Developing a Decision Support System for Evaluating an Investment in Fare Collection Systems in Transit

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Abstract

This article presents the initial development of a decision support system (DSS) to assess cost impacts of upgrading or replacing a transit ticketing and fare collection (TFC) system. Assessment of these costs, typically, requires extensive calculations and involves estimation of unknown parameters such as future ridership growth rate, equipment utilization rate, and interest rate on debt financing. This DSS is developed with two categories of policy- and decision-makers in mind—transit agency managers and transit industry researchers and policy-makers.

With the aid of this DSS, a transit manager or analyst is able to specify current TFC system characteristics, select desirable options for a new TFC system, and in a matter of minutes estimate capital costs, forecast operating costs, perform net present value and payback period analyses for alternative TFC systems. This article also presents a prototype TFC DSS including a model base, database, knowledge base, and the Microsoft Excel-based graphical user interface.

Introduction

The concept of decision support systems (DSS) evolved along with the development of computer systems in the 1950s and 1960s. With the advent of inexpensive and easy-to-use personal computers in the 1980s, DSS experienced further development and gained widespread acceptance. Today, DSS are a common tool for managers and other decision-makers in most areas of business, research, and science (Shim et al. 2002).

Being one of the major sectors of the U.S. economy, transportation was among the early adapters of computer technologies. As the use of computing resources in transportation continues to grow, more and more transportation operations and planning activities benefit from the aid of DSS.

Ticketing and fare collection (TFC) systems are one of the major elements of transit infrastructure and, thus, also require comprehensive assessment. Although new fare collection technologies offer increased flexibility in revenue collection, reliability of a TFC system, and convenience to transit riders, implementation of these technologies may require substantial investment on the part of a transit agency (Lovering and Ashmore 2000).

The DSS described in this article is intended to improve the decision-making process associated with upgrading or replacing a transit TFC system. More specifically, the proposed DSS should help a decision-maker to assess capital and operating costs of alternative TFC systems. With the aid of this DSS, a transit manager should be able to specify current TFC system characteristics, select desirable options for a new TFC system, and in a matter of minutes estimate capital costs, forecast operating costs, perform net present value and payback period analyses for alternative TFC systems.

The following section presents a general description of the purpose, structure, and functions of the proposed DSS. It is followed by a detailed description of each module of the DSS. The article concludes with a discussion of a prototype TFC DSS and a step-by-step example of using this DSS in the spreadsheet environment (Buehlmann, Ragsdale, and Gfeller 2000).

General Description of the TFC DSS

The composition of the TFC DSS is similar to that of a generic DSS and consists of four modules: graphical user interface (GUI), database (DB), model base (MB), and knowledge base (KB) (Beynon, Rasmequan, and Russ 2002). The structure and functions of the TFC DSS are illustrated in Figure 1 and further discussed below.

Figure 1. Simulation-Optimization Hybrid Method

The TFC DSS is intended to aid in estimating capital costs, forecasting operating costs, performing net present value analysis, and conducting payback period analysis for alternative TFC systems. Consequently, there are two categories of policy- and decision-makers who can benefit from this DSS—transit agency managers and transit industry researchers and policy-makers.

On the transit agency level, management should find this DSS helpful in TFC budget planning, performing evaluation of TFC improvement projects, and assessment of alternative TFC technologies. The TFC DSS can provide a crude TFC budget estimate for several periods in advance based on a number of forecast variables such as ridership and TFC equipment utilization rates. It can also help in comparing cost effects of TFC improvement projects, although evaluation of such projects is likely to involve more than just a cost analysis. Finally, transit agency managers and planners can apply this DSS to assess the impact of individual TFC technologies on TFC operating costs (e.g., discontinuing the use of certain fare media such as tokens).

