneers in this field, the financial industry. It should be noted that these technologies fall into the more general category of the **portable data carrier**. The relation of the portable data carrier to memory cards and smart cards are shown in Figure 2.1.

In this current study for UMTA, it is premature to select specific smart or memory card technologies since applications are not yet well-defined. It should be noted that the above MC/SC definitions are broad, and would include devices as simple as limited storage, magnetic stripe fare tickets. However, this study mainly concerns itself with the concepts requiring the off-line storage of large amounts of data. Magnetic stripe, and bar code technologies, among others, lack these storage capabilities. For this reason, the current study limits itself to the digital electronic and optical memory card/smart card (MC/SC) technologies. It is also premature to focus on one particular packaging format, such as the card. While the payment systems industry has had strong incentive to produce a device which meets all existing physical bank card standards, similar standards do not directly influence surface mass transit operations at present. The potential ability to merge bus fare collection with other consumer financial services does tend to suggest a standard bank card format, but this study is not restricted to that specific package format. A possible deviation from the bank-style card structure is likely in the areas of bus diagnostics and maintenance, where a card may be unsuitable for the environment.

2.1.2 Organization Of The Technology Discussion

This section provides a basic introduction to memory card and smart card (MC/SC) technology. It is organized into the following areas:

- 2.2 Historical Development Of The Financial Smart Card
- 2.3 MC/SC System Configuration
- 2.4 Industry Analysis
- 2.5 Technology Trends

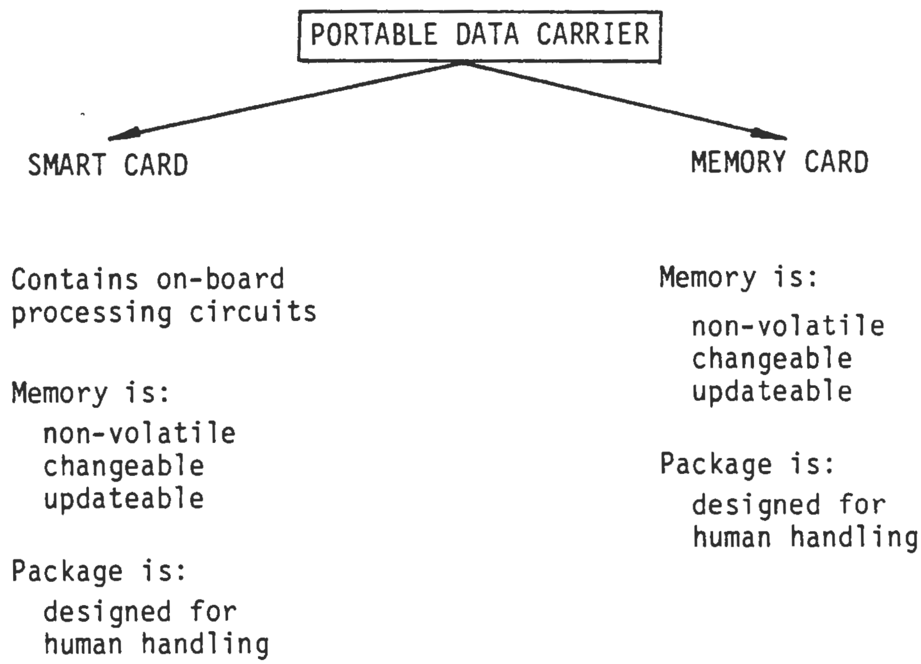


FIGURE 2.1 PORTABLE DATA CARRIER CONCEPT

2.2 Historical Development of the Financial Smart Card

The financial smart card has its roots in the early 1970's, when Roland C. Moreno conceived of an embedded microprocessor and memory as a replacement for the magnetic stripe on the back of the bank card. Moreno founded a firm called Innovatron and patented an "integrated circuit card" with important security and utilization features for transactional applications. Over the years, the organization of the French Postal and Telecommunications Systems (PTT) and three French companies (Philips Data Systems, CII Honeywell-Bull, and Flonic-Schlumberger) with non-exclusive production licenses granted by Innovatron, began to develop smart card-based systems and investigate potential applications.

Intelmatique, the official international marketing representative of the French Direction Generale des Telecommunications, assists in the promotion of French smart card systems worldwide and played a large role in its development in France. Originally, smart card systems, developed in France in conjunction with the the French banking system, were designed to replace the paper check and its associated processing methods by providing off-line support for point-of-sale terminals and thus, circumventing the archiac telephone-based communication system. In 1983, three cities in France were selected as pilot sites to test a smart card-based point-of-sale system. A description of this application is provided later.

It is this application which has sparked an international interest in MC/SC's. Nearly seven years later, the original French manufacturers are being joined by other industry players. While all are actively seeking to develop financial applications, the conservative nature of the banking industry has caused MC/SC manufacturers to provide systems for other off-line data processing needs. Since the basic principle behind the systems (flexible, distributed, off-line processing) addresses inherent needs in many industries, the manufacturers have continued to see enormous interest in the technology.

2.3 MC/SC System Configuration

There are a variety of memory card and smart card products available today, each of which having somewhat unique operating characteristics. The latter portions of this section describe these products in more detail; the discussion which immediately follows is intended to familiarize the reader with the MC/SC systems from a functional, "black box" point-of-view.

2.3.1 Overview

In general, the MC/SC system is comprised of three elements: the MC/SC (or package), the data transfer interface, and the input/output system. These are shown in Figure 2.2. Regardless of the application, the main function of the MC/SC is to serve as an off-line data carrier. This data can be transferred to various sites in the MC/SC system by inserting the MC/SC into a "data transfer interface" and access the information through conventional computer terminals. In essence, the MC/SC provides a flexible information network (or data bus), eliminating the need to install extensive on-line communication systems.

The data contained within the package is specific to the application, but will generally be categorized as follows:

- **static**, or **unchanging** data. (i.e. passwords, name, address, account numbers, issuing agency, etc.)
- **dynamic** data. (i.e. transaction amounts, repair histories, authorization codes, etc.)

Typically, the static data would be generated during the time of manufacture or distribution of the MC/SC. In the financial industry, for example, data pertaining to the cardholder is transferred into the card by the issuing agency in much the same manner as that currently employed with magnetic stripe bank cards.

While the static information on the MC/SC serves the function of identifying it to the rest of the system, it is the dynamic data storage capability that makes the MC/SC an attractive alternative to on-line systems.

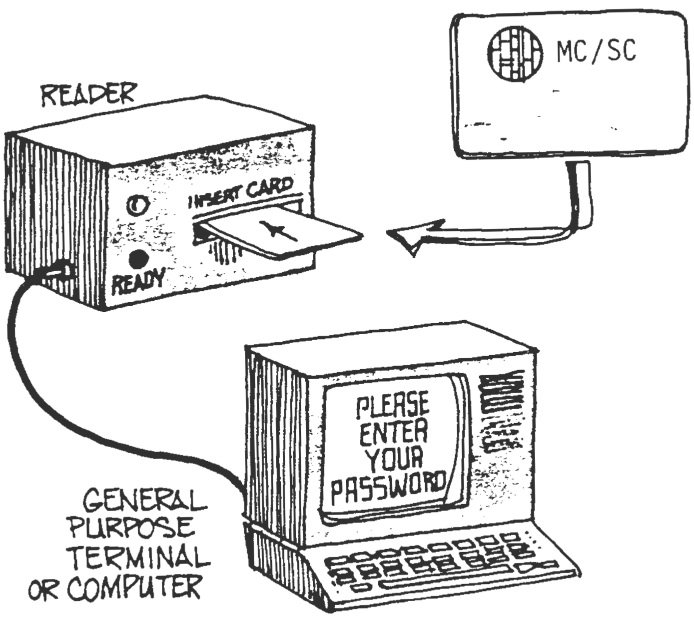


FIGURE 2.2 ELEMENTS OF THE MC/SC SYSTEM

The dynamic data areas are updateable (and, in many cases, erasable) and are used to hold information specific to the MC/SC data transaction. In the financial application, these data would include date and amount of transaction, and merchant identification codes. In a fleet fuel management application, it may include amount of fuel dispensed, and vehicle mileage. In any event, the importance of the dynamic data storage area is its ability to acquire transaction-specific information at quasi-random points in time without the necessity to employ an elaborate on-line data communication system.

If the portable package contains a processing device of some sort (i.e., it is a **smart card**), then it is possible to perform a limited amount of data processing directly within the device without the need to access any external processing capability. This data processing capability may be called upon for crediting or debiting of financial information, or simple numerical calculations such as amount of fuel remaining.

By far, however, the processing capability is typically used for data security and access control. For the French financial smart card, the microprocessor limits access to certain memory zones for security purposes.
In this case, the card's memory has accessible, conditionally accessible, and inaccessible sections. For example, one portion of the conditionally accessible memory allows a user to enter or read a financial transaction record by punching in a personal identification number (PIN) only. In another memory section, authorizations made by a card issuer, such as a bank, can only be written when a code word previously issued by the bank is used, although they can be read by using the PIN only. In some cases, if the proper passwords or PIN's have not been entered, then the processor can semi-permanently deny access to any memory areas. In order to reset this action, the card holder must return the device to the point of issue (i.e., the bank) where it is reset and placed back in service.

A major difference between the smart card and the memory card, then, is the level at which interrogations of and interactions with on-board memory is limited. Through the virtue of the imbedded microprocessor, memory access to the smart card is controlled within the card itself. However, with a memory card, access to memory is handled outside of the card by the card scanning terminal device. Data contained within the memory is stored in an encrypted fashion within the card and then is deciphered by the terminal through keys and/or passwords.

This does not suggest that a memory card system is any less secure than a smart card system for a similar application; it only dictates that the security be imposed at a higher systems level.

The issues surrounding the basic MC/SC system components are detailed in the following discussions.

2.3.2 Card (Or Package)

A package in the shape of a standard bank credit card has been the most popular form factor in use today. This stems from the standards set by the financial community, but other package formats have also been developed. For example, a device in the shape of a key is currently being utilized in access control, inventory control, and transportation applications. The United States Department of Defense is testing an electronic military dog tag for storing soldier's records. Cartridge-style data carriers have been used to transfer mission data to aircraft. It is likely that the success or failure of a MC/SC application lies in the ability to design the MC/SC package such that it is easily merged into the existing operation. Existing standards, environment, operational scenarios, and personnel attitudes all have a bearing on package design.

Regardless of the package, all of these devices utilize some type of updateable, non-volatile memory storage. **Non-volatile** refers to the ability of the memory element to store information without the need to apply constant power to the memory circuits. A magnetic stripe is a good example of non-volatile memory. Once encoded, the data is retained indefinitely; however, it can be erased and recoded at a later point. Digital electronic technology offers several methods of non-volatile data storage. These range from Mask-Programmable-Read-Only-Memories (ROM), which are programmed at the factory and non-alterable in the field, to Electronically-Erasable-Programmable-Read-Only-Memories (EEPROM), which can be programmed and altered in the field. (See

Table 2.1) A third, optical method of non-volatile storage occurs by burning "holes" into a reflective medium from a laser. The most common product using this technology today is the video disk. A card manufacturer has recently applied this technology to a new product which replaces the conventional magnetic stripe with the optical stripe.

2.3.2.1 Financial Smart Card Package. In the specific case of financial cards, an eight-bit microprocessor and a memory chip are embedded in the upper left corner (front view). This normally occurs by embedding the circuitry within a hermetically-sealed package, and then placing this package into the card structure.

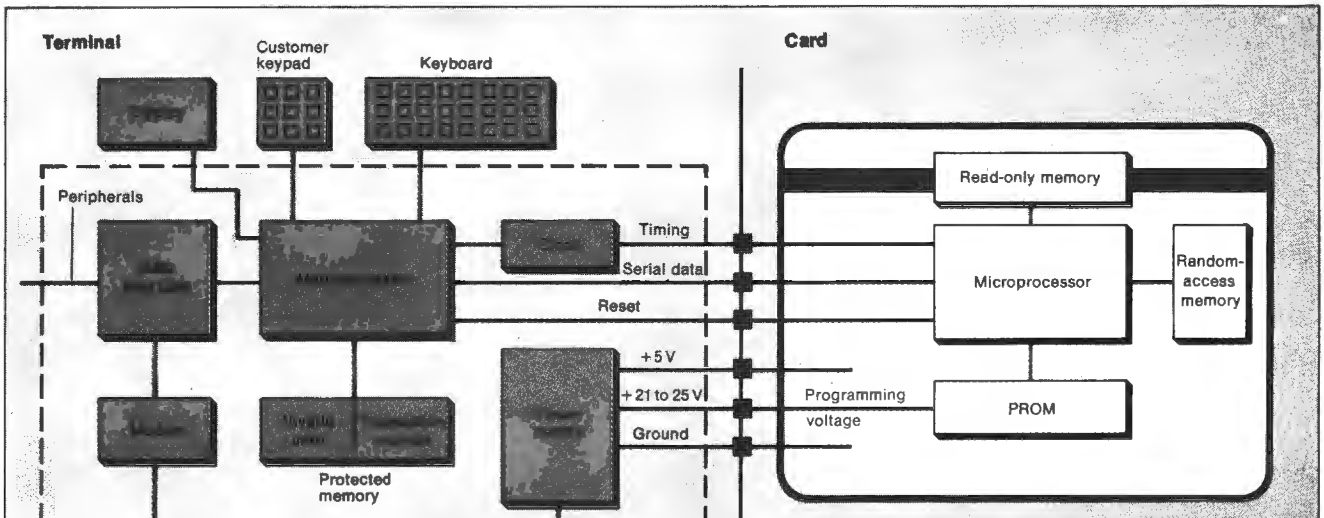
This hermetic package is necessary because the card's plastic does not provide a sufficient housing for the electronic elements. To date, assembly of the final device has been the most difficult task to be tackled by the smart-card manufacturers simply due to the thin package constraints. As conceived by the financial communities, the smart card must conform to existing bank card standards. This is because it must be compatible (particularly in overall size) with the infrastructure already in place for the plastic magnetic stripe card. This card has a thickness of .030 inches and has a variety of environmental and mechanical standards associated with it. It had been difficult for manufacturers to achieve the .030 inch thickness with the hermetically-sealed package and also meet requirements of the card. However, according to French manufacturer's current claims, the newest generation of financial smart cards meet or exceed these requirements.

2.3.3 Data Transfer Interface

Regardless of the form factor, MC/SC's do not contain any type of display or input device. Therefore some kind of terminal is necessary to allow information transfer to occur. An example of a smart card interface is shown in Figure 2.3. The current electronic MC/SC's utilize metallic contacts on the outside surface surface to achieve the electrical connection between the integrated circuits within the package and the data transfer interface. A

Memory type	Typical storage capacity in 1983	Typical non-EMC use	Comments
ROM (Read-Only Memory)	1.2 million bits (a 600-page paperback book)	• Fixed program storage • Video game cartridges • Japanese character set storage for language translator	• High manufacturing set-up costs • Long lead times due to custom manufacturing • Cannot be changed without redesign at factory
PROM (Programmable Read-Only Memory)	32,000 bits (12 typewritten pages)	• Address decoding within a computer	• Alterations are irreversible • Being displaced by lower-cost, erasable memory types
EPROM (Erasable Programmable Read-Only Memory)	256,000 bits (a 150-page paperback book)	• Microprocessor programs custom-written in the field	• Most used non-volatile memory type today • Erasable through exposure to ultraviolet light • Lower density than ROM
EEPROM (Electrically Erasable Programmable Read-Only Memory) and EAROM (Electrically Alterable Read-Only Memory)	64,000 bits (24 typewritten pages)	• Digital television tuners • Automobile engine control systems	• Can be erased electrically • Some require separate programming voltages but most are compatible with other memory types

TABLE 2.1 TYPICAL NON-VOLATILE SOLID STATE MEMORIES USED IN MC/SCs



[3] A smart card exchanges information with and obtains its power from a terminal through a six-contact interface. Permanent microprogramming and manufacturer-supplied data in a card reside either in a read-only memory (ROM) or in a section of a programmable read-only memory (PROM) that cannot be written on. The terminal allows a sales clerk and a customer to enter data for a transaction.

Weinstein—Smart credit cards: the answer to cashless shopping

IEEE spectrum FEBRUARY 1984

FIGURE 2.3 FRENCH SMART CARD 6-CONTACT INTERFACE receptacle in the terminal typically employs a set of mating contacts. (For example, see Figure 2.4) The major difficulty with physical connections is that they are subject to wear with repeated insertions.

Corrosion is also a factor in metallic contacts. For example, corrosive salts from perspiration can likely corrupt the electrical integrity of the contact surface. The use of gold-plated contacts has been used to help reduce this problem. Manufacturers claim their devices are reliable for thousands of insertions; however, the results of field tests have not yet been made available which validate the credibility of these claims.

An alternative to metallic contacts is the use of a non-contact interface technique such as radio waves or optical communication. Designs exist which describe the use of inductive coils within the flat card structure to achieve a magnetic communication coupling with the internal circuits. A German firm, Rexroth, is designing a microwave-based communications system. However, to date these technologies have not found their way into the commercial market place. While they offer more reliable contact life, they significantly increase the cost of the product at this time. The advantage of extended contact life has not been determined within the marketplace since it is likely that most devices will not see more than several hundred insertions over their lifetime. However, mass transit applications--particularly fare collection--could easily require well beyond 100 insertions, thus posing a potential reliability problem. It can be assumed that only the optical stripe media which utilizes a non-contact interface with a low-power laser is capable of reliably handling high volumes of insertions at this time.

2.3.4 Input/Output System

Because the memory card has no keyboard or display, it is necessary to connect the system to an input/output system in order to read or transfer data. Most commonly, this is accomplished by inserting the card into a reading device resembling a floppy disk drive in size and appearance. (With key-type devices, the reader resembles a conventional keyhole mechanism.) The readers are connected to desktop-style computers through standard

FIGURE 2.4 METALLIC CONTACTS SHOWN ON FINANCIAL SMART CARD

communication interfaces, and the keyboard and CRT serve the input/output function.

In specific applications, the above may be combined into one, custom-designed package to conserve space. This is the case with the financial smart card terminal, which houses the smart card receptacle, POS (point of sale) terminal electronics, keyboard, and display.

The current trend in the industry is to design a memory card reader which can be attached as a peripheral to standard personal computers. It is likely that initial memory card products in the U.S. will be configured this way.

2.3.5 Off-Line Processing

A significant benefit of the MC/SC system is its off-line information processing capability. In fact, it is this particular attribute that has caught the attention of most of the industries interested in the card. Because the card, as a portable data carrier, provides enhanced storage, as well as data security, it is possible to eliminate the necessity that all interactions have on-line access to a centralized data base. However, periodically it would be necessary to access and update the information in both the terminals and cards through the use of a centralized data base. In this manner, information in the network can be tailored dynamically. For example, in financial systems, a list of counterfeit cards or stolen cards can be brought to the attention of the satellite terminal, as well as other information being updated from a central source. In order to accomplish this, some type of telecommunications network is required. In most cases today, this is achieved using conventional phone lines and computer modems (modulator-demodulator).

2.4 Industry Analysis

The concept of embedding an integrated circuit into a plastic card is not new. As early as 1972, Castrucci at IBM patented an invention which describes embedding electronic circuits inside a plastic card. Other patents are described in Table 2.2. Very little MC/SC activity was made public until the latter 1970's when three French companies firmly committed themselves to the design, development, and manufacture of smart cards for financial applications using the Innovatron concept.

CII Honeywell-Bull, Flonic Schlumberger, and Phillips Data Systems, were the original three manufacturers who made public their intention to produce smart cards. Since that time, a variety of other companies from Europe, North America, and Japan have announced their interests and intentions in the memory card and smart card field.

Looking specifically to smart card technology, it is interesting to note that more than seven years have passed since the first set of manufacturers set forth to produce smart cards. Since that time--while a great deal of interest has been shown both on the part of the potential customer and the manufacturer--the industry itself has not seen the type of growth that is typical of the electronics industries. (In the same seven years, microprocessor and memory capabilities have increased dramatically while corresponding prices have decreased by orders of magnitude.)

Why, then, hasn't the significant interest by industrial and governmental sectors, coupled with low-cost base technologies, served as a catalyst to cause more manufacturers to enter the marketplace. An analysis of the technology, combined with interviews with potential MC/SC customers and manufacturers, provides the following rationale.

2.4.1 Business Climate And Available Products

A better understanding of the developmental state of the MC/SC can be obtained by examining the current business climate. This is accomplished by introducing many of the industrial players and briefly describing their products and applications.

The smart card/memory card industrial sector can be broken down into three groups:

TABLE 2.2 U. S. PATENTS RELATING TO MC/SCs

Date	U.S. Patent No.	Description	Inventor	Assignee
January 25, 1972	3,637,994	Active Electrical Card Device	Jules K. Ellingboe, Palos Verdes Peninsula, CA	TRW, Inc., Redondo Beach, CA
February 8, 1972	3,641,316	Identification System	Jurgen Dethloff, Hamburg, Germany; and Helmut Gottrup, Munich, Germany	None
November 7, 1972	3,702,464	Information Card	Paul P. Castrucci, Poughkeepsie, NY	IBM Corporation, Armonk, NY
June 11, 1974	3,816,711	Decoding Apparatus and System for an Electrically Encoded Card	William W. Bliss, Los Angeles, CA	None
February 25, 1975	3,868,057	Credit Card and Identity Verification System	Robert C. Chavez, Las Vegas, NV	None
September 16, 1975	3,906,460	Proximity Data Transfer System with Tamper Proof Portable Data Token	John W. Halpern, Novato, CA	None
January 20, 1976	3,934,122	Electronic Security Card and System for Authenticating Card Ownership	James A. Riccitelli, San Jose, CA	None
July 27, 1976	3,971,916	Methods of Data Storage and Data Storage Systems	Roland Moreno, Paris, France	Société Internationale pour L'Innovation, France
January 4, 1977	4,001,550	Universal Funds Transfer and Identification Card	Vernon L. Schatz, Northfield, IL	None
February 8, 1977	4,007,355	Data-Transfer System	Roland Moreno, Paris, France	Société Internationale pour L'Innovation, France
May 30, 1978	4,092,524	Systems for Storing and Transferring Data	Roland Moreno, Paris, France	Société Internationale pour L'Innovation, France
July 25, 1978	4,102,493	Systems for Storing and Transferring Data	Roland Moreno, Paris, France	Société Internationale pour L'Innovation, France
August 8, 1978	4,105,156	Identification System Safeguarded Against Misuse	Jurgen Dethloff, Hamburg, Germany	None
May 20, 1980	4,204,113	System for Keeping Account of Predetermined Homogeneous Units	Georges Giraud and Jean H. Mollier, Saint-Ouen, France	None
July 8, 1980	4,211,919	Portable Data Carrier Including a Microprocessor	Michel Ugon, Saint-Ouen, France	Compagnie Internationale pour L'Informatique, Paris, France
September 28, 1982	4,352,011	Subscription Card for a Videotex Receiver	Louis C. Guillou, Paris, France	Etablissement Public de Diffusion et de Télédiffusion de France, France
January 4, 1983	4,367,402	System for Keeping Account of Predetermined Homogeneous Units	Georges Giraud and Jean H. Mollier, Saint-Ouen, France	Cii Honeywell Bull France

- **Group I** - Manufacturers with commercially-ready products,
- **Group II** - Manufacturers who have made public their intentions to produce products, but have not yet demonstrated working systems,
- **Group III** - Companies that have not publically announced their business goals in this area, but who have been visible in the industry,

The discussion that follows describes each group in more detail, broken down by smart card and memory card activities, where appropriate.

