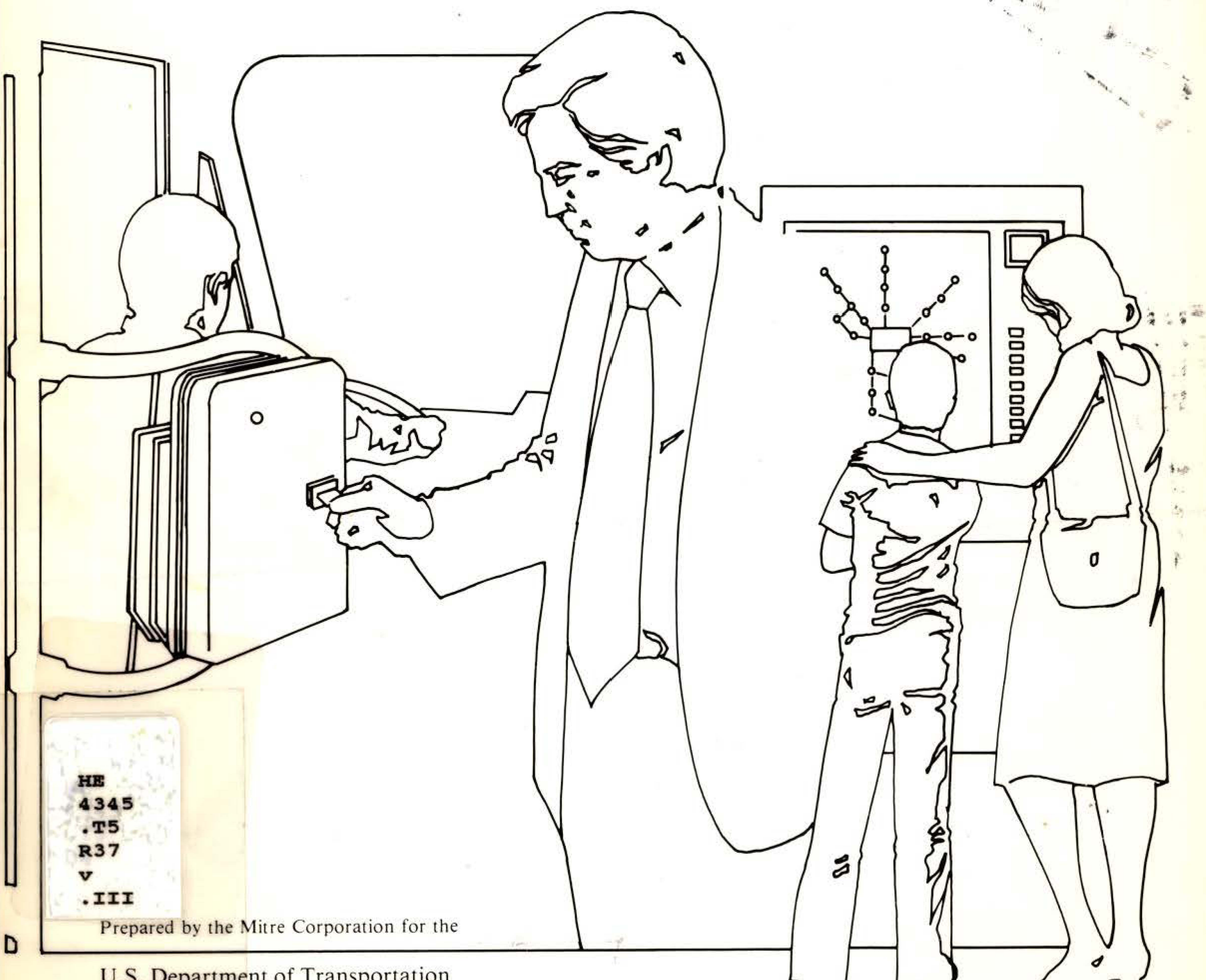
Self-Service Fare Collection

Volume III: Hardware Considerations



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Urban Mass Transportation Administration
Office of Service and Methods Demonstrations
Washington, D.C. 20590

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16. Abstract

European applications of self-service fare collection are typically supported by a variety of automated equipment to facilitate ticket purchase and validation by passengers and ticket sales by drivers and station attendants. This report describes the common hardware features employed by these ticket vending and validation devices and examines the general policy and hardware design trade-offs which need to be addressed by properties contemplating self-service implementation.

Other volumes in this series cover various aspects of the self-service demonstration project being sponsored by the Office of Service and Methods Demonstrations, Urban Mass Transportation Administration. Volume I provides an overview of the European approach to and rationale for self-service fare collection; documents the experience European transit systems have had with using and enforcing these procedures; and discusses the relative merits of alternative approaches to self-service with respect to their application in the U.S. Volume II summarizes the information obtained from a survey of European properties. Volume IV reviews the legal and labor issues associated with self-service fare collection.

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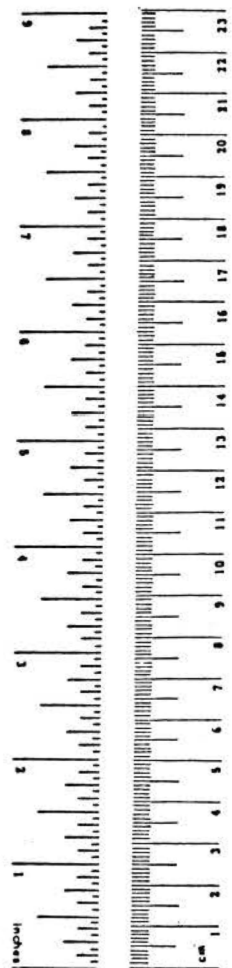
FOREWORD

The MITRE Corporation expresses its appreciation to the manufacturers which provided information regarding their current product line and the capabilities and features of the machines within their product line. We especially thank those individuals who generously devoted their time in discussing system features and directing tours of their facilities. The products pictured in this report were selected because they were considered representative of generic types of self-service equipment and not because they represent an exclusive product of the cited manufacturer. Neither the presence of nor omission of a specific piece of equipment should be interpreted as an indication of a manufacturer's capabilities or the extent of the product line offered by the manufacturer.

METRIC CONVERSION FACTORS

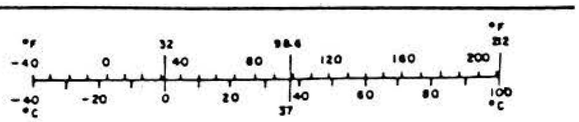
Approximate Conversions to Metric Measures

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



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



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1.0 INTRODUCTION

The Urban Mass Transportation Administration, U.S. Department of Transportation, in its efforts to raise transit system productivity, has investigated various improvements to transit fare systems. Numerous studies, design and development efforts, and demonstration projects have been undertaken to test such promising strategies as incentive, disincentive, and differential pricing, free fares and pre-paid fares and to evaluate such innovative techniques as automatic fare collection and credit card fare payment systems. As part of this effort, the Office of Service and Methods Demonstration is currently sponsoring a program to demonstrate, in the United States, a fare collection procedure widely used in Europe, generally known as self-service fare collection.

The European "self-service" form of fare collection, like many other self-serve operations such as gas stations, department stores, and unmanned toll booths, allows the customer relatively unrestricted access to the product or service. Direct monitoring of the patron's activity is reduced significantly but not to the point that the system becomes an "honor" system. In self-service transit operations the passenger becomes responsible for determining and paying the proper fare prior to making the trip. Complete monitoring or control of the payment of the proper fare is not performed by vehicle drivers, station attendants, or automatic equipment; instead all or nearly all responsibility for fare enforcement falls to special personnel who randomly check compliance.

European fare collection systems are often referred to as self-service fare collection systems not only because they provide for fare payment without direct monitoring but also because they incorporate numerous "self-serve" features such as ticket vending machines and passenger-actuated vehicle doors.

This report, the third volume of a four volume examination of SSFC, describes the equipment commonly used to support self-service operations in Europe and discusses the policy and design options which are presented during the selection and specification of equipment for self-service operations. Volume I provides an overview of the European approach to and rationale for self-service fare collection; documents the experience European transit systems have had with using and enforcing these procedures; and discusses the relative merits of alternative approaches to self-service with respect to their application in the U.S.(1) Volume II summarizes the information obtained from a survey of European properties.(2) Volume IV reviews the legal and labor issues associated with SSFC.(3)

2.0 OVERVIEW OF SELF-SERVICE EQUIPMENT

European self-service operations are typically supported by a wide range of automated devices. Most offer ticket vending machines from which the passenger may purchase single-trip and multi-trip tickets. Nearly all provide special devices for the validation of these tickets for individual trips, and some incorporate a variety of other automated and semi-automated devices designed to support driver and agent ticket sales, to provide fare and schedule information, to facilitate revenue accounting, and to monitor system performance. The following describes some of the typical features of the hardware currently being used in many European self-service systems. Subsequent sections address the trade-offs which face a transit property during the selection and specification of ticket-issuing and ticket-vending equipment for self-service.

2.1 Ticket Issuing Equipment

European self-service systems are highly ticket-oriented. More than half of all passenger trips are made using single and multi-trip tickets with multi-trip tickets accounting for more than half of all ticket-based trips. Tickets are available from numerous sources--ticket vending machines, drivers, transit agents, and other outlets such as newsstands, shops, and banks.

2.1.1 Direct Passenger Vending

The ticket vending machine is a common feature in European operations. Located at transit stops, station and transfer areas, and, in some instances, on the transit vehicle itself, the ticket vending machine provides for self-serve purchasing of all types of tickets. In general, single-trip tickets and multi-trip tickets are sold through different machines. However, newer generations of machines being offered by various manufacturers (see Appendix A for a list of equipment suppliers) combine these functions into a single unit.

Ticket vending equipment ranges from the very elementary to the very sophisticated. Some units, such as those used in Brussels* (Figure 1), are primarily mechanical devices which accept only a single coin denomination and dispense a single type of ticket. These machines are stocked with pre-printed tickets and no printing or other operation is performed by the machine. The more sophisticated machines, such as those recently installed in Stuttgart (Figure 2), dispense a variety of ticket types and print on the ticket stock at the time of purchase whatever information is needed to produce different types and values of tickets. Machines being developed for a few European rail systems (Figure 3) issue special "defined-destination" tickets and, therefore, offer scores of selections for the passenger using the unit. Most of these more complex machines are microprocessor controlled and incorporate needle printers to facilitate changes in fare structures or ticket design. Section 4.3 summarizes some of the features (options) offered for ticket vending machines.

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*Throughout this report city names are used to refer to the transit properties using self-service; Appendix B lists property names and addresses for each city.

Single-Trip Vending Machine--
Brussels, Belgium

Single-Trip Ticket--
Brussels

CHARACTERISTICS OF ILLUSTRATED EQUIPMENT

Machine accepts four coins of the same denomination and issues precut, pre-printed tickets from a single stack of tickets.

