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ASSESSMENT OF THE AUTOMATICALLY CONTROLLED TRANSPORTATION (ACT) SYSTEM AT FAIRLANE TOWN CENTER

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MENLO PARK, CALIFORNIA 94025

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Final Report

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16. Abstract
This final report describes and assesses the automatically controlled transportation system at Fairlane Town Center. The information and data presented in the report were collected by the authors through surveys of technical literature; formal site visits; interviews with operators, management, and engineering personnel; and a visit to the system manufacturer.

A draft form of this report, which is one of six site reports, has been reviewed by site personnel and the system manufacturer, according to the policy of the study's sponsor, the Urban Mass Transportation Administration (UMTA).

The purpose of the site reports is to provide a uniformly documented presentation of automated guideway transit installations for UMTA's Automated Guideway Transit Socio-Economic Research Program and for use by other research groups and interested parties.

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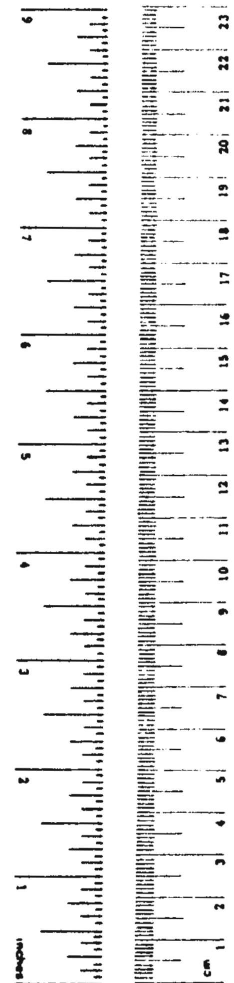
METRIC CONVERSION FACTORS

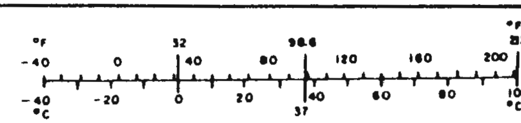
Approximate Conversions to Metric Measures

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



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



PREFACE

This project was conducted by the staff of SRI International's Transportation and Industrial Systems Center under the directorship of Dr. R. S. Ratner. Specifically, the work was completed in the Public Transportation Department directed by Mr. Joel Norman. Dr. Waheed Siddiqee, manager of the Transportation Systems Evaluation Program and supervisor of the project, coordinated the overall planning and policy level activities associated with the project.

Dr. A. M. Yen was the project leader and leader of Task 1, engineering-related data. Dr. M. Sakasita was the leader of Task 2, system economics and operational performance data. Mr. Marc Roddin and Ms. Nancy David shared the effort of Task 3, public perception. Mr. Clark Henderson was the leader of Task 4, the development process study. He also planned and monitored the special task effort for analysis of detailed cost data with the assistance of Dr. Sakasita.

Dr. R. Cronin, Mr. A. Hungerbuhler, and Mr. Steve Procter contributed to the project in an overall manner. Consultants to the project included Messrs. J. Barraza of DeLeuw, Cather (cost engineer); W. Flueckiger of GRC (cost analyst); J. W. Hall (guideway analyst); and F. T. MacInerney (mechanical engineer). The authors would also like to acknowledge Marjorie Cutler for her editing effort and various professionals and secretaries for their contributions to the project and the manuscript.

ACKNOWLEDGMENTS

The SRI assessment team would like to extend its gratitude to many parties without whose earnest cooperation this report would not have been possible. Among those who have given us their assistance are the staff of the Ford Motor Corporation, Fairlane Town Center, and the Hyatt Regency Hotel--Dearborn.

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1 EXECUTIVE SUMMARY

1.1 Summary Description

This report contains the interim findings of an assessment of Ford's Automatically Controlled Transportation (ACT) System, an Automated Guideway Transit (AGT) System for passenger transport in the Fairlane Town Center at Dearborn, Michigan.

SRI International is conducting this assessment as part of an assessment program sponsored by the Urban Mass Transportation Administration (UMTA). The purpose of the program is to gain an in-depth understanding of the performance, capabilities, and limitations of existing domestic and foreign AGT systems. SRI is under contract to assess the systems at Sea-Tac International Airport, Fairlane Town Center, Tampa International Airport, Houston Intercontinental Airport, WALT DISNEY WORLD, and King's Dominion Amusement Park.

In assessing systems at these sites, the overall objectives are to:

- Obtain factual engineering and operational data.
- Obtain descriptive economic, system performance, and user perception data.
- Review the design, development, and implementation process.

The findings are intended to establish the state of the art of AGT systems for ultimate use in planning, evaluating, producing, and deploying AGT systems.

The ACT system at Fairlane connects a large shopping center with a hotel situated about one-quarter mile across the center parking lot. The design was an integral part of the center and hotel development that was begun in 1970. The ACT project itself began in 1973 and was the second prototype demonstration of Ford's system, the first being that at Transpo '72.

The system is a two-car bypass shuttle operating on an elevated guideway; each car has a capacity of 24 passengers. The guideway is a single lane except for the double lane bypass area. The line capacity for two-vehicle operation is approximately 500 passengers/hr (in one direction) with a crush line capacity of 624 passengers/hr. These figures were calculated based upon existing performance parameters, assuming a maximum speed of 20 mph. The system is capable of speeds up to 30 mph, but design performance maximums are not now used. The reduced performance is used to increase passenger comfort, particularly the lateral ride quality at the curve of the guideway, and to reduce wear and tear of the running and guide wheels.

The Fairlane system has some unique features. One of the most interesting is the onboard switch, deployed by a combination of vehicle commands and wayside checks, that allows the cars to negotiate the bypass. The vehicle is equipped with a minicomputer for control of operational performance. The system represents the state of the art in so-called intelligent vehicle where in the responsibility of performing the bulk of control functions is placed on the vehicle itself.

1.2 General Findings

The Fairlane system represents a state of technology beyond the simple requirements of its present application. The technological sophistication is primarily evident in three areas: onboard computer (and related command and control design), onboard switch, and prefabricated guideway design.