2.4.1.1 Group I. The three French manufacturers are currently the only firms which have demonstrated and are selling complete working systems in the smart card area. Pictures of each of these products are shown in the Figure 2.5. While these devices are not compatible due to their internal hardware architecture and external metallic contact pattern, the companies have agreed to a common card-terminal interchange protocol for future use. (While there are three manufacturers of cards in France it appears that the overall technology and protocol utilized by the 8-bit "CP8" card from CII Honeywell-Bull is becoming somewhat of a de facto standard. Each of these cards offers a microprocessor and EPROM-type memory. The specialized architecture allows for the storage of program software, customer information, and transaction information in a secure fashion (See Figure 2.6.). A synopsis of each of the three French manufacturer's products are as follows:

CII Honeywell Bull (France) - U.S.
Subsidiary: Micro Card Technologies, Inc. (Texas)

Memory Card Technology: Microprocessor-Based Smart Card, .030" plastic package, M6805E processor, 8K EPROM

Interface Technology: Metallic contacts

Cost:

Initialization	$50,000-$100,000 (software customization)
Cards	$3 ("prepaid" card)
	$15-$20 ("subscriber" card)
	$3-$5 (CP8 card, >5M)

FIGURE 2.5 REPRESENTATIVE FRENCH SMART CARD PRODUCTS

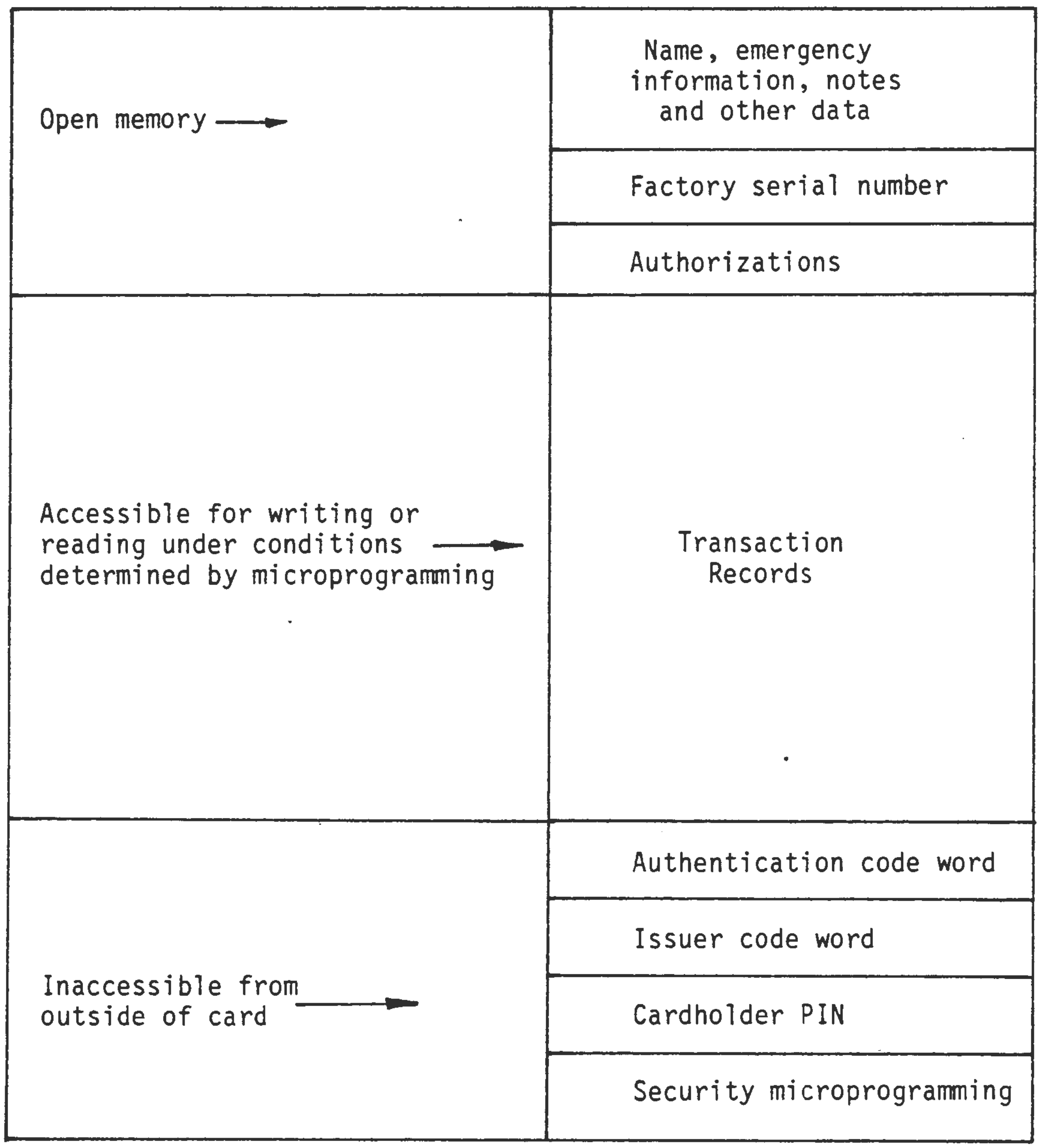


FIGURE 2.6 MEMORY ALLOCATION IN THE FINANCIAL SMART CARD

Terminal	$1,500-2,000 (with keyboard) $500 (reader only with RS232)

Primary Applications: Financial, medical recordkeeping

Description of Activity: Bull currently offers several products. A "prepaid" card is a simple device which is purchased by the customer in the same manner that he would purchase bus tokens, stamps, or subway passes. Electronic value is stored within the card and debited at a prescribed rate (example, 1 bit per bus ride) until all bits within the card are depleted. The card is then discarded. The CP8 card is targeted for transaction systems requiring storage of transaction histories, account balances, and security codes. This card is capable of several hundred transactions, and is then discarded when the memory space is used up.

The high quantity price for these cards ($3-$5 in quantities greater than five million) has not yet been substantiated, but it is Battelle's opinion that it is an overly-optimistic estimate. It is unlikely that the cost will fall below the $5-$10 range.

In order to use this technology, a significant up-front investment is required for card initialization and software customization. Special CP8 development systems and trained personnel are required for this effort. Battelle has found that the initialization costs can range from $50,000-$100,000, depending on the complexity of the application software.

<u>Philips Data System</u>

Memory Card Technology: .030" plastic card, licensed to use Bull-CP8 technology, now using Motorola IC and fabricating their own cards, reportedly 18K EPROM, earlier cards were based on Intel 8021 processor/16K EPROM.

Interface Technology: Metallic contacts

Cost:

Initialization	$50,000-$100,000
Cards	$15-$20 (CP8 card)
Terminals	$1500-$2000 (w/keyboard) $500 (reader only w/R5232 interface)

Primary Applications: Financial, personal recordkeeping

Description of Activity: Substantially similar to Bull-CP8 discussion discussion above. Prior to conversion to CP8, Phillips used their own 2-chip smart card in early prototype applications. The DOD RAPIDs test also used 200 Philips cards in its Ft. Lee trial.

Flonic-Schlumberger (France)

Memory Card Technology: Programmable Logic Array with 4.6K EPROM, .030" plastic card

Interface Technology: Metallic contacts

Cost:

Initialization	N/A
Cards	$10
Terminals	N/A

Primary Applications: Financial

Description of Activity: Substantially similar to CP8 discussion. Reportedly has had manufacturing quality control problems of unknown nature.

French Smart Card Experiments. Perhaps the most prominent applications of the smart cards has been in the financial industry in the payment systems area. Three separate point-of-sale (POS) experiments have been in progress since the beginning of 1983, with each manufacturer assigned a city-wide location: CII Honeywell Bull in Blois, Flonic-Schlumberger in Lyons, and Philips SA in Caen. The Blois trial is supposed to distribute 25,000 cards and the Caen and Lyons trials 50,000 each, for use in about 200 POS terminals in each location. It has taken much longer than anticipated to iron out administrative, marketing, and technical problems, particularly arrangements with the sponsoring banks and getting consumers to use the cards. Only 55,000 of the projected 125,000 cards were distributed as of last October. No results or use-statistics have yet been made public. A scenario for use in these systems is described below.

At the point of sale, the card is plugged into a terminal that has a separate customer keypad to protect privacy. The sales amount entered by the sales clerk through the main keyboard is displayed on the customer's unit and, if it is acceptable, the customer enters his PIN. If this PIN agrees with the one stored inside the card and if the store's terminal has previously been activated by a legitimate store-owner's card, the transaction can proceed. Factory-entered microprogramming in the card carries out the PIN comparison entirely within the card, a significant advantage over memory-only cards, which require that the transactional terminal be secured.

The terminal determines whether the purchase amount, plus the sum of the past month's purchases read from the customer's card, exceed the monthly authorization on the card. If there is enough credit left, the transaction is completed, and the transaction date and amount is written into the customer's card. A printed receipt may also be generated.

At the same time the date, amount, and the purchaser's account number are entered into an electronic memory inside the store's terminal. In this "store and forward" terminal attachment mode, an entire transactions file is delivered -- daily or at any convenient interval -- to the stores's bank via a dialed telephone link or by physically transporting the memory module to the bank. The bank clears the transactions by the electronic transfer of funds from the purchaser's account to the store's account.

Another electronic-payment experiment has recently begun in Norway using the CP8 microprocessor-based memory card. To be carried out in the city of Lillestrom, just north of Oslo, the experiment initially will involve 40 payment terminals in shops, 10 terminals in banks for loading and validating cards, 10 card-query terminals with which users could consult the data stored in their cards, and 24 card-payment telephone booths.

French technology has not "sold" well in the United States as yet. The main reason for this is that the French MC/SC technology has been primarily oriented toward financial applications. The U. S. financial industry has resisted attempts to move away from conventional magnetic stripe technology due to their multiple billion dollar investment in plastic cards, terminals, and ATMS--all of which are magnetic stripe-based. In order to expand the marketing capabilities of the French in North America, satellite offices are being set up in the United States and Canada. Honeywell Information Systems (Massachusetts) and TTI, Incorporated (Canada) represent the French Smart Card manufacturers directly. MicroCard Technologies (Texas) is a subsidiary of CII Honeywell-Bull, but has plans to manufacture the product in the U.S. soon. Amrix Corporation (Texas) is also licensed to work with Bull technology, and is producing their own reader/terminal technology.

In August of 1984, MicroCard Technology signed its first major contract, to provide CP8 cards for a drug-interaction system from Medication Services Inc., Menlo Park, California. When inserted and activated in a slot in a terminal, the smart card's 8-bit microcomputer chip will process and store patients medical records in on-board memory as well as track drug usage.

Amrix Corporation has also used CP8 cards in medicine. For two years, they have been designing medical insurance systems offering CP8 cards and read/write peripherals which are integrated into IBM PC and PC-compatible computers. Amrix uses Honeywell Information Systems as its source for CP8 cards.

Department of Defense Applications. In 1982, the DoD initiated a design, development, and test program to evaluate the Realtime Automated Personnel Identification System (RAPIDS). The RAPIDS program evolved in response to the concern expressed by Congress, the General Accounting Office and others regarding the waste and fraud associated with the way benefits are currently provided to the eligible personnel in the uniformed services.

Input Output Computer Systems Incorporated (Maryland) was the systems integrator for the smart-card-based identification system. Philips Data Systems supplied approximately 2,000 of their two-chip smart cards as the principal hardware, as shown in Figure 2.7. The smart card field test was conducted at Fort Lee in Petersburg, Virginia between April and October of 1983.

In order to determine card durability, accelerated life tests were also conducted. These included resistance to embossing, end peel, encoding, flexure, solvents, temperature, infrared radiation and ultraviolet light. Informal discussions between Battelle and RAPIDS project staff members indicate that the test results showed that there are still durability and security issues to be resolved.

Aside from the three smart card manufacturers mentioned above, no other firms currently offer a commercial-ready smart card package, which is in the form of a credit card. The volume of cards in use worldwide is difficult to estimate at this point, however it is likely that in excess of 100,000 cards have been produced and distributed to date.

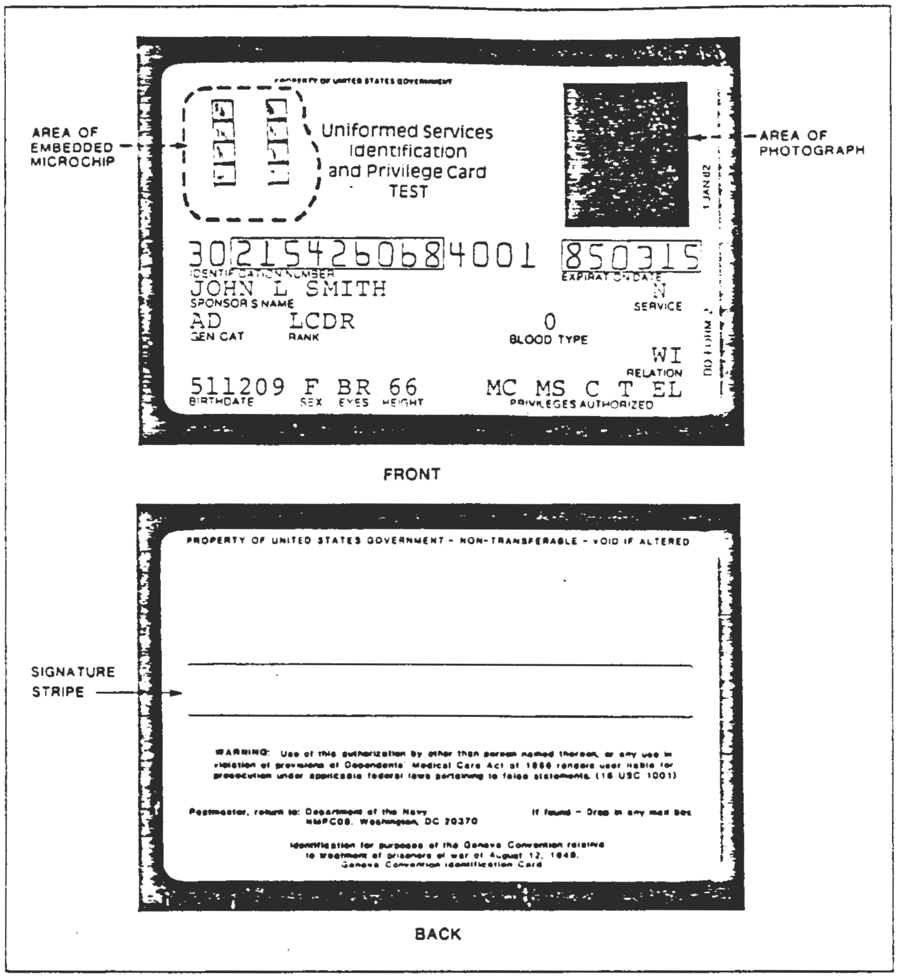


FIGURE 2.7 RAPIDS SMART CARD
(from Erdrich, Signal Magazine, May, 1984)

In the general memory card area, several non-card-shaped commercial products are available. **Datakey Corporation** in (Minnesota) offers several portable data carriers in the shape of keys, dog tags, and inventory tags.

The Datakey products are shown in Figure 2.8. This product differs from smart card technology in two ways. First, while some of the products contain an on-board microprocessor, this fact is purely transparent to the user; its function is for internal data management. Through the data key reader and appropriate controlling software, the user of the system can gain access to all information stored on the key. The second area of difference is that the data key utilizes electronically erasable memories; therefore, it is possible to update and change information on the key without exhausting its memory capabilities. Financial smart cards currently use a non-eraseable memory.

The Datakey systems are compatible with standard communications schemes and therefore can be hooked to any standard computer system. The portable data carriers can be thought of as disc files and can be treated similarly by any software designed to work with the product. Since the information contents of the devices are accessible by anyone with a reader, security can only be provided though the use of data encryption. The Data Encryption Standard (DES) or public key cryptosystems provide high measures of security and could be utilized in specific applications which necessitate security. The Datakey products range in memory capability from less than 2,000 bits to 64,000 bits of information at present, and range in price from approximately $5 (for a 2K device) to $170 (for a 64K device).

Applications of these devices include inventory management, access control and fleet fuel management. **Computer Dialysis Systems, Inc.** uses a Datakey positively attached to a dialysis cartridge to identify it at all times. Stored on this Datakey is the patients' name and medical condition, and the number of times the dialyzer has been used. The Datakey is utilized in controlling dialysis protocol and for cleansing systems for reprocessing dialyzers for reuse. In access control, the key system has been utilized as an electronic lock, thus allowing "tumbler" combinations to be set electronically. The lock mechanism is no longer a set of physical tumblers to

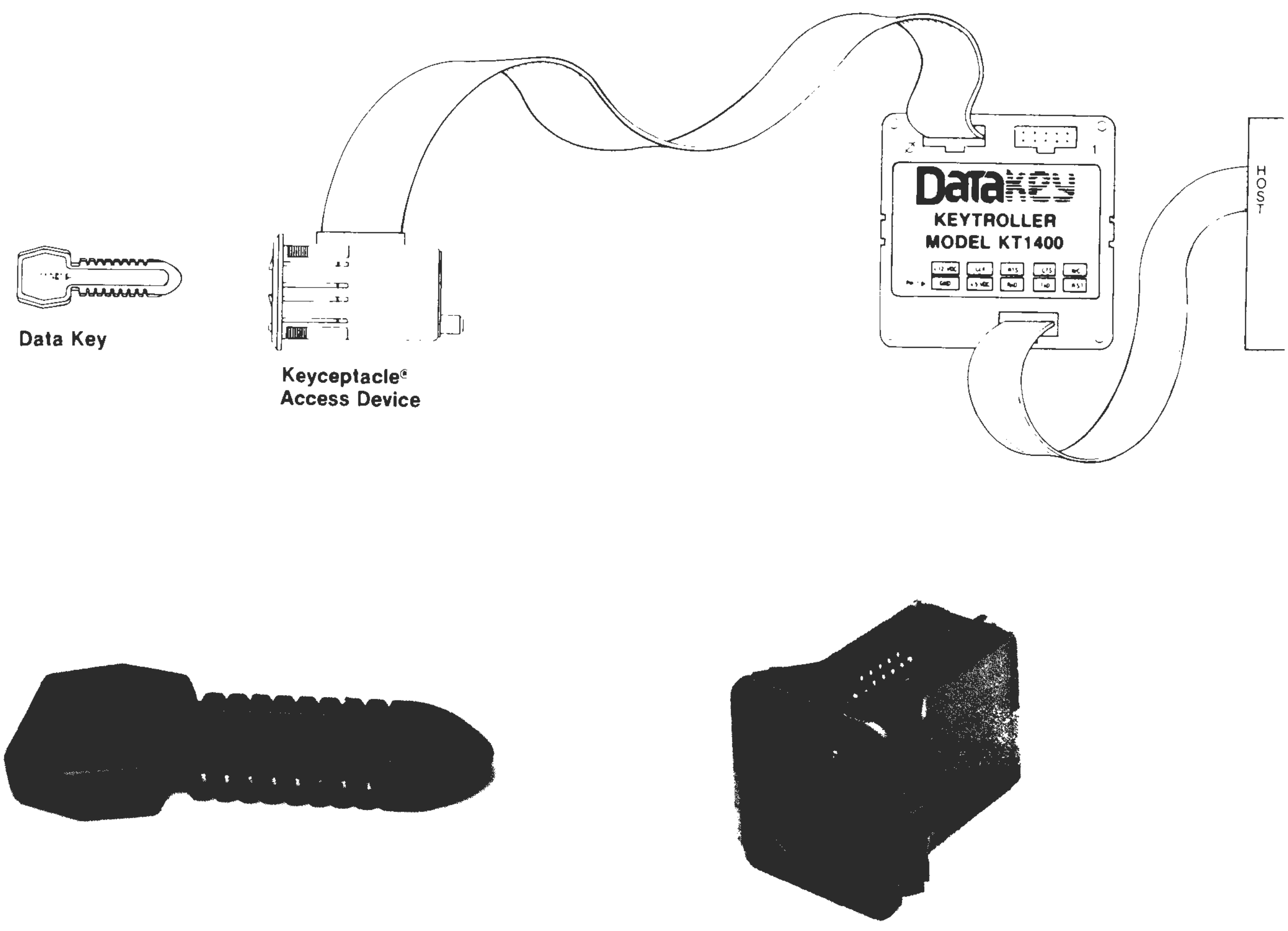


FIGURE 2.8 THE DATAKEY PORTABLE DATA CARRIER

be mechanically reset. Instead, the information is stored in the key's data base and must match identification numbers stored by the lock itself. New combinations can be implemented instantaneously. Because of the ease of system changing combinations, hotels and rental car companies have had strong interest in this concept.

A final application of Datakey has been designed by **Western Electronics Corporation** (Texas) and is marketed under the name "Datamax". Western Electronics markets and supports a fleet fuel management system. (See Figure 2.9). The Datakey is assigned to each vehicle for the purpose of providing and storing information about the vehicle and other parameters of the fueling process. The Datakey is encoded with a unique security access code. This 10 digit code is known only to Western Electronics and is encoded at the time of manufacture. The Datakey, after having been encoded with the security access code, is also encoded with (but not limited to) the following information which is supplied by the system operator (a master Datakey must also be inserted in order to allow any vehicle Datakeys to be encoded):

- **Vehicle Number** - This number is the actual 1 - 10 digit vehicle number used by the fleet and may take any form of alpha-numeric digits.
- **Vehicle Fuel Type** - When a vehicle Datakey has been authorized to a vehicle, only the specified fuel may be authorized by the remote fueling site computers.
- **Vehicle Tank Size** - The maximum whole number of gallons allowed the vehicle restricts the amount of fuel available at each transaction. When this limit is reached during a fueling transaction the computer will terminate the transaction.
- **Rationed Vehicle Tank Size** - The maximum whole number of gallons allowed the vehicle when the computer is in the rationing mode.
- **Vehicle Department Code** - The vehicle department code consists of a up to ten letter or number code used to identify the department responsible for the vehicle.

FIGURE 2.9 EXAMPLE OF FLEET FUEL MANAGEMENT
USING MEMORY CARDS
(Photo courtesy of Western Electronics Corporation)

- **Current Mileage** - The current mileage is updated each time a fuel transaction takes place. The current mileage is entered by the vehicle operator before an author-ization request is made to the central computer.

- **Odometer, Hourmeter, or None** - This field is used to specify if an odometer or an hourmeter is used by the vehicle.

- **Service Mileage** - The next mileage that service is due on the vehicle is inserted in this field. If this mileage is exceeded by the current mileage, the computer will display a message notifying the vehicle operator that service is due. Fuel may be denied or limited to this vehicle after a predetermined number of notifications

A final example of a memory card product is offered by the **Lear Siegler, Inc., Instrument Division** (Michigan). Termed the Data Transfer System, it is a user-oriented, multi-purpose computer system providing accurate mission planning and post mission planning analysis for aircraft applications.

A ground-based computer is first used to load key mission data into a pocket-sized, solid-state Data Transfer Module. A crew member then carries the module to the aircraft, and loads a comprehensive array of operational information required for the mission. At mission's end, the process is reversed and the module is returned to the ground-based computer where all post-flight data can be extrapolated, displayed, and evaluated, including maintenance data. Memory capacity is available from 2,000 words to 32,000 words. Figure 2.10 shows the data transfer module.

2.4.1.2 Group II

Companies included in this category have indicated a capability in MC/SC systems, but have not yet demonstrated working or available systems. The most prominent company in this category is the **Drexler Technology Corporation**, which manufactures an optical storage memory card. The optical stripe on the back of the card is of similar size to the conventional magnetic

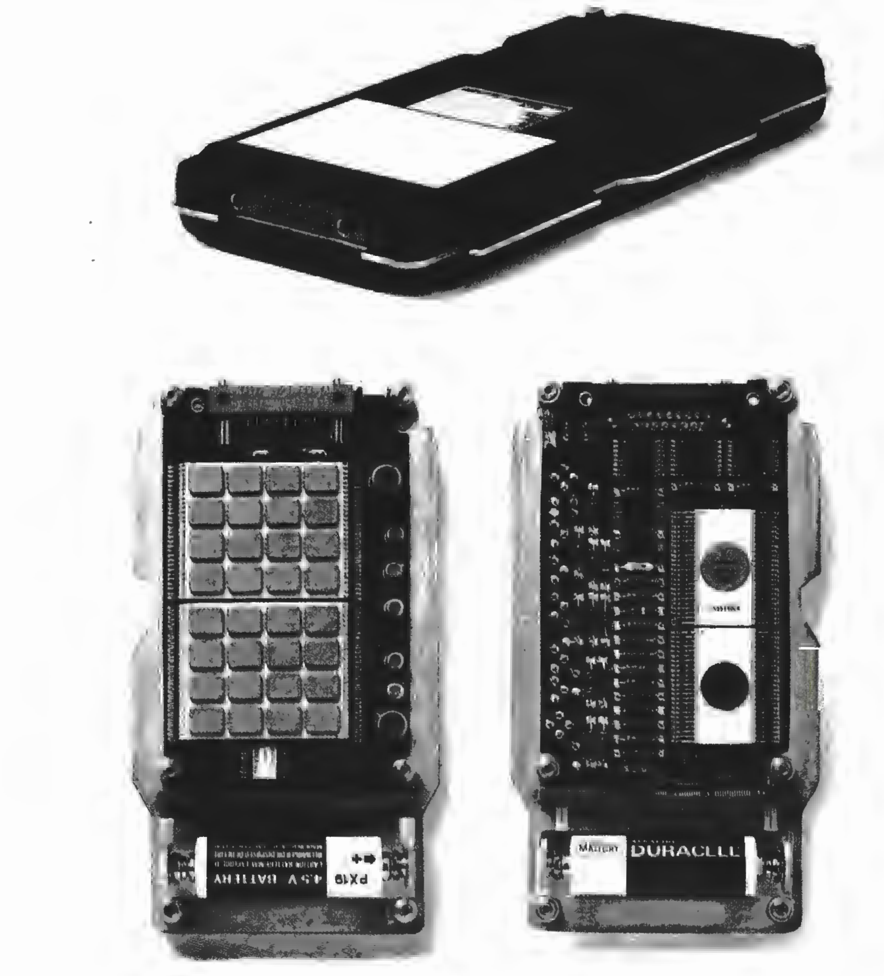


FIGURE 2.10 DATA TRANSFER MODULE USED BY LEAR SIEGLER, INC.

stripe but has the ability to store many times more information (approximately 1 million bits). It is read by a low-cost, laser-powered device. Data is not erasable, because the laser physically burns a microscopic hole in the media to signify the digital data, as shown in Figure 2.11.

Nine U.S. patents have been issued to Drexler Technology on this media and patent applications have been filed in 17 countries. One patent has been granted thus far on a laser memory card.

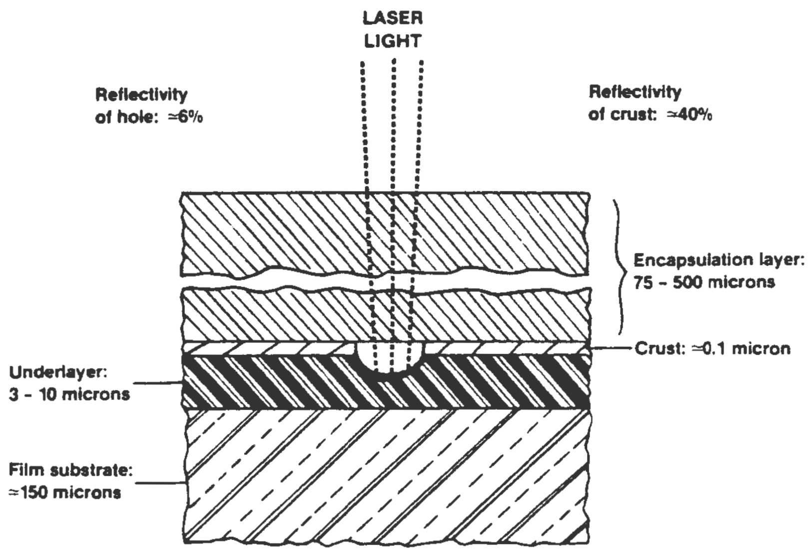
The gold-like reflective appearance of the card's recording stripe is actually created by a high concentration of two types of pure silver grains in a cross-linked gelatin matrix. One type of silver is the highly reflective type used in mirrors. The other silver grains are filamentary and create a black appearance, as in black-developed microfilm. The two types of silver are blended in a proportions to yield a 40 percent reflectivity. The quantity of silver is very small - less than $.01 per stripe. Cards are predicted to cost approximately $1.50 each. The Drexon™ tape is produced in 1,000-foot rolls for insertion in the card on a continuous basis in an automated manufacturing facility. TM The Drexon tape is sandwiched between two polycarbonate sheets which are bonded together to form the card.

