Self-Service Fare Collection Systems for LRT: State-of-the-Art Review

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Self-service fare collection (SSFC) began in Europe. Until the 1960s fare collection for transit had been monitored by special personnel that accompanied the trains and buses. Vehicles built after World War II usually had a seat for these conductors, and the passengers usually boarded the vehicles through the back door, passed the conductor, and left the car through the front or the center door. Regional buses usually use driver monitoring as is done in the United States. Labor shortage was the reason European transit authorities using conductors were forced in the 1960s to find a system of fare collection that permitted the same speed of operation but engaged significantly fewer personnel. The way SSFC grew in the transit system of the city of Zurich, Switzerland, is interesting because Zurich was one of the first cities to introduce elements of SSFC. SSFC was invented "step by step."

To begin with, trailers of the streetcars became available for passholders only and the conductors in the trailers were discontinued on those vehicles with automatic doors. From time to time inspectors checked whether all passengers using the trailer were holding a valid proof of payment, and a surcharge fare was collected from passengers without a valid pass. The system worked fairly well; the main problems were in the off-peak hours. Because relatively few passengers use passes during off-peak hours, the motorcoaches were overloaded and the trailers were half empty. To improve the situation, validators for prepaid tickets were installed at major stops so passengers using this mode of fare were able to use the first "metallic conductors." These validators printed station of boarding, time, and date. Therefore, no conductor had to handle these tickets and passengers using prepaid tickets could also board the trailers. Discontinuing the conductors on all trailers with automatic doors allowed a reduction in the number of conductors on the 2,500-employee system by more than 100. The next step of implementation was full self-service on the bus system. This step required the installation of automatic ticket dispensers at every stop as well as the installation of passenger-activated doors and the removal of the conductor's seat in all buses.

After a period of observation the last step was started--full self-service on the streetcars. Line after line, the conductor was also discontinued on the motorcoach and the necessary modifications made to the vehicles. The stations were also equipped with ticket dispensers. As the validators for prepaid tickets were built into these machines, the initially installed free-standing validators could be discontinued. Since 1974 the whole urban system has been operated under full SSFC conditions.

Many smaller steps have been taken since then. They primarily involved improvements on the vending machines, safety concepts for vehicle doors, fare inspection procedures, and cooperation with the courts. The installation of a data-processed radio communication system improved reports about defective vendomats as well as cooperation between drivers and road supervisors when problems with passengers occurred. Zurich transit is fully satisfied with SSFC and would employ more than 900 conductors if the old system were still in use. SSFC-related personnel number about 150.

Similar SSFC systems are in use throughout Europe and other parts of the world including Canada and the United States.

FARE COLLECTION SYSTEM OPTIONS FOR LIGHT RAIL TRANSIT

Essentially all existing fare collection systems can be used for the operation of a light rail system. The basic system options are

1. Full driver monitoring and vending of cash fares without proof of payment for all passengers. A satisfactory method of zone monitoring does not exist. This system is generally used on buses throughout the United States.
2. Full driver monitoring as in Option 1 but using proof of payment for all passengers. Zone monitoring becomes possible. This system is used throughout Europe on regional and suburban bus lines.
3. Self-service. Several terms are used for self-service in the United States: self-service fare collection (SSFC), self-service/proof of payment (SSPP), and self-service/barrier free (SSBF). These terms do not distinguish different alternatives of self-service because self-service is always barrier free and always uses proof of payment for all passengers. Therefore, the three terms mean the same thing and the term "SSFC" will be used in this paper. SSFC always works with random inspection of proof of payment, which means that only a few percent of the passengers are inspected, but a surcharge fare has to be paid by those passengers not carrying proper proof of payment.

4. Barrier-access systems. Fare collection systems that use barriers--also called automated fare collection systems--use magnetic tickets or tokens to control the barriers that give access to the transportation system. This method requires closed underground stations or fencing for stations on the surface. It cannot be used for LRT systems that have direct access from the street or for buses.