On the other hand, transit industry researchers and policy-makers from university transportation centers and organizations, such as the Volpe National Transportation Research Center, American Public Transit Association (APTA), and Federal Transit Administration (FTA), are also likely to find the TFC DSS useful in the following ways:

- to analyze performance of existing and new TFC technologies (as well as various combinations of these technologies) across the transit industry
- to analyze the effect of transit demand, transit mode, and other factors on costs of fare collection
- to determine trends and provide guidance in the development of fare collection systems on transit

As shown in Figure 1, the user of the TFC DSS will need to input three categories of data depending on the nature of the analysis requested. These categories of data include the current transit system performance data, current TFC system characteristics, and desired TFC system characteristics.

The current transit system performance data include transit ridership and TFC operating costs. These data are necessary to conduct various analyses on the transit agency level including TFC budget projections, evaluation of TFC improvement projects, and assessment of the impact of individual TFC technologies on TFC op-

erating costs. Current transit system performance data are not required for industry-wide TFC system analyses since these analyses rely on historic data contained in the database module.

The current TFC system characteristics data include three types of payment media utilization rates (cash, checks, and credit cards), three types of fare media utilization rates (cash, nonelectronic, and electronic), and percent of fare media sold by machine. Again, input of these data is necessary to conduct analyses on the transit agency level since the industry-wide TFC system analyses rely on the historic data contained in the database module.

The desired TFC system characteristics data are of the same format as the current TFC system characteristics data allowing the user to specify the payment and fare media utilization rates, and percent of fare media sold by machine. These data are necessary to conduct analyses on the transit agency level as well as for industry-wide TFC system analyses.

The output of the TFC DSS includes graphs and numeric results relating to estimation of capital and operating costs as well as graphs and numeric results relating to payback period and net present value analyses of alternative TFC systems.

The following sections describe each module of the proposed DSS in greater detail.

Model Base

The purpose of the model base module is to store mathematical equations describing relationships between variables and to execute programmatic procedures that perform various types of analyses. The mathematical models and procedures contained in this module include:

- a model describing the impact of transit demand, transit mode, and TFC technologies on TFC operating costs
- a model for calculating capital costs of alternative TFC systems
- a model for conducting payback period analysis that determines how quickly the investment in a new TFC system can be offset by reductions in operating costs associated with the new TFC system
- a model for conducting a net present value analysis that compares capital costs of a new TFC system to reductions in operating costs associated with this system over a certain period of time and takes into account discount and growth rates of the future cash flows

- programmatic procedures to access spreadsheet software's built-in tools to perform various statistical analyses

TFC Operating Cost Model

As reported by Plotnikov (2001), TFC operating costs (OC) are influenced by a number of factors including transit system demand, TFC and transit system technologies, labor rules, and fare policy.

$$TFC\ OC = f(x_i) \quad [1]$$

where:

x_1	is transit demand (ridership)
x_2	represents transit technology (mode)
x_3	equals TFC technology
x_4	is fare policy
x_5	represents labor rules

Furthermore, Plotnikov (2001) concludes that TFC OC can be estimated based on the transit system demand, transit mode, and TFC System Technology Index (TFCSTI)—a variable that describes components of a TFC system.

$$y_1 = b_0 + b_1x_1 + b_2x_2 + b_3x_3 \quad [2]$$

where:

y_1	equals TFC OC
x_1	represents transit demand (ridership)
x_2	is transit technology (mode)
x_3	equals TFCSTI

Plotnikov (2001) also presents the structure of the TFCSTI. The index is a weighted sum of scores associated with TFC technology groups (TG) comprising a certain TFC system and can be computed as:

$$TFCSTI = W_1 * S_{PM} + W_2 * S_{FM} + W_3 * S_{EQ} \quad [3]$$

where:

TFCSTI	is TFCSTI
S_{PM}	represents payment media TFC TG score
S_{FM}	equals fare media TFC TG score
S_{EQ}	is equipment TFC TG score
W_1, W_2, W_3	are coefficients (weights) reflecting the relative impact of fare media, payment media, and TFC equipment on a certain aspect of a TFC system performance.