In late 1981, Drexler Technology announced the laser card product. After studying the markets for a number of months, it became clear that there are a large number of applications and market segments for this technology. For many situations, optical/laser card equipment could be adjunct to existing equipment, either peripheral or eventually as an integrated part of the equipment. It would not be feasible for Drexler Technology to produce the wide variety of optical/laser card equipments needed for the various markets, so the following plan was developed.

The plan consisted of two parts. The company is establishing manufacturing and quality control facilties for producing cards in high volumes and at a low cost. This portion of the plan was announced in February of 1982. The goal is to have a production capacity of 100,000 cards per day, or 25 million cards per year.

The second part of the plan is to develop equipment designs and prototypes of four different versions of card equipment to satisfy the needs

STRUCTURE OF DREXON™ MATERIAL FOR LASER MEMORY CARDS



(Not to scale)

On top of the polyester film substrate are three layers: an encapsulation layer, a crust, and an underlayer. The encapsulation layer is a thick, transparent, plastic coating. The crust consists of silver grains of filamentary and spherical shapes dispersed in an organic colloidal matrix. The underlayer consists of the same organic colloid but is essentially devoid of silver particles. The underlayer thermally insulates the reflective crust and increases the laser recording sensitivity.

Digital data bits are recorded when a laser beam melts holes in the reflective surface of the material. The organic colloidal matrix melts at under 200° C, permitting the use of low power semiconductor-diode lasers. Data bits are decoded as the absence or presence of holes, as determined by the intensity of the reflected light. The DREXON™ material is the only laser recording medium now offered commercially.

FIGURE 2.11 RECORDING PRINCIPLE FOR OPTICAL MEMORY CARDS
(Courtesy of Drexler Technology Corporation)

of the majority of the various interested companies. These versions include a microbar code reader, a data spot reader for computer software, a writer/reader for data recording and documentation for many applications, and a debit card machine for reducing the monetary value of debit cards as value is used.

SRI International (formerly Stanford Research Institute) is funded by Drexler Technology to undertake the development of the four prototype machines. Concurrently, the company is offering license and knowhow agreements on these equipments to a group of companies in the United States, Europe, and Japan. It is estimated that card reader products will be announced by several companies before the end of the first quarter of 1985, and that the writer/reader products may be offered by the end of 1985.

SRI has completed work on the majority of card reader designs but, as yet, there are no manufacturers of the terminals. Drexler envisions that readers will be available from its licensees at a cost of $500 for a read/write terminal on an OEM basis. The reader is designed to be a peripheral to a standard personal computer system. Toshiba Credit, Sanyo Electric Credit, Sharp Finance, and Mitsubishi Electric Credit are jointly funding a new company called Card Japan to issue these cards.

Smart Card Systems, a division of International Micro Industries (New Jersey), also actively advertises manufacturing capabilities in the memory card/smart card area. The company has been very vocal in the industry and purports a specific technology advantage in its unique semi-conductor bombing capabilities. Efforts by Battelle to gain more information about their product line resulted in little information, due to proprietary work between Smart Card Systems and several sponsors. However, Smart Card Systems does not currently advertise a smart card product that is available for off-the-shelf purchase.

A third company active in pursuing smart card business is **Smart Card International** of New York. Smart Card International is the only U.S.-based company which holds license rights to the French Smart Card patent. However, the company is currently very small and has no production facility.

Casio Microcard Corporation has attracted a great deal of interest since announcing their intention to market and produce a smart card product in the United States. Already Casio produces a thin line calculator that approximates bank credit card specifications. The company claims to hold 30 patents for their technology.

The Casio smart card features an 8-bit microprocessor, a 16K EPROM memory, and a metallic contact interface. They plan on concentrating on financial transaction applications and have already verbally agreed to a market test with Mastercard in the spring of 1985 involving 50,000 cards. The projected per card cost ranges between $5 and $8.

Hitachi-Maxell is another company that is actively engaged in the design of a smart card product. They have just completed an initial prototype of an 8-bit microprocessor card with a 64K EPROM memory. Hitachi-Maxell is using wire-bonding techniques for the manufacture of the smart card and, while it does not meet bank card standards, the card is not designed for use within the financial industry. Instead, Hitachi-Maxell has targeted inventory control and diagnostic applications. On a large quantity production basis, the cost of the card is projected to be in the neighborhood of $20 each.

2.4.1.3 Group III

Many companies are categorized in this area. Information in this area is based on information which has appeared in the public domain over the course of the past few years. Companies in the U.S. which have had (or have current activity) in this area include:

- Chase Manhattan Bank
- Bank of America
- Intel
- Motorola
- IOCS
- NCR
- US Army
- IBM
- Stanford Business Research Foundation

It is likely that many of these companies have been involved in the funding and production of MC/SC prototypes within their own facilities, however, the extent of development or nature of the application is unknown or cannot be disclosed.

It is probable that a great deal of activity in the MC/SC area is taking place today in Japan. The following manufacturers have indicated a major interest in the industry:

- Dai Nippon
- Sharp
- Toshiba
- Fuji Advanced

The Japanese have generally indicated a strong interest in this area but have maintained an extremely low profile. They have claimed to produce prototypes of smart cards, but Battelle has seen no indication of these products in the United States. It is likely that the Japanese represent a very strong technical presence in the industry, following their proven track record in electronics, automotive industry, and consumer product design. Therefore, it is likely that they are waiting on the sidelines until a proven application to be identified so they may enter the marketplace.

2.5 Future Directions

The financial community was the first to show an interest in the memory card concept and has driven the development of standardization in both form factor and electronic contact. However, a large commitment to the magnetic stripe throughout the financial industry is impeding the progress of memory card systems. For this reason, it is unlikely that financial communities will be the first for the wide-scale use of the technology. On the other hand, several applications exist which have no technological precedence set and thus would allow the easier entry of smart cards into that environment. These applications include Department of Defense, Transportation, etc.

Obviously, the existence of a technological precedent such as the magnetic stripe card is not the only factor involved in a graceful transition to a smart card technology. For example, changes in accounting procedures and logistical factors also play an important role in the decision to select this technology. However, the additional existence of a physical specification (i.e., the magnetic stripe reader, ATM, etc.) and the wide distribution of these devices into the commercial marketplace add an extremely difficult hurdle for a successful market penetration.

While MC/SC technology offers enhanced storage and intelligence capabilities, these capabilities are considerably more costly. However, the MC/SC card is subject to the same drastic price decline as that witnessed by the other products in the micro-electronic revolution. While the cards are still somewhat expensive, an increase in production volume will help counteract the large investment necessary to embed a chip in the card.

Another difficulty in memory card systems is that to date they have been somewhat difficult to develop to a customer's requirements at a reasonable cost. For example, the development of a small-scale memory card experiment (perhaps involving one reader and several cards) involves significant interactions between the manufacturer and client to custom program and manufacture these devices. This is analogous to early developments in the microcomputer revolution where the knowledge necessary to operate these devices had not been adequately disseminated. In order for corporations to gain more confidence in these systems and to demonstrate their feasibility on a small scale first, it is not cost effective for them to heavily depend upon the manufacturer to provide applications support. Nor is it prudent for the manufacturer to get involved with each of these applications on a one-to-one basis if it is their ultimate goal to become a large manufacturer of cards and terminals. This limiting factor will significantly restrict the number of customers who are exposed to MC/SC technology; therefore, also impacting the number of applications that will ultimately reach commercialization on a large scale.

The memory card/smart card represents innovative packaging of micro-electronics but, from a strictly technical viewpoint, there have been and will continue to be a few technical barriers hindering its development. In the case of the bank smart card, the single largest barrier that needed to be overcome was the development of a packaging concept which would allow an integrated circuit (typically 18- to 20-mils thick) to be hermetically sealed within a metallic structure and subsequently placed in a plastic card, while still conforming to the .030-inch bank card standard. The earliest smart card, using an interconnection technology known as wire bonding, had difficulty meeting these requirements. However, innovations in wire bonding and other packaging methods such as tape automated bonding (TAB) have made it possible to easily place powerful microcomputers and memory into this thin package. Tape automated bonding allows the integrated circuit die to be bonded to external contacts using a flexible plastic tape with copper etching. This process significantly reduces the overall height of the circuit/bonding package.

In some applications, innovations and the utilization of portable data processing came much quicker. For example, the utilization of microprocessors and electronic memory in their conventional commercial package (dual in-line packaging) gave rise to a variety of "portable data carriers." Video game cartridges, digital watches, slim-line calculators, electronic keys, and military dog tags are all examples of the innovations made possible by the small size of microelectronics.

The future direction for memory card technology focuses on more straightforward utilization of the technology on a pilot level. Today, for instance, French smart card applications are extremely expensive endeavors. A fixed cost of approximately $100,000 is required to initialize and personalize the cards for the particular application, regardless of the card volume. Thus, for the company or organization interested in testing their application with only a few cards, the financial investment is enormous.

The new direction is to provide an easier mechanism for concept development and testing. Rather than requiring that the manufacturers get involved in each and every effort, regardless of volume, the customer will be given the means to customize his own application. The Datakey Corporation has adopted this sales philosophy and, with their hardware, one can test concepts for a hardware investment of only several thousand dollars.

A second major thrust with MC/SCs will be the increased use of erasable memories, such as the EEPROM. This will allow for MC/SCs which do not "wear out" after a small number of transactions and will allow their purchase cost to be amortized over larger usage periods.

3.0 POTENTIAL MC/SC BASED FARE COLLECTION APPLICATIONS

3.1 Introduction

The purpose of this section is to present a conceptual design for two different memory card systems to facilitate the fare collection process. An essential point implicit in cur analysis is that technical feasibility is not the only consideration that needs to be evaluated in designing a MC/SC based system for fare collection. Rather, cost and the suitability of the memory card to solve existing fare collection problems are also essential considerations that must serve as input into the design process. Consequently, this section explores both the business and technical issues associated with a MS/SC based system in deriving the design objectives of such a system.

3.2 Design Considerations

Thus far in the report, it has been established that the miniaturization in electronic circuitry made possible by advances in vary large scale integration (VLSI) technology has made the MS/SC a technically viable system concept. Over the past seven years, many of the technical problems associated with the MC/SC have been resolved to the point that a MC/SC can now be designed within the financial industry's ISO (International Standards Organization) and ANSI standards for a plastic credit card. The ANSI standards for a bank credit card are shown in Figure 3.1.*

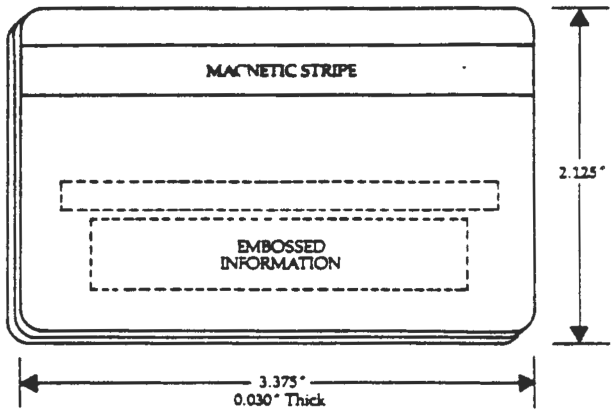
Despite the rapid technical developments and the number of companies actively involved in MS/SC development as described in Section 2.0, the technology has not yet been widely adapted by an industry segment in any country. As also discussed in the previous section, this absence of a widely demonstratable MC/SC system, means that the technology remains largely unproven under field conditions and relatively expensive to implement, even on a limited pilot basis.

* The most technically difficult standard for MC/SC manufacturers to meet is the .030 inch thickness requirement.

Magnetic Stripe Card Standards

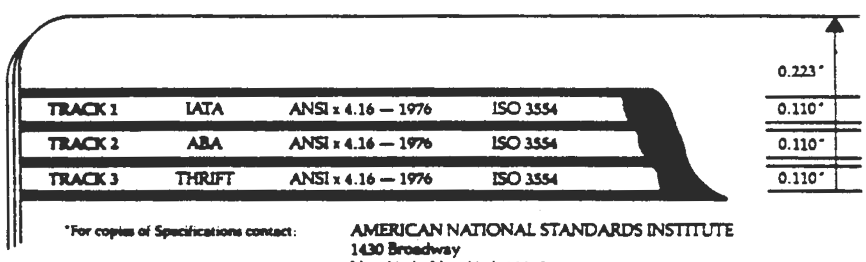
Credit Cards*

ANSI x 4.13 — 1971
ISO 2894



Magnetic Stripe Encoding*

ANSI x 4.16 — 1976
ISO 3554



*For copies of Specifications contact: AMERICAN NATIONAL STANDARDS INSTITUTE
1430 Broadway
New York, New York 10018
(212) 354-3340

The Magstripe is recorded with information for automation of transactions

Track 1 developed by the International Air Transportation Association (IATA), contains alphanumeric information for automation of airline ticketing or other transactions where a reservation data base is accessed

Track 2 developed by the American Bankers Association (ABA), contains numeric information for automation of financial transactions. This track of information is also used by most systems which require an identification number and a minimum of other control information.

Track 3 developed by the Thrift Industry, contains information, some of which is intended to be updated (re-recorded) with each transaction, e.g. Cash Dispensers which operate "off-line."

FIGURE 3.1 MAGNETIC STRIP CARD STANDARDS

This is not to say that MC/SC technology faces a dismal future. The inherent advantages of the MC/SC over the commonly used magnetic stripe are significant. The additional storage capacity allows for increased security provisions to be built into the card as elaborated upon in Section 2.0. Also, increased storage capacity allows for the capture of detailed transaction specific data. The most important feature of the MC/SC is that it serves as a decentralized data carrier thus providing certain advantages over communications dependent on-line systems.

As elaborated upon in Appendix C, the most notable problem is the magnitude of revenue loss due to fare evasion, internal fraud and other means. As reported by the Transportation Systems Center revenue loss due to fare evasion and other types of fraud may run as high as 20 percent of all operating revenues at some properties. Most importantly, as dollar bill processing increases, so will the extent of fraud.

Structural penalties caused in part by limitations of current fare collections systems are also a major problem. As outlined in the appendix, one study showed that structural fares could cover up to 60 percent of all operating costs based upon distance and time of day parameters. Today, fares at typical properties contribute only 40 percent of operating costs.

Problems in existing farebox systems are not limited to the current level of fraud losses and opportunity costs. Foreign debris in both coin and dollar mechanisms are a primary culprit of farebox malfunctions as are crumpled bills, and limiting vault capacities on the farebox, vibration, power surges, and a host of other environmental types of problems. Despite these obstacles improvements have been made. Procedural changes in most transportation properties have all but eliminated on-board robberies. Vandalism of fareboxes is also running at a very low rate. Counting accuracy has been measured at 96 percent and the mean time between farebox failures ranges in the 3 to 4 week range. Research studies have noted that maintenance procedures are facilitated by the easy assessibility of farebox component parts.

This suggests that new solutions are needed to eliminate some of the existing problems prevalent in the fare collection process. One primary design objective of a new fare collection system is to provide a substitute for currency and coin in fare payment. By displacing a percentage of dollar bill fares, vault capacities will not be as great of a limitation. Similarly, displacement of currency and coin fares are likely to reduce the number of mechanical failures due to debris while also lessening the opportunity for fraud and theft due to the reduced presence of bills and coins. In order for this design objective to be met, the system must be oriented to provide clearcut advantages to the ridership to spur widespread usage and thereby create a significant reduction in currency and coin usage. While it is recognized that paper passes, tokens, and even magnetic stripe cards are existing methods to displace currency and coin, the following discussion suggests that the MC/SC is a promising additional mechanism to satisfy this design objective.

An even more critical second design objective is to place an increased intelligence capability at the fare collection point. In this way, the opportunity is presented to accomodate distance and time of day based fares without requiring direct driver intervention in entering variable fare schedules or in verifying the deposited fare. This design objective if satisfied could increase consumer interest in the MC/SC given that incentive discounts are made available to MC/SC purchasers at the time of sale.

3.3 Design Components for a Memory Card System

With these two general design objectives set forth, the four major design components of a MC/SC system are now analyzed. These four components are:

- Microcircuitry
- Encasement
- Coupling
- Interface system.

The most significant design issue in the development of a MC/SC based fare collection system is whether the fare collection application requires a MC/SC merely for the storage of information (a memory card system), or if an on-card processing capability (smart card) is required such as was described for the Datakey system in Section 2.0.

The implications of this design issue extend beyond card design and are best determined by the design philosophy of the entire fare collection system. For example, will the MC/SC system be designed solely for the fare collection system or will it be a general purpose card adaptable to a variety of different functions? Is intelligence or decision making best performed by an external terminal, or does specialized logic (smart card system) need to be placed within the card? Can the MC/SC be designed to totally replace all currency and coin from the fare collection system or would this represent an unrealistic edict on the part of a transportation authority?

3.3.1 Microcircuitry

Deciding whether the card will need both storage and intelligence capabilities is dictated by the role that the card needs to serve in the fare collection system. In a memory card system where the decision-making takes place at the terminal (e.g., farebox) or central site, a primary issue is whether or not the data contained within the memory card needs to be protected and if so, through which encryption technique. Terminal design is also a more complex task in a memory card system in that the terminal must perform a more complicated function therefore increasing its design complexity and cost.

A smart card system presents the system designer with a different set of issues however. Typically a smart card is demanded by an application that features large storage requirements and a need to perform functions that are based on dissimilar parameters at decentralized locations. Although terminal costs can be less expensive, based upon a more simplistic terminal design, the logical circuitry required within the card itself adds cost to the system.

Analyzing the characteristics of the fare collection application, several conclusions become evident. First, transit fare collection is a high volume, low transaction value operation that is based upon a fairly small set of operational parameters (i.e., few types of different fare structures). This immediately leads to the determination that a MC/SC used exclusively for fare collection does not need to be complex in function. The primary role of a MC/SC in such a system is to contain stored value in a machine readable form, not to perform complex logical operations.

The natural conclusion to be made here is that based upon these requirements, a simple memory card system is all that is demanded by the fare collection application assuming that the card is used exclusively for fare collection and not for a variety of other payment purposes.

While a MC/SC with a wide range of uses would naturally be of greater value and utility to a card carrying consumer, other realities addressed within the report seem to preclude this option. For example, MC/SC technology while mature to a degree from a development standpoint, remains in its infancy in terms of operational systems. Few prototype systems have been tried. Rather than attempt to integrate an early stage MC/SC project into a variety of payment functions, it seems to be far more reasonable to isolate its use to a singular function, such as fare collection.

Other arguments can also be convincingly made against an attempt to design a highly integrated MC/SC system for fare collection as well as other applications. Perhaps the strongest is the simple logistical complications involved in obtaining a concensus on design decisions from retailers, banks or other institutions that may be interested in participating in such a program. As described in Appendix B, banks are not likely to be quick to embrace MC/SC technology in light of their investment in magnetic stripe technology.

A further point to be made here is the low value nature of bus fare transactions, generally up to one dollar. With transactions of this amount, a trade-off exists between the level of security, the value protected, the cost of processing a fare transaction, and the amount consumers are willing to prepay transit fares required for a MC/SC. In other words, it appears unlikely that a significant percentage of the bus ridership population is willing to prepay fares in dollar amounts that exceed $50 (for example), unless substantial discounts are provided. Given this, the amount of stored value in a fare collection MC/SC is not likely to invite unreasonable threat to the degree that encryption and personal identification safeguards need to be established. While basic security safeguards are necessary to discourage opportunistic crime, the overhead costs of designing and employing elaborate security features on the MC/SC are not necessary for this application because of the relatively small amounts of stored value.

Thus far, it has been established that the microcircuitry of the card need only be capable of an information storage capability since the card should be solely intended for use in the fare collection application. Futhermore, encryption features are not likely to be required due to the limited stored value of the card itself. The primary issue remaining pertinent to microcircuitry is the type of memory to be utilized. Given the comprehensive discussion contained in Section 2.0, it suffices to mention here that two types of solid state memory will be pertinent to the MC/SC based systems described later in this section.

The first is PROM (programmable read only memory), a simple and cost effective non-volatile memory type. The problem with PROM however is that the chip's contents cannot be updated and reloaded. It is best viewed as a card that contains a series of fuses that are blown every time the card is used. Therefore, memory cards utilizing PROM have a limited life and are disposed of once that their stored value in the form of blown fuses has been exhausted. A PROM can contain up to 32K bits of data and is relatively inexpensive to manufacture and issue. However, to gain all the benefits of its large storage capacity requires that the transit customer commit to a significant outlay of funds to purchase a 32K bit PROM based memory card (approximately $3 to $5 to produce a card).

A second type of non-volatile memory warranting mention here is EEPROM (Electrically Erasable Programmable Read-Only Memory). Unlike PROM, EEPROM incorporates features which allow its contents to be altered. This approach is more expensive to produce and has less storage capacity than PROM (approximately $4 to $7 to produce a card). Nonetheless, the trend is toward erasable memory because most fare collection applications are better suited to the utilization of a chip in which contents can be updated on a usage basis. EEPROM based cards are reuseable because of their design that permits the reloading of stored values. However, the high volume, low value nature of the fare collection process is not necessarily well suited to the expense of EEPROM based cards unless the ridership can be provided an incentive to purchase and maintain their cards over a long period of time.

3.3.2 Encasement

With a basic understanding of the microcircuitry related issues that play a major role in the possible use of memory cards in the fare collection process, we now turn to the issue of encasement; that is, the packaging of the circuitry within some type of container device. Keeping in mind that fare collection is today dominated by currency, coin, and cash surrogates such as tokens and prepaid fare passes, it seems to be a foregone conclusion that an appropriate container device is the plastic card, of which the dimensions should conform to the commonly used bank credit card. As described in an earlier section, other portable data storage devices have utilized other forms of encasement such as a key. Given that 500 million credit cards are used throughout the U.S., consumers are familiar with the credit card's size and shape and are accustomed to keeping cards of this size in wallets and purses.

Although fitting the necessary microcircuitry into a card that is as thin as a bank credit card (.030") has been a formidable challenge for MC/SC manufacturers, a strong case can be made for following bank leadership in the standardization process. Standards have been developed for plastic cards used in the nation's payment system, and the industry infra-structure is in place to support the manufacture and distribution of plastic cards conforming to the ISO (International Standards Organization) standards by which all financial institutions abide. Conformance to these standards ensures that future opportunities to integrate a MC/SC based fare collection system into other payment related applications are left open if and when integration becomes a feasible approach.

3.3.3 Coupling

Integral to the MC/SC design is some type of information transfer mechanism allowing communication between card and reader or terminal. The traditional method for smart cards has been metallic contacts on the outside surface to permit electrical connection with mating contacts in the reading receptacle. Optical cards are read by the use of a low power laser. New developments have permitted microcircuit cards to be read by microwave interfacing rather than direct metal to metal contact.

For transit system fare collection purposes, the metal to metal contacts are the most economical and would thus be best suited for the rider who would use the card not more than several thousand times. The optical laser technology may be cost effective in one or two years, since reader/writers are estimated to be $100-$300 in large quantities. However, Stanford Research Institute is still in the prototype stage of development at this time. Finally if conclusive data from the RAPIDS and French POS tests prove that the metal to metal contacts have a significant failure rate, transit systems may want to wait for the microwave technology by Germany's Rexroth to become affordable. (Section 2.3.3 provides technical detail on this subject.)

Another consideration is whether the card should be inserted into or swiped through the reader slot to activate the electrical connection. Since a rather uniform swipe is required to be effective, Battelle would suggest an insertion technique for more universal usage and fewer rejection and reinsertion situations.

In summary, the coupling feature presents several alternatives, but all the methods are functionally satisfactory and the coupling decision is not a critical one.

3.3.4 Interface System

The interface system refers to the hardware/software terminal configuration in which the MC/SC interacts. The farebox today functionally serves as both a transaction terminal and storage vault. Therefore, an adjunct card reader to the existing farebox configuration appears to be the natural interface system for a memory card based system. Already Cubic Western Data is developing a magnetic stripe card swipe reader as an optional component on their fareboxes. A memory card based system could utilize a similar farebox component.

One of the questions posed earlier in this section was whether or not currency and coin could realistically be eliminated from the bus transit fare collection system. While this objective would certainly eliminate many of the problems in existing farebox systems caused by mechanical failures, foreign debris, and pilferage, no precedent systems that exclusively use a cash substitute are currently in place in any of the nation's bus transit properties. An experiment in Portland, Oregon attempted to partially substitute various forms of prepayment with a European-style honor fare system, but the experiment was discontinued due to excessive cost. Since the issue is not directly related to the mechanics of a MC/SC system per se, it is viewed as being outside the scope of this particular report. For purposes of discussion here, it is assumed that the MC/SC based system will represent an additional payment mechanism for the ridership, not the only payment mechanism. Regardless of our assumption though, the conceptual design of the MC/SC portion of the system remains the same.

The interface component of the overall MC/SC system can yield great flexibility in satisfying the design objective of increasing fare revenue by accomodating time and distance sensitive fares. Already in this section it has been established that the generic fare collection application does not possess the necessary characteristics required for the design of a smart card type system. That is, farebox transactions are uniform in function. Value is collected on a per person per ride unit. The only elements that can vary is the amount of the fare. The only purpose that a passenger held MC/SC can serve is to hold stored value in a machine readable form; the determination of the actual fare amount must be made by the interface system based upon time and distance variables which may be prompted by driver entered parameters. There is no justifiable need for the passenger held MC/SC to contain stand-alone processing power.