There are mainly two factors that make SSFC advantageous for LRT systems:

- Barrier systems are much more expensive and fare evasion cannot be kept lower than it is with SSFC.
- SSFC is the most flexible mode of fare collection. Because integration of the fare collection methods in a multimodal urban transportation system is at least as important as the quality of a method used for a single mode, SSFC has great advantages: (a) Using proof of payment, SSFC can be easily mixed with all sorts of driver monitoring (buses), but the use of barriers in specific cases is possible. (Zurich uses a type of barrier access for stations near the soccer stadiums for the time after the end of games because fare evasion would be high and the trains are so crowded that everybody knows that inspections are not possible.) (b) Because LRT is always operated in combination with buses, and in many countries also with subways (heavy rail) and commuter rail, SSFC has a specific advantage of flexibility: it is the only system that can be used on all modes of urban transportation.

A detailed summary of all the advantages of SSFC over barrier systems follows:

- Authorities that use barrier systems have had the experience that barriers do not stop fare evasion at all and that manning of stations or inspection crews is necessary even when barriers are in use;
- The cost for automatic fare collection equipment is much higher than for SSFC (magnetic ticket technique, expensive vendomats, addfare machines, and gates for entry as well as exit if zone fares have to be monitored);
- Increased space requirements for gate areas;
- Operational problems during peak periods; for instance, the provision of enough gates for the peak 15 min in the morning or the evening of weekdays would generate high cost;
- Operational problems when several machines are out of service at any specific station;
- Design restrictions for line sections in streets because stations have to be fenced; this is not only expensive but there are also problems in preventing passengers from walking into stations along the tracks; and
- Design problems to avoid a fenced station looking like a jail.

The main reason SSFC is a better concept than a traditional fare-box solution is the need for additional conductors on multiunit trains, as the data given in Tables 1 and 2, from the San Diego LRT, show. The tables indicate that cost-efficiency of SSFC can become critical if an LRT system usually runs one-car trains only. This would of course be an exception, but such systems still exist. The elements of passenger convenience offered by SSFC, such as all-door boarding, better distribution of the passengers in the LRVs, no need to flash proof of payment at each boarding, and faster operation, remain the same.

TABLE 1 Cost Analysis of Capital Items for San Diego Self-Service

	SSFC ($)	Conventional ($)
16 nonregistering fare boxes with spare vaults		16,000
35 coin-operated ticket vendors	280,000	
60 ticket validators	30,000	
35% contingency	110,000	
Total	420,000	16,000
Difference	404,000	

TABLE 2 Cost Analysis of Operation Personnel for San Diego Self-Service

	SSFC (labor years)	Conventional (labor years)
Revenue collectors	2	2
Extra operator on each two-car train		20
Fare machine maintenance personnel	3	-
Transit supervisors/ticket inspectors	1	-
Senior transit supervisors	1	-
Salesman/bookkeeper for ticket sales outlets	1	-
Total	8	22
Approximate annual cost comparison ($)	320,000	660,000
Difference ($)	340,000	

SSFC is flexible enough to provide a cost effective approach even for these cases:

- Farebox operation can be combined with all-door boarding for passholders and also for users of multiride tickets if validators are installed. This method does not require any vendomats. Because such a concept usually saves "one train in ten" because of faster operation than with conventional front door boarding, the cost for the necessary fare inspectors is covered.
- If two-car trains are used during peak periods only, front-door boarding during off-peak periods can be combined with all-door boarding during peak. No conductor will then be necessary on the second car because cash-paying passengers will board through the front door of the first vehicle.

IMPLEMENTATION STRATEGIES

Experience has shown that it is no special problem to phase in SSFC on a new LRT system. The reason for this is that only one line is usually opened at any time. Implementation problems are caused by the bus system, if the fare system of buses is to be integrated into the LRT system, which of course is a desirable target.