FIGURE 1
SIMPLE SINGLE-TRIP VENDING MACHINE

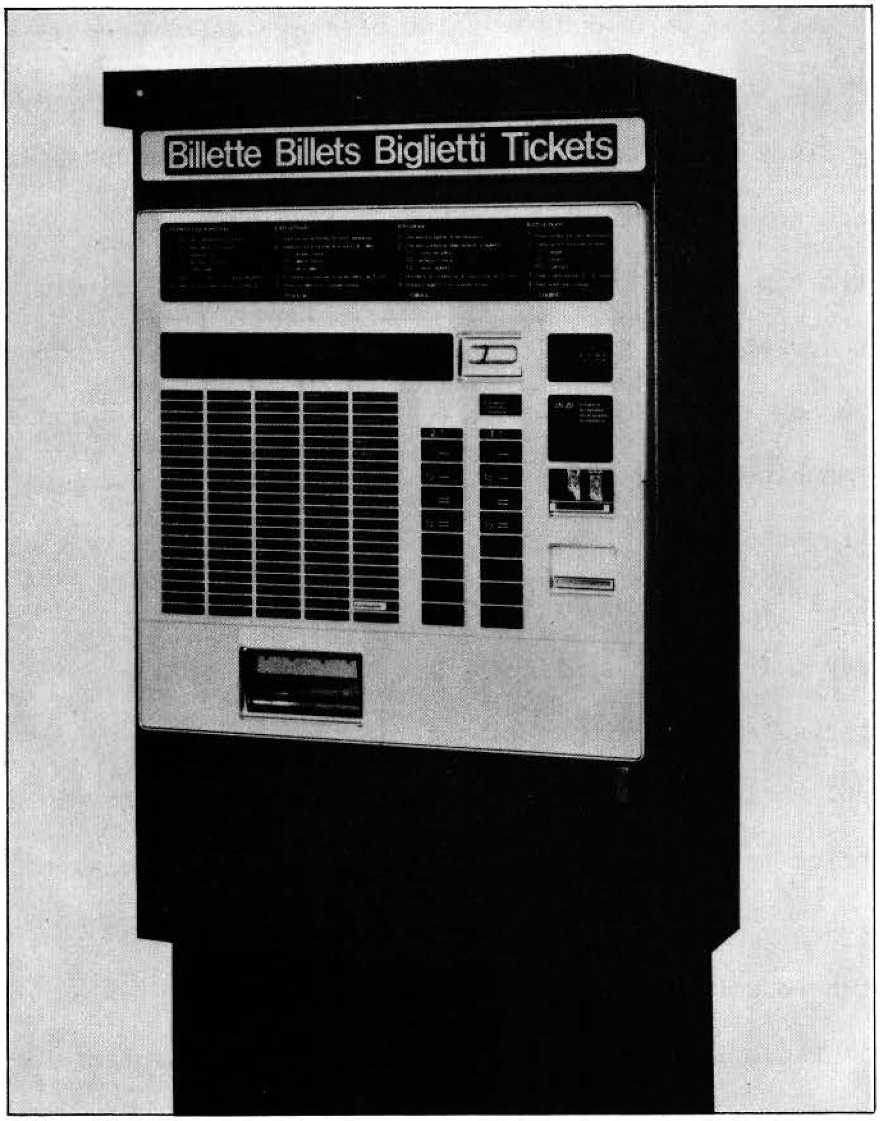
Ticket Vending Machine--Stuttgart, W. Germany (Manufacturer: Autelca AG, Bern, Switzerland)

Sample Ticket from Manufacturer's Demonstration Model

CHARACTERISTICS OF ILLUSTRATED EQUIPMENT

Machine accepts all denominations of coins through a single slot. Coins are electronically checked and held in escrow until transaction is completed. Tickets are printed at the time of transaction by a needle, mosaic printer. Machine is microprocessor controlled and tabulates revenue and ticket statistical breakdowns by type, amount, time, etc. Machine incorporates a recycling change-maker.

FIGURE 2
SOPHISTICATED MULTI-TRIP TICKET VENDING MACHINE



Prototype Commuter Rail Ticket Issuing Machine
(Manufacturer: Autelca AG, Bern, Switzerland)

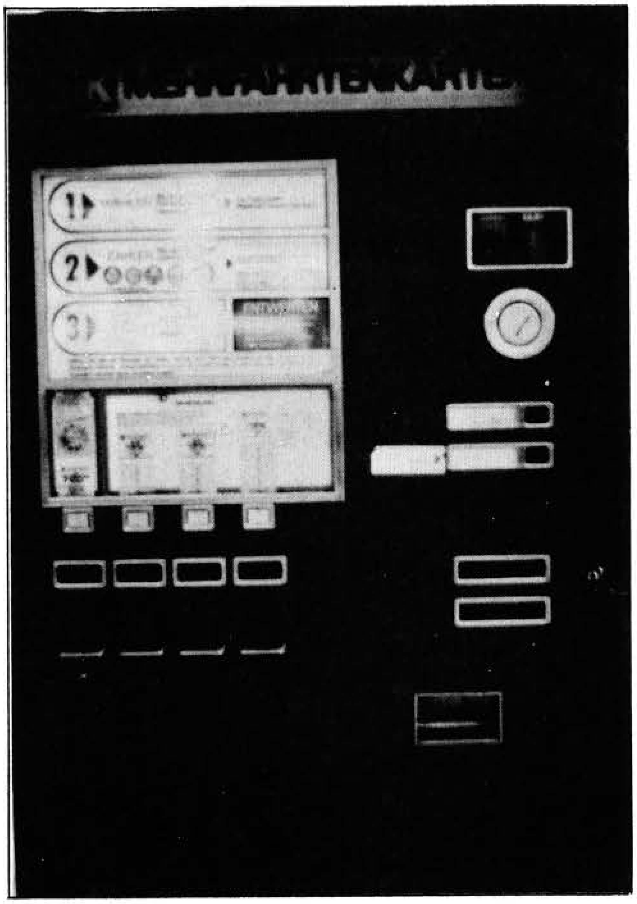
CHARACTERISTICS OF ILLUSTRATED EQUIPMENT

Machine for up to 100 specific destinations. Machine offers 16 ticket options and features bill acceptor.

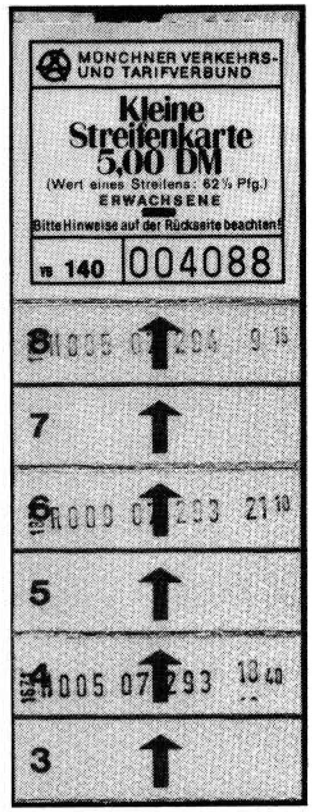
FIGURE 3
DEFINED-DESTINATION TICKET VENDING MACHINE

Machine functions depend to a large degree on the type of ticket stock that will be used and the value of the stock stored in the machine. The Brussels unit, for example, stores stacks of pre-printed tickets. Since the unit merely dispenses tickets, the stock stored in the machine has value and must be afforded protection from theft. The Stuttgart machine, on the other hand, stores a valueless ticket stock; it "creates" a valuable document only at the time of the transaction. Other systems such as in Munich represent a compromise approach. Munich's machines store pre-printed stock but emboss a design on the stock during the vending so that inspectors can routinely check for stolen stock (see Figure 4).

Nearly all current applications of vending machines are stationary installations. On-vehicle vending is largely confined to light rail (tram) applications because many properties consider the vibrational and electrical environment on buses to be too severe for vending applications. Milan and Munich originally attempted vending on its buses but have withdrawn because of the reliability problems experienced with these installations. However, several manufacturers are now testing prototypes of vendors for bus installations and expect more and more transit properties to pursue vehicular installations because of the added measure of security afforded by the presence of the vehicle operator. Several properties in Greece, for example, have reportedly installed machines on buses (Figure 5). (Figure 6 depicts other vending machines produced by various manufacturers.)



Multi-Trip Ticket Issuing Machine--
Munich, W. Germany

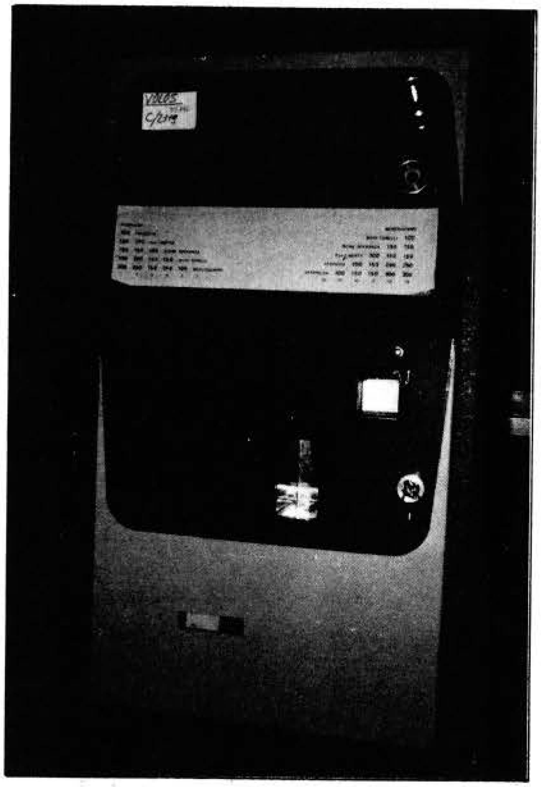


Adult Multi-Trip Ticket

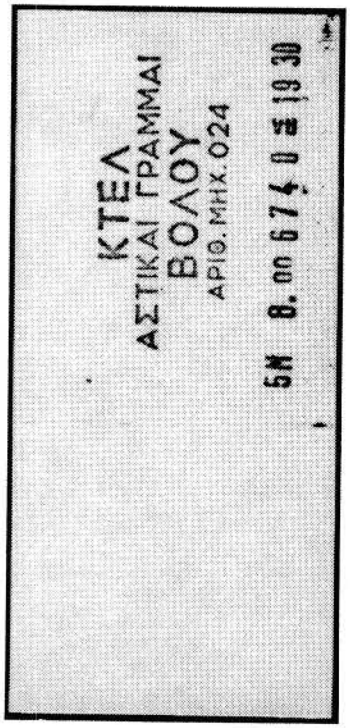
CHARACTERISTICS OF ILLUSTRATED EQUIPMENT

Machine accepts all denominations of coins but does not give change. Four types of tickets are issued: two types of adult multi-trip tickets, a child multi-trip ticket, and a 24-hour pass. Tickets are embossed when issued. Tickets are pre-printed and stored Leporello-fashion.

FIGURE 4
MUNICH'S MULTI-TRIP VENDING MACHINE



Single-Trip Vending Machine--
Manufacturer's Display Model for
Installation in Greece
(Manufacturer: Litton Sweda,
Milan, Italy)

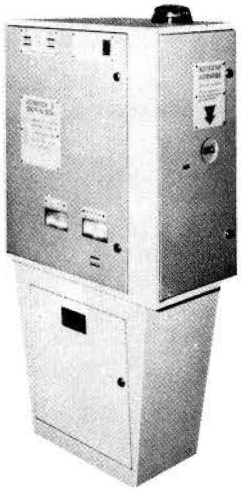


Sample Ticket Produced
By Manufacturer's
Display Machine

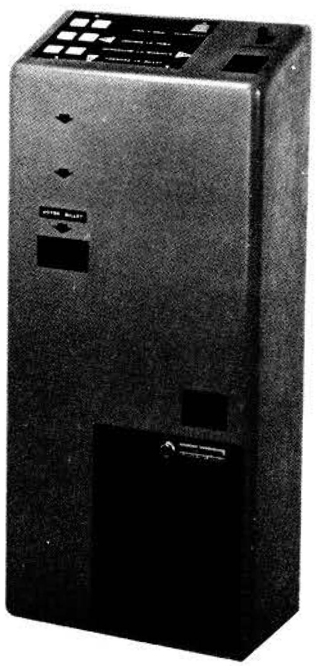
CHARACTERISTICS OF ILLUSTRATED EQUIPMENT

Machine accepts all denominations of coins through a single slot. Machine display panel indicates cost of ticket for particular destination using backlighted matrix advanced through driver's remote control unit. Tickets are printed on blank paper from rolls and are validated at time of issue.