As formulated by Plotnikov (2001), a TFC TG score represents the impact of a group of similar TFC technologies on a particular aspect of TFC system performance (in this case TFC OC). A TFC TG score is computed as a sum of products of utilization rates and weights associated with individual TFC technologies within their group.

$$TFC\ TG = w_1 * t_1 + w_2 * t_2 + \dots + w_i * t_i \quad [4]$$

where:

TFC TG	is TFC technology group (e.g. fare media) score
$t_1, t_2, \dots, t_i$	represents technology utilization rates
$w_1, w_2, \dots, w_i$	are individual TFC technology weights

Due to lack of comprehensive and uniform data on transit TFC systems in the United States, Plotnikov (2001) recommends the following variables to describe TFC systems: payment media utilization rates (expressed as percent of the total fare revenue paid with cash, checks, and credit cards), fare media utilization rates (expressed as percent of the total fare revenue collected with cash, nonelectronic fare media, and electronic fare media), and percent of fare media sold by machines. Once all these variables are specified, individual technology weights, TFC TG scores, and TFC TG weights can be estimated with the aid of regression analysis.

Finally, TFC OC can be forecast based on the specified values of transit demand, transit mode, TFCSTI, and coefficients obtained from regression analysis. The transit demand is measured in unlinked passenger trips (UPT), whereas transit mode is a dummy variable that assumes a value of 0 (for motorbus mode), or 1 (for heavy rail mode).

TFC Capital Cost Model

The TFC Capital Cost Model is designed to facilitate the evaluation of cost impacts of investing in an electronic TFC system as opposed to continue using a nonelectronic TFC system. The model should help the user to obtain a crude estimate of investing into a new (magnetic stripe or smart card) system based on the three types of variables:

- range of TFC system capabilities desired and type of TFC equipment necessary to provide these capabilities
- quantity of the equipment required for a given system, and
- unit price of equipment selected

The general form of the capital cost model is presented in equation 5 (Booz-Allen & Hamilton, Inc. 2000).

$$TCC = [(\text{\textit{£}}UC_i * q_i) * (1 + x_{PS} + x_{IC} + x_{ESPM})] * (1 + y_C) \quad [5]$$

where:

TCC	represents total capital costs
UC _i	is the unit cost of TFC equipment <i>i</i>
q _i	equals quantity of TFC equipment <i>i</i>
x _{PS}	are nonrecurring parts and services costs expressed as percent of the equipment costs
x _{IC}	are nonrecurring installation and construction costs expressed as percent of the equipment costs
x _{ESPM}	equals nonrecurring engineering, software, and project management costs expressed as percent of the equipment costs
y _C	represents contingency costs

To utilize the TFC Capital Cost Model, the user first needs to select the desired capabilities of the new TFC system through the GUI module. For example, the user may seek the capability of integrating the agency's fare collection system with other

transit systems in the region. Next, the user accesses the KB module and specifies the TFC equipment options associated with the desired TFC system capabilities. In the previous example, the user would be required to select smart card fare media and appropriate smart card readers. For each type of TFC equipment, the user enters the quantity of the equipment needed based on the mode, size, and other characteristics of the transit systems. The KB module will assist the user by providing logical cues and ranges of values to ensure that the parameters entered are sensible. For example, the user can be advised to estimate the initial number of smart cards required based on the percentage of the number of unique transit system riders and the number of smart card readers based on the number of vehicles operated in maximum service. Finally, the user can change default values of unit costs corresponding to the equipment selected. The KB module is evoked to provide estimates of TFC equipment unit costs as well as the likely ranges for these values.

Once all types of the required TFC equipment, their quantity, and unit costs are specified, the procedure based on equation 5 is run and the user obtains an estimate of the total capital costs associated with a new TFC system. This estimate can be subsequently used to perform payback period and net present value analyses.