Two approaches are possible:

- The bus system is adapted before the first LRT line is opened. This procedure is planned for the systems of Portland, Oregon (using full proof of payment on the bus system before LRT operation will start), as well as in Santa Clara County. In this case full integration of buses with LRT is possible from the opening day of the LRT. The opposite concept is the one used in San Diego: SSFC has been implemented on the LRT first and full integration of the buses will follow later.
- Most old LRT systems have implemented SSFC step by step. They were almost forced to do so because they could not dismiss all the conductors from one day to another. Such a smooth implementation strategy has several advantages: The system as well as the hardware elements (door operation, door

safety, vending equipment) can be tested on a small scale and improved if necessary. Also, the employees involved in SSFC have more time to adapt to the new system and to learn the new routines. This is also important for the courts, which are more easily motivated to cooperate if they are given time to get used to the new aspects and can generate the specific routines and gain the experience necessary to deal with repeat fare evaders.

FARE STRUCTURE AND HARDWARE CONFIGURATION

General

When the decision to use SSFC fare collection has been made, many questions about its exact design and about the fare structure to be used have to be answered. SSFC offers flexibility--ranging from the use of barriers under specific conditions to the handling of fares by bus drivers. General answers for specific questions cannot be given.

Two targets, however, are set in almost every case and pretty much direct the detailed design of an SSFC system:

1. Reduction of cash fares to a minimum, such as 10 to 15 percent of all trips. Cash fares slow down operations when tickets are sold on the vehicle and they increase the number of vendomats needed. Multiride tickets (MRTs) should become the standard way of paying the fare for those passengers who do not use the system on a daily basis; passes should be used for commuters.
2. Use of a zone fare structure to improve equity and to generate higher revenue without losing passengers on short travel distances.

It is common to all design options of SSFC that all the tickets need a printing of their value criteria (zones, date, time, station of boarding, and so forth) that can be read manually. Tickets with magnetic coding only cannot be used in an SSFC environment.

Vending of Prepaid Tickets

Because reaching a high percentage of prepaid ticket use is an important policy issue for SSFC, multiride tickets and passes are of special importance. There is often a lack of convenient points of sale, such as LRT stations and platforms themselves; therefore many transit authorities have added vendomats for multiride tickets to their system of manned outlets. The most important advantage of such machines is that they make MRT available when other outlets are closed.

The development of vendomats for passes is far behind. At least several authorities now have studies under way to test prototypes of pass-vending equipment.

The experience with MRT vendomats has shown that a considerable number of customers still prefer to buy their tickets at manned outlets and in stores. Therefore a well-balanced system of outlets and vendomats will remain necessary even when vending equipment for passes has come into regular use.

Types of Multiride Ticket Design

There are several options for the design of multiride tickets. The choice of any one of the different possibilities shown has an impact on the specifications of the vending equipment, validators, and transfer design if such are still used. The four typical kinds of MRT are

1. Multivalidation card,
2. Ticket booklets with "transfer-type" tickets,
3. Booklets with pieces of blank paper to be validated or given to the driver as payment in return for a proof of payment, and
4. Stored-value cards (electronic money).

Types 2 and 3 are often used for transition periods because there is no need to equip all stations or vehicles with a validator; drivers can punch the tickets or issue a transfer.

Type 1 is the typical multiride ticket. It is convenient for the passenger, who can easily see how many trips are left on his card; it is also convenient for the authority because production costs are significantly lower than for booklets and there are fewer trash problems in vehicles and on platforms.

Stored-value cards are the most recent form of multiride ticket. They can be used for any value trip, independent of fare category and number of zones traveled. There have been numerous studies on whether or not these tickets should be implemented. The government of The Netherlands has decided to make a real test of such tickets for their nationwide transit-fare system.

Flexibility of use, the opportunity to use the same card in different cities (even if the fares are different), and the lack of need to issue new cards when fares change have been the main reasons The Netherlands has initiated this test.

Stored-value cards also have disadvantages:

- They are expensive because magnetic code is necessary as well as conventional printed trip data for the inspectors.
- The passenger can no more just insert the card in the validator. He has to push at least one button to indicate to the validator which category of fare and which distance he wants to pay for.
- Every vehicle and platform has to be equipped with at least one complex validator including magnetic card reader as well as printer. Ticket outlets also need electronic equipment to issue the cards.

It will be interesting to observe the field test in The Netherlands, which will be started in 1986, especially because it will run in a system that has used conventional MRT before. The decision to replace classical MRT with a stored-value system is much more significant than is an implementation of stored-value in a system that has had no MRT at all. The test in The Netherlands will produce valuable information about whether the traditional MRT can be given up when stored-value cards are implemented, although the classical MRT appears to be more convenient for the regular user of these tickets who usually travels the same distance.