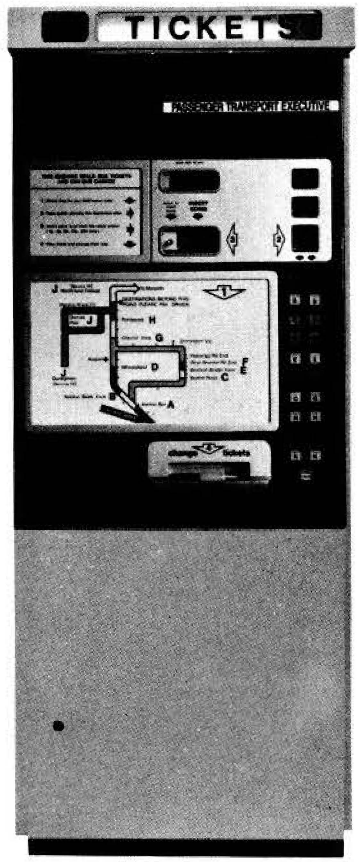
FIGURE 5
BUS-MOUNTED VENDING MACHINE



Vendor for Single-Trip and Multi-Trip Booklets Manufactured by CAMP, Paris, France



Mobile Vendor Manufactured by Sadamel, La Chaux-de-Fonds, France



Multi-Fare Ticket Machine Manufactured by Control Systems Uxbridge, England

FIGURE 6
OTHER SELF-SERVICE TICKET VENDING MACHINES

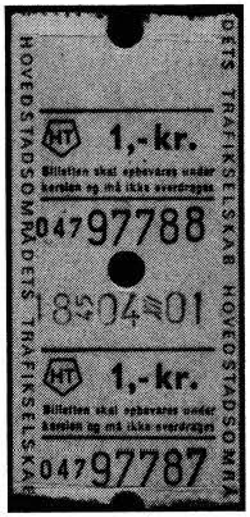
2.1.2 Driver-Operated Issuing Equipment

A few European cities, e.g., Geneva, make such extensive use of ticket vending and other means of ticket distribution that driver sales have been eliminated entirely. However, most cities continue ticket sales through vehicle drivers but actively discourage these sales by charging premiums or greatly limiting the types of tickets which are available from the driver.

Most driver sales continue to be carried out without the use of special driver-operated issuing machines. Usually the driver is given a quantity of pre-printed tickets which he simply exchanges at face value for monies received. Revenue and ticket accountability are strictly manual activities carried out through periodic inspections (counting) of the total cash and tickets held by the driver. This total can be a substantial amount (in Munich, for example, a bus driver is responsible for 2,000 DM ($1,000), and can be a major security concern. Partly as a result of the security problems of driver handling of preprinted tickets and partly to provide greater convenience and numbers of tickets, a number of European transit properties provide drivers with machines for issuing tickets to passengers.

In systems with flat fares or a very limited number of zones, the machine is usually a simple ticket dispenser of the type shown in Figure 7. The information printed on the ticket corresponds to the date and time of purchase so that the ticket also serves as a

Ticket Dispenser for Driver Sales--
Copenhagen, Denmark (Manufacturer:
Almex, Stockholm, Sweden)



Single Trip Ticket Sold by
Driver in Copenhagen, Denmark

CHARACTERISTICS OF ILLUSTRATED EQUIPMENT

Machine issues a single ticket for each stroke of lever. Each ticket is printed (mechanically) with data which has been set manually by the driver.

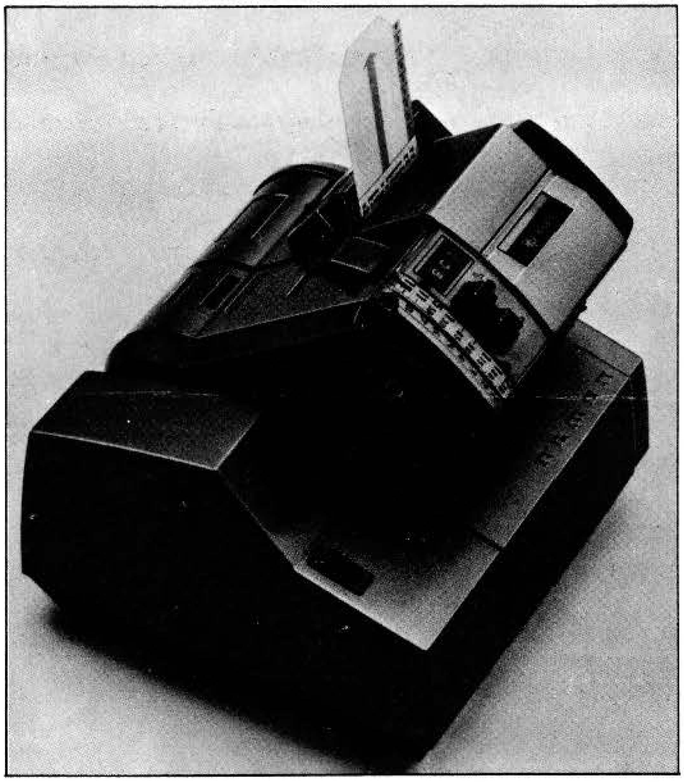
FIGURE 7
DRIVER-OPERATED TICKET DISPENSER

receipt (no subsequent validation is required) but any information which transforms the pre-printed stock into a valuable ticket may be used. Such devices generally incorporate a simple mechanical counter to record the total number of transactions. Several different ticket types are accommodated by "banking" several units together, each with its own type of stock.

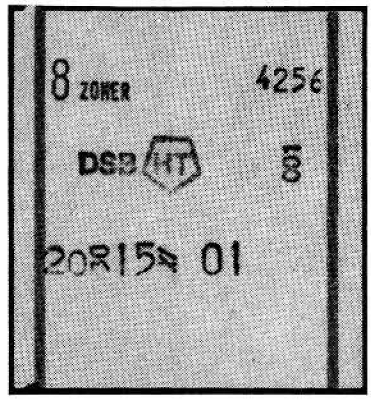
Systems which offer a variety of single-trip ticket types and/or have a relatively large number of zones frequently use an issuer, such as shown in Figure 8, that can print (and record) more information. Such machines are also frequently used to assign value to the ticket stock for other types of tickets which the driver may sell but which the machine is not capable of dispensing (see Figure 8).

2.1.3 Agent-Operated Issuing Equipment

Most sales by ticket agents in European cities continue to be performed manually or are supported by equipment similar to theater ticket vending equipment. A few properties have turned to relatively sophisticated machines which not only maintain detailed statistics on the types and numbers of tickets sold but also feature special security checks to prevent compromises by ticket agents or other personnel. The machines used by station agents in the Paris Metro (Figure 9), for example, monitor ticket sales by each agent; the agent must insert a special magnetically encoded card at the start and end of his shift to identify himself and to "enable" the machine.

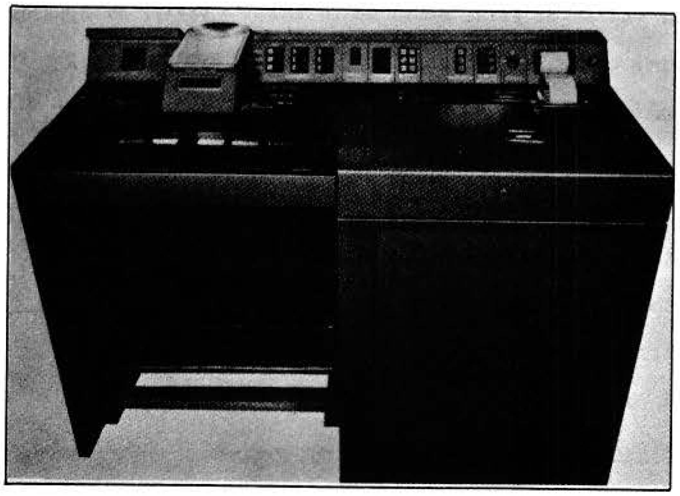


Ticket Issuing Machine--
Copenhagen, Denmark

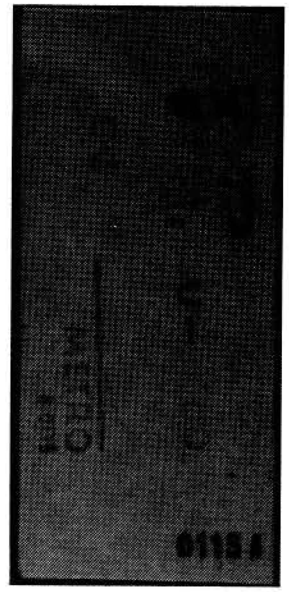


Sample 8-Zone Single-Trip
Ticket which will be used
in Copenhagen

FIGURE 8
DRIVER-OPERATED TICKET ISSUING MACHINE



Agent Ticket Issuing Machine--Paris, France
(Manufacturer: CAMP-CGA, Paris, France)



Paris Metro Ticket

FIGURE 9
STATION AGENT TICKET VENDING MACHINE

2.2 Ticket Validation Equipment

A primary characteristic of self-service fare collection systems is the random inspection of passengers to ensure that each has paid the correct fare for the trip which is being taken at the time of inspection. Consequently, each passenger must be provided a document which can serve as proof-of-payment during such an inspection.

Passes inherently contain sufficient information to serve as proof-of-payment and therefore require no action by the passenger prior to the trip. Similarly, single-trip tickets issued by one of the driver-operated machines described earlier are sufficient proof-of-payment if they contain enough information, e.g., time and date, to match the ticket to the actual trip being taken. Other fare documents such as single and multi-trip tickets purchased from machines and agents must be validated in a special device just prior to the trip to provide this information.

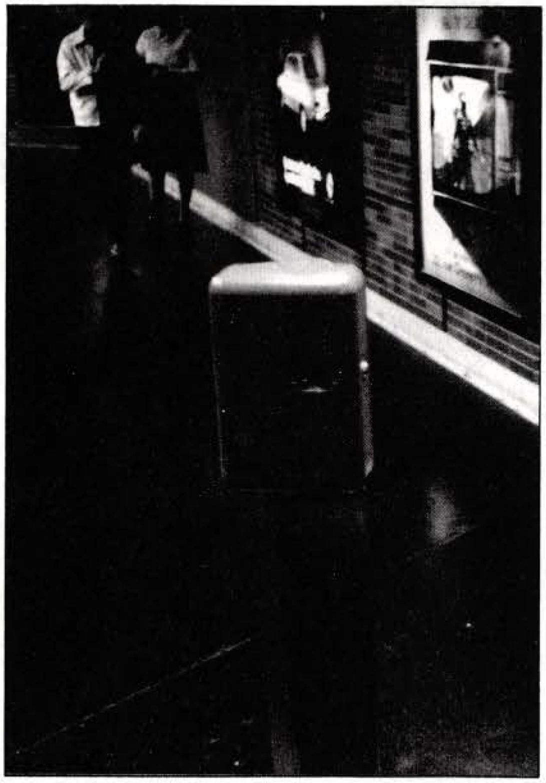
2.2.1 Validation Devices

The device used to provide this proof-of-payment is a validator (also called a canceller). When a passenger inserts a ticket into the validator, appropriate information is printed on the ticket to show when and where the validation was made. Validators differ markedly according to the type of information printed on the ticket, the type of checks which are made to ensure that a legitimate ticket is being used, and the type of alterations made to the ticket during the validation process.