The command and control design and onboard switch seem to provide some potential for expansion of this system to short headway network applications. The modular command and control approach allows for increased sophistication in wayside logic independent of changes to the vehicle. In the present application, failsafe wayside logic provides the necessary headway protection. No scheduling or routing are required. In a more complex network, schedule and route selection could be managed by a central computer that would augment the wayside logic. Because of the modular design, the addition of the central management computer should not be difficult.

The potential advantages of onboard switching include reduced headways, elimination of extra maintenance or heating of guideway switches during inclement weather, the capability of repairing the switch off-line at a maintenance location, and mechanical possibility of providing short bypasses in single lane shuttle systems.[4] Reduced headways can be accomplished because two vehicles can independently set the on-board switch before the switch point. Thus, the headway constraint is the same as the vehicle headway and is not dependent upon switch action times. Disadvantages of the onboard switch involve increased complexity in checking switch positions and increased costs in systems with large numbers of vehicles that have to be equipped with the switch.

The Fairlane system has only recently passed out of the development stage, during which many design changes and related failures occurred. For this reason, some of the operating costs and related maintenance and reliability data will not be representative of a more mature deployment. A mature system may cost somewhat less to build and operate in reference to 1973 dollars. The Ford system is attractive due partly to its setting in a new shopping center and hotel complex, but also because of the system design. The vehicle interior and exterior design is very clean with smooth ride quality.

The project development process for the Fairlane ACT system is not typical of most other such efforts in that the Ford Land Development Corporation, which owns the site, is a subsidiary of the system manufacturer.

1.3 Outline of the Report

The report contains seven major sections and a comprehensive information checklist attached as Appendix A.

The background of the project, including a brief description of the UMTA program that provided the funding for this study, is given in Section 2, as is the method of approach used in the assessment.

The engineering system description and assessment is given in Section 3, which contains all major engineering subsystems including site-specific subjects. Tables summarizing the engineering description are provided whenever appropriate.

Section 4 addresses the subjects of operation, maintenance and reliability, and passenger-oriented system performance. The description of operations is standard, using such terms as capacity and headways. The study of maintenance and reliability centers around the maintenance policy practiced by the site operator whose professional goal is to maintain the system so as to accomplish high service availability. For uniform reference, however, calculations in this report have been made for mean time between failure (MTBF) and mean time to restore (MTTR).

Systems economics, including capital; operations & maintenance costs, are the subject of Section 5, which includes an examination of the data, escalation, and equivalent annual cost.

The development history of the system is examined in detail in Section 6, which includes all major events that led to the present AGT system. Many system features, such as guideway type and vehicle subsystem, are predetermined in an early stage in the development process. These features have numerous impacts on all subsequent designs.

A comprehensive checklist with standard AGT assessment measurements and units appears in Appendix A and provides a convenient means of access to all system information for the reader.

A public attitude survey was conducted for the Fairlane ACT system. A summary of the survey is presented in Section 4.7; the questionnaire used in the survey is attached to the report as Appendix D.

2 INTRODUCTION

2.1 Background of the AGT Socio-Economic Research Program

In 1975 several Federal research programs in new transit systems were integrated to form a consolidated technology program--the Automated Guideway Transit (AGT) Program.

There are several programs within the general AGT Program: the Advanced GRT Program; the Automated Guideway Transit Technology (AGTT) Program for advancing all key aspects of AGT technologies; the AGT Applications Program for actual deployment projects, such as the Downtown People Mover (DPM); and the AGT Socio-Economic Research Program, which sponsors the assessment activities. The total AGT program is structured so that its elements complement and support each other for maximum achievement of program goals.

The AGT Socio-Economic Research Program had a modest beginning in 1973, when a macrolevel analysis of urban transportation with AGT emphasis was carried out. Beginning in 1974 the first of a series of AGT system assessments was initiated, namely the assessment of AIRTRANS system at Dallas/Fort Worth Regional Airport. Qualification guidelines for capital assistance funding of AGT systems were formulated.[1] An assessment of the Jetrail system at Love Field in Dallas, Texas was also conducted. The assessments of AIRTRANS, Jetrail and Cabintaxi/Cabinlift systems in W. Germany have been completed and published.[2,7,8] An assessment of the Morgantown system is underway.

In 1975 the program was significantly enlarged. Major research efforts were initiated in AGT system needs and market analyses, R&D delivery improvements, and socio-economic analyses of AGT systems including public perception, financial and institutional impediments to urban AGT system emplacements, and an expansion of the AGT assessment programs to include domestic airports, commercial sites and foreign sites.

An independent report on AGT systems was prepared by the Office of Technology Assessment (OTA) in June 1975 at the request of Congress.[3] This report, which was commissioned to provide the Senate Appropriations Committee with some background and status of AGT systems, has in part underscored the need for an ACT Socio-Economic Research Program.

During the 1976 Senate Appropriations Hearings, a new program area entitled "Social and Economic Research in AGT" and an appropriate level of funding were recommended. The Senate referenced the OTA report stating that the

> "finding of the OTA report is that social and economic research is needed on AGT systems. The Committee recommends providing $2 million for such research to be used to study the comparative advantages of AGT systems over other forms of mass transportation, evaluation of performance and cost experience of existing AGT systems, assessment of the market potential for urban application of AGT, and simulation and experimentation with existing AGT systems to determine what can be learned about the human response to them."

The goals of the AGT Socio-Economic Research Program are to:

- Determine the particular types of urban applications for which AGT systems are most appropriate.
- Identify and examine the institutional, social, economic, environmental, land use, and performance considerations associated with urban implementation of AGT and evaluate the acceptability of these characteristics by the various impact groups affected.
- Ascertain the capability of AGT systems to meet the mobility needs and the socio-economic requirements of the urban environment by a comparison of the performance and socio-economic characteristics of AGT and other transportation systems.
- Ascertain the nature and magnitude of the potential national market for the classes of automated guideway transit systems (SLT, GRT, and PRT) on a preliminary scale.
- Identify and assess policy options and financing mechanisms necessary to achieve significant implementation of AGT systems if warranted.
- Determine further research, development, and demonstration requirements for AGT system technology.
- Establish a central repository of current information on AGT socio-economic and performance characteristics and regularly disseminate this information to interested audiences in formats most useful to each.