Another barrier to the implementation of stored-value cards is the necessity of purchasing and installing the hardware for issuing, validating, and monitoring stored-value cards at the beginning. The whole investment is lost if it turns out that the system does not satisfy the operator or the customers. It appears that it is still appropriate to plan for conventional MRT until more experience with stored-value cards has been gained.

Electronic Money (credit-debit microchipcards)

The development of stored-value cards is linked with the whole issue of the use of electronic money for transit fare collection systems. These systems will

not affect SSFC as a system of fare collection generally, but might significantly affect the specifications of its hardware.

The use of electronic money for transit is dependent on whether a way can be found to deal with small amounts of money per transaction. A system that accepts major credit cards at all vendomats or even on board does not appear to stand a chance of widespread acceptance because the cost of accepting cards and checking their value (which requires online communication between the points of sale and any bank or credit card organization) bears no relation to the amount paid per transaction when a patron buys a single-ride ticket. Electronic money could, however, become important for vending of stored-value cards and passes. In Toronto, Canada, a field test is under way that uses bank-teller machines not only to get cash but also to "load" a stored-value card, which can also be used on a limited basis for telephone calls and transportation.

Automatic teller machines could of course also be used to issue passes. The second basic problem with the use of electronic money is that the existing conventional channels of distribution have to be maintained for those segments of the market who prefer to buy their proof of payment the same way their fathers and grandfathers did: at a manned ticket outlet. At major points of sale it is relatively easy to provide the conventional and modern modes of vending, but at small places the provision of two or more methods of buying a ticket becomes too expensive. Because many tests are under way worldwide to figure out the best use of electronic money for transit, the recommendation for builders of new LRT systems might still be to stay with the classic channels and with the existing and proven pieces of hardware for vending and validation.

Platform Versus On-Board Vending and Validation

Vending and validation can be done either on the wayside or in the vehicles themselves. The following concepts are possible:

1. Vending of single-ride tickets is done by the operator who issues a proof of payment. There are validators in the vehicles, and multiride ticket vending is by outlets only or by outlets and separate wayside machines at major stops.
2. All equipment used for vending and validation is on the wayside; the driver has no fare collection tasks. This is the classical LRT SSFC approach.
3. Single-ride ticket vending and validation is done by machines installed on board the vehicles, multiride tickets are sold by outlets only or by machines on the wayside as well.

Concept 1 is restricted to streetcar-like LRT operation with relatively low patronage and frequent use of one-car trains. Passengers paying cash have always to board the first car because no conductor can be justified on the second car for a small number of passengers paying cash fares.

Concept 2 is the most frequently used approach. Its major advantage is that the passenger can use the time he is waiting for a train to purchase or validate his ticket. There are no space restrictions for the machines as there are when they are installed in the vehicles. The on-board concept also creates information problems for passengers when a zone fare system is in use: because the vendomats are moving through the system, it is difficult to provide clear information about the correct fare to any specific station. Another advantage of wayside installation of the equipment is that passengers do not have to handle the machine in a moving vehicle and that access to the machines is usually easier than in a (crowded) vehicle. Vehicle installation might, however, be recommendable in areas with significant vandalism problems.

Wayside validators are usually integrated in the vendomats for single-ride tickets. Because a validator is much less expensive than a vending machine, free-standing additional validators can be justified at less important points of access to LRT stations, which are not worth the installation of additional vendomats. Validators on board are separate from the vendomats.

Most of the fare- and customer-related specifications for mobile SSFC equipment are similar to those for equipment designed for wayside use. The technical specifications are significantly different because machines for use in vehicles are protected against the influence of weather but have to withstand the movements and vibrations of the vehicles. As was said before, they also have to be built smaller to meet the space restrictions on the vehicles.