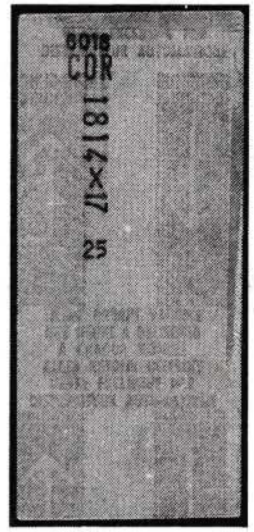
Validators may be located either at wayside locations or on-board the transit vehicle. Most Swiss systems use wayside validators and usually incorporate them in the vending machine enclosure. Most other European systems prefer to place validators on the vehicles; one or two validators are located near each vehicle doorway.

The most elementary form of validation is that which accompanies a fare policy allowing unlimited travel within a specified time period after validation. With such a fare policy, only time/date information must be supplied during a validation. Lyon, for example, uses a validator which will time/date stamp any piece of paper which fits into the validator throat (Figure 10); no check of ticket legitimacy is made during validation. Multi-trip tickets are sold in the form of booklets of single-trip tickets.

Geneva's validators (Figure 11) are similar to Lyon's in that very limited information is printed during validation. Because Geneva also offers a "short-trip" ticket which entitles the bearer to travel up to three stops from the point of validation, the location of the validation is also printed. Geneva's validators also incorporate a guillotine device which clips a small section of the ticket during validation to prevent over-printing when the ticket is subsequently inserted into a validator. The guillotine feature permits the use of a single document for multi-trip usage without the passenger having to fold or orient the ticket to ensure that the data is stamped at the correct location on the ticket. Copenhagen's



Ticket Validator--Lyon, France
(Manufacturer: CAMP, Paris, France)



Metro Ticket Used in
Lyon, France

FIGURE 10
TIME/DATE TICKET VALIDATOR

Ticket Validator--Geneva, Switzerland

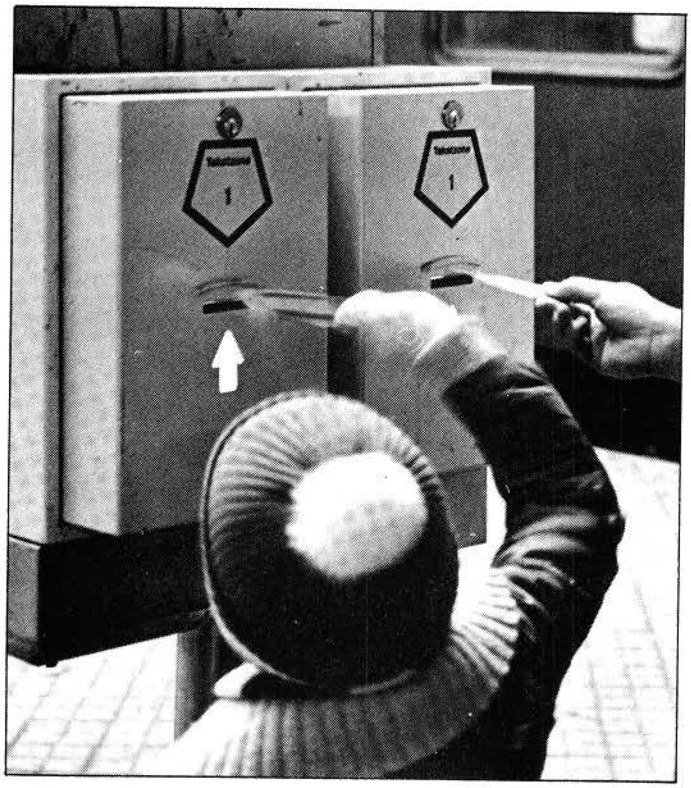
Six-Ride Multi-Trip
Ticket Used in Geneva

FIGURE 11
GUILLOTINE-TYPE TICKET VALIDATOR

new machines employ a similar guillotine feature. They also electronically verify that the document inserted into the machine is a valid ticket; conductive-ink strips are printed on the back of each ticket (Figure 12). Although Copenhagen is using this feature to reduce fraud and counterfeiting, other systems are considering the feature as a means of counting the usage of different types of tickets. Other validators on the market use reflective strips on the ticket to facilitate this counting (Figure 13).

2.2.2 Driver Control of Validation

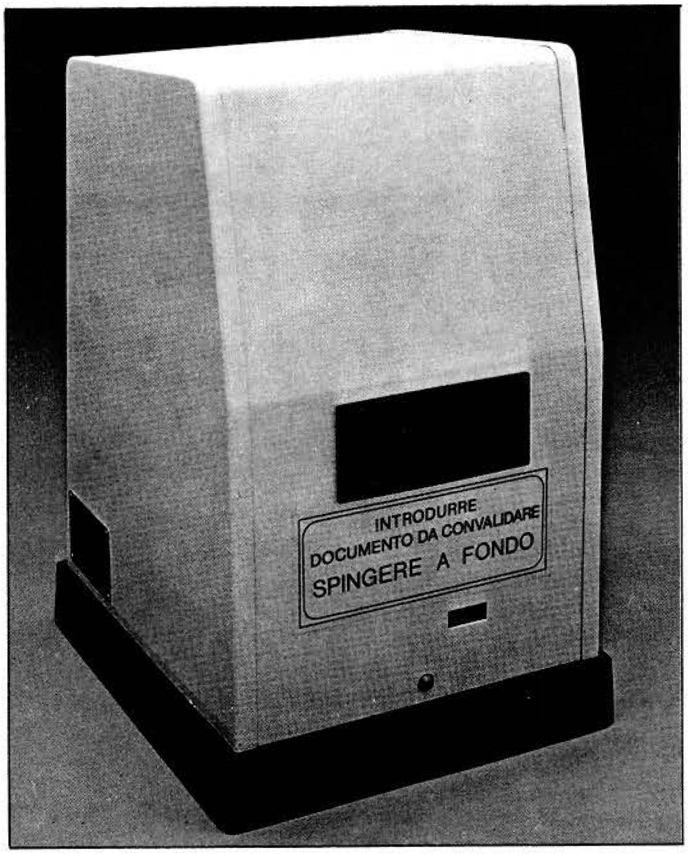
Systems with a flat-fare, time-based fare policy may locate validators on-board vehicles without affecting driver workload or responsibility. Since time/date information is automatically provided by an internal clock, the driver need not participate in the validation process. However, when zonal or line-based fares are used, other information must be stamped on the ticket during validation and the vehicle driver is responsible for updating the information. For example, in a zoned-based system the driver must change the zone indication each time a zone boundary is crossed so that the validator will stamp the code of the zone in which the vehicle is operating. With line (route) based fares, the driver is responsible for setting route codes to correspond to the number of the line which the vehicle will be serving. Most of the present generation of validators are controlled through the use of a driver console such as shown in Figure 14. (Figure 15 depicts other validators supplied by other manufacturers.)



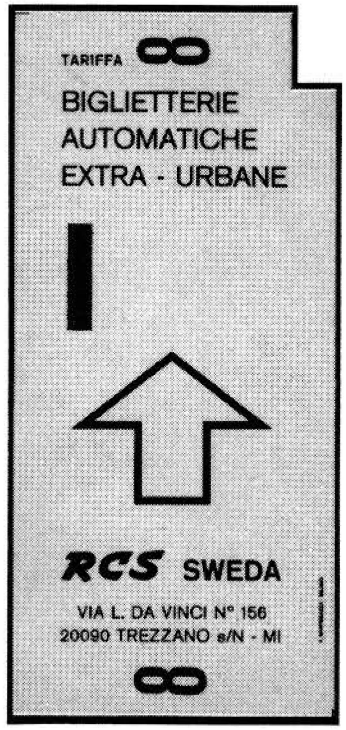
Ticket Validator--Copenhagen, Denmark
(Manufacturer: AB Almex, Stockholm, Sweden)

Back of Multi-Trip
Ticket Used in
Copenhagen, Denmark

FIGURE 12
VALIDATOR INCORPORATING CHECK OF TICKET GENUINENESS

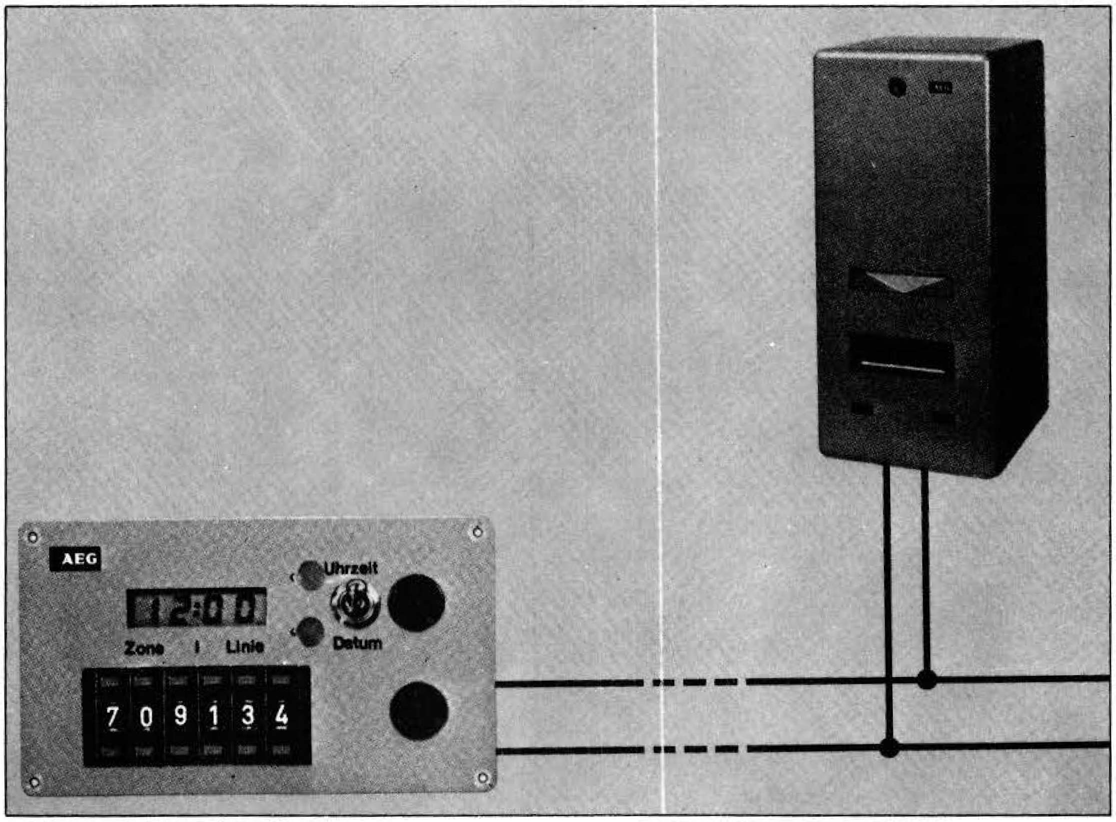


Ticket Validator--Manufacturer Display Model
(Manufacturer: Litton Sweda, Milan, Italy)