Information obtained through this program will be valuable to local governments in undertaking their local alternatives analysis process, a recent UMTA requirement in seeking capital assistance funds. Furthermore, this Program will develop information to determine the domain of AGT in the hierarchy of urban public transportation and assess its merits and demerits associated with implementation in U.S. urban areas.

The AGT Socio-Economic Research Program is structured around several basic research activities, as follows:

- Generic Alternatives Analyses--This activity is to examine the relative merits and demerits of AGT systems in comparison to other forms of urban transportation.
- Assessments--The studies under this activity are concerned with the operating experience of existing AGT systems.
- Costs--Under this activity, detailed costs and economic studies are conducted for AGT systems.
- Markets--Under this activity, studies are conducted to estimate the market potential of AGT systems.
- Communications--This activity is concerned with disseminating information about AGT systems to all interested parties and receiving local expressions of views about AGT.

The work presented in this report was performed under the AGT Assessments activity.

2.2 Discussion of the AGT Assessments Activity

The UMTA AGT Socio-Economic Research Program defines the goal of the AGT Assessments as follows:

> These Assessments collect, aggregate, and uniformly present the performance and associated socio-economic characteristics from experience to date with AGT installations operating in public service, as well as document the implementation history and learning experiences of each major AGT deployment. The operational, economic, environmental, and passenger response data on all existing domestic and foreign AGT systems will be organized into a central inventory of AGT information for use in conducting the Generic Alternatives Analysis activity, the Markets activity, other activities of this research Program, and by other research groups and interested parties external to this program requiring such data.

To accomplish the above noted goal, several AGT assessment projects were initiated in 1975 for assessing existing domestic and foreign AGT systems and the Morgantown Personal Rapid Transit Demonstration Project.

This site report is one of several for the domestic AGT system assessment. The emphasis of the effort in conducting the assessment was in four major areas:

- Technology-related data--The performance of vehicle subsystems, steering, switching, propulsion, suspension, command and control, guideway, and power distributions are assessed, and the engineering system as a whole is reviewed. Many innovative designs are used in the engineering of the AGT systems. Assessments are based on the functions that an automated system must perform, its effectiveness, and its ability to be deployed in other environments.
- System economics and performance--The effectiveness of the AGT system is assessed by its throughput and layout parameters. System economics, capital, and operations and maintenance cost data are obtained and reviewed. Maintainability. from maintenance strategies and procedures to crew training, is thoroughly examined. Reliability, as a consequence of both maintenance and design, is assessed. Mean time between failure (MTBF) and mean time to restore (MTTR) are calculated wherever appropriate.
- Public response and acceptance--This subject is assessed both subjectively and objectively. Assessments by both owners and operators are obtained, and user perceptions are observed and recorded. An attempt is made to distinguish between the specified and actual comfort for passengers.
- System development process--The systems assessed represent the first generation of deployed AGT systems. The conception, design, development, procurement, testing, and acceptance of these systems vary greatly. In this task we review the entire development process and the relationship of the participants at each site to develop findings that will be applicable to planning and producing future AGT systems.

The rest of this report presents detailed discussions in these four areas.

3 TECHNICAL DESCRIPTION

3.1 System Description

The AGT system built by Ford at Fairlane Town Center in Dearborn, Michigan, is a shuttle with midroute bypass to allow simultaneous operation of two vehicles on the same stretch of guideway. The route is elevated, about 2,600 ft long, and links a large shopping mall with an 800-room hotel. The system opened in spring 1976, providing service during the shopping center open hours. It operates in both scheduled and on demand modes. No fare is charged for the use of the system.

The AGT service is not essential to the functions of the hotel or the shopping mall, but the substantial patronage experienced since the system began operations suggests that its novelty, visual appeal, and shuttling service attract additional people to the center. However, the true value of any profits and benefits attributable to the AGT system cannot be easily determined.

A model of the guideway layout and the locations of the mall and shopping center are shown in Figure 3-1. The guideway, including the curved approach to the hotel, is constructed of prestressed reinforced concrete sections with parapet walls to provide lateral retention and power rail mounting locations. The guideway surface is also equipped with guideway heating elements for snow removal.

The stations at each end of the shuttle have clear glass doors that allow for entry and exit from both sides of the vehicle at the shopping center station and from one side of the vehicle at the hotel station. Each station can accommodate one vehicle.

The vehicles (see Figure 3-2) are the second generation to be built by Ford (the first were for Transpo '72) and feature a number of heavy truck parts. The outer body of the vehicle is an all-aluminum design,