Payback Period Analysis

Although the TFC Operating Cost Model and TFC Capital Cost Models can be used separately to estimate operating and capital costs associated with different types of transit TFC systems, they can also be used together to perform payback period analysis or calculate the net present value of a certain investment project. Payback period analysis can be used to evaluate how quickly the investment into a new TFC system can be recovered based on the savings in OC associated with the use of new TFC technologies. The formula for payback period analysis is presented in equation 6 (Ross, Westerfield, and Jaffe 1996).

$$x = TCC / (TFC\ OC_E - TFC\ OC_N) \quad [6]$$

where:

x	equals payback period
TCC	is total capital costs
TFC OC _E	represents TFC OC of the existing system
TFC OC _N	represents TFC OC of the new system

To perform payback period analysis, the user needs to specify all the parameters required for calculating:

- OC of the existing TFC system
- OC of the new TFC system
- capital costs of the new TFC system

Net Present Value Analysis

Net present value analysis shows whether the investment in a new TFC system can be recovered based on the savings in OC associated with the use of this system over a specified period of time. Unlike payback period analysis, net present value analysis takes into account the discount rate on the future cash flows as well as the potential growth rate of future cash flows. The formula for net present value analysis is presented in equation 7 (Ross, Westerfield, and Jaffe 1996).

$$NPV = -TCC + (TFC\ OC_E - TFC\ OC_N) * \left[\frac{1}{(r - g)} - \frac{1}{(r - g)} \times \left(\frac{1 + g}{1 + r} \right)^T \right] \quad [7]$$

where:

NPV	is net present value
TCC	equals total capital costs
TFC OC _E	reflects TFC OC of the existing system
TFC OC _N	equals TFC OC of the new system
r	is the discount rate
g	is the rate of transit ridership growth
T	represents number of periods

To perform net present value analysis the user specifies all the parameters required for calculating: (a) OC of the existing TFC system, (b) OC of the new TFC system, (c) capital costs of the new TFC system, as well as the discount rate of the future cash flows and transit ridership growth rate.

Access to Spreadsheet Software Built-in Tools

In addition to the models described above, the model base module contains programmatic procedures that allow the user to access the spreadsheet software built-in multiple regression and optimization tools to perform regression and risk analyses. When the user runs the TFC Operating Cost model in the Microsoft Excel environment, the multiple regression tool from the Data Analysis Plus add-in component is evoked. Similarly, the user can access Excel's Solver add-in component to perform risk analysis with the TFC Capital Cost model, payback period, and NPV analyses. Then, the user can specify the objective function (e.g., total capital costs or payback period), define variable parameters (e.g., equipment unit costs), set the constraints (e.g., quantities of TFC equipment), and evaluate different investment scenarios and outcomes.

Database

The database (DB) of the proposed DSS consists of operational and financial data on selected transit agencies in the United States as well as data describing transit TFC systems. These data are used to assess the strength of relationship between a dependent variable (TFC OC) and a set of independent variables (transit demand, transit mode, and TFCSTI) formulated in the model base module. Based on the nature and strength of this relationship, future operating cost of a desired or existing TFC system can be forecast.

The transit operational and financial data include transit agency ID, fiscal year, transit mode, transit demand, and annual TFC OC, and can be obtained from the National Transit Database (NTD). The transit TFC system data include payment media utilization rates (expressed as percent of the total fare revenue paid with cash, checks, and credit cards), fare media utilization rates (expressed as percent of the total fare revenue collected with cash, nonelectronic fare media, and electronic fare media), and percent of fare media sold by machines. Since, currently, there is no reliable source of the specified transit TFC system data available, these data should be obtained directly from transit agencies as described by Collura and Plotnikov (2001).

Tables 1 and 2 present the initial database of the proposed DSS. They build upon the data obtained from a survey of transit agencies conducted by Plotnikov (2001) (numbers in bold typeface denote estimated values). The initial database includes data entries on 15 bus and 9 heavy rail systems for the 1993 and 1998 fiscal years. The database can be accessed, modified, and populated via the GUI module.