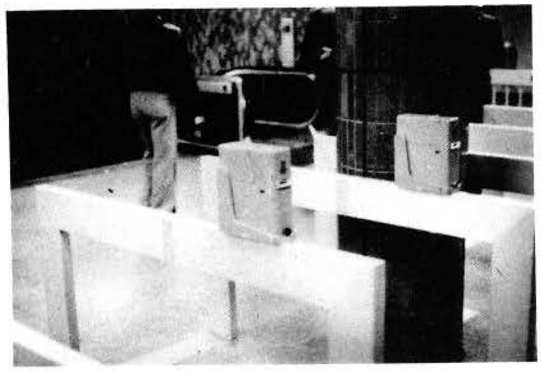
Sample Multi-Trip
Ticket

FIGURE 13
VALIDATOR INCORPORATING TICKET COUNTING CAPABILITY

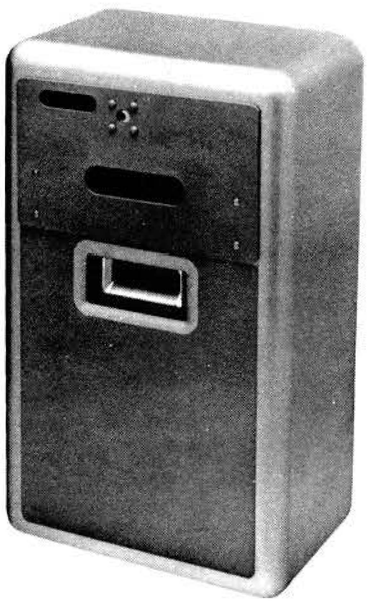


Driver Control Console Manufactured by AEG Telefunken, Kassel, West Germany

FIGURE 14
DRIVER CONSOLE FOR VALIDATOR CONTROL



Cologne Validator Manufactured
by Elgeba, Bad Honeff, W. Germany



Validator Manufactured by
Ticket Equipment, Cirencester, England

Munich Validator Manufactured
by Heinrich Klüssendorf, Berlin,
W. Germany

FIGURE 15
OTHER SELF-SERVICE TICKET VALIDATORS

2.3 Ancillary Self-Service Equipment

In addition to ticket vending machines and validation equipment, self-service operations are often supported by other automated devices. These devices, while not necessary to the self-service fare collection operation per se, nevertheless complement it and increase its efficacy.

2.3.1 Vehicle Access Control

Nearly all European transit properties have adopted a policy of unrestricted access to vehicles. Since passengers are responsible for paying their fare without being monitored by the driver, all doors are available for boarding and alighting. Rather than require the driver to control each door, which in the case of some triple articulated trams would be highly impractical, most have equipped their vehicles so that door operation is a "self-serve" function. Each door is independently controlled by a push button on the exterior of the vehicle (Figure 16) and another push button in the vehicle's interior. A passenger wishing to enter or exit actuates the door by means of these buttons. The driver is responsible only for the locking and unlocking of the doors; premature closing of the doors and vehicle operation while doors are open are prevented through a series of safety interlocks.

2.3.2 Passenger Information

Passenger information continues to be largely a manual operation. System schedules, route maps, fare policies and regulations, and orientation brochures are distributed widely; usually instruction on

FIGURE 16
EXTERIOR PUSH BUTTON FOR PASSENGER ACCESS

use of the transit system is part of the school curriculum. Automation has generally been limited to applications such as the announcement of the destination and arrival time of the next subway train.

The Deutsches Bundesbahn, Germany's Federal Railway, which merges with and becomes part of the self-service operations of various local regions, provides automated schedule information for both its local and international trains using the machine shown in Figure 17. The passenger using this machine enters a three digit code corresponding to his desired destination, selects the time period desired for the beginning of the trip, and receives a print-out of all train departures fitting these criteria (Figure 18).

2.3.3 Pass Distribution

Most European systems distribute period passes through a variety of outlets usually on a concession basis. In most cases, printing and accounting for these period passes are supported by a device similar to a cash register. Recognizing that many transit properties are facing increasing resistance by concessionaires to handling greater numbers and types of period passes because of the transaction time (and cost) involved, several manufacturers are investigating a new line of products to support this pass distribution network. The machine in Figure 19, for example, prints a new period pass using data encoded on the permanent I.D. portion of the pass; thus, renewals of period passes can be completed in a fraction of the time of existing procedures.

FIGURE 17
DEUTSCHES BUNDESBAHN SCHEDULE INFORMATION MACHINE

Die DB hat einen Tip für Sie!
Schauen Sie mal auf die Rückseite!

FAHRPLANAUSZUG

DB

Von	Nach	Gültig bis
MUENCHEN HBF	KIEL HBF	26. 05. 1979 2818632110

Abfahrt Std Min	Verkehrstag	Gleis	Zuggattung Klasse ⊕	Service i. Zug	Ankunft Std Min	★	Reiseweg	Erstes Umsteigen in	Ankunft Std Min	Abfahrt Std Min	Zuggattung Klasse ⊕	Service i. Zug	Zweites Umsteigen in	Ankunft Std Min	Abfahrt Std Min	Zuggattung Klasse ⊕	Service i. Zug
0755	T	21	D	B	1736		A										
0823		16	IC 1	B	1814	1	A	HANNOVER	1445	1452	TEE	B	HMB-ALTONA	1629	1707	E	
0840		24	IC 1	B	1943	2	A	WUERZBURG	1105	1131	D	B	LUENEBURG	1648	1656	E	
0907	T	17	D	B	2045	3	A	HANNOVER	1655	1712	D	B	HMB-ALTONA	1921	1935	E	
1044		16	IC	B	2001	4	A	HANNOVER	1638	1645	IC 1	B	HMB-ALTONA	1821	1852	E	
1044	T	16	IC	B	2045	5	A	HANNOVER	1638	1712	D	B	HMB-ALTONA	1921	1935	E	

★ Besonderheiten:
1=MO-FR NICHT 23. 12. -01. 01. ,13. 04. -16. 04. AUCH 21. 04. -22. 04.
2=MO-SA NICHT 24. 12. -01. 01. ,14. 04. -16. 04.
3= NICHT 24. 12. ,31. 12.
4=MO-FR NICHT 23. 12. -01. 01. ,13. 04. -16. 04.
5= NICHT 24. 12. -31. 12.

Reiseweg	Fahrpreise ohne Zuschläge in DM: Einfache Fahrt 2. Klasse	Einfache Fahrt 1. Klasse	Hin- und Rückfahrt 2. Klasse	Hin- und Rückfahrt 1. Klasse	D-Zug Zuschlag	Reiseweg über
A	119. 00	187. 00	238. 00	374. 00		WUERZBURG HAMBURG
B						
C						

FAHR UND SPAR: SENIOREN-PASS

Service im Zug
B = Zug ist bewirtschaftet
K = Zug führt Schlaf- u. Liegewagen
L = Zug führt Liegewagen
S = Zug führt Schlafwagen

Verkehrstage
T = täglich
U = sonn- und feiertags
V = werktags außer samstags
W = werktags
X = täglich außer samstags
Y = täglich außer sonntags
Z = samstags, sonn- und feiertags

⊕ = Wenn Züge die 1. und 2. Klasse führen, sind keine Angaben über die Klasse vorgesehen.
TEE- und IC-Züge führen nur die 1. Klasse.
Für TEE- und IC-Züge werden Sonderzuschläge erhoben.
Telegramm ist nur vollständig, wenn als letztes Zeichen # erscheint.

Ohne Gewähr

FIGURE 18
OUTPUT FROM AUTOMATIC INFORMATION MACHINE

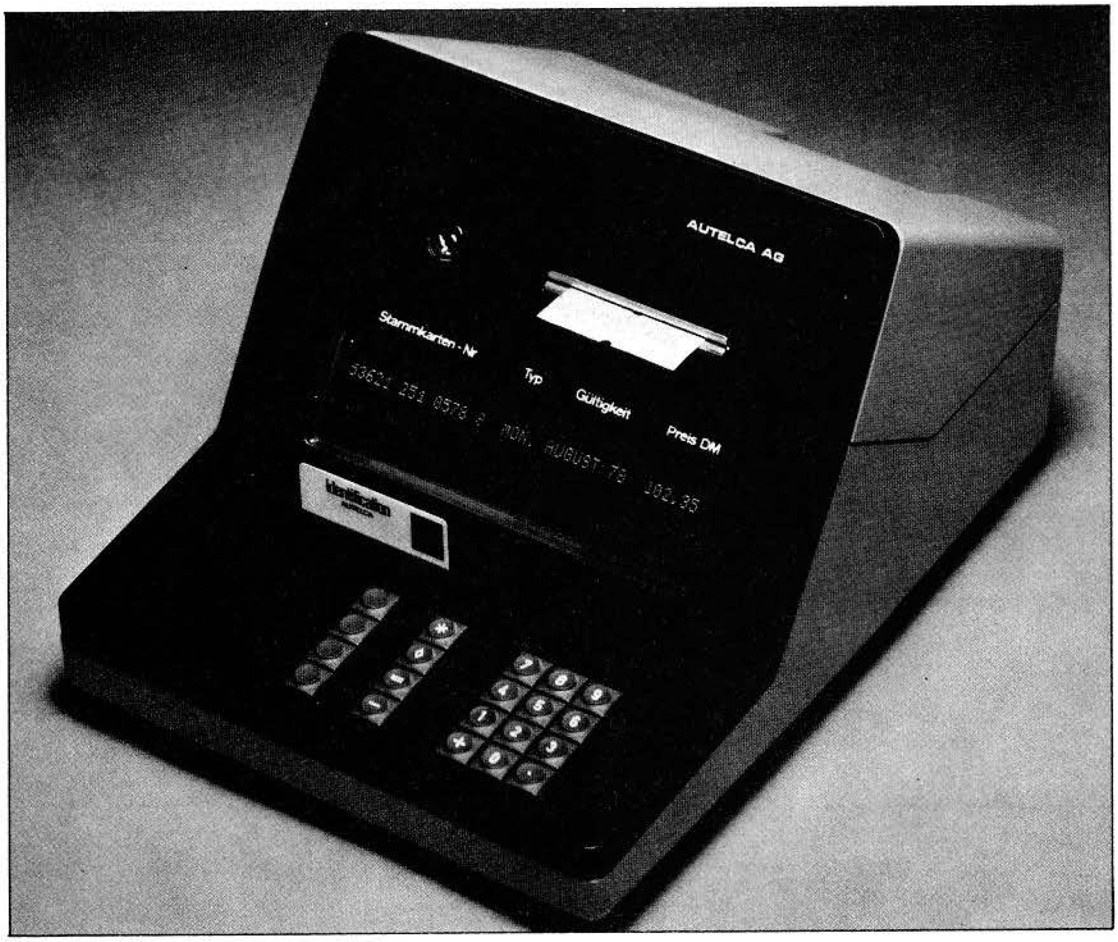


FIGURE 19
DESK-TOP TICKET/PASS PRINTER

3.0 POLICY FACTORS AFFECTING SELF-SERVICE

Implementing SSFC involves two types of decisions -- policy decisions and hardware design decisions. The following discussion highlights the fundamental transit policy decisions regarding fare policy, location of self-service hardware, and ticketing procedures which determine the basic configuration of self-service to be adopted. The numerous hardware design features and trade-offs that need to be considered in conjunction with these policy deliberations are discussed in Section 4.0.