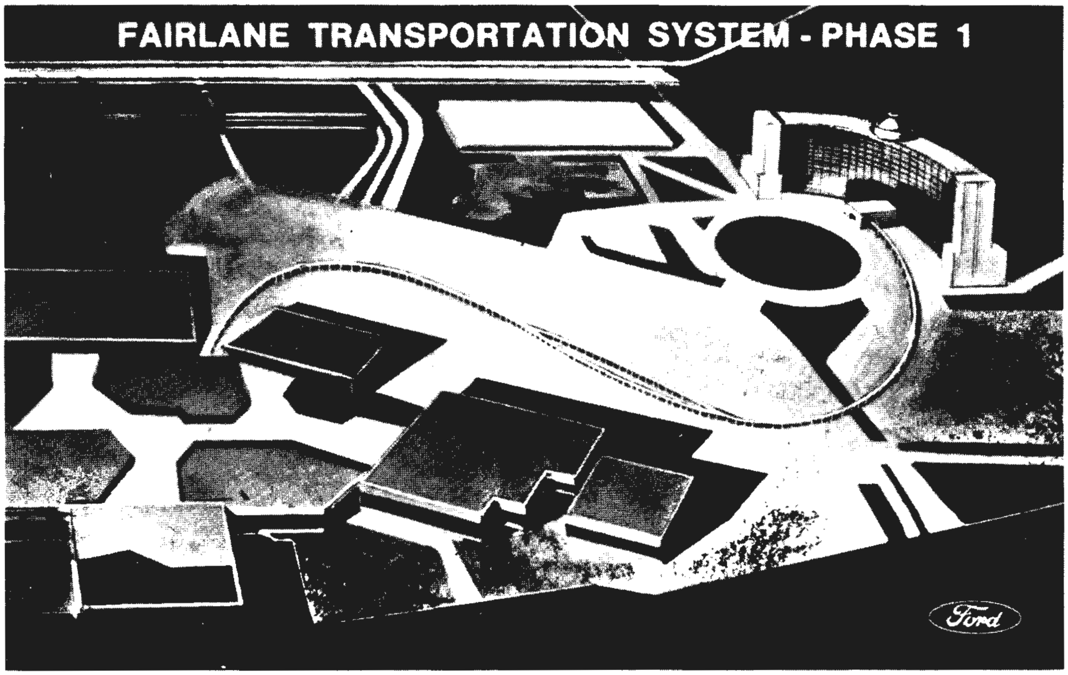

FIGURE 3-1 MODEL OF FAIRLANE TOWN CENTER SITE

FIGURE 3-2 FORD VEHICLE

which is welded and bound to the frame to provide an uninterrupted exterior surface.

The maximum speed is 30 mph, but the operating speed at Fairlane is currently 20 mph. Acceleration and deceleration rates are controlled by an onboard minicomputer. Propulsion is through electric motors with power rail pickup. The capacity of each vehicle is 24 passengers (10 seated, 14 standing); the crush capacity is 30. Other pertinent characteristics are summarized in Table 3-1. For more detailed information refer to Appendix A.

The vehicle features a unique onboard switch controlled by the onboard computer. Deployment of the switch at the proper time allows the vehicle to negotiate the bypass section in the guideway. Primary control of the vehicle is by the onboard computer responding to a limited set of wayside control signals.

The Fairlane system operates 12 hours and 30 minutes on Mondays through Saturdays and 5 hours and 30 minutes on Sundays and carried 2,434,076 passengers from March 1976 to February 1977.

The ACT system has a number of other interesting features. The prefabricated prestressed concrete guideway sections were constructed using a steel form that can be adjusted to proudce any desired curve or superelevation. The bypass allows most of the guideway to be single lane, thus reducing guideway costs. The wayside communication requirements are relatively low because most of the vehicle control functions are performed on board.

3.2 Vehicle Subsystem

3.2.1 Description of Vehicle and Performance Parameters

The Fairlane ACT vehicles are the second type of vehicle built by Ford. The vehicle features a step-down frame and low-profile body which facilitates its passage through existing buildings without much intrusion. The overall parameters are shown in Table 3-2 and the vehicle structure breakdown is shown in Figure 3-3.

Table 3-1

ACT CHARACTERISTICS: FAIRLANE TOWN CENTER

Manufactured by Ford Motor Company

Opened Spring 1976

Vehicle	
Capacity	
Crush--maximum	30
Normal	24 (10 seated, 14 standing)
Maximum speed	30 mph (20 mph operating)
Headway	
One vehicle	5.8 min. (incl. dwell)
Two vehicle	2.9 min. (incl. dwell)
Number	2
Type of operation	Single Car
Command and control	
Type	Onboard computer, wayside logic/controller
Management policies	Cars leave stations simultaneously
Modes	Scheduled or demand responsive
Guideway	
Length	Approximately 2,600 ft
Type	Elevated
Material	Prestressed concrete
Routing	Bypass shuttle
Stations	
Number	2
Platforms	3
Berths	2
Operating conditions	
Weather	All weather (heated guideway)
Maximum operating speed	20 mph
Capacity	
Maximum	624 passengers/hr/lane (two-vehicle operation)
Normal	500

Table 3-2

ACT VEHICLE SUBSYSTEM PARAMETERS: FAIRLANE TOWN CENTER

		Fairlane Installation
Size, length x width x height	(ft)	24.7 x 6.67 x 8.67
Weight empty	(lb)	12,500
Capacity	(lb)	4,500
Floor area	(ft^2)	66
Interior volume	(ft^3)	1,080
Operating speed (maximum)	(mph)	20
Acceleration	(mph/sec)	1.36
Deceleration		
Service	(mph/sec)	1.36
Emergency	(mph/sec)	4.1
Jerk limits		
Acceleration	(mph/sec^2)	2.1
Deceleration	(mph/sec^2)	2.1
Maximum train length	(number vehicles)	1

The Ford vehicle uses a steel frame with an aluminum superstructure. The superstructure is designed to present a smooth appearance without seams. The two vehicles at Fairlane, designated F1, F2, have identical superstructures but slightly different undercarriage arrangement. The vehicles are bidirectional but have a front and back orientation. The front of both vehicles faces the hotel station and the back faces the shopping center station. Vehicle F1 has one set of switch arms and one set of collector shoes on one side of the vehicle. Vehicle F2 has one set of switch arms on the side opposite to that of F1. It has two sets of collector shoes, i.e. one on the same side as that of F1 and the other on the opposite side. This configuration has the advantage that the power and signal rails are needed only on one side of the guideway except near the bypass areas where the rails are needed on both