It follows from this that the interface system must be loaded with the appropriate parameters to accomodate time/distance fares. At transit properties today where state-of-the-art electronic fareboxes are used, various category fare amounts are set by the driver at the start of each day (or start of a fare cycle where rates uniformly change at a specific time of day). Once the appropriate fare amounts are entered on the driver's keypad, the passenger deposited fare amount is compared to the driver entered passenger category for correct payment and is acknowledged by the farebox.

Given the desire for time/distance sensitive rates, this type of procedure no longer remains feasible. The amount of information needed to establish time/distance rates becomes too great to practically and accurately manually enter the rates for each source/destination/time-of-day combination at the start of his route. Given that the farebox itself already must have a card reading mechanism to accomodate passenger held MC/SC, it only follows that this same card reading component can be used for the initialization of the system with the appropriate rate structures for that bus's route.
Therefore, given the need to set distance/time-of-day sensitive rates, the interface system can be best initialized through a driver held MC/SC (EEPROM to allow for rate changes). The distance and time-of-day parameters can then be utilized by the software within the farebox to calculate the passenger fare amount. Time based fares can be calculated through the incorporation of a clock into the farebox electronics. Distance based fares would more than likely require the driver to utilize a keypad to acknowledge a bus stop number from which distance is then calculated by the interface system. This same data can also be stored within the farebox memory for reporting of ridership information and other reporting related requirements.

The interface system needs to also contain many of the functions and features not directly linked to the MC/SC portion of the fare collection system (e.g., registers, displays/audible tones, cash/coin mechanisms, security vaults).

To summarize, it has been established that the processing power needed to calculate the appropriate fare amount needs to reside in the farebox interface system, not the passenger held MC/SC. Therefore a passive MC/SC is more appropriate than an active MC/SC system. If distance/time-of-day sensitive rates are to be utilized, a driver held MC/SC containing the appropriate parameters would be an efficient procedure in which the farebox interface system could be loaded. Even if static rates continue to be used as in the past, a driver held MC/SC could be used in lieu of the present keypad initialization procedure although the need for a MC/SC for this process is much less compelling.

3.4 Scenario One: A Simple Adaptation of the Memory Card to Fare Collection

Keeping in mind the absence of a large scale installed MC/SC system to serve as a precedent to the bus transit industry, a good argument can be made that a MC/SC based fare collection application should first be designed to perform only the most basic functions. Scenario One describes the most basic use of the MC/SC as a functional substitute to the stored-ride card type of system in which cards are manually punched to indicate that one ride has been used.

The design of this Scenario One system is similar in many respects to that used for Flonic-Schlumberger's telephone (PTT) pilot program in Lyon, France. Each time the memory card is used for fare payment purposes, a stored value register (or fuse) contained within the chip is burned out. Because of the simplicity of the memory needed to satisfy this requirement, an 8K PROM chip is sufficient for the design of the memory card. However, the inherent limitations of PROM would necessitate the card to be a disposable payment vehicle. After the stored value has been exhausted on a physical card, it cannot be updated.

The interface system requires a very simple memory card reader on the farebox for memory card reading purposes. The card reader can easily be adapted to interface with the existing counters, registers, and other features of the electronic type of farebox. The card reading device needs to incorporate an LED display to permit the cardholder to view the remaining value stored within the fare payment memory card. An optional feature is an audible alarm or message on the LED signalling a low number of remaining fare values stored on the card.

From a procedural standpoint, this basic scenario is identical to most existing fare collection schemes. Since this adaptation of the MC/SC should not initially accomodate distance/time-of-day sensitive fares, little need exists to design a capability allowing the driver to use a companion card for farebox initialization procedures. As is current practice, the driver at the start of his route uses the key pad on the electronic farebox for initialization purposes. Passengers upon boarding the bus, use either the MC/SC or currency and/or coin to pay their fare. Sales distribution of the MC/SC is handled in virtually the same manner as paper monthly passes today. Discounts are provided to the ridership to serve as an incentive for them to purchase the MC/SC. From a practical viewpoint the payment MC/SC must contain uniform ride units, although cards can be sold for variable amounts as is done for reduced senior citizens fare cards at BART.

The primary advantage for the consumer of this type of system design over the typical coin fare system is that it provides greater convenience in offering a payment mechanism that is easily stored and can be used many times as compared with the burden of needing to carry the correct change. Incentive prices for the sale of the memory card also can provide the consumer with somewhat of a cost savings although the economics of the system may likely permit only a marginal cost break at best. The throughput rate of customers at the farebox should be improved especially at peak rush hour times. While this type of system merely represents an electronic version of a stored-ride card fare pass, it does have the advantage of being more durable and presumably more difficult for an individual to misplace.

Assuming that consumers embrace the MC/SC as a more convenient payment mechanism, this system should serve to displace a certain percentage of currency and coin within the system thus alleviating a proportionate amount of the pilferage, mechanical, and other problems associated with the handling of currency and coin. Since the MC/SC is sold through distributorships on a prepaid basis, the transit property's cash flow is enhanced due to the time value of collecting money in advance.

The simple design described in this scenario has the added advantage of emulating the existing environment thus minimizing the transitional stages of implementing this type of MC/SC based system. Although this type of limited scope system is obviously of an unproven nature, it does present a less risky approach as compared to the design of a more complex MC/SC based system described in Scenario Two. Implementation of Scenario One is the first step to a more elaborate MC/SC based system with a potentially greater payback to the transit property.

Two potential problems exist with the Scenario One conceptual design however. The first involves cost. While the absence of a precedent MC/SC system makes the overall costs particularly difficult to estimate, it is reasonable to expect per card costs to range between $3 to $5 on a large quantity production basis. The $3 to $5 production costs combined with sales distribution costs cast some uncertainty over the price in which the MC/SC could be offered to the customer. Without a substantial financial incentive, a small proportion of the overall ridership is likely to prepay fares over an extended month period. Prepaid fares have generally not been well accepted in the U.S. Milwaukee reportedly enjoys the largest percentage of prepaid fares at approximately the 40 percent level. Most other transit authorities have far fewer prepaid fares.

The card itself does not appear to pose unreasonable limitations on the amount of fare trips that can be physically stored. The memory card used in Flonic's pilot program in France utilized a 4.6K bit memory in which 120 stored value units were contained. However, a different card design utilizing an 8K PROM chip could yield several thousand stored value units depending upon the number of bits used to designate a stored value. The main difficulty lies in determining at what level consumers are willing to prepay (e.g., monthly, every two months, semiannually, etc).

A second problem of this conceptual design is that one of the primary design objectives set forth earlier in this section, the structural fare problem is not completely satisfied. As discussed, structural fares represent an opportunity to increase revenues by as much as 50 percent. As described here, Scenario One includes a fairly static fare structure, one in which distance and time-of-day parameters are not widely utilized.

The Scenario One design can only accommodate one set fare increment irrespective of any variables since the fuses in the card are all of uniform value. The nature of the PROM design does not allow for a percentage of a given fuse to be exhausted. From a technical standpoint however, it would be possible to design (for example) a card with lower increment fuses,(e.g., 5¢) where the farebox blows more fuses during certain time periods (e.g., peak times) versus others (e.g., non-peak times). Variations of this type are possible to build into the card reading device interface system, although it increases the complexity of the interface system and may be confusing to the ridership. Since Scenario One is designed to closely mirror existing fare systems, it only includes a single card reader located at or near the farebox. This precludes the incorporation of distance based fares unless an "honor" system is used.

3.5 Scenario Two: A Dynamic Memory Card Based Fare Collection System

A more sophisticated alternative to the former conceptual design is a MC/SC based system that incorporates an EEPROM chip to allow for the storage of a dynamic value within the card. Like the former scenario, this system utilizes a passive card that does not have processing capability. However, unlike the Scenario One approach, the stored value of the MC/SC here can be updated and, therefore, can be used for the charging of variable amounts. It does not involve the concept of blowing standard value fuses. Rather, at the time of issuance or reloading, the card is initialized with the desired dollar amount, followed by the decrementing of variable amounts from the value stored within the memory contents of the card. The approach can be viewed as an electronic checkbook type of concept.

The Scenario Two design is intended to accommodate the need for a structural fare requirement based upon a desired set of distance and/or time-of-day parameters. In order to properly satisfy this requirement however, riders must utilize a card reading terminal upon boarding and disembarking. Compliance with the two step card reading function can be ensured by subtracting the maximum possible fare from the stored value balance upon boarding and then adding back the difference upon disembarking (see Figure 3.2).

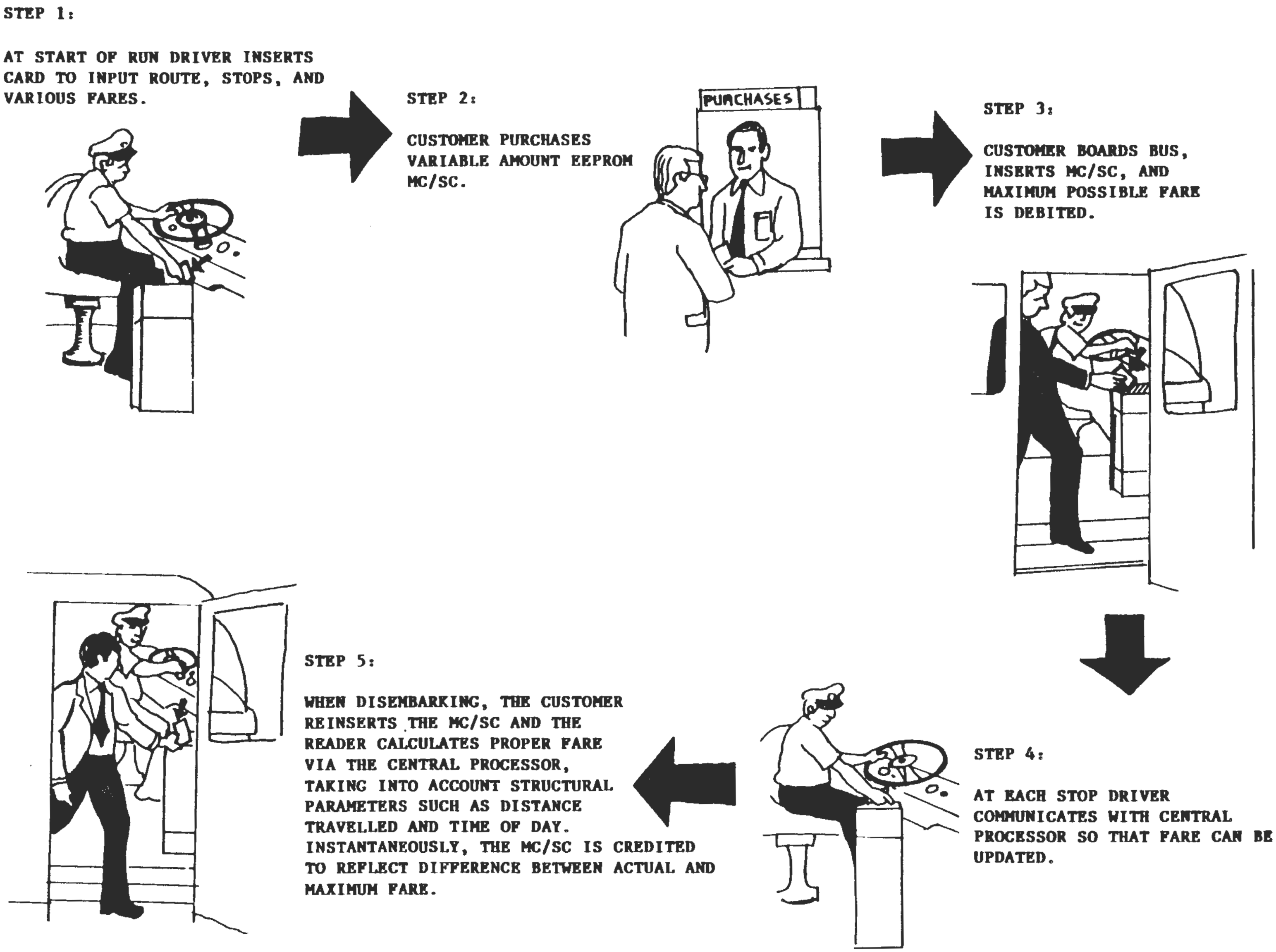


FIGURE 3-2 SCENARIO TWO: A DYNAMIC MEMORY CARD BASED FARE COLLECTION SYSTEM

Figure 3-2 provides a demonstration of a typical usage situation under Scenario Two. At the beginning of a run (Step 1) the driver uses his card to set the route and structural fare parameters. At Step 2, the customer purchases the MC/SC in much the same fashion as a pre-paid pass, but at a variable amount of the purchaser's choice. The clerk inputs the customer name, ID, and amount into a read/write device, and the card is ready to be used. During Step 3, the customer inserts the MC/SC into the main terminal causing the maximum fare to be deducted from the card, providing an incentive to reinsert the card upon departure.

Step 4 shows the driver inputing either time or zone information by physically keying in data (e.g., to bus stop number) to change the fare at specified stop or time of day.

Finally, Step 5 represents the customer's departure, at which time the MC/SC is reinserted, and the terminal credits the card to reflect the difference between actual and maximum fare amounts based upon the distance traveled.

This type of design is considerably more complex in terms of both hardware and software required within the interface system. Each bus must be equipped with three terminals (farebox terminal for boarding and one card reader per bus door for departing riders). Additionally, a communication capability must exist between all three of the terminals. The central processor contained within the main terminal (farebox) has to be capable of (1) potentially storing several thousand bytes of distance and time-of-day parameters, (2) directing the communication between the card reading terminals, (3) calculating the fare amounts, and (4) handling the actual input/output functions of updating the stored value of the passenger's MC/SC.

The primary advantage that this design offers the consumer is the ability to purchase a prepaid variable amount MC/SC. In describing the Scenario One design, one concern involved the willingness of consumers to pay up to five months fare in advance. This design allows the rider to purchase prepaid fares for one month or even one week, depending upon preference and individual need. More importantly, this design allows the bus transit system to be far more viable to the public since fares can more easily be based upon distance and time-of-day. Instead of paying a static fare for a relatively short ride, passengers can pay for the amount of service received as long as the MC/SC is used. For many, this will lead to increased usage since shorter bus trips become far less expensive. It also will serve to encourage the use of the MC/SC versus currency and/or coin.

The transit property's increased revenue due to both the structural fare and presumably increased ridership is the overwhelming benefit from the operational side. This design alternative also yields the same advantages cited in the earlier scenario relating to the decreased processing of currency and coin.

The enhanced data capture capability also provides the opportunity for extremely detailed ridership and bus route analysis reports since the rider's source and destination point can be tracked as well as the time-of-day. Nonetheless, Scenario Two causes many concerns. Its conceptual design alone is complex and requires three card reading terminals to properly serve the data capture of incoming and departing passengers. Throughput congestion is a potential problem at peak hours since passengers must usethe card reader upon both boarding and leaving the bus. Obviously, this system requires a major change from existing customer procedures for fare collection and may be rejected on this basis alone by many riders. Nonetheless, somewhat similar systems are not without precedent. For example, several European manufacturers of honor fare-type equipment (Camp-CGA, Almax and Autelca among others) tie their cancelling devices (which the passenger uses to cancel the appropriate spaces on the honor-fare card) into a central processor. This device collects data on the various fare categories as the cards are cancelled. The device is also used by the driver to signify the fare zone the bus is travelling in, and that the cancelling device in some cases has the ability to recognize a pattern of magnetic stripes on the honor fare card and determine if the correct card is being used for the zone. Thus, remote terminals have been tied into a central processor in a bus-mounted fare collection system. The question is whether the more sophisticated communications needed for the stored-value system described here is practical in the severe bus environment.

The cost of the system is also a concern. The EEPROM version of the MC/SC is a more recent product than its PROM counterpart and is more expensive on a per card basis, probably in the $4 to $7 range on a large quantity production basis. Aside from the increased terminal requirement and card costs, the on board computer hardware and software cost also is likely to be many times more expensive than the configuration described in Scenario One.

Other possible problems are more subtle to assess. For instance, the fare scheme requires a maximum fare be first subtracted from the passenger's MC/SC upon boarding, and then the difference between the maximum and actual fare to be added back to the card upon departure. What happens if insufficent value is stored on the card for the maximum fare, but sufficent value is stored for the actual intended ride? Questions such as this need to be addressed during the detail design of such a system.

Regardless of the uncertainties surrounding the Scenario Two design, it can be concluded that this design affords tremendous revenue opportunities to the transit property since greater flexibility exists than with the Scenario One design. However, the costs are proportionally higher with this design than the more basic system alternative.

3.6 SUMMARY

The fare collection process does not demand the capabilities of a MC/SC with stand-alone processing capabilities, only one in which the MC/SC is capable of storing fare value. Two conceptual system designs appear feasible to meet the requirements of the fare collection process at varying levels of sophistication. One, where a limited life PROM MC/SC serves as the nucleus of the system, is very basic in design and can be viewed as an electronic version of today's prepaid stored-ride pass type of system. The second design involves a more sophisticated EEPROM MC/SC and provides a flexible capability to easily allow for fares to be charged according to distance and/or time-of-day variables, thus creating tremendous revenue opportunities to the transit property. However, this second design alternative is more complex, costly, and thus subject to increased reliability problems.

4.0 MAINTENANCE/REPAIR/RECORDKEEPING FOR THE BUS TRANSIT INDUSTRY

4.1 Introduction

A recent estimate by the ATE Management and Services Corporation suggests that almost one third of the bus transit industry's budget is allocated for the maintenance function. A sizeable portion of this amount is dedicated to the recordkeeping necessary for adequate maintenance and repair. Because of its distributed processing nature, it is probable that the MC/SC will find application in automating the acquisition and routing of pertinent maintenance information. In doing so, it is likely that errors will be reduced and the process will be streamlined, thereby reducing the operating costs of the maintenance function.

Since the MC/SC is a portable data carrier, it is relevant to first examine the types of information that are necessary to support hte maintenance operation and the manner in which this information is distrubited to the personnel which must utilize it. The project team had the opportunity to tour the Transit Authority (COTA) to review their maintenance procedures. In addition, ATE Management Company of Cincinnati, Ohio, maintains information pertaining to the recordkeeping procedures used by other facilities throughout the country.

While there are certain recordkeeping requirements which are specified by federal law, there is no standard logistical procedure for management of this information. As such, it is impossible to provide a detailed discussion of recordkeeping procedures for bus transit system maintenance which would apply to all properties in question. For the purposes of identifying potential memory card applications, the general information flow between maintenance managers, service islands, shop floors, and other maintenance-specific areas, can be provided. This section discusses these generic information flows and lays the groundwork for the selection of candidate memory card applications, presented in the next section.

4.2 Information Requirements

The basic objective of any maintenance operation is to maximize the operational availability of its transit vehicles. This includes providing preventative maintenance at periodic intervals, as well as repairing the equipment when it breaks down. A bus transit system maintenance operation has three geographic areas key to information exchange:

- Service island,
- Shop floor,
- Parts room.

4.2.1 Service Island

The service islands are typically staffed with low-skilled labor and, in general, is an after-hours operation. It is here that fluids and other similar consumables are checked and, as needed, installed in the vehicle. Also, safety checks are made and interior cleaning takes place. Finally, driver defect reports are collected at this station.

The driver defect report is a checklist which is completed by the driver on a daily basis. The defect report indicates which defects, if any, were observed during the operation of the bus on a particular day. A set of defects, ranging from cosmetic problems to engine, transmission, and brake difficulties, can be indicated on the report. Other information acquired at the service island includes odometer readings, amount of fuel added, amount of oil added, and amount of coolant added.

4.2.2 Shop Floor

The shop floor is the area within the facility where most equipment repairs are made. Skilled trades are required, including subsystem specialists as well as general repairmen. Because of the broad scope of the repair work which occurs on the shop floor, it is the principal source of maintenance data collection.

4.2.3 Parts Room

The parts room is responsible for stocking, ordering, and supplying the parts necessary to maintain the equipment. These parts may be new, used, or rebuilt, and may or may not have warranties associated with them. It is in the parts room that computerized recordkeeping first had an impact on the bus transit industry in the form of data management programs. These software programs are typically used for inventory control and resource planning.

4.3 General Information Flow in the Maintenance Function

The types of information exchanged at three points described above, relevant to the maintenance function, may be categorized according to major operations within the transit system (see Figures 4.1-4.3). The operations are:

Vehicle operation
Service Island operation, and
Shop Floor operation.

Figure 4.4 is a generic flow diagram for a bus transit system. It should be noted that the scenarios presented in this figure is of the most general form and does not attempt to depict the logistics utilized by any specific transit property. The actions are, nevertheless, typical of those in the transit industry. The scenarios and potential applications for memory cards (presented in the next section) will be organized based upon this generic information flow. Finally, the transfer of information which takes place in Figure 4.4 is enumerated in Table 4.1. Combining the three points of information exchange with the fundamental information types, a generic characterization of the information flow for the maintenance function may be accomplished.

The most effective maintenance is achieved when all information pertinent to the repair is made available to the appropriate maintenance personnel in an easy-to-use and timely manner. For example, historical