3.1 Fare Policy

Fare policy is the result of several conflicting goals:

> "The object of fares policy is to ensure the maximum traffic revenue combined with the highest standard of service to the public, the lowest fares level, and the minimum cost of operating the services."[4]

Self-service offers the opportunity to tailor a fare policy that will encourage increased ridership and, at the same time, increase revenue from each market segment by providing the transit property with the ability to adopt more flexible fare structures and to implement such features as short-term passes, special user discount passes and tickets, off-peak differentials, etc.

The manner in which the transit property attempts to use self-service and the extent to which the property relies on automation to accomplish the various features has significant hardware ramifications. Although self-service facilitates changes in fare structure and accommodates a variety of prepayment options, the system must be carefully planned and take into account possible future expansion and modification of fare policy. A self-service system designed to support a flat-fare structure, for example, cannot be readily adapted for a zone fare structure unless the validation equipment is designed for such expansion (zonal fare structures acquire the printing of zone data during validation). Similarly, the transit property must decide the number of ticket types it expects to distribute through ticket vending machines -- taking into account the range of incentives, discounts, and user classes which might be accommodated.

One particularly important consideration is transfer policy. Self-service provides each passenger with a receipt which serves as proof-of-payment similar to a transfer. However, because the passenger must retain this receipt in case of an inspection, it cannot be surrendered as conventional transfer documents are. Consequently, self-service systems do not lend themselves to separate transfer charges and cannot provide data on the number of passengers making transfers unless special, additional features are incorporated.

Brussels and The Hague are among the few properties which have continued a line (route) based fare structure. Brussels incorporates special machines which issue transfers to passengers; the machines are electronically tied to the validator and will issue a transfer only if a ticket is validated. The Hague continues to charge an additional fee for transfer privilege; special tickets are used and validators imprint the line number onto the tickets. Both systems are reportedly considering phasing out the transfer.

3.2 Equipment Location

The location of ticket vending and validation equipment is also largely a policy decision which must be made in light of the experience of European operators and of the relative advantages and disadvantages of each approach. Table I summarizes these advantages and disadvantages.

3.2.1 Installation and Environmental Factors

The primary concerns in on-board installations are vibration, space, and power supply. Vibration, particularly the levels experienced on buses, is a major cause of reliability problems for all on-board equipment. European experience indicates that vehicular installations of vending hardware should be attempted only on light rail vehicles because vibration is less severe compared to buses. Light rail applications have been limited as a result of the amount of space consumed by the typical vending machines.

Validators are much less of a problem; they consume little space and have been proven reliable on all types of vehicles. Most European systems now wire most of their on-board equipment directly to the vehicle's batteries because of the numerous problems they experienced using the vehicle's chassis-ground supply.

TABLE I

COMPARISON OF ON-BOARD VS. WAYSIDE INSTALLATION

1. ADVANTAGES TO ON-BOARD INSTALLATION:

   Allows imprinting of route- and direction-related information onto tickets, during validation.

   Installation problems are less severe.

   Weathering is of less concern.

   Procedures for passengers to locate and operate equipment are more uniform.

   Allows hurried passengers to board immediately, without having to first purchase and/or validate a ticket.

   Facilitates periodic servicing at a central maintenance location.

2. ADVANTAGES TO WAYSIDE INSTALLATION:

   Facilitates imprinting of zone-related information onto tickets, during validation.

   Does not require any periodic action by transit employees to update location-related validation data.

   Space restrictions are less severe.

   Vibration is of less concern.

   Crowding is likely to be less severe.

The primary concerns in wayside installations are environmental and security protection and capital cost. The equipment must be designed to withstand and operate under adverse weather conditions and thwart vandalism and theft. Because wayside installation involves extensive individual site preparation, installation costs may be substantial; some installations have reportedly cost more than twice the cost of the equipment being installed.

3.2.2 Capital Costs

Depending on the particulars of an individual property, the wayside location may be more or less costly in terms of equipment requirements than the on-board location. Wayside installations are usually supported by a single vendor or validator; sometimes several are used but multiple units are usually justified on the basis of passenger volume rather than redundancy for reliability. Vehicular installations almost always are multiple-unit installations; validators are usually located at each vehicle entrance so that the passenger may validate a ticket immediately upon boarding. Consequently, total equipment requirements of wayside validation versus on-board validation is a function of number of stops versus number and type of vehicles.

3.2.3 Patron Convenience and Fraud Deterrence

Vehicular installation of equipment tends to make for more uniform procedures in ticket cancellation, compared to searching out locations for wayside equipment prior to boarding. However, a certain amount of confusion may ensue, regardless of location chosen. If validation equipment is on-board the vehicles, passengers may experience difficulty in getting to the machine(s) if the vehicle is very crowded. This may complicate enforcement by ticket inspectors, as defrauders may claim (with some justification) that they have been unable to get to the ticket validators. Wayside installation of validators however may occasionally cause passengers to miss a vehicle's departure, because they must take the time necessary to validate their tickets prior to boarding.

3.2.4 Maintainability

Periodic and unscheduled maintenance is required of all SSFC equipment. Periodic maintenance and servicing is generally more easily performed with vehicle-mounted equipment than with wayside equipment, as vehicle-mounted equipment maintenance can be scheduled to coincide in time and place with maintenance of the vehicle itself. Unscheduled maintenance can be a significant problem for either wayside or vehicular equipment, as maintenance personnel must be dispatched to repair or replace failed equipment. The installation of redundant equipment units on-board a vehicle can circumvent this problem, as maintenance on a single unit may be delayed until the vehicle reaches a maintenance depot, provided that the other equipment units can handle the fare collection task. Unfortunately, the relatively large size and cost of ticket vending equipment (compared to validators) tends to dictate against redundant on-board vending equipment, despite the fact that this equipment is more complex and potentially less reliable.

3.2.5 Impacts on Fare Structure Implementation

The location of self-service fare collection equipment favors certain fare structures over others. A fixed, flat-fare structure requires the least sophisticated of validation schemes and can be implemented easily with wayside or on-board equipment. A zoned fare structure requires a more sophisticated scheme, as the starting zone of a passenger's trip must be imprinted onto the ticket during validation to permit ticket inspectors to determine the extent (and thus the required fare) of a passenger's journey. With wayside equipment, this is relatively straightforward; the transit zone in which the equipment is located is imprinted with each ticket validation. For vehicle-mounted equipment, the procedure is the same. However, validation equipment must be closely monitored to ensure that the imprinted data corresponds to the actual zone in which the vehicle is operating. For vehicles whose routes cross transit boundaries, the imprinted data must be changed each time a boundary is crossed. Generally, this is done by the vehicle driver, manually or by means of a remote control system connected to the validation equipment. This function is critical, however; an error or omission by the driver can frustrate passengers and hinder enforcement by ticket inspectors.

As previously noted, equipment location also impacts on the manner in which transfers may be handled. If transfers are route and/or direction based, validating equipment is best located on-board the vehicles, where this information may be readily obtained, as information regarding route and direction is not easily provided via wayside validators.

3.3 Ticket Configuration

The manner in which a ticket is given value and the method used to validate a ticket are also policy decisions.

3.3.1 Assignment of Value

Tickets generally consist of paper or cardboard stock. The stock itself is virtually worthless, but by the time a passenger obtains a ticket, it has been assigned a value. The location where this assignment takes place can vary.

If this assignment of value is made when the tickets are initially manufactured, a high degree of control is necessary, from the time that they are manufactured until they are sold, as stolen tickets will be readily usable. If the value assignment is performed when the tickets are issued, by imprinting data onto the tickets, pre-issue controls are considerably reduced as stolen or lost tickets are worthless.

Hardware is also affected by this choice. Issuing equipment must have imprinting capabilities to assign value to tickets, whereas equipment which issues pre-valued tickets generally does not require these capabilities. The disadvantage of non-pre-valued tickets, is that the necessary imprinting subsystem increases overall equipment complexity. However, if a large variety of ticket types are to be vended (i.e., for a more sophisticated fare structure), the situation may be reversed. When numerous ticket types must be provided, vending equipment for pre-valued tickets must have separate storage and issuing systems for each separate ticket type, whereas equipment for vending non-pre-valued tickets may use a single ticket stock, and establish ticket type by imprinting information onto the ticket. Under these circumstances, equipment may be more complex with pre-valued tickets. The periodic maintenance task for the pre-valued system can also be more severe, as a larger variety of ticket stocks must be continually monitored and restocked.

3.3.2 Single-Trip Tickets

Single-trip tickets may be either issued and validated simultaneously (tickets are used at time of purchase) or issued and validated separately (tickets may be used at any time after purchase). If issued and validated simultaneously, issuing equipment must be capable of printing necessary validation data onto the tickets at time of sale, a potential increase in cost and complexity for ticket issuers. The tickets need not be compatible with validators; in fact, it is preferred that they not be compatible, to prevent confusion among passengers. A disadvantage of this scheme is the lessening of passenger convenience; tickets may not be purchased until time of travel. In addition, the tickets must be vended from a machine located in the vicinity of the trips' starting points.

A system in which issuing and validation of single-trip tickets are separated is of more convenience to passengers, as tickets may be purchased far in advance of actual travel. Tickets must be compatible with validators. Issuing equipment need not print any validation-related information onto the tickets. In addition, the tickets may be sold manually, by drivers, ticket agents, or concessionaires particularly where ticket sales volumes do not justify installation of automated vending equipment.

3.3.3 Validation Process

Validation is the most significant passenger action (short of actual ticket purchase) in the fare collection process. The validation process must be easy for passengers to understand and use, be quickly performed, and facilitate checking by ticket inspectors.

The manner in which multi-trip or multiple fare tickets are cancelled is a key issue. Such a ticket will generally be validated several times, for several different trips, before ticket value is exhausted. During each validation, data is imprinted onto the ticket, to facilitate checking by ticket inspectors. Each successive validation should print data onto a segment of the ticket which has not been previously validated, both to prevent over usage of a ticket beyond its initial value, and to ease reading of the validation data by ticket inspectors. The prevention of overprinting may be an automatic function of the validation equipment, or it may be the passenger's responsibility.

Automatic systems generally rely on a physical modification to the ticket to signify validation. A portion of the ticket is cut off or punched with each validation, to provide a characteristic which the machine can subsequently detect to facilitate further validation(s) while preventing overprinting. This is a very straightforward scheme from the passenger's standpoint; the passenger simply inserts the ticket into the validator to achieve validation. But if the passenger must validate several segments of the ticket to pay his fare, he must reinsert the ticket however many times are necessary. This can be a time-consuming process for several segments (say, five or six), and tends to lessen one of SSFC's great advantages--reduced passenger processing time. (Such reinsertions are usually minimized in most systems by providing different tickets for different types of travel; Bern, Switzerland, for example, uses three different adult multi-trip tickets each valid for a different number of zones.)