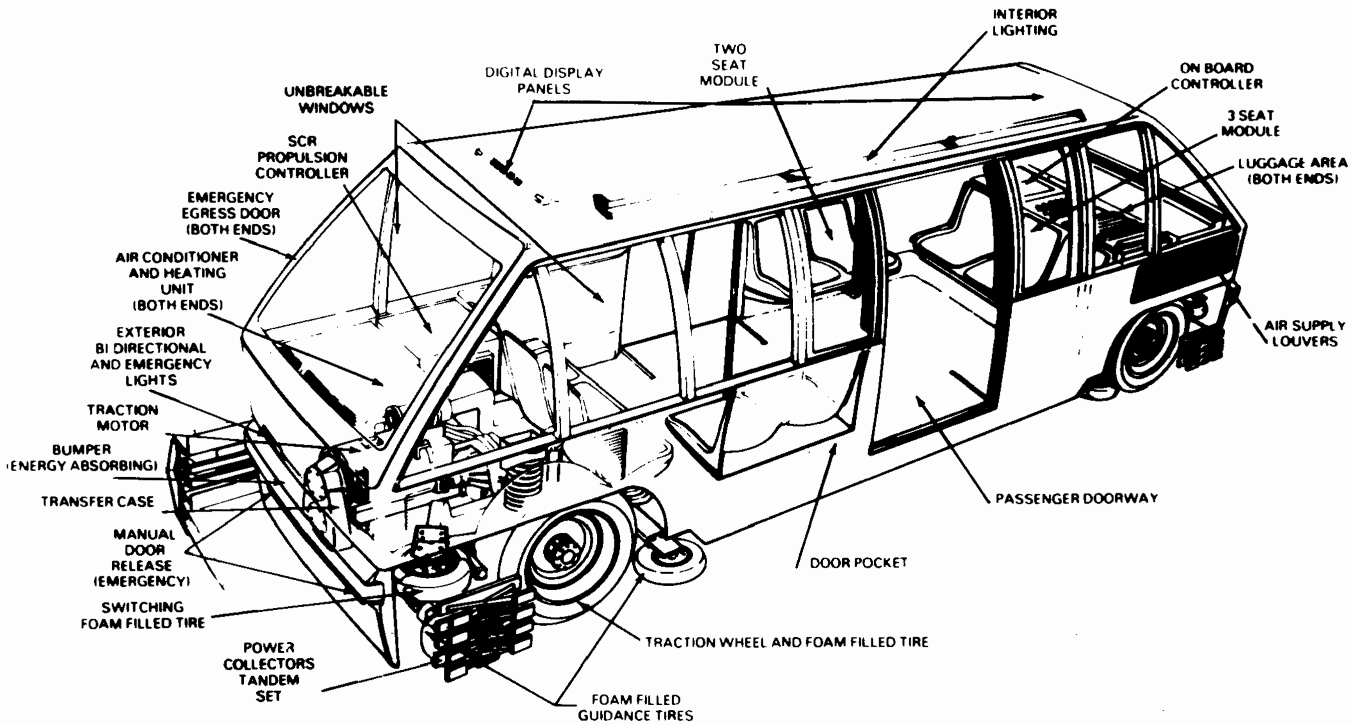

FIGURE 3-3 FAIRLANE VEHICLE STRUCTURE

sides. Vehicle F2 uses the opposite set of collector shoes when passing through the bypass frog.

3.2.2 Braking

There are two kinds of braking used on the Ford vehicle. Service braking is regenerative and is used to bring the vehicle to a complete stop at the station. To avoid the difficult problem of holding the vehicle motionless at the station by torquing the motors, the friction braking system is applied when the vehicle is at rest. Each vehicle has two hydraulically applied disc brakes. The brakes are mounted on the differential drive shaft on each axle below the motor. Hydraulic pressure is admitted to the brakes by flutter valves. For safety reasons the friction brakes are held off by the presence of a control signal and applied in the absence of the signal.

The friction brake system also serves as an emergency brake system if the normal service braking fails. Emergency deceleration is limited by a pendulum valve that releases hydraulic pressure at a preset level. Significant redundancy is provided in the emergency brake system in the form of completely separate hydraulic systems for each brake. Hydraulic pressure is stored in an accumulator at each end of the vehicle. If the hydraulic pump fails, there is sufficient capacity for three full stops. Since the friction brakes are used for station holding, the emergency braking system is automatically tested at each station stop.

3.2.3 Minor Subsystems

3.2.4.1 Doors

The Ford ACT vehicles have two sets of biparting doors, 41 inches combined width, one set on each side. Door height is 80 inches. All doors have safety edges. Door reliability has been acceptable; however, larger doors might prove desirable since the system operates near full capacity most of the time. The present arrangement works better in dual-platform stations where traffic enters on one side as passengers leave on the opposite side.

3.2.4.2 Heating, Ventilating, and Air Conditioning

The vehicle interior environment is controlled with 9 kW of electric heating and 4 tons of air conditioning.

3.2.4.3 Passenger Environment

The Ford vehicle at Fairlane has a total of 66 ft^2 of floor area available between the two step ends of the vehicle for passenger or freight accommodations. In the present configuration of ten seats, all but 27 ft^2 are taken up by seats and associated leg room requirements.

Vehicles are equipped with curved windows above the seat backs to the ceiling and provide a full 360 degrees view from within. End windows in the vehicle function as emergency exits. The windows are tinted, offering an attractive exterior but with full visibility from inside the vehicle.

The interior is finished in various types of high-durability synthetic materials. The molded plastic seats have vinyl inserts that can be changed quickly, and the floor is carpeted.

Two-way radio communication with the control center is provided. The passengers can initiate communications if necessary.

3.3 Command, Control, and Communications

The Fairlane system is a basic shuttle system. Ford, however, wanted to design a command, control, and communications system (CC&CS) that could not only perform certain baseline onboard functions needed for shuttle system but also be expanded with minimal hardware change to meet large network requirements. Hence the CC&CS used at Fairlane contains a variety of features (such as an onboard computer that keeps track of vehicle position with limited external information) that have potential advantages in other applications.*

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*Reference 4 discusses some of these advantages.

3.3.1 Vehicle Protection

Vehicle protection in this shuttle system has two aspects: collision avoidance and precision stopping at the ends of the line. We have chosen to treat the stopping protection in Section 3.3.2 because the vehicle stopping control system concerns the operation of a vehicle rather than the protection of it from another. This section contains information regarding collision avoidance.

Fairlane's CC&CS assures vehicle separation in the bypass area through the use of a fixed block wayside control system. The entire signal rail is segmented into fixed blocks. A wayside vital control system detects vehicle presence and transmits vehicle command signals which assure safe movement. The major functions of the system are to control the direction of motion, synchronize the bypass of two vehicles operating on the system to avoid collision, and accomplish precision stops of the vehicles at both stations. The block command mechanism is discussed in Section 3.3.2. The system does not have logic for controlling closely following vehicles or merges since these conditions do not occur at Fairlane.