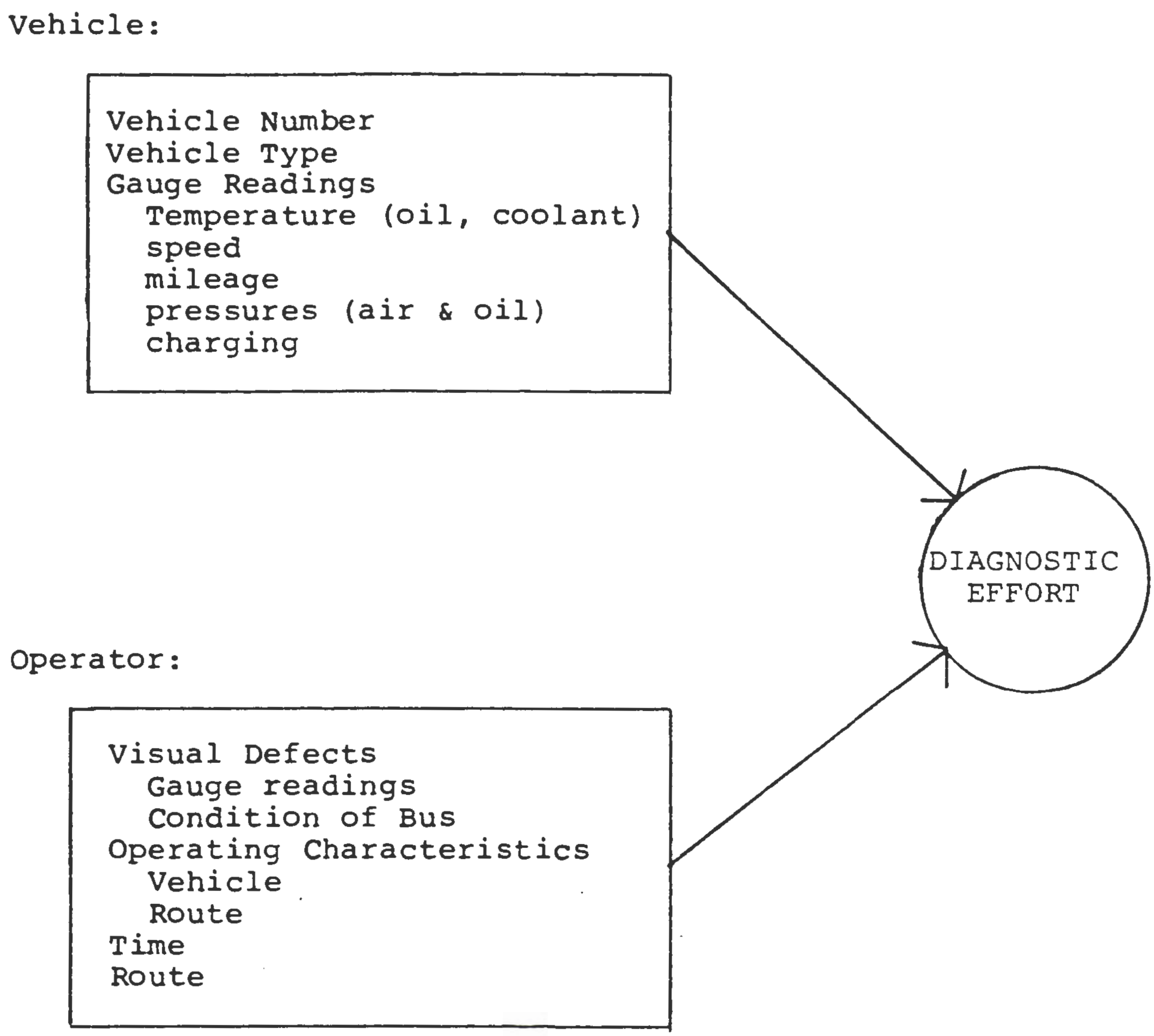


FIGURE 4.1 VEHICLE OPERATION

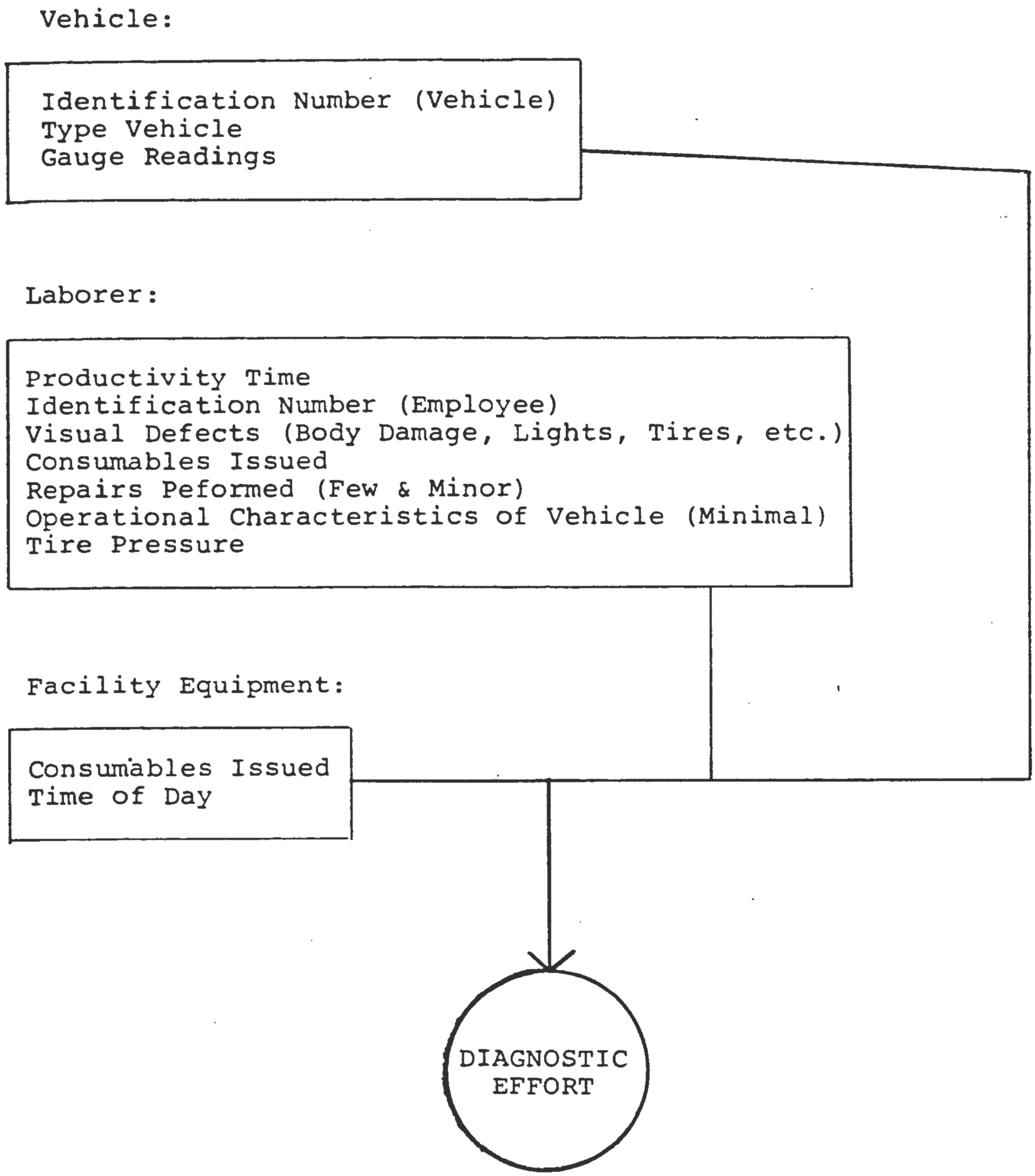


FIGURE 4.2 SERVICING OPERATION

SHOP

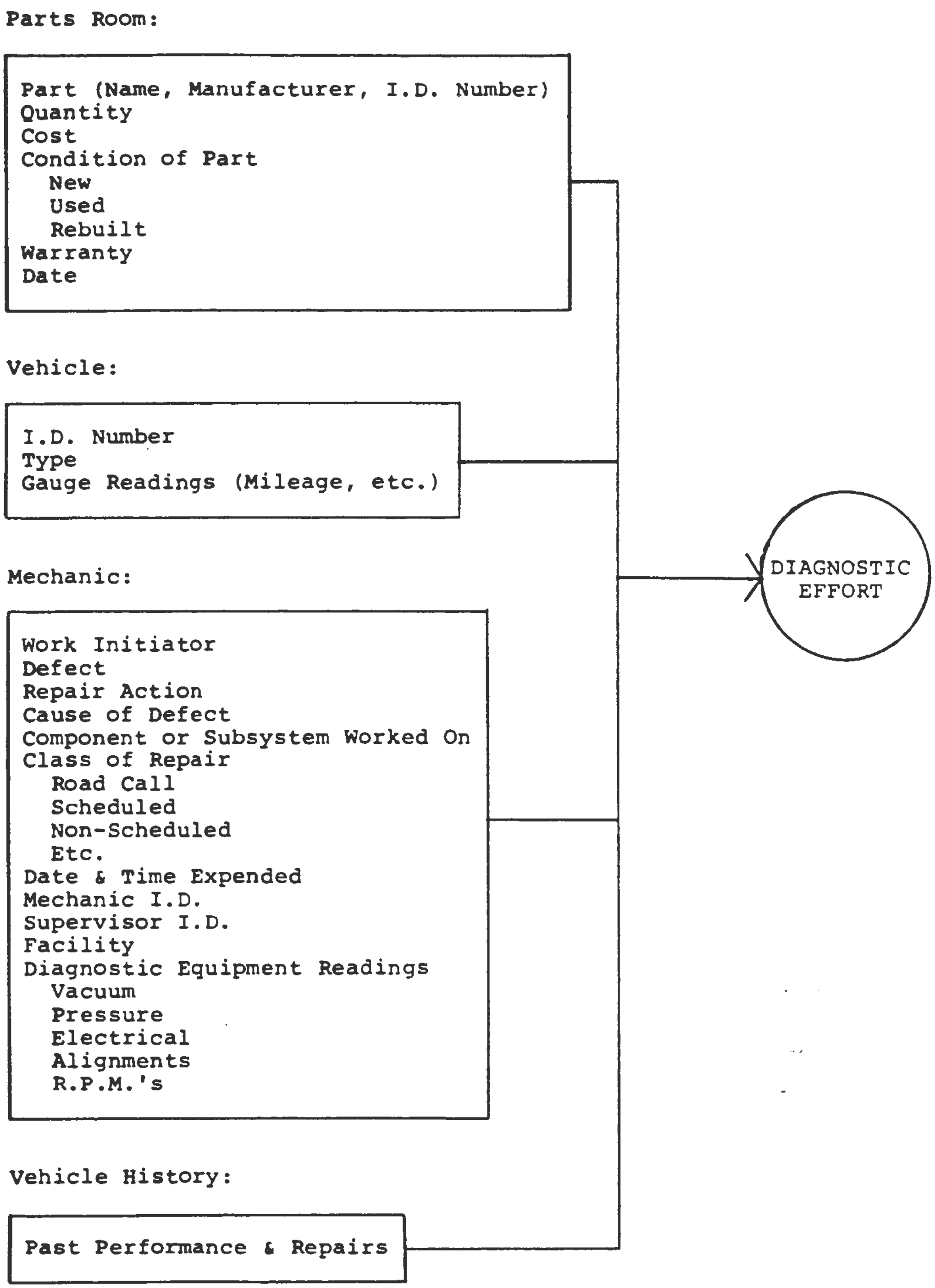


FIGURE 4.3 INFORMATION EXCHANGE AT SHOP FLOOR

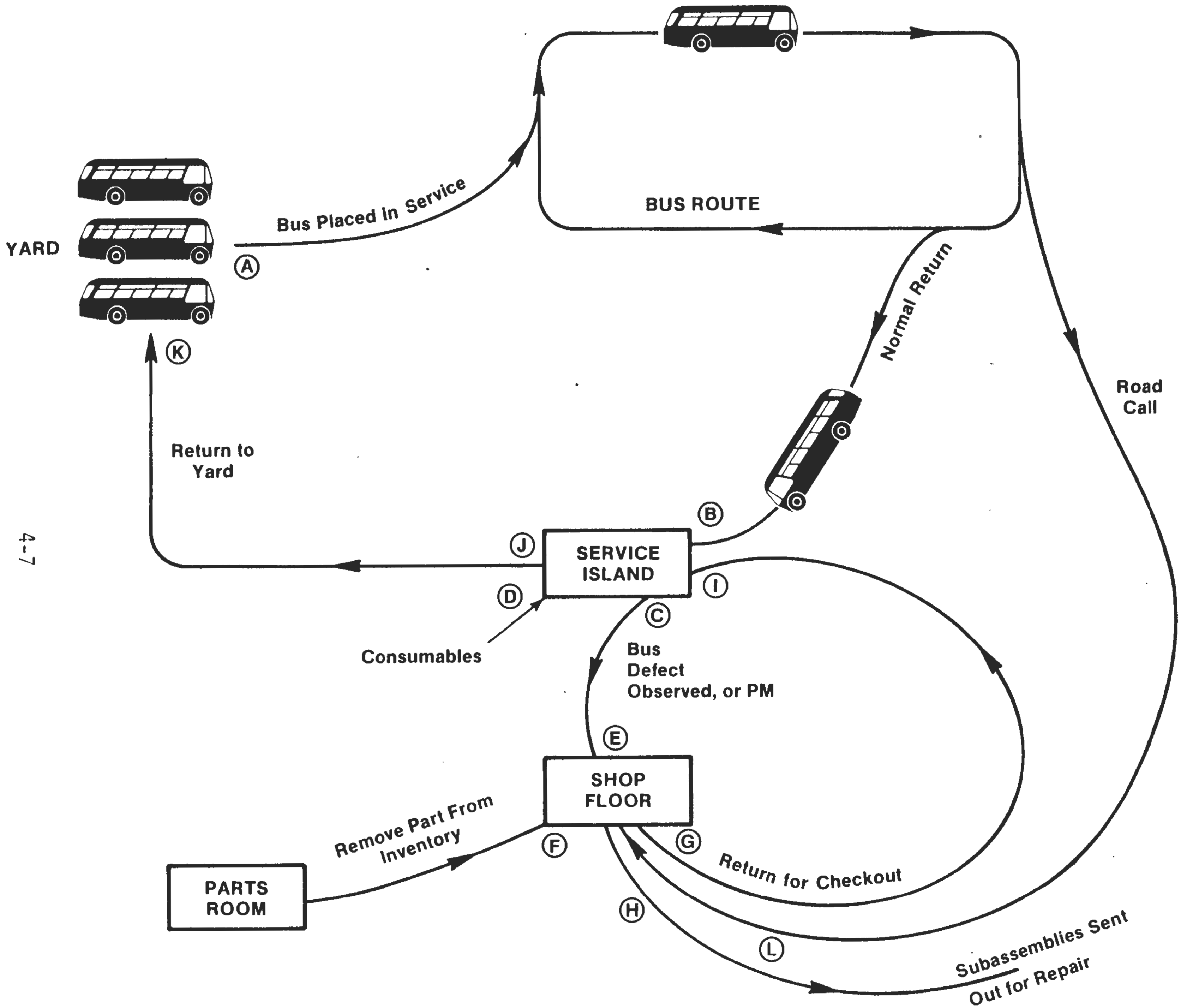


FIGURE 4 .4 GENERIC INFORMATION FLOW DIAGRAM FOR THE MAINTENANCE PROCESS information about past problems and repairs on a vehicle are crucial information when trying to track down intermittent or repeat problems.

TABLE 4.1 DESCRIPTION OF GENERIC INFORMATION FLOW FOR THE MAINTENANCE PROCESS

- A - Bus is placed in service. A driver is assigned to a specific vehicle and route. The vehicle is given an initial safety and defect check, and then the bus is placed in service.
- B - Normal bus return. At the end of the shift, the driver returns the bus to the service island where defect report is transferred to the personnel at the island.
- C - Bus defect is observed, or preventative maintenance scheduled. The service island personnel deliver the bus to the maintenance area for work to be performed.
- D - Consumables delivered at service island. A bus at the service island receives refueling, oil and coolant checks as well as other pertinent fluids, and mileage readings are recorded.
- E - Bus delivered to shop floor. A bus, along with a specific work order, is delivered to the shop floor for maintenance.
- F - Parts are delivered to shop floor from parts room.
- G - The bus has been repaired and is returned to the service island for checkout.
- H - Subassembly from the vehicle is sent off the shop floor for repair or rebuilding.
- I - A bus returning from the shop floor is again serviced and consumables delivered at the service island.
- J - The bus is returned to the parking yard and ready to be placed in service.

Shelf lives and date-of-rebuild for replacement parts are also critical data. Finally, operational data and parameters from the vehicle acquired during operation can drastically reduce troubleshooting and repair time.

Examining Figure 4.4, it is apparent that information relevant to preventative maintenance and repair of buses is generated by many geographical locations and at various times during the operational cycle. However, this information is not always being acquired or transferred to the appropriate locations effectively. In the small number of systems which utilize integrated computerized maintenance sytems, the ability to tie this information together is implicit because the information transfer network is already in place. However, most maintenance systems are still based on outmoded, paperwork filing systems where the paper-based information is so highly distributed that it is very difficult to efficiently gather and integrate the information necessary for a particular repair.

4.4 The Maintenance Recordkeeping Problem

Regardless of the system, some of the most critical information pertaining to bus operations is acquired manually by the driver during vehicle operation. This information is summarized on a bus defect report and supplied to the attendant at check in. The reliance on the driver to adequately describe malfunctions in a timely manner is an inherent problem in maintaining buses. According to a spokesman at a transit authority visited during the project approximately 30 percent of buses sent to the shop for repair are misdiagnosed on the first try. The reason for this is most probably that the repairman did not have the proper information at his disposal during the time of repair. With proper maintenance information, it may be possible to reduce labor expended during troubleshooting, increase the operational time for each vehicle, and improve the efficiency of the maintenance operation.

In summary the information for bus transit maintenance is generated at diverse geographical locations and at quasi-random times throughout the operational cycle. Unfortunately, the points of data acquisition are far from coincident with the points of information exchange for repair purposes.

A flexible data transfer mechanism for the maintenance purpose is a solution to making available all information pertinent to the problem regardless of who discovered the problem and when it was encountered. In this way, the most effective maintenance can be achieved since information useful to making the repair is recorded at the maximum information collection point, (i.e., the time while the vehicle is displaying faulty behavior).

It is imperative however that only critical information be collected via the portable data carrier. Extraneous or excessive amounts of data collected can overburden the maintenance function, thus adversely impacting the overall effectiveness of the repair function. In the next section, potential applications are discussed in which MC/SC technology can be utilized to enhance transit operational functions.

5.0 MEMORY CARDS FOR MAINTENANCE/REPAIR RECORDKEEPING

5.1 Introduction

As a technology, the memory card can be viewed as a portable element which forms the basis for a very flexible information network. In the standard computer system, we often think of data being transferred throughout the system on a data bus--a physical communication wire which transfers electrical signals from the computer's memory to the various satellite stations. In such systems, therefore, it is necessary to physically run wires to each of the sites selected for data entry and transfer.

The memory card, viewed as a portble databus, replaces the standard databus since it inherently carries all of the data with it. This increases the flexibility of the information network based on the memory card because each of the entry/access stations need not be connected by any physical link to a central computer site.

Therefore, perhaps the most significant advantage of the memory card is its ability to travel and track information in a highly mobile and flexible fashion, thereby allowing it to acquire field data in a manner which has not before been possible. Before examining several applications which may be possible with the memory card, it is first necessary to establish some guidelines which will aid the system designer in selecting potential applications.

5.2 Memory Card Application Constraints

Examining the potential advantages of the MC/SC in maintenance recordkeeping applications requires one to look at several parameters of the transit bus property. These include:

- Number of buses in the fleet
- Level of automated recordkeeping already in place
- Economic constraints

- Attitudes of personnel
- Level of recordkeeping desired.

If one examines the current maintenance recordkeeping practices, three distinct categories arise. These are illustrated in the following table:

TABLE 5.1 MAINTENANCE RECORDKEEPING SYSTEM

Recordkeeping System	Sample Function
1. Fully Automated	Allows tracking of spare parts, consumables, repairs, and repair histories
2. Partially Automated	Inventory control, work order tracking and accounting
3. Paper-Based System	Manual generation of reports, highly distributed filing structure

A small percentage of facilities currently have a highly automated recordkeeping system. These integrated packages allow the personnel to track repairs in progress, parts inventories, and repair histories. Reports generated by these integrated management systems allow maintenance managers to accurately maintain their fleet and identify and predict impending failures before they become catastrophic. In addition, several automated data collection systems may also tie into this integrated approach. Although several automated systems have been installed, they are costly and return on investment is uncertain. The ATE EZ Fleet System (shown in Figure 5.1) is an example of this. (In essence, although the package is different, one can view the EZ Fleet data entry device as a relative to the MC/SC technology.)

FIGURE 5.1 EZ FLEET™ MAINTENANCE RECORDKEEPING SYSTEM

With these integrated management packages in place, the users can also identify important trends in repair procedures, thereby allowing diagnoses to be more easily obtained. Also, computerized diagnostic equipment which directly interacts with the bus engine control systems may also help in generating repair procedure information.

The second system utilizes automated recordkeeping to a much lesser extent. Isolated areas, for example, parts shop, utilize inventory control equipment. Other examples might include automatically tracking work orders in the shop floor area. In this second level of maintenance recordkeeping, there is no infrastructure in place which will support the types of information flow necessary to adequately deliver the proper maintenance information to the maintenance personnel.

The final type of recordkeeping system is an all manual, highly distributed, paperwork-based system. Much like the previously described recordkeeping system, the desire for an integrated maintenance management system results in the selection of either an on-line data base approach or flexible memory card approach. The following section describes examples supporting the latter approach.

5.3 MC/SC Applications

In the case of the maintenance operation, MC/SC's can be associated with **actions** (i.e., repairs, defect identification, etc.) or associated with **physical objects** (i.e., personnel, parts, vehicles, work orders, etc.). This section describes several concepts which employ the MC/SC in order to improve the maintenance efficiency of a property. These concepts were arrived at based upon site visits to several bus transit properties in central/southern Ohio and northern Kentucky, and through internal concept generation session with Battelle staff knowledgeable in maintenance and diagnositc procedures.

The following scenarios have been initially screened according to the constraints itemized previously. In addition, parameters specific to the MC/SC have also been factored into the concept generations. These include:

- Highly portable package is subject to being lost, stolen, or broken
- Although the cost per device is small, if it is attached to items of large inventory, the investment for the device quickly adds up
- The logistics involved in physical transfer of these devices.

With the above constraints in mind, it is necessary to select applications which not only show clear information transfer benefits, but also inherently provide the incentives for the system users to carefully maintain and keep track of the memory cards. The scenarios which follow have these attributes.

5.4 Bus Maintenance Applications

Figure 5.2 illustrates, in broad terms, the kinds of applications which could be realized using the MC/SC principle. The figure arbitrarily breaks down the maintenance and repair cycle into three information transfer area:

- **Technical Information Management** -- utilization of information specific to the maintenance process
- **Diagnostic Process** -- evaluation and determination of faulty equipment
- **Logistics** -- procedures which are necessary to support the maintenance funciton.

It has been suggested that memory cards can be associated with either actions or physical objects. The applications illustrated in the rectangular "MC/SC" symbol are examples of each, and no attempt is made to evaluate their relative merits. They are simply provided for illustration purposes.

In selecting an application which ties an MC/SC to a physical object, it is important to insure that there is some interest incentive to keep these items together. For example, a specific MC/SC could be associated

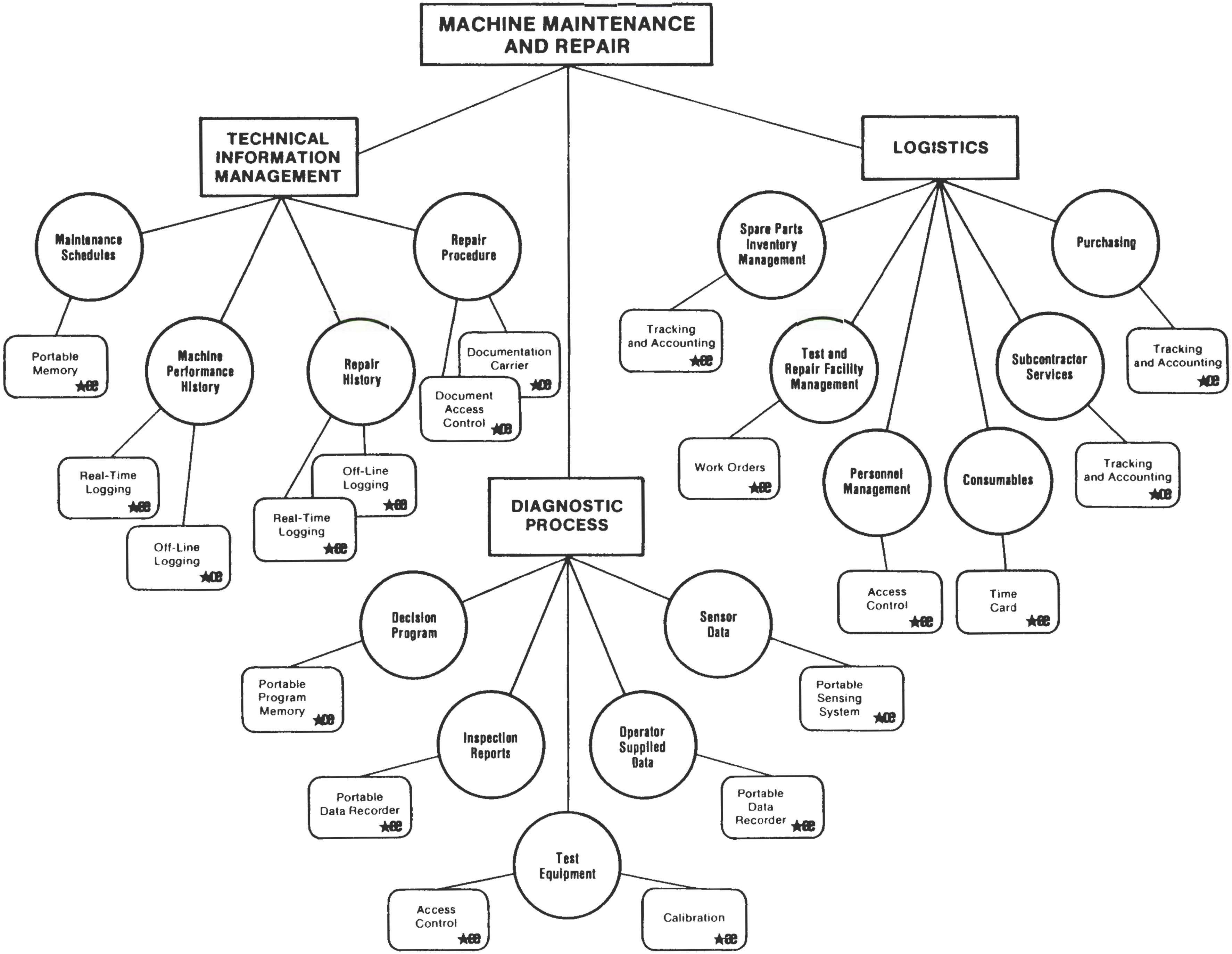


FIGURE 5.2 POTENTIAL ROLES OF SMART CARD TECHNOLOGY

with each major part in the inventory room, storing history and vendor information. While this would have the advantage of localized data storage, it would be extremely vulnerable to being lost or misplaced during usage. A centralized system would be necessary, and the existence of the system would displace the need for the MC/SC system.

More appropriate applications are those which provide an inherent incentive to maintain the integrity of the MC/SC system. These applications are most commonly those in which a human is the "owner" of the device. For example, if an MC/SC is used as an employee timecard in addition to tracking specific repair actions, then there is a basic incentive for the employee to use his card. This can also work to a disadvantage if taken to extremes. For example, if the employee views the MC/SC as a "big brother", past experience has proven that the system is prone to be sabotaged by its users. Therefore, it is necessary that any MC/SC system have clear benefits to all those involved. This usually occurs by making jobs easier and more efficient, in addition to adding new services.

Referring once again to the generic information flow diagram in Figure 4.4, the following MC/SC opportunitites are present:

- A -- Driver uses an MC/SC as ID card and ignition key. Daily assignments are supplied through the MC/SC.
- B -- Driver's MC/SC doubles as the bus defect report, interfacing with the bus control systems. Driver inserts MC/SC into service island reader as he exits bus.
- C,E,G -- Repair work order is stored in MC/SC. Could be stand alone work order, or may be assigned to repair personnel.
- D -- The use of consumables is authorized by service island employee's MC/SC inserted into proper dispensing equipment.
- F -- MC/SC's are attached to specific spare parts.
- H -- A repair order is stored on the MC/SC.
- J,K -- Bus routes and asignments are made through driver's MC/SC.
- L -- Subcontracted repairs are specified by MC/SC.

A major source of maintenance information comes from the driver defect report. This report is lacking of important detail. The repair personnel ususally could rely on conversation with the driver to determine the extent of the problem, however, this important information exchange usually does not occur. A potential application of the MC/SC is the automation of the driver defect report. Figure 5.3 depicts a block diagram of a system capable of generating a more extensive report by interacting directly with the bus control system. Intermittent problems (noises, etc.) are stored on the MC/SC through interaction with the driver's touch panel. An artist's conception of this application if Given in Figure 5.4

5.5 The MC/SC Opportunity in Maintenance

The above discussion has illustrated some possible uses of MC/SCs in maintenance. Each is technically feasible today, however the true cost/benefit performance has not been investigated. The applications are simply provided to illustrate the breadth of capabilities brought about by the technology.

The utilization of MC/SCs in maintenance represents a closed-end application. As such, there is never a time when the MC/SC device is truly outside the "control" of the system. This is not the case with fare, collection where one cannot predict the use characteristics of the device.

The closed-end attribute of the maintenance application makes it an attractive first-use of the device in bus transit. Incentives to correctly use the MC/SC system can be inherent in the application--such as in the case of lessening the workload of a driver in the generation of reports. These systems, though small scale in comparison to the volumes required for fare collection, appear to have the potential to positively affect the large percentage of operating budgets devoted to the maintenance function.