Table 1. Historical Database of the TFC DSS (HR Systems)

Year	NTD ID	Ridership	TFC OC	PM Checks	PM Credit Cards	EM Non-Electronic	EM Electronic	Sold by Machine
93	2008	1,178,121,493	\$ 188,495,819	0	0	100	0	0
98	2008	1,535,830,314	\$ 202,687,176	0	10	25	75	0
93	2075	1,132,302	\$ 1,262,707	10	0	0	100	95
98	2075	10,751,747	\$ 1,332,125	10	0	0	100	95
93	2098	61,814,595	\$ 1,700,000	0	2	0	30	87
98	2098	69,974,295	\$ 2,945,000	0	6	0	42	67
93	3019	94,332,492	\$ 17,804,981	5	20	42	34	10
98	3019	81,219,794	\$ 20,003,679	5	20	42	39	11
93	3030	191,428,020	\$ 3,802,612	15	20	0	100	90
98	3030	213,064,900	\$ 3,895,772	15	20	0	100	90
93	3034	11,114,213	\$ 2,682,195	0	5	50	50	50
98	3034	12,833,591	\$ 2,827,025	0	5	50	50	50
93	4022	65,005,000	\$ 1,621,079	10	0	34	33	90
98	4022	77,802,000	\$ 1,300,810	15	20	34	33	90
93	4034	14,817,894	\$ 1,162,967	10	0	67	0	10
98	4034	13,482,522	\$ 727,636	15	5	67	0	10
93	9003	78,301,800	\$ 4,060,262	0	0	0	100	60
98	9003	80,256,779	\$ 5,405,513	0	35	0	100	60

Table 2. Historical Database of the TFC DSS (MB Systems)

Year	NTD ID	Ridership	TFC QIC	PWM Checks	PWM Credit Cards	PWM Non-Electronic	PWM Electronic	Sold by Machine
93	0002	7,510,779	\$ 80,896	10	0	5	45	0
98	0002	7,944,416	\$ 99,006	10	7	5	48	0
93	0008	52,421,893	\$ 985,374	40	0	100	0	25
98	0008	67,073,805	\$ 959,260	60	0	100	0	25
93	0024	4,255,417	\$ 338,701	0	0	100	0	0
98	0024	7,208,587	\$ 710,175	0	0	100	0	0
93	1048	18,479,404	\$ 230,931	25	0	62	38	0
98	1048	16,816,826	\$ 287,469	20	5	57	43	0
93	1055	11,623,692	\$ 153,049	25	0	62	38	0
98	1055	10,518,633	\$ 157,169	20	5	57	43	0
93	2004	23,101,063	\$ 681,872	3	2	50	0	0
98	2004	19,765,737	\$ 660,003	5	3	50	0	0
93	2008	620,555,564	\$ 12,599,176	0	0	100	0	0
98	2008	689,246,563	\$ 18,758,754	5	5	25	75	0
93	3006	18,724,993	\$ 193,950	25	0	50	0	0
98	3006	15,674,112	\$ 211,863	25	0	25	5	0
93	3019	166,639,551	\$ 5,305,814	5	20	42	34	10
98	3019	134,713,078	\$ 6,365,047	5	20	42	39	11
93	3034	84,836,122	\$ 1,250,000	0	5	50	0	0
98	3034	79,944,812	\$ 1,251,275	0	5	50	0	30
93	4034	63,806,513	\$ 2,510,317	10	0	100	0	10
98	4034	62,768,586	\$ 7,533,770	14	1	90	10	10
93	6008	83,419,977	\$ 825,139	50	0	25	75	0
98	6008	96,373,280	\$ 1,079,632	40	5	25	75	0
93	6011	43,666,032	\$ 264,872	15	0	35	0	0
98	6011	41,059,704	\$ 453,357	35	0	25	0	0
93	6019	6,419,422	\$ 66,110	0	0	50	0	0
98	6019	6,630,080	\$ 71,830	0	0	50	0	0
93	9033	18,180,511	\$ 82,000	50	0	50	0	0
98	9033	15,739,805	\$ 40,360	50	0	25	25	0