The guideway is divided into 14 control blocks, including 3 two-pair blocks at the bypass area (see Figure 3-4). These blocks are designated as A blocks and B blocks according to whether they are in the A station (shopping center) or B station (hotel) zone. Two wayside transmitters, each devoted to a zone, are wired through occupancy relay contacts to the blocks in a zone for command and information exchanges. The transmitters are switched when both vehicles are in the bypass.

Blocks 4A through 7A and 4B through 7B form the bypass area where vehicle protection, in the sense of preventing collision, exists. Vehicle protection control is accomplished by both vehicle-borne and wayside vital relays. The wayside vital relay functions as a sorter by which the proper command signal is sent to the vehicle once its presence is detected in a block. The vehicle-borne vital relay functions as a check-out list to ensure the vehicle is ready to implement a proper command.

The principle of Fairlane block control at the bypass is based on a "truth table" of synchronization for approaching vehicles, blocks the

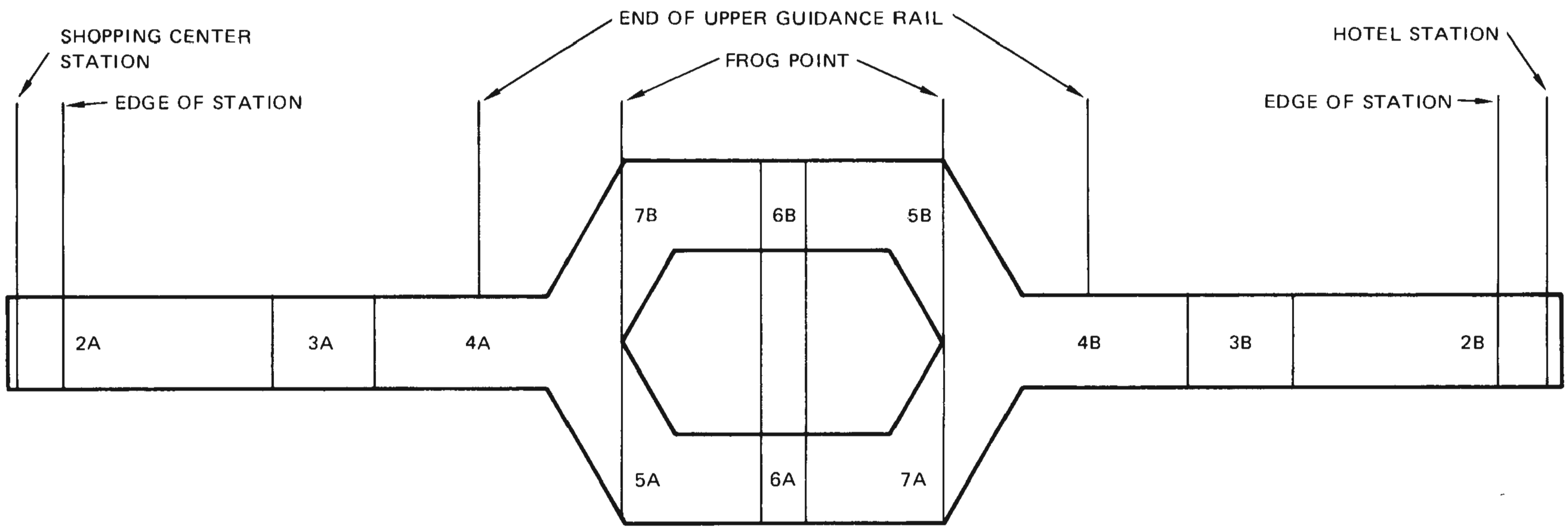


FIGURE 3-4 COMMAND AND CONTROL BLOCK LAYOUT

vehicles must enter at specified times, and the speeds at which they should travel to complete the bypass. It verifies all parameters for safe bypass.

Vehicle presence in a block is detected by the shunting of the signal rails by the coil of an onboard vital relay. This dc signal appears at the wayside vital relays via the dedicated communication line for the block. The vital relays, after consulting information received from the adjustment blocks, select a speed command and send it back to the vehicle via the same line. The speed command, upon being received by the vehicle, initiates two actions. First, there is a check of vehicle status for the command implementation, which is reported back to the wayside by an "echo" of the command. Second, the command triggers the onboard computer for performance adjustment as required.

If approaching vehicles are not synchronized for the bypass, violation of the "truth table" occurs, and the vehicles will be commanded to slow down and adjust their performances for synchronous rematch. Two block lengths are usually given for performing adjustment. An emergency stop will be implemented if the adjustment fails to match the synchronization. However, due to the onboard computing capability, vehicles seldom have to implement such an emergency stop since onboard processing is usually accurate.

An emergency stop can also be commanded by the onboard vital relays in response to the loss of a wayside command. The onboard vital relay system is completely independent of the onboard computer, but not vice versa, since the onboard computer utilizes vital control system commands and status in performing the various vehicle control functions. The onboard computer performs these control functions within the safety constraints imposed by the vital control system and seeks to avoid the necessity for emergency protective action by the system.

3.3.2 Operational Control

3.3.2.1 General

Once a vehicle leaves the bypass area, its sole mission is to proceed to its destination station and perform a proper stop there. This mission requires the vehicle to complete the following phases:

- Switch arm enable (SAE)
- Queuing stops (Q-stops)
- Begin vernier stops (BVS)
- Station stop and hold.

Because the stations are located at the very ends of the guideway, stringent requirements are imposed on the vehicle command and control system. This is evident from the fact that a vehicle is required to follow a precision speed stepdown profile during the Q-stop section, and then is fine tuned by the BVS section until it creeps into the station at 1 ft/sec. This entire operation is usually accomplished successfully in about 11 to 13 sec, including traversing the last 25 ft to the station and performing station line-up.

3.3.2.2 Switch Arm Enable (or Disenable)

Sensors on the guideway detect the position of the switch arms (extended or retracted). Unless inputs from the system program and the block occupancy relays indicate an arm check is inappropriate, the switch arm logic insists that the correct sequence and count of arms pass by the sensors. This logic check occurs at the end portion of No. 3 blocks and beginning of No. 2 blocks.