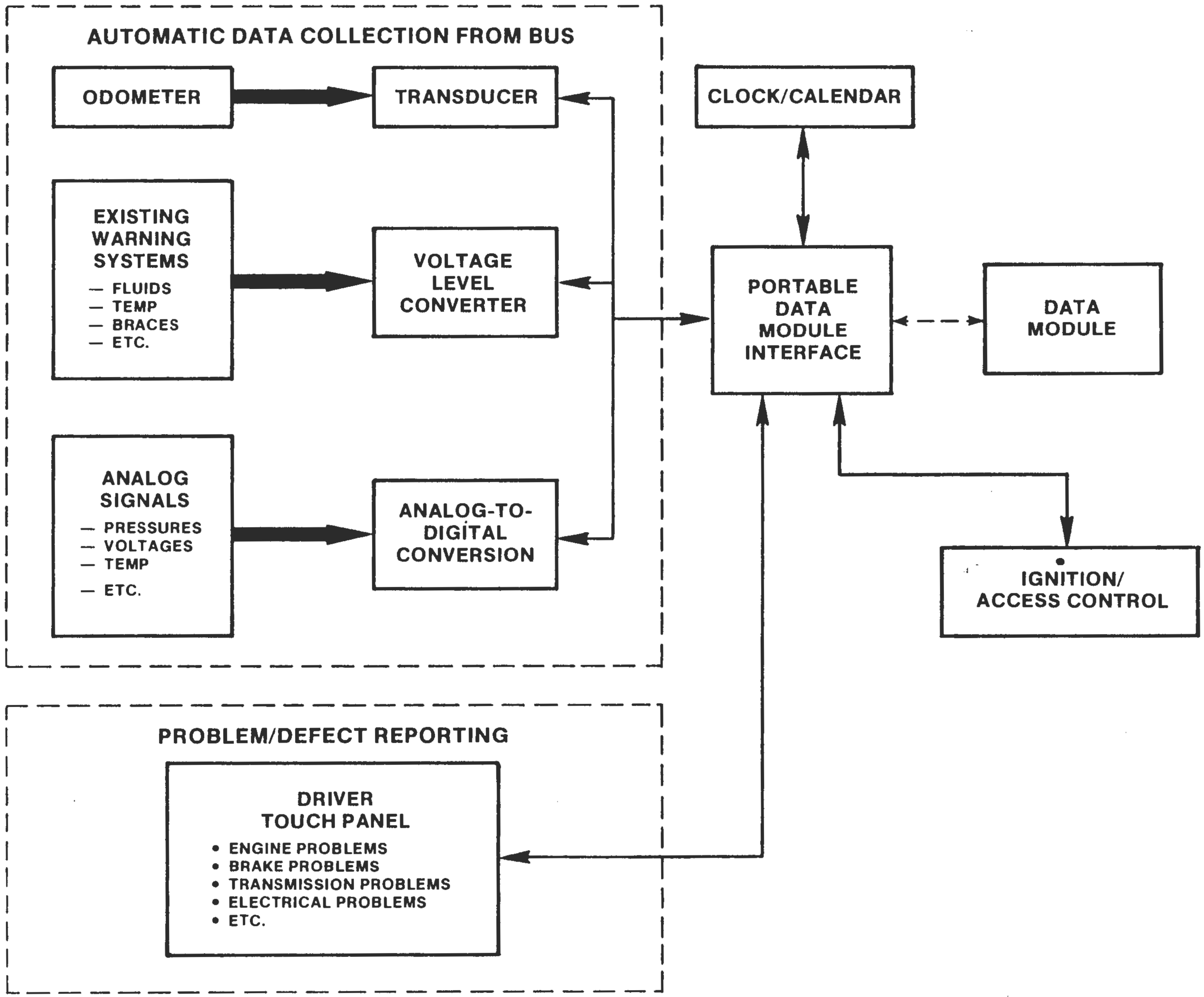


FIGURE 5.3 AUTOMATIC SYSTEM FOR GENERATING DRIVER DEFECT REPORT USING MC/SC

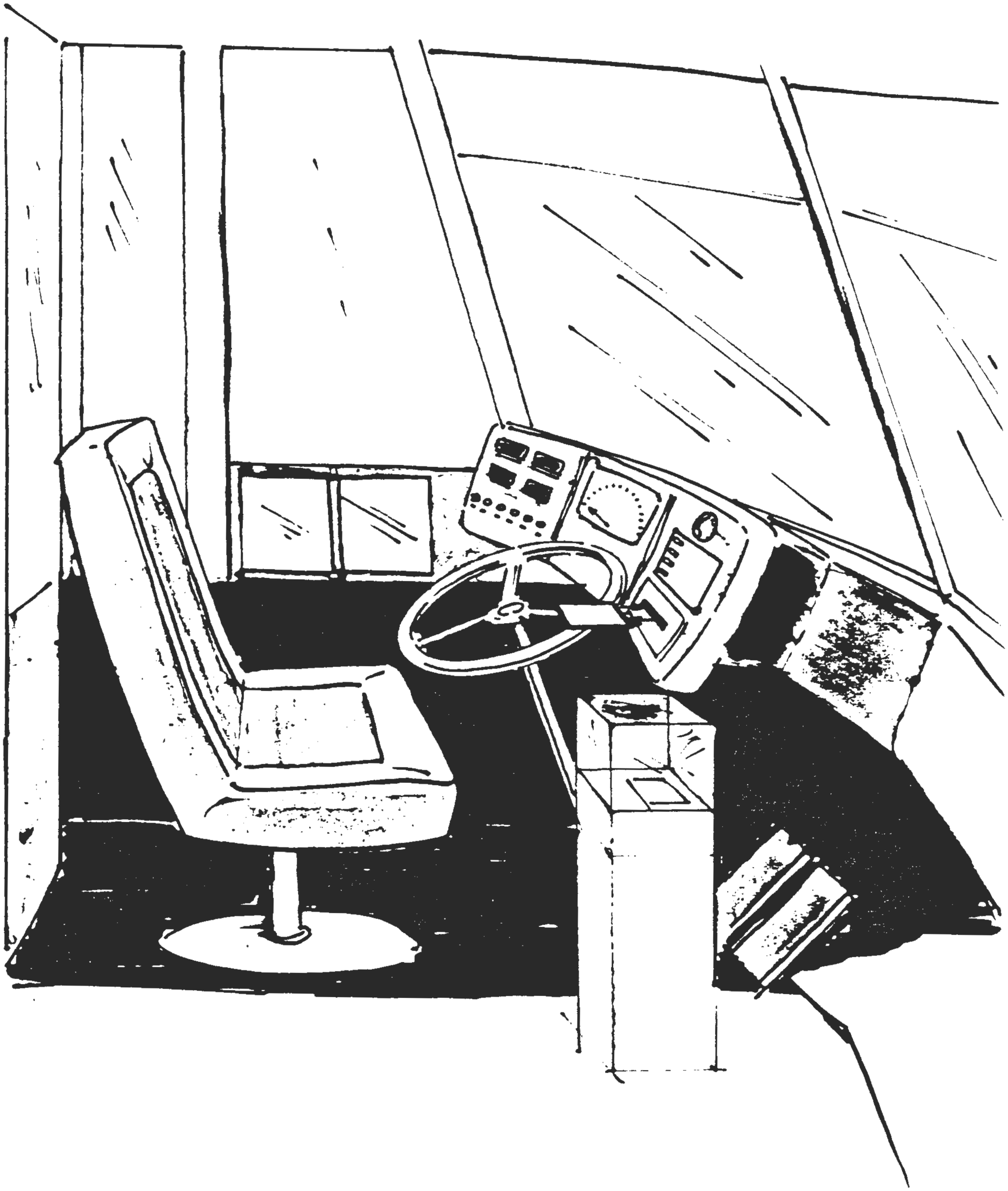


FIGURE 5.4 RENDERING OF AUTOMATED BUS DEFECT REPORTING

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

MC/SC technology has been in the development stages for over a decade and is rapidly emerging as a technology that is no longer experimental since several companies now offer commercial products. While rapid technical advancements have been made over this time period, the number of MC/SC system installations are few and limited in scope as pilot programs.

Three principal features offered by MC/SC technology seem to make it an attractive product for the payment needs of the financial and retailing communities. These are:

- offline processing capability
- enhanced storage capacity
- improved security provisions

Payment transactions appear to be a natural application for the MC/SC because of:

- the need for detailed data capture at decentralized locations,
- obvious security considerations,
- the relative expense of depending upon online systems to satisfy these needs.

Despite this, the prospects for the widespread usage of MC/SC in the financial transaction arena are surprisingly negative over the near term. A primary reason for the lack of progress in the financial community is the universal usage of the magnetic stripe as a storage medium, and the equipment infrastructure that is in place to support magnetic stripe technology.

Other potential applications for MC/SC technology do not have the same existing industry barriers present in the financial community. The transportation industry, for example, seems to be an industry particularly well suited to pioneer MC/SC technology applications due to:

- the lack of uniform systems for similar applications among different transit properties,

- the high volume reality of the business in terms of people and buses, and,
- the capital intensive nature of transportation as an industry.

MC/SC producers and manufacturers have been seeking industries where natural applications exist and adequate funding can be obtained to spearhead the development of a state-of-the-art MC/SC based system. Because of this, and the potential benefits of the technology for the transportation industry, a favorable climate currently exists for a mutually beneficial partnership between UMTA and a MC/SC technology company to initiate an investigation into the detailed design of a MC/SC based system.

This report has explored several possibilities for the application of MC/SC technology in the bus transit industry, specifically fare collection and maintenance/recordkeeping. While the design scenarios presented within the body of the report are all deemed to be technically feasible, the conceptual design of these systems cannot be fully and accurately assessed until a detailed requirements analysis is conducted and specifications are developed in conjunction with a specific transit property and a pilot test conducted. Notwithstanding the need for further study and development work to achieve this end, it appears from the analysis completed during this project that the maintenance and recordkeeping application has greater potential than fare collection to serve as a pilot application.

Maintenance and recordkeeping possesses three basic attributes that allow it to be particularly well suited as a test application for MC/SC technology.

1. As described in Section 5.0, the maintenance function is highly dependent upon the gathering and storage of data in a flexible fashion at a variety of different locations and work areas, a functional need in which the MC/SC is particularly well suited to address.
2. Maintenance remains an area that has yet to be highly automated at many transit properties, especially the smaller properties with less than 100 buses.

3. Perhaps most important, maintenance is a closed end system with a limited number of users, all of whom are employers of the property. This consideration is in sharp contrast to that of fare collection in which a pilot would need to be conducted with the ridership's cooperation, thus greatly complicating the process of disseminating information and encouraging usage.

Despite the favorable characteristics associated with the maintenance and recordkeeping function, it should be recognized that the greatest revenue enhancement oppor-tunity for the transit industry with MC/SC technology lies within the fare collection process. The data from past studies indicate that the level of fraud and opportunity costs resulting from the inflexibility of existing fare collection systems is indeed significant. Two conceptual designs are presented in Section 3.0 that have the potential to displace a significant proportion of currency and coin from the fare collection process, thus re-ducing a percentage of the fraud losses. In one of these two conceptual designs, the issue of accomodating rate sensitive fares based upon time and distance parameters is more readily satisfied resulting in a far greater potential payback. Unfortunately, the design of this second system has inordinate hardware and software costs as compared to existing fare collection systems, and is also complex in design.

Other serious questions remain regarding the application of MC/SC technology in fare collection in lieu of the magnetic stripe card that is currently being tested. MC/SC's can best be applied to fare collection if they become the standard for the industry, so that development costs can be spread across a large base. This may be possible if applications are coordinated and financed collectively by the bus transit industry, rather than by individual transit authorities. However, the largest portion of the industry, both from the number of buses involved and the level of ridership, operates in large cities with multi-modal transit systems such as New York, Chicago, Boston, San Francisco, Washington, etc. The tariff structure applied on the buses in most of these cities is expected to thoroughly interface with that of the rail system (exceptions are Boston and New York). A number of rail transit systems (San Francisco, Washington, Miami, Baltimore, Atlanta and, experimentally, Boston and Chicago) are already utilizing some degree of automated fare collection involving magnetic stripe tickets, and it is likely that New York will follow suit sometime in the near future. Thus, given current trends, interfacing the fare collection system on the buses will require the use of magnetic stripe technology. Because of this, the potential market for a bus-mounted MC/SC system is reduced considerably. The situation is somewhat analogous to that described for bank cards in Appendix B, although it is not quite in such an advanced stage of development.

None-the-less the following conclusions can be drawn:

1. There is little doubt that MC/SC technology has been developed and tested to the point that it can reliably be applied to industrial applications,
2. The maintenance and fare collection processes are two viable candidates to serve as a pilot for the application of this technology,
3. The window of opportunity for MC/SC applications in fare collection is closing rapidly because of magnetic stripe pilot systems; if MC/SC's are to be fitted to fare collection, steps must be taken quickly before a broad acceptance of systems combined with a reluctant attitude to other technologies magnetic stripe preclude the opportunity to try other alternative technologies,
4. The transportation industry as a whole seems well suited to assume a leadership role as a pioneer for the commercial application of MC/SC based systems because of both its capital structure and high volume nature of the transit industry.

6.2 RECOMMENDATIONS

Given these conclusions, Battelle recommends UMTA continue to monitor MC/SC technology applications development. This recommendation can best be accomplished by:

- tracking technological advancements occurring in MC/SC technology,
- co-ordinating efforts to move this technology forward within the industry, and
- managing the ongoing efforts to intiate a pilot project within either the maintenance and record keeping, or fare collection application areas.

Second, Battelle recommends that UMTA immediately pursue a follow-up study to:

- conduct a detailed evaluation of the conceptual designs contained within this report for the purposes of prioritizing the best candidate for a pilot test project,
- develop the detailed requirements of that pilot application, and
- recommend which transit property should serve as the pilot site.

The conceptual design scenarios presented in this report warrant a further more detailed study. It is only through a continuing effort in these endeavors that the benefits from this fast developing technology can be fully applied to urban transit systems.

APPENDIX A

A CURRENT PROFILE OF THE U.S. PAYMENT SYSTEM

APPENDIX A
A CURRENT PROFILE OF THE U.S. PAYMENT SYSTEM

Introduction

Due to the functional similarity of the fare collection process to retail point-of-sale payments, a perspective of the payment system is essential to understanding the implications of smart card usage in bus transit operations.

The fare collection process is similar to the payment function at the point-of-sale in that value is being exchanged for a product or service. The fare collection box facilitates the transaction in much the same way as a cash register or point-of-sale device. Like the cash register, the fare collection box serves both a computing and storage function.

The high volume nature of the fare collection process demands that customer queuing be kept to a minimum. Therefore, throughput speed as well as reliability are considerations in both the point-of-sale and fare collection processes. Additionally, customer convenience is a major factor in maximizing revenues. The payment system is a necessary support function in operating a retail establishment or transit property. A primary objective is to expedite the payment process through an efficient and convenient system that accomodates virtually all customers. A payment system that excludes or is inconvenient to a portion of the customer base is highly undesirable. Unfamiliar forms of payment that are dissimilar to commonly used payment mechanisms can be a major barrier to payment convenience.

These considerations are integral to the assessment of smart card applications in the fare collection process. The purpose of this particular section is to profile the current state of the nation's payment system. Who is using what forms of payment, where, and why, are the questions that will be answered. The answers to these questions will provide valuable insight into where the payment system is headed over the next several years, and most importantly, whether or not innovative forms of fare collection payment will be feasible.

Commonly Used Forms of Payment

Currency and Coin

Aside from the barter system, currency and coin is the oldest form of payment used in society, dating back several thousand years. As the computer age matured in the 1970s, many futurists predicted the demise of currency and coin in what was dubbed the "cashless society". The many disadvantages of currency and coin lends support to the trend away from cash and toward more advanced forms of payment.

One of the major disadvantages associated with cash is security. Currency is easily concealed and not easily traceable, at least in smaller denominations. Therefore, most individuals limit the amount of cash carried for security purposes. This however can be a disadvantage when making certain purchases which tend to be of a high value and variable amounts (e.g., groceries).

Retailers share the same concerns of consumers. Robbery is a fairly common criminal act, particularly in certain retail segments with extended night hours (e.g., gas stations and convenience stores). In 1982 for example, one out of every three gas stations in California fell victim to robbery.

Internal pilferage is also a problem with cash handling. Elaborate internal control procedures are mandated by regulators in the commercial banking industry. Independent auditors serve a similar function to a more limited extent in reviewing internal cash handling controls of publicly held companies of all types. Never-the-less, internal pilferage remains a major cost item in business although few statistics are available to quantify the extent of the losses.

Aside from security, cash transactions present other problems. More times than not, a cash transaction requires change to be returned to the consumer thus reducing throughput speed and increasing the likelihood of error. Particularly with larger purchases, consumers are many times uncomfortable with the easily misplaced sales slip as the only proof of purchase.

From the consumer perspective, cash represents lost interest revenue in that interest bearing NOW accounts are universally available throughout all parts of the country.

Cash does have its advantages however. It is a relatively quick form of payment when compared to transactions that require an authorization, it is well understood, does not require an identification, is universally accepted, and is welcomed by merchants as indicated by the trend toward cash discounts, particularly in the retail petroleum industry.

In terms of the overall payment system, cash is used for 87 percent of the nation's financial transactions, but only accounts for 3 percent of the total dollars transacted. This means that of the 350 billion financial transactions that were estimated to have taken place in 1980, 305 billion were for cash.

However, most of the 350 billion transactions (230 billion) were for insignificant amounts of $1 or less, the same range as bus transit fares. Ninety percent of all transactions of $10 or less were also completed via cash. Not until transactions exceeding $10 are considered is cash no longer a dominant payment mechanism. For these transactions, cash is used only 28 percent of the time.

The 3 percent dollar share that cash transactions represent deceivingly under-estimates the importance of cash as a payment mechanism. Business transactions and bill payments are virtually 100 percent non-cash. If retail transactions at the point-of-sale are considered instead of the total population of financial transactions, cash accounts for 42 percent of the total dollar amount of purchases. This means that despite predictions of a cashless society, cash remains the dominant payment mechanism within the nation. While the trend is downward from the 1965 total share of 50.9 percent, cash will remain as an important form of payment for the foreseeable future, particularly for small transaction amounts.

Other statistics indicate that the prevalence of cash is indeed increasing. As of December 1980, approximately $137 billion in cash was in circulation in the U.S. Since 1970, paper money in circulation has been growing at a rate of 6 percent per year, considerably greater than both GNP (2 percent) and population (1.5 percent). On a per capita basis, cash has risen from $265 per head in 1970 to $600 in 1981. This growth ironically occurred during a period when consumers were increasingly using both credit cards and checks, the two most common substitutes for cash.

The cost of accepting a cash transaction has been widely debated based upon which items should be included in the calculation. Employee pilferage, robbery, reconciliation time, counting, and sorting are seen as direct cost items to the acceptance of cash, whereas security cameras, safes and other types of equipment are indirect costs, but none-the-less are largely attributable to the need to handle cash. A study by Payment Systems Inc. (PSI) revealed that the combined cost to the merchant and bank is $.45 per transaction. This estimate, if accurate, is significant when taken as a percentage of the $16 average cash transaction amount at the point-of-sale.

Cash is used most often in those retail segments where either the average dollar sales amount is small, or few other payment options are available. Convenience stores have one of the highest concentrations of cash transactions. For the most part, convenience store profit margins are too slim to accomodate the risk of accepting bad checks. Bank credit cards (Visa and MasterCard) are not accepted by convenience stores because of the 2 percent to 3.5 percent "discount fee" of the sale price that is paid by the convenience store operator to the card issuing bank. Similarly, convenience stores cannot afford to offer their own credit card due to the overhead expense associated with offering such a service.

The drugstore retail segment is somewhat similar. Purchases are often for small amounts, thus indicating that payment alternatives are not as important to the customer as compared to those retail segments where the average purchase price is much higher. Again, profit margins are slim indicating that drugstore operators are not eager to pay the fees demanded by the bank card associations for the acceptance of Visa and MasterCards unless the amount of purchase exceeds a set floor limit. Although drugstores, like convenience stores, cannot readily accept the potential risk of bad checks, most drugstores do in fact allow checks to be written due to the more personalized service that is provided and due to the greater familarity of drugstore operators with their clientele.

Retail gas stations are the third category of retailer that is typified by a high percentage of cash transactions. Like the convenience store and drugstore, profit margins for gas station operators are typically 1.5 percent or less, thus indicating that petroleum retailers cannot afford the fees required to honor Visa and MasterCards. However, all but one of the top ten petroleum companies do in fact offer their own credit cards as a convenience to their customers and to help bolster customer loyalty to their brand stations. The primary reason that the petroleum companies can afford this overhead item is because of the historic high profitability of the oil industry in general. Unlike the companies that own convenience and drugstore chains, the retail operation is a very small portion of petroleum company profits. The refining and wholesaling operations provide the oil companies with a far greater return on their investment than the actual retailing of gasoline through company owned and/or dealer operated gas stations. Because operators of gas stations are operating on a slim profit margin personal checks are rarely accepted at most high volume stations since the risk is too great. Cash is the dominant form of payment due to the relatively small purchase amount, followed by the usage of oil company credit cards.

Supermarkets are far different from that described for other types of retailers. Since the average purchase price for groceries is far higher than in retail petroleum, drugstores, or convenience store industries, customers cannot depend as readily on cash for payment. Additionally, grocery expenses tend to be more variable in amount due to the number of individual items purchased versus that in other retail segments. For these reasons, supermarket operators are impelled to offer a viable payment alternative to their customers. Since profit margins are generally below 1 percent, bank credit cards are not widely accepted at supermarkets. For the same reasons, they also cannot afford the overhead of their own in-house credit program. Despite the risk of bad checks, the personal check is the only other mechanism currently available to supermarket operators. Statistics indicate that cash acceptance in super-markets is far below that of the other retail segments described thus far in the chapter. While a high percentage of transactions are indeed for cash, dollar sales transacted are virtually split evenly between cash and checks.

Department stores are similar to supermarkets in that purchase prices tend to be for greater amounts than in many retail segments. Unlike necessity items like food and gas though, durable goods sold in department stores are generally shopped for by customers less frequently with purchases made more impulsively. Consequently, the availability of credit is far more advantageous than for necessity goods. For this reason, virtually all major department stores offer some form of credit card. High mark-ups on both durable and fashion merchandise allow department store retailers sufficient margins to support in-house credit programs. In addition, it also allows close to 70 percent of the top 150 department stores nationwide to accept either Visa, MasterCard, or American Express cards. Since many purchases are in fact impulsive, department stores also accept personal checks to ensure that the widest array of payment choices are available to their customers. Because of this, cash transactions are least prevalent in the department store retail segment when compared to the others that have been discussed. Nonetheless, cash remains the most often used form of payment in terms of both transactions and sales dollars. Other retail segments, notably the specialty stores with high mark-up items and narrow product lines and the mass merchandisers with high volume sales of low mark-up items, are more difficult to classify. However, both general categories of retailers are similar to that of department stores in that checks and bank credit cards are widely accepted and cash is not used as frequently as in other retail segments. Even here however, cash is used more frequently than with other forms of payment.

<u>Checks</u>

Aside from cash, checks are the most commonly used form of payment at the point-of-sale in terms of transaction volume and sales dollars. From the consumer perspective checks are advantageous because they are well accepted by many retailers except gas stations and convenience stores. Also, checks minimize the amount of cash that needs to be carried, provide a paper receipt of payment, and even allow for as much as 5 to 6 days float on funds. From the merchant's perspective however, check handling is expensive in terms of float and processing costs, time consuming, and risky in areas of bad check incidence.

Notwithstanding the potential margin of error with most check studies, indications are that, as a percentage, checks are being increasingly written at the point-of-sale. For example, the 1974 Arthur D. Little study showed 28 percent of all personal checks are written for retail purchases. Subsequent studies have since identified this same statistic to be 31 percent in 1976 (SRI), 32 percent in 1979 (BAI), and 43 percent in 1982 (PSI).

For purposes of quantifying the number of checks written at the point-of-sale in 1982, a whole host of estimates are available. According to the Federal Reserve Board, the number of checks written at the end of 1982 approximates 36 billion. Other sources such as the Nilson Report place the volume of checks at 44 billion. Most agree that of all checks written, about one half are for personal use. Using a mid-range estimate of 40 billion checks written per year, of which 20 billion are by individuals, this means that between 8 billion and 9 billion checks are written per year at the point-of-sale using PSI's most recent percentage described above.

The Visa organization estimates the total sales volume for which checks at the point-of-sale are written will be around $300 billion in 1983. Using these estimates loosely, the average check is written for $30 to $40. According to BAI (1979), 57 percent of these checks are written to non-food retail establishments, indicating that grocery stores are receiving the remaining 43 percent of checks that are written.

In a report released in December of 1983, the Antietam Group studied the payment volume of eight different retail segments. The study accounted for about 58 percent of the retail trade reported by the U.S. Commerce Department for 1982. As expected, they found that supermarkets had the highest incidence of check transactions (17 percent) and check sales volume (48 percent). No other retail segments were even close to the supermarket's figure. Specialty stores were a distant second with 15 percent of all transactions begin with a check, representing 18 percent of check volume.

These statistics in total reflect that checks are indeed a significant method of payment at the point-of-sale and have been growing as a percentage of all checks written. The use of checks is highly skewed toward the retail food industry, most notably supermarkets. Obviously, all households utilize cash as a payment mechanism at the point-of-sale. Federal Reserve estimates are that 90 percent to 95 percent of all households currently have a checking account, suggesting that the usage of checks is virtually universal. Most estimates place the average number of checks written monthly per checking account at around 20. Using the PSI estimate, 8 of these checks (43 percent) are used for purchases at the point-of-sale.