Knowledge Base

The knowledge base (KB) of the TFC DSS consists of problem-specific rules and facts relating to a particular transit system, TFC technology, or investment scenario. Information contained in the KB can be grouped in the following categories:

- TFC equipment unit cost averages and ranges
- ridership growth and interest rate averages and ranges
- quantity of TFC equipment selection rules
- type of TFC equipment selection rules

The TFC equipment unit cost averages and ranges support the user information needs for estimating capital costs of a new TFC system. As indicated in [5], the unit cost and quantity of TFC equipment are the major determinants of the total capital costs of a TFC system. Therefore, it is important to provide the user with cost estimates that are as close to those that could be found in the marketplace as possible. In some cases, the user might already have cost quotes on selected types of TFC equipment directly from a vendor or a system integrator in which case the KB information can be used to verify the reasonableness of vendor quotes. Since the TFC equipment unit cost information is time sensitive, it will need to be updated periodically, perhaps, on a biannual basis.

Table 3 presents TFC equipment cost averages and ranges included into the KB module. These numbers are based on the estimates presented to the Greater Washington region transit operators by Booz-Allen & Hamilton, Inc. in 2000.

Another category of the KB information is the ridership growth and interest rate averages and ranges. These rates are necessary to perform net present value analysis of TFC system alternatives. As discussed above, net present value analysis shows whether the investment in a new TFC system can be recovered based on the savings in OC associated with this system over a specified period of time. It takes into account the discount rate on the future cash flows as well as the potential growth rate of future cash flows. In this analysis, the discount rate reflects the cost of borrowing capital invested into the new TFC system and would generally depend on the state of the U.S. economy. In turn, since the investment in a new TFC system is expected to be recovered based on the savings in OC associated with this system and since future TFC OC are forecast based on the future ridership, the growth

Table 3. TFC Equipment Cost Averages and Ranges

Type of Equipment	Average	Low Estimate	High Estimate
Bus magnetic ticket processor (stand alone)	\$ 6,500	\$ 4,000	\$ 9,000
Bus smart card processor (stand alone)	\$ 5,800	\$ 4,400	\$ 7,200
Magnetic stripe card (long life)	\$ 0.20	\$ 0.10	\$ 0.30
Magnetic stripe card (1 or 2 uses)	\$ 0.02	\$ 0.02	\$ 0.02
Smart card	\$ 9	\$ 3	\$ 15
Ticket vending machine	\$ 55,000	\$ 45,000	\$ 65,000
TVM - additional cost for magnetic stripe processing	\$ 5,000	\$ 5,000	\$ 5,000
TVM - additional cost for smart card processing	\$ 3,000	\$ 3,000	\$ 3,000
Smart card initiation device	\$ 12,500	\$ 10,000	\$ 15,000
Point of sale device for magnetic stripe card	\$ 7,500	\$ 5,000	\$ 10,000
Point of sale device to recharge smart card	\$ 4,250	\$ 2,500	\$ 6,000
Stand alone validator for magnetic stripe card	\$ 13,500	\$ 10,000	\$ 17,000
Stand alone validator for smart card	\$ 6,500	\$ 5,000	\$ 8,000
Hand-held device to read smart card	\$ 4,250	\$ 2,500	\$ 6,000
Farebox with smart card reader	\$ 13,750	\$ 11,000	\$ 16,500
Garage data system	\$ 35,750	\$ 33,000	\$ 38,500
Revenue collection vaults	\$ 21,350	\$ 14,100	\$ 28,600
Mobile bins	\$ 11,000	\$ 8,800	\$ 13,200
Money room equipment	\$ 16,500	\$ 11,000	\$ 22,000
Initializing device	\$ 12,500	\$ 10,000	\$ 15,000
Central data system	\$ 44,000	\$ 38,500	\$ 49,500
Smart card reader	\$ 5,275	\$ 4,400	\$ 7,150
Data reporting system	\$ 16,500	\$ 11,000	\$ 22,000

rate of future cash flows reflects potential increase or decrease in transit ridership for the given system.