This operation is designed to be completed within the distance span of the arm-out and arm-in guideway detectors, which are 150 ft apart.

3.3.2.3 Queuing

The Q-stop provides end-of-guideway failure detection to protect against any possibility that the vehicle might contact the protective bumper, which is located at the end of the guideway. The signal rails approaching the end station berths are segmented into shorter and shorter sections, with 24 such segments in all. Alternate sections of signal rail are tied together into even and odd groups, in a "daisy chain" arrangement.

The Q-stop is a failsafe timer. Thus, the protected speed profile is one in which the vehicle takes at least the predetermined minimum time to traverse each of the shorter and shorter segments (switching from an odd to an even segment) as it approaches the station.

Essentially, a vehicle is checked every 550 msec in the 325-ft Q-stop area within the No. 2 blocks to ensure its deceleration.

3.3.2.4 Begin Vernier Stop

Begin vernier stop (BVS) serves to slow a vehicle down for a station line-up. The actual BVS action starts at the last portion of the Q-stop area. The length of the BVS section is about 25 ft, with a $\pm$ 12 in. stopping requirement. BVS spans from the edge to the end of station.

3.3.2.5 Onboard Computer

The onboard computer is a Digital Equipment Corporation model PDP-8/M minicomputer that controls all vehicle functions in the automatic mode of operation. (The computer has a capacity of 4,096 12-bit words.) The computer performs control functions within the safety constraints imposed by the vital relays and seeks to avoid the necessity for emergency protective action by the onboard safety system.

The computer software is capable of running all operating tasks independently and has its own scaling routine. This includes the capability of altering the operating constants used by the control equations, such as speed, nominal acceleration, and jerk limit.

The computer software has seven basic routines: digital signal, tachometer read, velocity/position, vernier stop, safety stop, command output, and alarm status.[5]

3.3.2.6 Tachometer and Position Feedback

Two tachometers are used in a failsafe, self-checking manner onboard the vehicle. These tachometers form the heart of the vehicle positive location, which, in turn, provides a base of reference for the computer and other onboard equipment.

The self-checking and accuracy assurance design of the tachometer circuitry will not be discussed here because of the detailed nature of the subject. However, the Ford design utilizes the tachometer counts in a cumulative manner to furnish position as well as velocity information to the feedback control systems. This is made possible by the onboard computer. Such a feedback control system tends to be more accurate than the velocity feedback that is generally used.

The tachometer provides digital output to the circuit at a rate of 150 pulses/ft. The tachometer results are accurate down to 0.6 ft/sec per count. Any discrepancy larger than this amount will cause the vehicle to stop if it is not corrected in time. The tachometers are of proven quality,* with a reliable operating experience.

3.3.3 Central Control

Overall system control is provided through the central control console, which is composed of three sections: one provides central operator status displays of the CC&CS, another controls the support facilities, and a third displays and controls all voice communications. The support facilities panel controls guideway power, guideway heating, and the barrier between the automated guideway and the maintenance facility, which is at the end of the guideway beyond the shopping center station.

Five central control closed circuit TV (CCTV) displays cover various areas of the system (see Section 4.6.1). A display of guideway blocks indicates the locations of vehicles. The system modes that can be selected at the console include scheduled/demand, 100%/50% performance, and run/no motion. The scheduled mode automatically controls the vehicles so that

*Trump-Ross Manufacturing Company.

they shuttle between the end stations: both vehicles are dispatched simultaneously as soon as both sets of vehicle and station doors are closed. Reduced speed (50% performance) can be selected when required. Run/no-motion control is used to shut the system down.

The relationship of central control to other subsystems is shown in Figure 3-5. Since the Ford vehicle is equipped with automatic devices, and wayside control is separated from central control, the main function of central control is supervision and operator interface.

3.3.4 Commands and Communications

The Ford vehicle at Fairlane, being an "intelligent" vehicle, requires few wayside-to-vehicle communications and has the advantage of being less susceptible to communication errors.

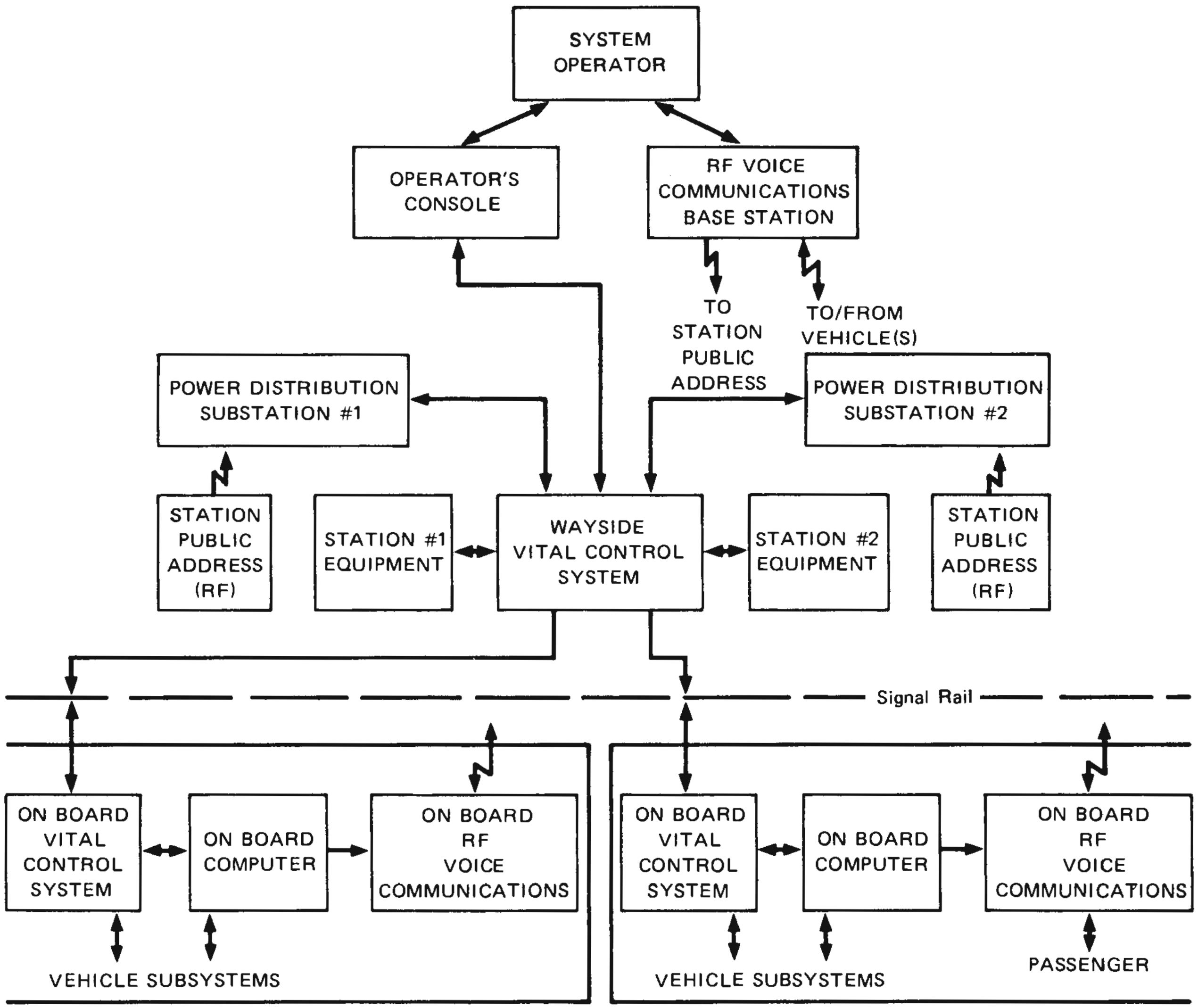
The command and control communications between vehicle and wayside are accomplished by five tones and five echoes through the signal rail. Tones are pure frequency signals that carry commands from the wayside to the vehicle. Echoes are vehicle responses to the wayside commands. The tones and echoes are given in Table 3-3; the commands and checked responses are listed in Table 3-4.