Another approach is to provide tickets which are perforated to allow folding between fare segments. A passenger simply folds the ticket at the segment he wishes to validate, then inserts the ticket into the validator. The validator then validates the ticket by printing information onto the segment next to the fold. A passenger can validate several segments simultaneously, by folding it at the last segment to be validated and inserting the ticket. The validator prints onto the last segment, and inspectors treat the unmarked segments as belonging to the last validated segments. The disadvantage of this scheme is that for even the simplest of trips passengers must decide where to fold their tickets before validation.

A third approach combines some of the features of the two schemes described above. Validators punch a single hole in the ticket, and print validation data. Fan-folded multi-trip tickets, or stacks of tickets whose total value corresponds to the fare, may be validated with a single ticket insertion. The location of the punched hole is selected by the machine at random. Ticket inspectors inspect stacks of tickets to verify that hole locations in the tickets match each other.

4.0 HARDWARE OPTIONS FOR VENDING AND VALIDATING

The basic policy decisions addressed in Section 3 constitute the preliminary steps toward determination of the final configuration and design of a self-service system for a particular application. Other significant considerations include:

1. The review and selection of fundamental features considered essential to the functional operation of the system, e.g., whether or not ticket issuing machines should incorporate change-making and bill acceptance capabilities.

2. The examination and determination of preferred procedures and designs for selected functional features, e.g., whether a machine having change-making capabilities should be of the self-replenishing or non-replenishing type.

3. The evaluation of the merits of ancillary features which may be desirable but are not necessary, e.g., whether or not the equipment should provide statistical data reporting or remote failure monitoring functions.

4. The establishing of performance criteria for system and component operation.

Numerous manufacturers currently offer a variety of hardware to support the ticket issuing and validating functions of self-service fare collection. Although each manufacturer supports and promotes specific hardware designs and features, it is not possible to describe any individual piece of equipment as an off-the-shelf device, particularly with respect to ticket issuing machines, since each application represents unique characteristics and requires some tailoring of equipment to individual property needs and desires. The following describes and summarizes the numerous considerations involved in the selection of particular features, options and characteristics, highlighting the trade-offs associated with this selection process. A principal trade-off, of course, underlying the selection of appropriate hardware will be costs vs. benefits. Equipment costs, in general, will increase as features are added, options are chosen and characteristics modified; the discussion will therefore focus primarily on the relative benefits yielded and their relationship to the operation of a self-service system.

4.1 General Design Considerations

Although the functions of ticket vendors and validators are completely different, many design considerations are common to both types of equipment and are, in fact, characteristic of commercial and industrial electro-mechanical design in general. Environmental specifications, for example, are essentially comparable to those for registering fareboxes and other similar devices already being used. Other general design considerations common to both vending and validating equipment include:

- Passenger usage characteristics
- Security
- Maintenance
- Statistical reporting
- System flexibility and adaptability

4.1.1 Passenger Usage Characteristics

To promote the public acceptance of SSFC which will help to maximize system usage and revenue, the automated equipment to be used in the system should facilitate passenger self-service. It should be easy to operate and should convey two basic kinds of information to passengers:

- Operating instructions
- Equipment status

These kinds of information are provided by various kinds of indicators. The design of equipment indicators should enhance passenger operation and minimize confusion. Both active and passive indicators must be considered. Active indicators include flags, digital displays, and back-lit illuminated signage used to convey information which changes with time. Passive indicators include permanently displayed information, such as system maps and fixed operating instructions which may be engraved or otherwise displayed on the front surface of equipment. Equipment operation by the elderly and handicapped and other transit disadvantaged riders will require special attention since most foreign manufacturers are not accustomed to providing equipment designed for these types of users.

4.1.2 Environmental Considerations

All equipment must be capable of proper operation within its projected operating environment. Operating temperature range, storage temperature range, and thermal shock are primary considerations.

Physical shock and vibration levels must be established and specified for all vehicle-mounted equipment and equipment installed at wayside most be of demonstrated reliability in all expected weather extremes, including wind, snow, ice, rain, and sleet. If SSFC is to be developed for installation on-board existing vehicles, tests may be necessary to determine if vehicle-generated EMI will require unusual or special design efforts.

4.1.3 Security

Security considerations include both external and internal security. External security involves the prevention of forced entry of equipment to obtain tickets or cash; internal security deals with actions by employees to steal cash or tickets from equipment.

External security can be enhanced with a combination of hardware features--sturdy enclosures (resistant to vandalism and forced entry), secure locks, and alarms (either silent, or audible and visible). Silent alarms allow security personnel to respond and, consequently, apprehend the intruders, while the primary purpose of audible/visible alarms is to frighten away intruders rather than to summon authorities.

The entire question of providing external security involves decisions regarding the value of goods protected, and the number of anticipated attacks on equipment, as well as policy-dependent means of securing equipment versus hardware-dependent means. For example, properties can combat break-ins by reducing the value of tickets held within equipment, by collecting revenue more frequently, or by increasing security checks by a security force--features which increase equipment security with little or no hardware implications.

Internal security is a more complex problem, as many transit employees must have access to equipment in order to do their work (maintenance, revenue collection, ticket replenishment, etc.). A hierarchy of locks is generally used so that each major subassembly may be individually secured; employees are entrusted only with those keys necessary for their work. The degree of internal revenue security offered by typical SSFC hardware is generally comparable to that of most modern registering fareboxes.

As is true of external security features, the incorporation of internal security features must be weighed against the expected losses which could ensue from their absence or against policy-based security alternatives. In some cases, it may be preferable to limit the value of stored tickets and cash (to lessen the attraction and limit potential losses) rather than to incorporate additional security features.

4.1.4 Maintenance

The complexity inherent in typical SSFC equipment requires comprehensive maintenance planning. To facilitate servicing, SSFC equipment must be designed for rapid and accurate problem diagnosis and testing. The high passenger visibility which SSFC equipment enjoys dictates that failed equipment be quickly restored to service.

Many of the maintenance features developed for other electromechanical systems are applicable to SSFC equipment. Built-in diagnostic test features may be incorporated to facilitate the isolation of defective subassemblies. Plug-in modules may be replaced in total in the field to put failed equipment back in service. Periodic maintenance must also be considered. This includes replacement of ticket stock and ink or ribbons, and emptying of containers holding cash and chad (from punching tickets).

4.1.5 Statistical Data

A useful feature of SSFC is the ease of gathering transit usage data. Mechanical counters provided within ticket vending and validation equipment can be used to record quantities of tickets sold by type, and other data regarding trip origins and destinations.

The data may be read and manually recorded by maintenance personnel. Equipment may also be configured so as to periodically print all statistical data onto tally sheets, which may be subsequently tabulated and analyzed. The security checks mentioned previously may provide some of the data elements for these functions; whether or not the functions should be combined is dependent on cost savings compared to independent security and accounting functions. Cost considerations will dictate the sophistication of the accounting system; the capital and maintenance costs for a system which automatically prints a record of statistical data can be substantial.

Providing data transmission lines to wayside equipment facilitates the transmission of data to a central data collection point. This data may transmit status indicators ("in service", "out of service", "out of ticket stock", etc.) to enable a transit property to dispatch maintenance forces quickly in response to equipment problems. Statistical data may be gathered on a "real-time" basis, to permit a transit property to assign additional vehicles in response to sudden and unexpected peak demands. Integrity of equipment enclosures may be monitored, to provide instant indications of attempted vandalism or break-in. The desirability of these features must be weighed against the capital and operating costs for the data transmission lines and the necessary data processing facility.

4.1.6 Adaptability and Flexibility in Implementing Fare Structure

An obvious goal in developing SSFC hardware is to provide a means of implementing the desired fare structure. A less obvious goal is to facilitate later changes in the fare structure. Some changes such as fare increases to handle increased operating costs, will be anticipated far in advance. Other changes may be unexpected and more significant, i.e., changes in discount status or zoning structure (which might be prompted by shifting urban transportation patterns). Although it is impractical to specify equipment which could be adapted to any fare structure, a reasonable effort should be made to provide an acceptable level of flexibility so that a transit property will not be forced to accept an undesirable fare structure because of equipment limitations. Features providing such flexibility would typically include additional imprinting mechanisms within validators which could subsequently be used to imprint zone or transfer-related information, provisions within vending equipment to subsequently add bill accepting and testing equipment, or capabilities within issuing equipment for a future increase in ticket variety.

4.2 Vending Equipment Design Considerations

Ticket vending equipment accepts cash and, in turn, dispenses tickets of appropriate value to patrons. It is generally the most sophisticated and costly type of self-service hardware. Table II and the discussion which follows indicates the major features to be considered in selecting vending equipment and the available options associated with these features.

4.2.1 Coin Acceptance and Testing

Vending equipment must provide for accurate checking to reject counterfeit or false coins. A mechanical check can be performed by measuring dimensions (diameter, thickness) and weight; an alloy check can be performed by subjecting the object to a magnetic field; the object's reaction to the magnetic field can be checked; or the alteration of the magnetic field can be measured (the so-called "electronic" method).

TABLE II

SELECTED TICKET VENDING MACHINE OPTIONS

Feature	Option
Coin Testing	Mechanical (weight/size) Electronic (alloy)
Currency Acceptance	Coin only Coin and bill acceptor
Change-Making	None Non-replenishing Replenishing hoppers Recycling drums
Overpayment Procedure	Automatic transaction cancel Voluntary overcharge feature
Ticket Stock	Stack Roll Leporello
Printing	Impact Dry process (pressure-sensitive paper) Mosaic needle printer
Machine Control	Hardwired Microprocessor control

Reducing the acceptance of slugs and counterfeit coins through sophisticated test must be weighed against added complexity, increased maintenance requirements (including periodic adjustments), and increased cost. This is especially true for the electronic alloy test. The effects of a rigorous coin testing should also be taken into account; while a stringent test may reduce acceptance of bad coins (reducing fraud in the process), it may also increase rejection of good coins (increasing irritation among honest passengers).

4.2.2 Bill Acceptance and Testing

Most of the existing SSFC vending equipment will accept coins but not bills. Existing technology, however, does allow for effectively testing bills with automated equipment. This feature may be incorporated into the vending equipment to enhance passenger convenience, particularly to facilitate payment for high value multi-trip tickets and period passes. Decreased reliability, increased cost, and added attraction to thieves are, however, frequently cited as negative features of bill acceptors and are factors to be considered when weighing a bill acceptor system.

4.2.3 Changemaking Capabilities

Changemaking equipment is widely provided in existing SSFC systems in order to increase passenger convenience. The non-replenishing system issues change from a storage unit which must be periodically refilled as part of the regular maintenance program. The replenishing system transfers coins accepted from patrons into a change storage unit, significantly reducing the restocking task and extending restocking intervals.

A potential problem with any changemaking equipment involves the exchange by dishonest patrons of bad or counterfeit coins for good coins. To prevent this, it is desirable for equipment to hold coins in escrow until transactions are completed; should a transaction be cancelled, the identical coins inserted by a patron will be returned to him. The coin testing system also becomes more critical with changemaking equipment in order to prevent the completion of a transaction and the issuance of change after accepting a high demonimation counterfeit coin. Coin testing is especially important in replenishing changemakers to prevent any previously accepted fake coins from being returned to passengers as change. These factors can sometimes justify the inclusion of more sophisticated coin testing systems in changemaking equipment than would be included in comparable exact change equipment.