Credit Cards

The credit card is the third major payment mechanism for point-of-sale purchases in the country. Two generic types of credit cards are commonly used today throughout the nation. The first category includes the bank credit card and travel and entertainment card. These types of cards are accepted by a variety of different merchants who generally pay a percentage of the sales price to the issuing organization. The percentage paid, or discount fee, ranges between 2 percent for Visa and MasterCard to as much as 5 percent for American Express and Diners Club. In addition, annual fees are usually charged to individual holders of the cards, and usually range from $15 to $100. Because of the cost and credit qualifications needed, bank credit card usage (Visa, MasterCard) is restricted to around 50 percent to 55 percent of the nation's households while the travel and entertainment cards (e.g., Diners Club, American Express) are only carried by about 10 percent of the nation's adults. Demographic studies of card carrying individuals show that the highly educated and most affluent categories of individuals in the country use these types of cards.

Retail credit cards on the other hand are issued by retailer organizations without annual fees charged to the consumer and of course without any type of discount fee being paid by the store that accepts the card. With only a few minor exceptions, retail credit cards can only be used in the issuing retailer's chain of stores. Unlike the bank and travel and entertainment cards, retailers do not generally reap a direct profit from their credit card operations. In other words, it costs more to operate a credit card program than it receives in interest revenue (interest received on outstanding balances at the end of each month).

The predominant reason that retailers issue credit cards is for the convenience of their customers, translating into additional sales for impulse purchases. Retail credit cards also allow for more individuals to have access to credit cards than would otherwise be the case. Since 1980, the bank credit card organizations have instituted more stringent income requirements to qualify for a Visa or MasterCard credit card. This has served to reduce the number of individuals that can qualify. However, retail credit card requirements are not nearly as stringent since retailers can better control credit abusers since usage is restricted to a single chain of retail outlets.

Usage figures for credit cards have risen dramatically over the past twenty years. Today, almost 70 million individuals carry a bank credit card whereas 90 million carry a retail credit card of some type. Bank credit card transactions in 1982 totaled 1.3 billion charging $66 billion in merchandise (including cash advances). During the same year, 3.3 billion retail card transactions took place on sales of over $100 billion.

Most bank credit card transactions take place in specialty stores and mass merchandising stores for mostly durable goods. Most retail credit card transactions take place in the retail petroleum segment and in department stores.

Debit Cards

The last notable payment mechanism is the debit card. To date, the debit card has seen limited usage at the point-of-sale. The critical difference between the credit and debit card is the timing of when the funds are paid. With credit cards, the consumer is billed monthly for charges incurred throughout the month. Except for travel and entertainment credit cards, consumers can either elect to pay the credit balance in full, or a portion of it, leaving the remainder to be paid in future installments at established interest rates.

On the other hand the debit card is essentially a paperless check. Ideally, the debit card transaction causes the transaction amount to be immediately subtracted from the demand deposit account (checking account). Debit card transactions generally are conducted through an on-line link to the card issuing bank where the consumer account is set up. When the consumer presents his/her card, the account information and security related information encoded on the magnetic stripe on the back of the card is read by a terminal and "sent downline" to the appropriate bank's host computer. The account is first verified along with the PIN (personal identification number) entered at the terminal by the consumer to ensure that the cardholder is authorized to use the card. Second the account is checked to ensure that adequate funds are in the account to cover the sales amount entered by the cashier. Once these two verification processes are then complete, the sales price is either subtracted from the consumer's account and added to the store's account, or put "on hold" in the consumer's account until that night when the funds are transferred to the store's account.

Because this type of debit card system does not require a paper document such as a check to be sent to the bank before funds are transferred from one account to another, this type of transaction is called an electronics funds transfer (EFT) transaction. In order for an EFT transaction to take place, several system components must be in place. The consumer needs to have an appropriate debit card with the encoded magnetic stripe, a terminal must be available to read the magnetic stripe and to permit the entry of a PIN, and a communication network is needed to link the store with the bank. The initialization of a smart card system that utilizes a stored value concept would likewise constitute an EFT capability since dollar value would be electronically transferred to the storage medium in the card.

The processing cost of an EFT transaction is much less for both the bank and the retailer since paper documents (currency, checks, and credit card receipts) do not need to be sorted manually, sent to a processing facility, key entered into a computer system at the processing facility, and mailed back to the consumer. The ability to handle debit card transactions at the point-of-sale have yet to be implemented, although many experimental programs are currently taking place throughout the country.

Debit cards can currently be used however at 50,000 ATM (automated teller machine) locations nationwide to obtain cash. While these transactions are not point-of-sale transactions per se, they are similar because value, in this case cash, is being received through the use of a plastic debit card. In 1983, over 3 billion ATM transactions were completed through the use of debit cards at ATM locations. It is estimated that 20 percent of all adults use their debit card in an ATM at least once annually. Like the plastic credit card, most debit card users tend to be the better educated individuals in our society, in the younger age brackets, and in the higher income categories.

Conclusions

A profile of today's payment system is important to possible applications of the smart card in the fare collection process for several reasons. First, a smart card can be viewed as a sophisticated type of plastic card. In today's payment system structure, we can see that cash continues to dominate as a payment mechanism. Checks are also prevalent, but are limited to some degree because retailers are not always willing to assume the risk of loss from a bad check. Most importantly, credit and debit card usage is not nearly as prevalent as the more traditional methods of payment, specifically cash and checks. This indicates that despite the electronic sophistication of our society, individuals continue to cling to the traditional forms of payment.

What implications does this have? First of all, consumers much prefer the use of cash, particularly for smaller dollar value transactions. While cash usage declines markedly for transactions of $10 or greater, virtually all transactions that take place for lesser amounts are paid with currency and coin. Why? The main reasons seem to be that case is quick, universally acceptable, and easy to obtain. The advent of cash changing machines and ATMs are having their effect of making currency and coin even easier to obtain. This means that if a system utilizing a smart card were to be implemented in today's environment, a radical change in consumer behavior would have to take place in order for it to be acceptable. While it is likely that security is a concern in carrying large amounts of money, most consumers are accustomed to having nominal amounts available for incidental purchases.

A second conclusion appears obvious. Since credit cards and debit cards bear the greatest physical and functional similarity to a smart card, it is interesting to note that the prime users of these mechanisms are those who are young, well educated, and of higher income levels. This means that for those of the lower socio-economic levels, plastic cards being used as a payment device are an unknown commodity. Again, a radical change in behavior would need to be effected in order to make a smart card a successful product in today's fare collection system.

In analyzing plastic card usage further, it should be recognized that many if not most individuals are likely to use their cards for reasons that may not apply to fare collection in a bus transit system. As we have seen, credit card usage is greatest in those segments where purchases are likely to be for relatively high purchase amounts, thus allowing consumer the luxury of paying for the purchase through installments to lessen the burden. While we have also seen that many retail segments do not accept credit cards because of the prohibitive chargeback system to the store operator, this at least demonstrates once again that consumers have been influenced toward the usage of cash for smaller types of purchases. Being creatures of habit, consumers are acclimated to cash and will need a strong incentive to be weaned from the use of cash, at least for smaller types of purchases.

The usage of the paper check also yields an interesting insight into consumer preference. That is, consumers are accustomed to being able to "see and feel" the payment transaction. In other words, they write a check for a specific amount, it is used in the transaction, and they eventually receive the check back, confirming that the transaction did indeed occur. The penetration level of checking accounts in the nation's households suggets once again that consumers are accustomed to tangible proof of a transaction. EFT systems require a high degree of trust. While a paper receipt at the point-of-sale may show the amount of the EFT transaction that is to occur, no document confirming the value transacted is received like a returned check, or a carbon copy of the credit card receipt. It remains to be seen if many consumers will be willing to trust an EFT system to correctly remove funds from their bank account.

Debit card transactions at ATMs certainly hold some promise for consumer acceptance of EFT types of transactions. However, only 20 percent of the adult population are currently responsible for the 3 billion ATM transactions that took place in 1983. This suggests that an interesting dichotomy exists among the nation's adults. That is, one group has embraced the time and location convenience offered by ATMs and are using their debit cards with great frequency to obtain cash. A second and far greater segment (the other 80 percent) prefers the more traditional forms of cash, checks, and credit cards to serve its payment needs.

The main thrust of this section is that smart cards in a fare collection system are a radical departure from the nation's current payment system chemistry. Consumers remain traditional in the types of mechanisms that are used for point-of-sale purchases. This certainly does not indicate that smart cards in a stored value type of system cannot and will not be a successful innovation. Rather, our conclusion is that if a smart card system is introduced today it will be a foreign concept to an abundance of consumers when considering the current state of the nation's payment system. However, the fare collection process is unique in that exact change is required, thus burdening the rider to some degree. A smart card system offers the advantage of precluding the need for exact change. This poses the possibility that riders may embrace the usage of the smart card although it is a new type of payment system mechanism.

APPENDIX B
THE PAYMENT SYSTEM OF THE FUTURE

Introduction

As established in the previous section, consumers have yet to embrace EFT types of payment mechanisms on a widespread basis. For the most part, cash is used on virtually a universal basis for transactions of $10 or less with checks being dominant in most retail segments for transactions of $10 or greater. Credit cards while being popular among certain segments of the population, are used mostly by the higher socio-economic classes of adults and predominantly in stores where either durable goods are sold or in gas stations. Therefore, from a societal point of view, a smart card system may face less than an enthusiastic response due to a lack of precedence within the overall payment system.

This section attempts to provide a forecast as to how the payment system will evolve over the remainder of the decade. A major question here is that while today's rather unsophisticated payment system may not be conducive for the acceptance of a smart card system, is it possible that major changes may be imminent that could cause a rapid development and acceptance of more efficient forms of payment using EFT types of transactions?

Given that changes will be occurring rapidly in the nation's payment system, a second question dealt with in this section will be the likelihood of a widespread need for a smart card capability within the overall payment system. While it is not crucial for a smart card system designed for the fare collection function to be integrated into the overall payment system, it certainly is desirable. Token systems, prepaid paper passes, and other such payment systems have existed for years in certain public transit properties totally void of any other application outside of the specific transportation authority. One of the ultimate objectives of this report however is to investigate the possibility that a smart card system designed for fare collection could also find other applications within the overall payment system. Therefore, included in our look of the payment system of the future will be an examination of the long term viability of the magnetic stripe. Most in the industry agree that the smart card is not likely to be accepted within our financial payment system unless the magnetic stripe breaks down as a restrictive storage medium that lacks sufficient capacity or cannot be properly secured to protect against fraud.

The Need for Change in the Payment System

The previous section detailed the different forms of payment being used, by whom, and at which types of stores. However, it did not address the increasing costs associated with our largely paper-based system of cash, checks, and credit cards. Within the payment system, it is important to remember that three concerns must be satisfied: that of the consumer, retailer, and bank.

From the consumer perspective, two basic payment options are available to virtually everyone: cash and the check. With these two simple options, most consumers can conveniently use cash for smaller type purchases and the more secure check form of payment for larger purchases. Annual fees and credit eligibility prevent many from carrying and using credit cards.

While these simple facts remain true today, evidence suggests that a major catalyst for change is imminent. Banking as an industry has recently lost its protective regulatory umbrella as Congress has eliminated certain past restrictions that controlled interest rates paid out for deposits. Additionally, other major changes have occurred which have allowed more organizations to compete with the banks. This has had the net effect of increasing costs for banks while reducing revenues. As a result, many banks are now struggling to sustain a profit. In the past, it was unusual for more than two or three banks to fail in a given year. Beginning in 1981, the number of bank failures skyrocketed to around 50 per year with up to 70 predicted for 1984. According to the FDIC (Federal Deposit Insurance Corporation) over 750 banks are in danger of failing.

With this background in mind, it is not surprising that banks have begun to charge larger fees for services and products that traditionally have been free. For example checking accounts used to be largely a free service to consumers. Today however, banks need to pay interest on checking balances (NOW accounts) in order to remain competitive. This represents an enormous cost that needs to be counterbalanced by increased revenues.

In addition, it is very expensive for banks to manually process paper checks, especially in light of the fact that over 40 billion checks are written per year. Some industry estimates place the actual bank cost of handling a check to be $1. Yet, until 1980, most checking accounts only had a nominal charge, if any at all.

Needless to say, the environment has changed rapidly. Banks have increased fees rapidly for checks although the average charge remains at $.11 per check, merely 10 percent of the actual bank cost to process that check.
It is clear that the cost for checks will continue to rise, with some consumers eventually being forced to close their account because of increasing fees. Already in 1984, the California and New York state legislators are addressing the issue of "lifeline accounts", a concept that ensures that consumers regardless of income level would still be able to have access to basic banking services, such as a savings and checking account, without having to pay the rising costs of those accounts.

It remains to be seen what the ultimate effect of this legislation will be. It appears obvious though that some major changes are inevitable and that fewer individuals will be able to afford the privilege of the traditional checking account, especially when more inexpensive alternative systems are available.

EFT Broadens Its Base With the Debit Card

One alternative that consumers are likely to turn toward is the debit card. Unlike the paper check, an EFT transaction initiated by a debit card requires little manual effort for the bank to process and is therefore a far less expensive service that banks can offer. As described in the previous section, debit cards essentially initiate a transaction that serves as a paperless check. Instead of writing a check to obtain cash at a bank office or supermarket, consumers merely can use their debit card at an ATM. ATMs can also be used to pay many monthly bills. As will be described later in this section, debit cards will be increasingly accepted by retailers for point-of-sale transactions.

The essential point here is that debit card transactions can be viewed as a direct replacement for a check. They can be used for purchases and to pay bills, as well as to obtain cash. Furthermore, since bank costs are much less for debit card transactions than for processing a paper check, banks are likely to price debit transactions far below that for checks. While few banks today are charging their customers for debit transactions at an ATM, checking costs continue to rise. As banks continue to raise their checking fees to be more in line with actual costs, individuals will be influenced to write fewer checks and instead use their debit cards. Therefore, simple economics are likely to drive consumers toward EFT transactions.

Increasing checking fees are not the only reason why a rapid migration toward EFT types of transactions may be imminent. Availability of ATMs has also been a fast changing phenomenon. Although ATMs and debit cards have been around for fifteen years, relatively few consumers had access to either a debit card or an ATM in close proximity. Since ATMs until recently cost banks an average of $30,000 in hardware costs alone, banks were judicious as to where they placed the machines. The last two years have seen dramatic change however.

ATM costs have now decreased more than 50 percent as hardware costs have declined and more ATMs are being installed within stores where the security requirements are far less. Most importantly, a majority of ATMs are now part of a shared network. Prior to 1980, most banks restricted the usage of their ATMs to their own customers. Today, over 50 percent of all banks allow other banks' customers to use their machines. Each time a competing bank's customer uses another bank's ATM, the bank which owns the ATM receives a small transaction fee that is usually in the range of $.10 to $.30. While this appears to be a trivial amount, many ATMs have over 10,000 transactions per month. The bottom line effect of these trends is that ATMs are far more accessible to a wider range of individuals than ever before.

The number of debit cards issued confirms this trend. Banks in trying to encourage their customers to use ATMs instead of writing checks have mailed free debit cards to virtually all of their checking account customers. The number of debit cards issued has swelled to over 110 million, greater than the number of VISA and MasterCards issued nationwide. Statistics indicate that 33 percent of those who carry an ATM card actually use it. Other statistics indicate that only one out of every five non-users has ever tried an ATM. This in total suggests that very few individuals have actually rejected ATMs. Rather, most individuals have simply not tried them. Major marketing campaigns planned by the larger ATM networks are likely to attract many first time users. Other networks have been successful in increasing their customer user percentage to 50 percent and 60 percent by offering discount coupons based upon usage and by randomly offering cash prizes.

While increased ATM usage is certain to increase consumer awareness and acceptance of EFT forms of payment, it is only one of two major areas being promoted by the banking and retailing industry. The retailer is also being impacted by certain shortcomings within the existing payment system. As alluded to in the previous section, many retailers, most notably convenience stores and gas stations, do not accept checks because of the risk of collection problems. Because a debit transaction involves an immediate transfer of funds at the time that the purchase is made, retailers do not run the risk of not being able to collect on the customer's account. Additionally, since debit card transactions are handled through an electronic terminal, the speed of the transaction is normally a few seconds. This represents a major improvement over manual check and credit card approval processes which can often take minutes to obtain. Therefore, retailers, particularly supermarkets where throughput speed is a major factor, are eager to provide a debit transaction capability at their retail establishments.

Cost is also a consideration to retailers. Similar to consumers, retailers are charged for the checks that are deposited with their bank. These charges have also been spiraling as banks have been seeking to bolster their service charges. While it is not clear if and for what amount retailers will be charged for debit card transactions, it is safe to assume that it will be significantly less than the current charges for depositing of checks.

Also as mentioned in the previous section, many retailers today cannot afford to offer their customers the convenience of using credit cards at the point-of-sale since retailers are charged a 2 percent to 3.5 percent discount fee of the total sales price. It has become clear that the pricing structure for debit card transactions will be much different. Using the Visa debit card cost structure as an example, the retailer will pay a fixed $.25 charge per transaction. MasterCard will not charge the retailer for the acceptance of its debit card. This means that many retailers who cannot afford to accept credit cards can now afford to accept debit cards. This will again serve to promote the usage of EFT debit card transactions since the number of retail locations accepting them should increase dramatically.

It is for these reasons that dozens of banks nationwide are now conducting debit card experiments at the point-of-sale. Pilot programs are taking place in at least twenty states currently with some retailers already committing their organizations to a nationwide program for accepting debit cards. For the consumer, this means that one more payment alternative will be available that will be cheaper to use, faster, and more convenient since cash need not be carried to make a purchase. For the retailer, debit transactions will also be less expensive, faster, and less risky since the funds are transferred at the time of the transaction although some concern exists that the "immediacy" of the debit could limit impulse purchases that are indicative of credit transactions. Meanwhile the bank enjoys the advantage of avoiding the prohibitive costs of processing paper checks and currency while also capitalizing on new income opportunities made available through the usage of debit cards.

All of these developments are significant for the prospects of smart card acceptance in fare collection systems since consumers will become more accustomed to the concept and mechanics of an electronic transfer of funds. A main question remains though. Within the nation's payment system, is there a need for the smart card, or does the existing magnetic stripe plastic card currently used for debit card transactions suffice?

The Smart Card's Role in the Emerging US Payment System

The previous section suggests that a larger and more heterogeneous proportion of Americans will soon be using plastic cards and EFT devices such as ATMs and POS. The important question for this investigation is--Will the smart card replace magnetic stripe technology in the near future?

Three distinct constituencies are involved here. The consumer and retailer will use the new technology if it is at least as easy, fast, and inexpensive as existing technology. Today and for the next few years, the smart card and its terminals will have a significant cost disadvantage. More importantly, the financial institutions, who are traditionally responsible for introducing payment system innovations, are not favorably disposed toward replacing magnetic stripe technology with anything. Even more important than the fact that bankers have been traditionally conservative is the level of commitment and capital investment they have poured into magnetic stripe technology over the past 15 years.

Examining the bankers' apprehension more closely, we see that over 50,000 ATMs have been installed thus far, at an average cost of $30,000 per machine. Thus, bankers have invested nearly $1.5 billion in this technology alone and are not very anxious to retrofit this hardware with new readers and software. Similarly, over 200 million bank credit and debit cards are now in circulation, and the complete changeover cost to smart cards could cost banks up to $2 billion simply to reissue cards to the existing cardholders. Understandably the financial industry in the US is not likely to convert to the use of smart cards for data capture or data entry in the payment system for the foreseeable future, since they have invested so heavily in on-line technology and have obtained a reasonable level of security negating the need for premium priced smart card technology.

However, several forward-thinking bankers, most notably John Fisher of BankOne, see the chip card potentially being used as an identification and security access device for home access of confidential information. The intelligence and memory of a smart card could allow an advanced customer identification technology, such as signature dynamics or voice recognition to be used for access to secure levels of a home information system, allowing customers to perform secure banking transactions in a remote home or office environment.

Conclusion

Several industry analysts predict that 5 percent to 10 percent of American households will be conducting their banking activity from their residential personal computer within the next ten years. If these forecasts are accurate, the smart card may find its way into the financial institution networks as well as the wallets and pocketbooks of a large group of Americans by 1990. However, similar to the credit card customer base, the consumers most likely to own a personal computer and conduct home banking are the upper income individuals who are least likely to use urban transit in most U.S. metropolitan areas.

APPENDIX C

PROBLEMS AND COST OF EXISTING FARE COLLECTION SYSTEMS

APPENDIX C
PROBLEMS AND COSTS OF EXISTING FARE COLLECTION SYSTEMS

Introduction

The objective of this appendix is to summarize existing fare collection systems in terms of effectiveness, reliability, revenue loss, security, and customer satisfaction.

First, overall costs of the fare collection function are examined, followed by discussions on structural fare penalties and fraud losses. These problems are of particular concern due to the magnitude of hard dollar losses and opportunity costs to the transit property. Specific design problems for each system are also outlined with a sampling of customer implications drawn. This discussion provides a backdrop against which MC/SC based fare collection systems are conceptually designed.

Costs of Fare Collection

According to the National Urban Mass Transportation Statistics Second Annual Report (June 1982), operating revenue for motor bus operations total $1.8 billion, while total costs equal $3.7 billion. Fare collection costs have been estimated to account for anywhere from 2 percent to 10 percent of operating revenue. These costs include salaries and overhead for ticket selling agents, maintenance personnel, revenue and data processing personnel as well as the equipment necessary to collect, count, and store fare revenue. Fare collection costs are determined by a variety of variables, the most important being degree of automation, use of prepaid passes, fee levels, and the associated usage of dollar bills. In fact the difficulty of accepting and processing a dollar bill adds an incremental cost of 2 to 10 cents per bill handled. Specific fare system costs vary, but electronic fareboxes typically cost $2000 to $3000 each. Components needed to newly equip an entire system would be: the vault receiver unit ($20,000 to $40,000); data processing system (probe and microprocessor) ($30,000); and the farebox audit unit ($10,000). To equip a new system with 35 fareboxes and the required peripheral fare collection equipment would typically cost approximately $200,000 in hardware and software.

Motor bus operators experience revenue loss due to several factors, including patron fare evasion, transit employee fraud, and even transit management fraud. In an UMTA Fare Collection Task Force memorandum dated February 6, 1984, studies were cited where revenues lost were estimated to be in a range of 20 to 30 percent of deposited revenue. In one transit property where rigid security measures were installed a 50 percent increase in revenue was observed. Concerning employee fraud, the three basic types of fareboxes have varying degrees of security. The nonregistering farebox presents ample opportunity for patron fare evasion and driver fraud, since the only count of ridership (if any) is a manual tally performed by the driver. Also, vault pullers and cashiers have an opportunity to absorb revenue, since accountability is minimal. The mechanical registering farebox maintains ridership and revenue tallies, so fraud is checked somewhat, but drivers often handle dollar bills as well as tickets and passes, presenting an opportunity to bypass the farebox altogether. Also, maintenance is required, creating another fraud opportunity. The electronic registering farebox accepts dollar bills and reduces drivers' direct contact with payment media.

The present fare collection systems are not well designed to vary the fare depending on length of trip although techniques exist for simple driver enforced "zone checks". Structural fare loss refers to the revenue lost by the system's inability to easily accomodate fares based upon distance and time of day parameters without direct driver intervention. In the same memorandum referenced above, experts estimated that the motor bus industry is foregoing about 10 to 20 percent of its potential operating revenue from its multifare collection limitations. In fact, one study cited in the memorandum suggested that "fares charged according to distance could cover 60 percent of operators' costs in comparison with the 40 percent that current fares typically cover." This estimate translates into an increase in revenue of $800 million annually or 40 percent over current revenues if multizonal fares could be implemented at all transit authorities. In some cities, distance based fares are not implemented because of political considerations. Therefore, both technological and political forces can be obstacles to the implementation of distance based fares. However, the political influence has not precluded the use of distance based fares in rail transit. Most of the dollar benefit which could be achieved from distanced based fares would come from the large cities such as New York or Chicago, where enormous service areas are covered at a single base fare.

Another point is that one of the major structural penalties is the inability to segment the market, so as to charge the marginal amount which a given market segment is willing to pay. This problem is faced by rail and bus systems alike. A good example of a successfully segmented fare structure is the airline industry, where a wide variety of fares are charged and the market is segmented to a high degree. Most of the fare prepayment systems which have been implemented have totally ignored market segmentation, except for the federally-mandated half-fare for elderly and handicapped passengers. In addition, most prepayment systems have resulted in reduced revenue to the transit authority, since the typical "monthly pass" has a utilization rate far in excess of the "forty-rides-per-month" on which the price of most passes is based. A memory card system based on a stored number of rides rather than an unlimited monthly pass type of system would greatly enhance transit revenues.

Surprisingly, on-board robberies and vandalism of fareboxes have decreased sharply in recent years, and are now infrequent occurences. The important reasons for this phenomenon are the lack of driver contact with payment media, and the increased structural security of the farebox and cashbox design and construction.

Consumer Attitudes

Motor bus customers have a basic motive for riding - they want cost-effective, convenient, timely transportation. Concerning passenger convenience, the present fareboxes contribute to slow throughput in several ways. First, coin and bill jams can delay passenger loading. Also, searching for exact change lengthens wait time. These elements combine with traffic congestion to make bus arrival and departure schedules one of the least reliable in public transit. Reciprocally, the consumer is inconvenienced by having to carry correct change media, and having to wait for the payment to clear the recognition meter and inspection plate before boarding.

APPENDIX D

SAMPLE FARE COLLECTION REPORTS

APPENDIX D

SAMPLE FARE COLLECTION REPORTS

Today's electronic registering farebox collection systems utilize microcomputers to interpret the ridership and revenue data into useful management reports. Although new software is continually being developed, Appendix D presents several useful reports which are currently available. The reports to be discussed are: The Daily Summary Report; The Route Summary Report; The Monthly Summary Report; The Current Bus List; and The Daily Data Report.