Nominal interest rates (based on three-month Treasury Bills) for the United States over the last two decades varied from about 15 percent in the early 1980s to about 3 percent in early 1990s with the average about 6 to 7 percent. Therefore, the range of interest rates that the user can specify via the KB module is between 3 and 15 percent with the default value of 6 percent.

The transit system ridership data included in the database indicate that average annual ridership growth rates for heavy rail systems for the period 1993 through 1998 varied from -2.95 percent to 5.45 percent with the median value of 2.16 percent. For the motorbus systems, this statistic varied between -4.24 percent and 11.12 percent with the median value of -1.18 percent. Consequently, the range of ridership growth rates that the user can specify via the KB module is between -5.0 and 12.0 percent with the default value of 1.0 percent.

The next category of the KB information contains rules for selecting proper quantities of equipment for a new TFC system. As with the TFC equipment unit cost information, these rules should help the user calculate a gross estimate of the total capital costs associated with a new TFC system. Ultimately, equipment needs and unit costs will depend on the specific functionalities and configuration of a new TFC system as well as the vendor and specific equipment options selected. Table 4 presents allocation parameters for estimating quantities of different types of TFC equipment.

The last category of the KB information contains rules for selecting the proper type of equipment for specified TFC system capabilities. Based on these rules, the user is advised whether a magnetic stripe or a smart card TFC system is required. The TFC equipment selection rules contained in the KB are illustrated in Table 5.

Table 4. TFC Equipment Allocation Parameters

Type of Equipment	Allocation Parameter
Magnetic stripe card (long life)	annual ridership
Magnetic stripe card (1 or 2 uses)	annual ridership
Smart card	annual ridership
Smart card initiation device	operator
Revenue collection vaults	operator
Mobile bins	operator
Money room equipment	operator
Initializing device	operator
Central data system	operator
Data reporting system	operator
Garage data system	garage
Ticket vending machine	station
Point of sale device for magnetic stripe card	station
Point of sale device to recharge smart card	station
Stand alone validator for magnetic stripe card	station
Stand alone validator for smart card	station
Bus magnetic ticket processor (stand alone)	vehicle
Bus smart card processor (stand alone)	vehicle
Hand-held device to read smart card	vehicle
Farebox with smart card reader	vehicle
Smart card reader	vehicle

Table 5. TFC Equipment Selection Rules

Desired Capability	Type of System
Convenience for occasional users	MS
Time-based pricing	MS, SC
Distance-based pricing	MS, SC
Volume discounting	MS, SC
Usage discounting	MS, SC
Intermodal transfer	SC
Multi-operator pricing	SC
Minimization of fare evasion and fraud	SC
Increased passenger throughput	SC
Increased passenger convenience	SC
MS - magnetic stripe system	
SC - smart card system	

Graphical User Interface

The GUI of the TFC DSS features five main screens: TFC DSS Front screen, OC Analysis screen, Capital Cost Analysis screen, Payback Period Analysis screen, and Net Present Value Analysis screen. These GUI screens are presented in Figures 3 through 6 and are briefly described below.

The TFC DSS Front screen (see Figure 2) is the starting point of the TFC DSS. This screen allows the user to input the current transit system performance characteristics and specify existing and desirable TFC system parameters. This screen also offers the user links to the OC Analysis, Capital Cost Analysis, Payback Period Analysis, and Net Present Value Analysis screens.