It should be noted that the entire task of changemaking may be substantially eased by judicious policy decisions regarding fares. By setting fares at values which correspond to coin values (e.g., multiples of 25¢), the need for changemaking can be lessened.

4.2.4 Overpayment

For non-changemaking equipment, and for changemaking equipment which is out of change, definite procedures must be established to define how the equipment will react to overpayment. One response is to cancel the transaction and return all cash to the patron. Another choice is to accept the overpayment and vend the ticket. The more desirable reaction may be to present to the patron the two choices. For example, a sign could be lit, asking "Do you agree to overpay?" The patron could respond by pressing a "yes" or "no" button to complete or cancel the transaction. Any decision on these options will be based on policy decisions regarding overcharging, since the hardware factors are relatively uncomplicated. As described above in Section 4.2.3, setting fares at levels which allow payment with minimal quantities of coins will tend to minimize the extent and frequency of overpayment.

4.2.5 Ticket Stock Storage

Vending equipment must have provisions for adequate storage of ticket stock. The stock may be precut or uncut, perforated or non-perforated. If uncut, the stock may be in roll form, or in a fan-folded ("zig-zag") stack. Storage in roll form generally facilitates printing of different length tickets. Zig-zag ticket storage tends to facilitate replenishing of ticket stock without waste, as new ticket stock may be fastened to the last section of nearly depleted ticket stock. Uncut ticket stock is generally cut with a self-sharpening guillotine cutter.

4.2.6 Ticket Data Imprinting

Vended tickets are generally imprinted with data at time of sale. Ink printed data provides information to passengers and ticket inspectors. Ink printing may be performed by a conventional alphanumeric impact printer or by a microprocessor-controlled mosaic (needle) printer.

The needle printer has considerably more versatility-abstract logos and symbols may be printed in addition to alphanumerics, but is slower than an impact printer because the impact printer prints characters simultaneously while the mosaic printer does so sequentially.

4.3 Validating Equipment Design Considerations

Validating equipment encodes necessary data onto tickets in order to tie it to a particular trip taken. Table III lists some of the features which should be considered in selecting validators and available options. Section 3.3 has already described the different available approaches to validation and some of the methods used to detect the genuineness of a ticket inserted into the validator.

4.3.1 Clock

Virtually all SSFC systems imprint time onto tickets during validation. This necessitates inclusion of a clock in each ticket validating machine. Clocks may be electronic (quartz-crystal) or electromechanical. The electronic clocks have very high accuracy (to within minutes a year) and may be provided with considerable flexibility--seasonal corrections for daylight savings time, for example, may be accomplished automatically. Electromechanical clocks are suitable only for equipment installed at wayside as they require a synchronous line frequency to operate. This provides accuracies to within several seconds a day; accuracy, however, deteriorates during loss of electrical power. Since power losses of unknown duration may occur unexpectedly, validators must be provided with a means to continue

TABLE III

SELECTED TICKET VALIDATION OPTIONS

Features	Option
Validation Process	Print only Print and cut Print and punch Print and cancel (e.g., magnetic erasure)
Clock	Electromechanical Electronic
Validity Check	None Optical Magnetic or conductive ink detection
Statistics	None Count of insertions Count by ticket type
Data Entry	Manual Manual-remote

operation upon restoration of power with no loss in time keeping accuracy. Electromechanical clocks may be provided with a spring-wound "carry-over" feature to ride through any power losses, but such a system provides rather poor accuracy (on the order of several minutes per day).

The precision of the clocks must be such as to facilitate enforcement of the allowable time limit for travel after cancellation. A precision which allows printing of time in increments of 5 or 10 minutes is generally adequate; less precise time keeping may even be allowable if the validity period is long enough (e.g., several hours).

4.3.2 Variable Data

In addition to time, there may be certain other imprinted validation data which will vary due to external inputs. This is especially true for fare structures which are zoned or base transfer eligibility on zone- or route-related information. The data indicates transit route traveled, direction of travel, and/or zone(s) of travel.

In SSFC systems with vehicle-mounted validators a means for the updating of variable data by the vehicle driver must be provided. Two options are available: the driver can unlock each validator to adjust the print mechanism, or he can change the data with a remote control station. Either option requires effort by the driver to keep the data accurate and current.

Wayside validators generally can not imprint route- or direction-oriented information. Zone-related data, however, may be easily imprinted since each validation machine merely imprints the zone in which it is located.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The single most important decision which must be made by a transit property deliberating the development of a self-service system is whether to pursue a wayside or an on-board application. As noted in Section 3.0, each has advantages and disadvantages relative to the other. An attempt to rank these options relative to one another (see Volume I) indicated that the wayside configuration represented the best alternative since this option requires little or no driver participation even in systems having a large number of zones. Since validators are stationary, zone information is pre-set; with the on-board application, drivers must set new zone information each time a zone boundary is crossed. Nevertheless, the analysis concluded that the on-board validator approach was a better near-term application because:

1. Total capital costs were likely less.
2. The on-board validator application offers greater revenue and equipment security.
3. The on-board installation presented fewer changes to passenger activity since "payment" would continue to be made on-board.

The ultimate decision, however, depends on site-specific considerations. Even within these two options, numerous variations are possible and final self-service designs must be based on these specifics.

Site specific considerations will also help to determine the kind of features to be incorporated into each type of hardware used. Very few constraints are posed by the equipment itself; equipment designed to meet the specific needs of the individual property does not usually present major developmental problems as demonstrated by the myriad of applications used by European transit properties. Many European systems repeatedly emphasize that self-service hardware should be tailored to the fare policy rather than vice-versa.

Equipment design and policy formulation, however, should not be treated as completely separate decisions. Frequently, a relatively minor change in fare policy may contribute to a substantial reduction in or simplification of equipment. Rigid adherence to existing on transfer policy, for example, has already been cited as a possible source of increased costs without achieving an equal return on investment. Similar policy alterations such as the setting of fares to minimize the amount of change returned during a transaction should be considered in light of their effects on equipment capital and operating costs.

Finally, it must be recognized that self-service fare collection hardware considerations are only part of the planning, implementing, and operating of a self-service system. Passenger information provision, system management, and enforcement are also important aspects of the total effort involved in achieving a successful implementation. Since passengers become responsible for determining what fare must be paid, what ticket must be used, how the ticket must be validate, etc., passenger information aids are critical to the successful operation of a self-service system. Similarly, the property must plan for system maintenance and establish well-defined procedures for revenue collection and accountability, performance monitoring, etc. And finally, effective enforcement procedures must be established. All of these elements must be considered in the process of developing and implementing a self-service fare collection system.

REFERENCES

(1)
Deibel, L., S. Stern, L. Strickland, and J. Sulek, Self-Service Fare Collection--Review and Summary, Volume I, MTR-79W00087 01, The MITRE Corporation, 1979.

(2)
Strickland, L., Self-Service Fare Collection--Survey of European Transit Properties, Volume II, MTR-79W00087 02, The MITRE Corporation, 1979.

(3)
Eiseman, G. G., Self-Service Fare Collection--Legal and Labor Issues, Volume IV, MTR-79W00087 04, The MITRE Corporation, 1979.

(4)
Robins, R.M., and R. Postgate, "Passenger Fares-A Consideration of the Economic Aspects of Alternative Fares Structures", Proceedings of the 34th Congress of the International Union of Public Transport (UITP), Brussels, France, 1961.

APPENDIX A
LIST OF MANUFACTURERS

LIST OF MANUFACTURERS

AEG Telefunken	Nachrichten- und Verkehrstechnik, Fachbereich Fahrgastabfertigung, Lilienthalstrasse 150, D-3500 Kassel B, West Germany
AB Almex	Sankt Göransgatan 160 B, S-11251, Stockholm, Sweden
AMG Sasib	Via di Corticella 87 Casella Postale 311 40100 Bologna, Italy
Autelca AG	CH-3073 Gümligen/Worbstrasse 187 Bern, Switzerland
CAMP	(Sociéte de Construction d'Appareils Mécaniques de Précision) 8 Rue de Torcy 75018 Paris, France
CGA	(Compagnie Generale d'Automatisme) Le Plessie-Pate, 91220 Bretigny s/Orge, France
Control Systems Limited (also known as Bell Punch Co., Ltd.)	The Island Uxbridge, Middlesex, UB82Ut England
Crouzet Transport	B. P. 1014 26010 Valence Cedex France
Elgeba	Geratebau GmbH Eudenbacher Str, 10-12 D-5340 Bad Honnef 6, West Germany
Hasler Italiana	Via Nettunense Km. 65, 100040 Ariccia (Roma), Italy
Heinrich H. Klüssendorf(HHK)	Zitadellenweg 20 E 1000 Berlin 20 Spandau West Germany
Litton RCS Sweda	Via L. Da Vinci, 156, 20090 Trezzano S/N, Milan, Italy

LIST OF MANUFACTURERS (Concluded)

Makomat	Frankfurter Strass 74, 6050 Offenbach an Main, West Germany
Sadamel	Rue Jardiniere, 150-CH-2300 La Chau-de-Fonds, France
Ticket Equipment, Ltd.	Love Lane, Cirencester GL71UF England
XAMAG AG	Birchstrasse, 210 8050 Zürich, Switzerland
Zawadil	Steigergasse 15-17, A-1150 Wien, Austria

APPENDIX B

EUROPEAN AND CANADIAN SYSTEMS SURVEYED

EUROPEAN AND CANADIAN SYSTEMS SURVEYED

Bern, Switzerland

Städtische Verkehrsbetriebe Berne (SVB)
Eigerplatz 3
3007 Bern
Switzerland

Brussels, Belgium

Société des Transports Intercommunaux de Bruxelles/Maatschappij Voor Het Intercommunaal Vervoer Te Brussel (STIB/MIVB)
15 Avenue de la Toison d'Or
Bruxelles-1050
Belgium

Cologne, West Germany

Kölner Verkehrs-Betriebe (KVB)
Scheidtweilerstrasse 38
5000 Köln 41
Germany-West

Copenhagen, Denmark

Danske Statsbaner (DSB)
Sølvgade 40
1349 København K
Denmark

Hovedstadsområdets Trafikselskab (HT)
Gothersgade 53
1123 København K
Denmark

Düsseldorf, West Germany

Rheinische Bahngesellschaft (RB)
Erkrather Strasse 30
D-4000 Düsseldorf
Germany-West

Geneva, Switzerland

Transports Publics Genevois (TPG)
Avenue de la Junction
Case Postale 237
1211 Geneve 8
Switzerland

The Hague, Netherlands

Haagsche Tramweg Maatschappij (HTM)
Lijsterbesstraat 2
2563 KW's--Gravenhage
Netherlands

London, England

London Transport
55 Broadway
Westminister
London SW1H OBD
England

Milan, Italy

Azienda Trasporti Municipali-Milano (ATM)
Foro Buonaparte, 61
20 121 Milano
Italy

Munich, West Germany

Stadtwerke München Verkehrsbetriebe
Einsteinstrasse 28
D-8000 München 80
Germany-West

Münchner Verkehrs- und Tarifverbund (MVV)
Postfach
D-8000 München 26
Germany-West

Paris, France

Régie Autonome Des Transports Parisiens
14 Rue Crillon 75004
Paris
France

Vancouver, British Columbia, Canada

B.C. Hydro Transportation System
850 South West Marine Drive
Vancouver, B.C. V6P 5Z1
Canada

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