Daily Summary Report

The Daily Summary Report provides a summary of the entire day's activity in easy-reference form. The report first presents security alarms which may need management attention; management may then review the menus to determine which buses have been affected by these alarms and take appropriate action. Revenue and ridership counts are presented next, then a listing of buses with fareboxes needing preventive maintenance. Any buses which were not probed on that day are listed. Finally, any bus which has not been probed for more than a month (and so is about to be deleted from the bus list) is presented. See Figure D-1.

Route Summary Report

The Route Summary Report presents the data from the various route/run lists. The program first displays revenue summarized by route, as in Figure D-2. The program then displays the revenue from the route/run lists for each route, divided by the time of day when the route/run list was created. This report is one of the most useful for service planning, and is shown in Figure D-3.

DAILY SUMMARY REPORT FOR: METRO AREA EXPRESS MAX

REPORT PRINTED ON: MAY 30, 1984 AT 11:24:10 AM

##

TOTAL NUMBER OF BUSES PROBED: 100 TOTAL REVENUE COLLECTED: $10661.89

TOTAL CASHBOX ALARMS RECORDED: 1 EXTRA REVENUE COLLECTED: $419.29
TOTAL BY-PASS ALARMS RECORDED: 1 TOTAL DUMP COUNT: 2896

BILL COUNT: 2242 TICKET COUNT: 12 LARGE TOKENS: 121 SMALL TOKENS: 27

FARE 1: 10553 FARE 2: 100 FARE 3: 649 FARE 4: 3

KEY 1: 4043 KEY 2: 310 KEY 3: 215 KEY 4: 10 KEY 5: 732
KEY 6: 2027 KEY 7: 139 KEY 8: 1230 KEY 9: 4064

BUSES REQUIRING PREVENTATIVE MAINTENANCE:

BUSES NOT PROBED TODAY: 110 204 314 322 402 408

BUSES ABOUT TO BE DELETED FROM BUS LIST: 615

)))) GFI PROGRAM VERSION 2.10 -- COPYRIGHT 1984 ((((
)))) PROGRAM RESTART AT: 11:24:27

FIGURE D.1 DAILY SUMMARY REPORT

ROUTE - SUMMARY REPORT for 05/29/84 METRO AREA EXPRESS MAX 30 MAY 84 11:26 AM Page 1

Route #	# of Records	# of Buses	Route Revenue	Fare #1	Fare #2	Fare #3	Fare #4	Key 1	Key 2	Key 3	Key 4	Key 5	Key 6	Key 7	Key 8	Key 9	Lrg Tok	Sml Tok	Bill Cnt.	Tick Cnt.
0	29	17	139.25	140	0	2	0	8	0	0	0	0	0	0	2	20	0	1	32	0
1	25	11	875.75	919	0	0	0	277	18	18	0	54	135	2	97	349	8	2	168	1
2	1	1	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	25	8	491.41	513	0	0	0	167	7	4	0	16	116	1	54	199	6	0	116	0
4	2	2	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	16	11	442.24	453	0	0	0	155	24	6	1	16	70	7	66	176	1	0	101	0
6	39	13	688.13	634	0	0	0	206	33	2	0	73	83	15	179	219	9	2	141	0
8	41	12	660.40	663	0	0	0	201	30	17	0	95	101	10	82	269	6	1	117	1
9	1	1	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	12	5	301.67	304	0	0	0	118	15	6	0	16	53	2	51	158	6	1	59	1
12	19	4	242.12	237	0	0	0	111	2	14	0	30	72	0	24	114	6	0	45	0
14	3	1	99.41	98	0	0	0	36	1	4	1	12	33	2	14	35	1	0	15	1
17	2	2	34.12	38	0	0	0	5	2	0	0	0	9	0	2	30	1	0	7	0
18	24	4	187.25	190	0	0	0	75	0	8	0	31	28	0	9	67	5	1	32	0
20	16	5	490.07	486	0	0	0	223	21	16	0	26	131	55	39	193	4	2	114	2
22	9	3	408.43	414	0	0	0	100	4	8	0	30	53	8	43	123	0	2	96	2
23	7	3	426.48	432	0	0	0	161	2	6	0	37	81	0	39	189	11	1	80	0
28	29	9	646.75	667	0	8	3	245	15	11	3	40	96	0	71	227	12	5	122	0
38	27	7	677.73	685	0	45	0	256	12	8	1	36	116	14	79	150	19	2	130	0
39	15	4	137.79	145	0	0	0	47	3	4	0	7	43	0	16	97	0	0	21	0
40	31	7	388.83	373	0	0	0	145	24	4	0	11	64	0	99	171	6	2	99	0
41	8	4	327.80	330	9	0	0	127	16	7	0	25	37	0	30	101	1	0	55	0
42	10	4	215.40	198	0	45	0	124	4	6	0	4	58	22	31	91	1	0	44	1
45	12	8	518.95	547	0	0	0	142	17	6	2	41	64	0	47	139	1	2	93	1
48	25	8	541.34	559	0	0	0	179	16	12	1	47	78	0	50	152	6	0	125	1
49	6	3	241.06	226	19	0	0	121	5	9	1	27	69	0	10	125	0	0	84	0
50	4	3	25.70	29	0	0	0	11	0	0	0	0	8	0	0	31	0	0	3	0
51	4	3	83.20	91	0	0	0	54	0	2	0	3	25	0	0	80	0	0	19	0
72	11	6	147.86	69	80	0	0	61	8	0	0	2	27	1	1	7	1	0	73	0
88	2	1	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	9	5	138.02	0	0	549	0	0	0	0	0	0	20	0	0	0	0	0	1	0
92	2	1	13.00	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	3	0
221	1	1	9.50	1	0	0	0	0	0	0	0	0	0	0	17	0	0	0	3	3
399	1	1	39.06	39	0	0	0	18	2	0	0	0	6	0	8	3	1	0	8	0
501	3	2	37.60	41	0	0	0	18	0	0	0	0	10	0	1	37	0	0	6	0
502	3	2	67.07	69	0	0	0	58	0	1	0	1	21	0	0	0	0	1	27	0

FIGURE D.2 ROUTE SUMMARY REPORT REVENUE BY ROUTE

ROUTE - SUMMARY REPORT for 05/29/84 — Summary route revenue listed by hour logged ... 30 MAY 84 11:26 AM Page 3

ROUTE #	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12
0	0.00	0.00	0.00	0.00	0.00	0.00	3.20	0.00	0.00	0.00	0.00	123.95
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	103.40
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	67.55	43.51	51.16	40.96	17.56	14.85
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.60	0.00	92.24
6	0.00	0.00	0.00	0.00	0.00	13.45	35.45	86.40	125.32	0.00	45.83	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	21.00	71.28	15.00	47.40	0.00	71.10
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.56	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	11.24	25.95	0.00	31.64	3.95	7.90
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	34.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	17.00	67.46	18.65	0.00	14.85	20.15
20	59.38	0.00	0.00	0.00	0.00	0.00	64.54	35.37	39.80	0.00	0.00	32.25

ROUTE #	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-00
0	0.00	0.00	11.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	206.11	3.25	68.90	0.00	25.50	20.85	0.00	272.90	85.54	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	80.11	0.00	13.25	65.47	25.81	14.80	18.45	0.00	35.33	0.00	2.60	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	19.95	40.05	60.40	0.00	19.80	104.49	0.00	0.00	51.41	43.30
6	36.95	75.40	58.06	63.36	88.68	14.50	33.78	0.00	0.00	0.00	0.00	10.95
8	110.56	0.00	73.56	87.66	13.90	120.74	6.00	13.80	4.40	0.00	3.20	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	100.58	0.00	5.45	0.00	4.00	0.00	49.55	96.53	0.00	0.00	0.00	0.00
12	20.62	11.50	11.62	19.85	20.80	15.45	0.00	0.00	0.00	0.00	4.85	56.75
14	0.00	54.56	0.00	0.00	0.00	0.00	44.85	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	22.25	0.00	0.00	12.00	6.60	0.00	0.00	0.00	8.29	0.00	0.00
20	13.34	0.00	0.00	0.00	0.00	0.00	72.96	172.43	0.00	0.00	0.00	0.00

FIGURE D.3 ROUTE SUMMARY REPORT REVENUE BY ROUTE BY TIME-OF-DAY

Monthly Summary Report

A Monthly Summary Report is also available. This displays the totalled master lists for each day of the month and Figure D-4 shows an example. The current program also provides a histogram of daily revenue for the month, as seen in Figure D-5.

Current Bus List

The computer maintains in memory a list of the bus numbers active in the transit system. This list can be accessed, along with the most recent date each bus was probed. See Figure D-6.

Daily Data Report

The Daily Data Report presents the complete contents of all memory of the farebox for a single day, and is found in Figure D-7. The master list is printed first, showing the cumulative revenue to date (since the last time the memory was cleared), the current revenue (e.g., the amount collected since the last time the bus was probed), the "Extra Revenue" (e.g., revenue which was "dumped" by the farebox without being attributed to a particular ridership class--an indication of how well the driver is doing his job of classifying revenue), the "dump count" (e.g., the number of times revenue was dumped without being classified--another indication of driver performance), the ridership in the various fare classifications, the number of large and small tokens, the number of dollar bills collected, and the number of tickets collected.

The computer next prints the "diagnostics". These are a variety of figures which indicate voltage conditions to the farebox (warm start, cold start) and may indicate bus electrical problems. Following the report's columns to the right, the cumulative number of coins and tokens processed by the coin mechanism is presented indicated by SMLTOK, dimes, pennies, etc; this can be used to schedule preventive maintenance. The next two lines (beginning

MONTHLY SUMMARY REPORT FOR MAY   METRO AREA EXPRESS   MAX   30 MAY 84   07:56 AM

TRANSIT DAY	DAILY REVENUE	# BUSES	# not PROBED	#C ALRM	#B ALRM	FARE #1	FARE #2	FARE #3	FARE #4	KEY 1	KEY 2	KEY 3	KEY 4	KEY 5	KEY 6	KEY 7	KEY 8	KEY 9	Lrg TOK	Sml TOK	BILL Cnt.	TICK Cnt.
01 MAY 84	11810.60	91	4	5	3	11536	115	912	0	4163	343	225	15	867	1609	23	1469	4247	124	41	2491	13
02 MAY 84	11606.19	98	5	2	2	11392	115	636	0	4330	300	253	16	733	2043	59	1550	4424	121	40	2546	11
03 MAY 84	9903.58	92	14	4	2	9718	85	544	0	3486	204	187	18	718	1698	34	1211	3439	99	23	2171	3
04 MAY 84	18874.74	138	6	4	3	18722	116	989	0	5754	832	477	22	2123	2685	73	1700	5742	193	61	3775	10
07 MAY 84	13771.74	99	11	3	4	13459	89	1031	0	4736	525	333	12	1153	2167	56	1721	4713	144	31	2788	12
08 MAY 84	7496.19	66	43	3	2	7381	30	677	0	2622	195	159	4	446	1297	17	999	2555	99	18	1547	8
09 MAY 84	16087.34	94	17	32	2	15699	177	966	0	5921	530	467	27	1275	2844	91	2019	6075	154	54	3325	20
10 MAY 84	12200.62	95	15	4	7	11936	92	982	0	4564	458	318	8	887	2123	54	1501	4699	147	29	2667	7
11 MAY 84	12731.03	99	13	3	7	12446	88	1042	0	4660	409	378	12	1062	2038	55	1520	4477	127	29	2776	11
12 MAY 84	4658.79	36	74	1	0	4942	0	0	0	1000	385	119	4	472	690	4	246	1079	3	3	954	2
14 MAY 84	12172.74	93	18	0	7	11990	94	952	0	4300	507	280	6	932	2187	46	1445	4485	133	26	2512	14
15 MAY 84	11208.74	91	19	1	6	11012	90	641	0	4104	351	284	16	831	2329	67	1430	4187	124	49	2428	11
16 MAY 84	11361.43	101	14	5	5	11014	131	1011	0	4090	343	270	15	804	2078	56	1507	4225	152	27	2455	19
17 MAY 84	11710.22	100	13	1	3	11527	89	672	0	4390	386	310	13	773	2118	40	1511	4522	147	30	2521	4
18 MAY 84	12080.24	104	13	5	6	11685	84	1550	0	4401	449	313	10	972	2128	28	1445	4415	134	23	2536	16
19 MAY 84	4024.18	34	77	0	0	4221	0	0	0	1024	285	127	0	496	619	9	170	980	9	7	875	2
21 MAY 84	10449.20	96	19	4	3	10148	163	794	0	3741	311	212	14	681	1922	55	1313	3825	154	29	2218	19
22 MAY 84	10527.38	91	21	2	3	10221	123	802	0	3838	257	254	7	642	2039	61	1494	3928	171	13	2309	6
23 MAY 84	10700.76	96	19	4	3	10430	118	811	0	3987	311	258	17	786	2055	74	1417	4070	142	40	2399	6
24 MAY 84	11010.52	101	13	3	2	10759	62	846	0	4271	319	254	7	799	2103	61	1476	4273	141	31	2527	18
25 MAY 84	11317.33	99	14	6	0	11066	115	923	0	4233	473	246	4	829	2000	52	1406	4209	132	14	2623	7
26 MAY 84	3472.30	36	74	1	0	3676	1	4	0	877	213	84	8	352	532	7	167	812	2	4	809	0
28 MAY 84	2850.33	98	14	2	2	40	0	10825	0	22	246	2	0	1	1444	2253	1	2834	72	8	104	1
29 MAY 84	10661.89	100	12	1	1	10553	108	649	3	4043	310	215	10	732	2027	139	1230	4064	121	27	2242	12
TOTALS =	252688.08	2148	988	96	73	245573	2085	28179	3	88557	8862	6025	265	19366	44775	3422	29948	92279	2845	665	53598	232

#C ALRM = cashbox alarms; #B ALRM = by-pass alarms

FIGURE D.4 MONTHLY SUMMARY REPORT MASTER LIST

MONTHLY SUMMARY CONTINUED; COMPARATIVE DAILY REVENUE FOR MAY

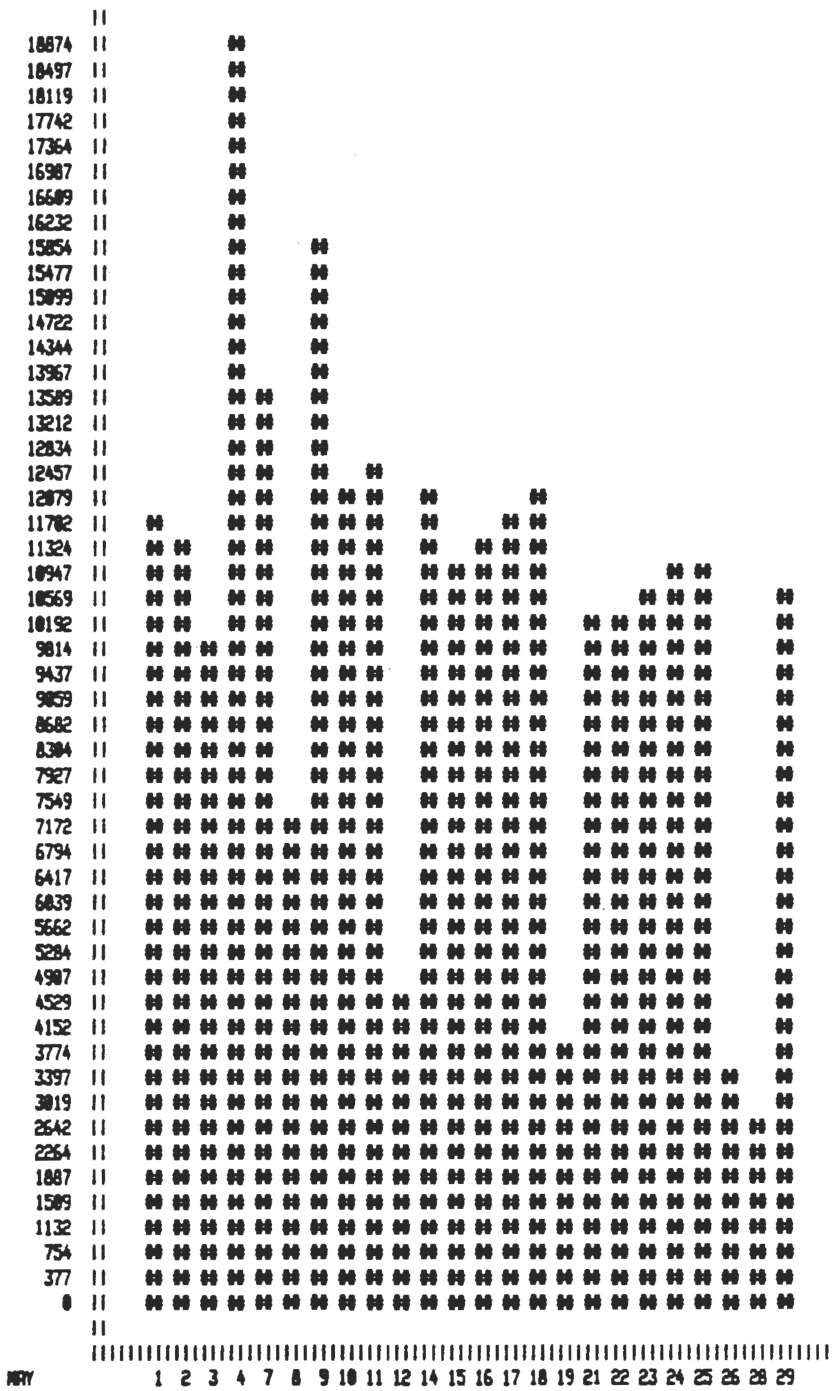


FIGURE D.5 MONTHLY SUMMARY REPORT DAILY REVENUE

CURRENT BUS LIST   METRO AREA EXPRESS   MAX   30 MAY 84   08:54 AM   Page 1

BUS #	PROBED	BUS #	PROBED	BUS #	PROBED	BUS #	PROBED	BUS #	PROBED	BUS #	PROBED
101	05/28/84	102	05/28/84	103	05/28/84 #	104	05/28/84	105	05/28/84	106	05/28/84
107	05/28/84	108	05/28/84	109	05/28/84	110	05/10/84 #	201	05/28/84	202	05/28/84
204	05/13/84 #	205	05/28/84	206	05/28/84	207	05/28/84	209	05/28/84	210	05/28/84
211	05/28/84	212	05/28/84	213	05/28/84	214	05/28/84	215	05/28/84	216	05/28/84
217	05/28/84	219	05/28/84	221	05/28/84	222	05/28/84	301	05/28/84	302	05/28/84
303	05/28/84	307	05/28/84	308	05/28/84	309	05/28/84	310	05/28/84	311	05/28/84
312	05/28/84	314	05/27/84 #	315	05/28/84	316	05/28/84	317	05/28/84	318	05/28/84
320	05/28/84	321	05/28/84	322	05/06/84 #	324	05/28/84	326	05/28/84	327	05/28/84
328	05/22/84 #	329	05/28/84	401	05/28/84 #	402	05/07/84 #	404	05/28/84	406	05/27/84 #
407	05/28/84 #	408	05/24/84 #	409	05/28/84	410	05/28/84	601	05/28/84	602	05/28/84
603	05/28/84	605	05/28/84	606	05/28/84	607	05/28/84	608	05/28/84	609	05/28/84
610	05/28/84	611	05/28/84	612	05/28/84	613	05/28/84	614	05/28/84	615	04/25/84 #
616	05/28/84	617	05/28/84	618	05/28/84	619	05/28/84 #	620	05/28/84	621	05/28/84
623	05/28/84	624	05/28/84	625	05/27/84 #	626	05/28/84	627	05/28/84	628	05/28/84
629	05/28/84	630	05/28/84	631	05/28/84	632	05/28/84	633	05/28/84	634	05/28/84
635	05/28/84	636	05/28/84	637	05/28/84	638	05/28/84	1653	05/28/84	1740	05/28/84
1741	05/14/84 #	1742	05/28/84	1835	05/28/84	1837	05/28/84	1919	05/28/84 #	1920	05/28/84
1921	05/15/84 #	1922	05/28/84	1923	05/28/84	1924	05/28/84	1925	05/28/84	2179	05/28/84
2232	05/28/84										

# indicates alarms present for this bus

FIGURE D.6 CURRENT BUS LIST

```
              DAILY DATA REPORT FOR:          METRO AREA EXPRESS       MAX                                05/29/84

                                         REPORT PRINTED ON: MAY 30, 1984 AT 09:28:13 AM

PROBED   BUS   TO DATE CURRENT  EXTRA DUMP FARE FARE FARE FARE  KEY  KEY  KEY  KEY  KEY  KEY  KEY  KEY  KEY  LRG  SML BILL TICK
  AT      0     REV $   REV $   REV $  CNT   1    2    3    4    1    2    3    4    5    6    7    8    9   TKN  TKN  CNT  CNT
#############################################################################################################################
 6:42 RTE =    38 RUN =  3822 REV = $19.75  22    0    0    0   11    0    0    0    0    9    0    1    2    0    0    0    0
 7:50 RTE =    39 RUN =  3822 REV = $10.35  12    0    0    0    0    0    0    0    0    3    0    1   16    0    0    1    0
 7:52 RTE =    38 RUN =  3822 REV = $ 0.00   0    0    0    0    0    0    0    0    0    0    0    0    1    0    0    0    0
 8:42 RTE =    38 RUN =  3822 REV = $25.13  25    0    0    0   13    1    0    0    0    1    0    3    1    1    0    4    0
                                      DRIVER NUMBER  1626
 8:47 RTE =    39 RUN =  3823 REV = $ 1.60   2    0    0    0    0    0    0    0    0    2    0    0    2    0    0    0    0

17:32   407    42.15   11.85   0.10    2    0    0   47    0    0    0    0    0    0    0    0    0    0    0    0    0    0
+++++ CASHBOX REMOVED WITHOUT PROBING FAREBOX AT: 15:59.  ++++ AMOUNT COLLECTED WITH NO CASHBOX = $ 11.85.
        RUN NUMBERS:  9024
DIAGNOSTICS:
        X-STORE WARM-ST COLD-ST  SMALL  SML TOK   DIMES PENNIES NICKELS LRG TOK QUARTER   SBA $  HALF $
            8       0       2      0       0       74      30      39       0     130       0       0
          D/D     D/P     P/P    D/N     P/N      D/Q     P/Q     N/Q     Q/Q TOO BIG   COINS   BILLS TICKETS
            0       0       0      0       0        0       0       0       0       0     273       0       0
                                      DRIVER NUMBER  1146
 9:49 RTE =    90 RUN =  9024 REV = $ 0.00   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
17:32 RTE =    90 RUN =  9024 REV = $11.85   0    0   47    0    0    0    0    0    0    0    0    0    0    0    0    0    0

17:34  1837   667.89   93.39   2.64   33   94    0    0    0   64    0    1    0    1   16    0   11   10    3    0   30    0
        RUN NUMBERS: 20230   2023      122
DIAGNOSTICS:
        X-STORE WARM-ST COLD-ST  SMALL  SML TOK   DIMES PENNIES NICKELS LRG TOK QUARTER   SBA $  HALF $
            4     154       7      0       0      870     939     615      10    1400       2      13
          D/D     D/P     P/P    D/N     P/N      D/Q     P/Q     N/Q     Q/Q TOO BIG   COINS   BILLS TICKETS
            3       1       0      1       1        0       1       0       0       1    3929     162       1
                                      DRIVER NUMBER  1235
 5:26 RTE =    20 RUN =  2023 REV = $ 0.00   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 6:16 RTE =    20 RUN =  2023 REV = $64.54  68    0    0    0   42    0    1    0    1   10    0    3   10    3    0   23    0
                                      DRIVER NUMBER  1508
 6:17 RTE =     1 RUN =   122 REV = $ 0.00   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
17:34 RTE =     1 RUN =   122 REV = $28.85  26    0    0    0   22    0    0    0    0    6    0    8    0    0    0    7    0

17:41   634   387.50  139.96   5.71   49  140    0    0    0   65    5    2    0    6   13    1   20   43    0    1   35    1
        RUN NUMBERS:  4502   2242      145
DIAGNOSTICS:
        X-STORE WARM-ST COLD-ST  SMALL  SML TOK   DIMES PENNIES NICKELS LRG TOK QUARTER   SBA $  HALF $
            5       6       8      0       1      430     340     382       1     912       0       8
          D/D     D/P     P/P    D/N     P/N      D/Q     P/Q     N/Q     Q/Q TOO BIG   COINS   BILLS TICKETS
            1       0       0      0       0        0       0       0       0       0    2074      90       1
                                      DRIVER NUMBER  1414
 4:57 RTE =    45 RUN =  4502 REV = $ 0.00   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
                                      DRIVER NUMBER  2017
14:16 RTE =    22 RUN =  2242 REV = $122.91 131    0    0    0   63    3    2    0    6    7    1    3   25    0    1   32    1
15:00 RTE =    22 RUN =  2242 REV = $ 0.00   0    0    0    0    0    0    0    0    0    0    0   15    0    0    0    2    0

17:42   618   536.93   16.10   1.15    5   17    0    0    0    9    0    0    0    0    6    0    0   37    0    0    2    0
        RUN NUMBERS:  5020   5047
DIAGNOSTICS:
        X-STORE WARM-ST COLD-ST  SMALL  SML TOK   DIMES PENNIES NICKELS LRG TOK QUARTER   SBA $  HALF $
            7      14       0      1       2      686     528     564      11    1296       0       1
          D/D     D/P     P/P    D/N     P/N      D/Q     P/Q     N/Q     Q/Q TOO BIG   COINS   BILLS TICKETS
            0       0       0      0       0        0       1       0       0       1    3088     110       0
```

FIGURE D.7 DAILY DATA REPORT

with "D/D D/P P/P etc.") show the number of coin combinations where two coins went through the coin counter while touching. If this happens too many times, it indicates that the coin counter needs servicing.

Next, the computer prints the contents of the route/run lists, showing the time they were created, and the route and run numbers as entered by the bus driver.

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