Change-Making Capability and Bill Acceptors

Modern ticket vendomats can be equipped with built-in bill acceptors and change-making capability, with or without a coin-recycling system. In the beginning most transit authorities using vendomats were afraid that replacement by machines with these capabilities would significantly increase the cost of fare collection. The reliability of machines with change-making capabilities and bill acceptors was indeed relatively low in the beginning. In the meantime, the public in many countries has learned that this convenience is available and does not accept any installation of new machines without the capability to make change and accept bills. In many places, including Switzerland, the implementation of vendomats for regional rail and even intercity railroad connections has accelerated the whole process. Ticket prices for trips on regional trains or even intercity connections reach amounts that make change makers and bill acceptors a necessity.

In the United States, bill acceptors, which have significant impact on the vendomat prices, are as necessary as is change-making capability. The provision of separate bill-changing machines instead of integration of bill acceptors in the vendomat is not recommended for three main reasons:

- They are more expensive and space consuming;
- They are inconvenient for the passenger who has to deal with two machines to get a ticket; and
- There is danger that the bill- coin-change machine will be used for nontransit purposes (e.g., telephone calls).

The latest bill acceptors available for the United States accept up to four different bills, such as $1, $5, $10, and $20 and also include an escrow.

The additional cost for bill acceptor and change-making devices makes it even more important to reduce cash fares as much as possible and to reduce in this way the necessity of numerous vendomats at the stations. Because there will always be passengers who are dependent on cash fares, it would be a strange policy not to offer bill acceptor and change-making devices and to think that the ratio of cash fares could be reduced this way. The reaction of the public would be to complain about a poor fare collection system. A better policy is to charge a relatively high price for single-ride tickets (making the multiride ticket price the "base" fare) and to

offer good convenience for those passengers who pay a cash fare. Because most passengers who pay cash fares do not use transit frequently and often do not understand how to use transit, convenience is more important for them than is a low price.

Ticket Dispensers for Drivers

Using a proof of payment system for LRT usually means that the integration of the bus system includes proof of payment on the buses. This has the consequence that drivers have to issue proof of payment to all cash-paying passengers who do not transfer from another vehicle.

Ticket dispensers, which replace the use of transfers for proof of payment, have been developed to help the driver issue these tickets. Two different types of machines are on the market:

1. Driver monitored machines. The driver has to indicate to the machine the fare and the machine produces the ticket. Such machines are in wide use on regional bus systems. Most of them, such as the well known Almex and Tim types of machines, work mechanically. An electric machine of this type was used in the Portland SSFC fare collection demonstration project.
2. Electronic machines with microprocessor. Such machines receive continuous input about the location of the vehicle they are installed in (from the driver or from automatic vehicle location determination). The dispenser also "knows" the whole fare structure and the zone configuration. The driver needs only to input the category of fare and the destination zone or station and the machine automatically issues the correct ticket. With additional memory and a card reader such a machine can also issue and identify tickets that are magnetically coded.

This type of machine makes possible the sale of tickets for complex trips in multizonal systems, including intermodal transfers directly to the destination, by the driver without generating an overload for him.

CONCLUSIONS

SSFC is the most efficient and convenient way of collecting fares on an LRT system and therefore became the standard mode of fare collection for LRT.

SSFC offers possibilities for easily integrating the bus system into the fare system of an LRT system. A step-by-step implementation program is recommended.

SSFC can also be used for heavy rail and regional train services as many applications in Europe have shown in recent years.

SSFC, including the idea of proof of payment for all passengers, is more a general philosophy than it is a system of fare collection as such.

SSFC has gone through an intense development process since the method was used for the first time. The most important improvements can be found in the fields of hardware quality, fare inspection procedures, and cooperation between the transit authorities in the courts.

SSFC can be implemented in many various forms because it is a flexible mode of fare collection. That every concept "works" appears to discourage many agencies from going through a clean evaluation process to define the best solution for their environment.

In the United States a psychological barrier against barrier-free fare collection still appears to exist. The reason for this problem might be that many professionals know barrier systems better than the barrier-free approach and therefore have a problem trusting SSFC.

As it did in the past the idea of SSFC will certainly grow further and be fine tuned as new technologies and new needs come up. The next challenge for SSFC (as well as for other methods of fare collection) will be the integration of the electronic money systems.