The TFC OC Analysis screen (see Figure 3) presents forecasts of the existing and new (desired) TFC system OC for the near future in tabular and graphical formats. These forecasts are based on the parameters specified in the front screen of the DSS. The OC Analysis screen also provides links to access historical databases for heavy rail and motorbus modes.

Figure 2. TFC DSS Front Screen

Figure 3. TFC OC Analysis Screen

Operating Cost Analysis

Future period	Forecasted annual TFC operating costs, in thousand collars		
	Existing TFC System	New TFC System	Annual Savings
1	\$ 166,833	\$ 140,595	\$ 58,268
2	\$ 209,807	\$ 149,327	\$ 61,473
3	\$ 221,340	\$ 156,455	\$ 64,854
4	\$ 233,513	\$ 165,032	\$ 68,421
5	\$ 246,366	\$ 174,172	\$ 72,194
6	\$ 259,906	\$ 183,752	\$ 76,155
7	\$ 274,201	\$ 193,856	\$ 80,343
8	\$ 289,282	\$ 204,520	\$ 84,762
9	\$ 305,182	\$ 215,785	\$ 89,424
10	\$ 321,976	\$ 227,536	\$ 94,372

Access HR Database

Access MIB Database

Back to Front Page

The Capital Cost Analysis screen (see Figure 4) allows the user to select desirable TFC system capabilities, estimate nonrecurring costs as percent of total equipment costs, specify TFC system equipment options and quantities, and obtain an estimate for the total capital costs of the system.

Figure 4. Capital Cost Analysis Screen

Capital Cost Analysis

Select TFC system capabilities

☒ Time-based pricing

☐ Distance-based pricing

☒ Free-mile transfer

☐ Multi-operator pricing

☒ Minimization of fare evasion and fraud

☒ Increased passenger throughput

☒ Increased passenger convenience

☐ Convenience for concessionaire

Magical at the end

Smart card

Select Components

Back to Front Page

Estimate non-recurring costs as percent of total equipment costs	
Parts and services	15%
Installation and commissioning	20%
Engineering, software, and project management	25%
Contingency	15%

Total system costs	\$ 9,004,095	\$ 10,550,785
	TFS card system	Smart card system

The Payback Period Analysis screen (see Figure 5) facilitates presentation of the payback period analysis outcome in tabular and graphical format based on results obtained from the TFC OC and capital cost analyses.

Figure 5. Payback Period Analysis Screen

Finally, the Net Present Value Analysis screen (see Figure 6) shows results of the net present value analysis.

Figure 6. Net Present Value Analysis Screen

Net Present Value Analysis

Specify NPV analysis parameters

Discount rate, %	7%
Forecast horizon, years	5

Specify TFC system capital costs

Net Present Value	\$	114,754,788
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Back to Front Page

Summary, Conclusions, and Recommendations for Future Research

This article presents the development of a DSS to assess cost impacts of upgrading or replacing a transit TFC system. This DSS is built with two categories of policy- and decision-makers in mind—transit agency managers and transit industry researchers and policy-makers. On the transit agency level, management should find this decision support system helpful in TFC budget planning, performing evaluation of TFC improvement projects, and assessment of alternative TFC technologies. Transit industry researchers and policy-makers are also likely to find the TFC DSS useful in:

- analyzing performance of existing and new TFC technologies (as well as various combinations of these technologies) across the transit industry,
- analyzing the effect of transit demand, transit mode, and other factors on costs of fare collection, and
- determining trends and providing guidance in the development of fare collection systems on transit.

Although the major focus of this article is on a conceptual framework for financial analysis of TFC system performance, the article also provides details and specifics on the implementation of the TFC DSS in the spreadsheet software environment. To ensure the applicability of the TFC DSS as well as accuracy and precision of its forecasts, the database used in the DSS needs to be expanded and enhanced. Furthermore, it would be desirable to fine-tune the TFC DSS with reliable time-series data from individual transit agencies.

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