Table 3-3

ACT COMMAND AND RESPONSE FREQUENCIES: FAIRLANE TOWN CENTER

Command Tones		Response Echoes	
F1	15.467 kHz	F6	8.000 kHz
F2	17.846 kHz	F7	9.231 kHz
F3	19.333 kHz	F8	10.000 kHz
F4	21.091 kHz	F9	10.909 kHz
F5	23.200 kHz	F10	12.000 kHz

Note: Frequency voltages vary between 2 mV to 10 V, with a duration of approximately 15 msec.



SA-5949-4

SOURCE: J. J. Logan, Ford Motor Company, "ACT – Ford's Automatically Controlled Transportation System," paper presented at the Automotive Engineering Congress, February 25–March 1, 1974, Society of Automotive Engineers, No. 740226.

FIGURE 3-5 RELATIONSHIP OF CONTROL SUBSYSTEMS

Table 3-4

ACT COMMAND AND RESPONSE CODE: FAIRLANE TOWN CENTER

Code Number	Command or Checked Response	Tone* F1	F2	F3	F4	F5
1	Maximum speed 30 mph, but slow down	1	1	1	0	0
2	Maximum speed 30 mph, and go at 30 mph	1	1	0	1	0
3	Extend or retract switch arms	1	1	0	0	1
4	Maximum speed 15 mph, but slow down	1	0	1	0	1
5	Maximum speed 15 mph, and go at 15 mph	1	0	0	1	1
6	Decelerate for station stop	1	0	1	1	0
7	Command forward and open doors	0	1	1	1	0
8	Command reverse and open doors	0	1	1	0	1
9	Are vehicle doors closed?	0	1	0	1	1
10	Is vehicle at zero motion?	0	0	1	1	1
11	Emergency stop†	0	0	0	0	0

Note: Echo uses the same zero-one code at frequencies F6 through F10.

*1 = presence of tone; 0 = absence of tone.

†Absence of command includes emergency stop.

Absence of command, or its equivalent of removing all command tones, results in an emergency stop. This scheme further assures continuous communication between vehicle and wayside. It will also stop a live vehicle if it loses its response capability.

Nonvital communication is accomplished by a radio link, consisting of a half duplex tone/voice communication system, between the vehicle and central control. If an ACT vehicle develops an alarm condition, such as equipment failure, digitally selected tones are generated in the RF control package. This equipment automatically actuates the vehicle transmitter and sends these signals to central control. The tone codes are decoded by the base station control package, and the proper alarm indicator on the central control panel is illuminated. This action also causes an audible alert to be sounded.

3.4. Steering

The Ford steering system utilizes many commercial truck parts. It consists basically of two common rigid truck axles arranged to pivot about a vertical axis for curve negotiation. Each axle is steered by four guide wheels mounted horizontally in front and back of each load-carrying tire. The guide wheels run just above the road surface, bearing outward against vertical guiding surfaces about 7 in. high, or about the height of common curbs. The wheels are preloaded to bear against the guiding surfaces with a force of 550 lb each, which reduces lateral hunting, makes the vehicle track the guideway more accurately, and improves transition at switch points.

3.5 Switching

The Ford vehicles use onboard rather than guideway switching. Each vehicle can be equipped with four switch wheels, one at each corner of the vehicle, which are swung outward on arms to engage auxiliary guide surfaces at switches. One switch wheel at each axle is sufficient to substitute for the lateral restraint temporarily lost as the opposite guide wheels leave their guide surface at a switch. Fairlane requires switch wheels on only one side; only two per vehicle are installed. The vehicle and guideway arrangement is shown in Figure 3-6.

The Ford switch system positions the switch wheels forward of the axle in the direction of travel--16 in. on the leading axle, and 3 in. on the trailing axles--which causes the axle to steer slightly toward the side wall. This makes the load-carrying wheels provide part of the lateral force required to hold the active guide wheels firmly in contact with the guiding surface. As a result, the load on the switch wheels is reduced.

Onboard switching requires somewhat different safety considerations from guideway switching but is otherwise analogous to guideway switching

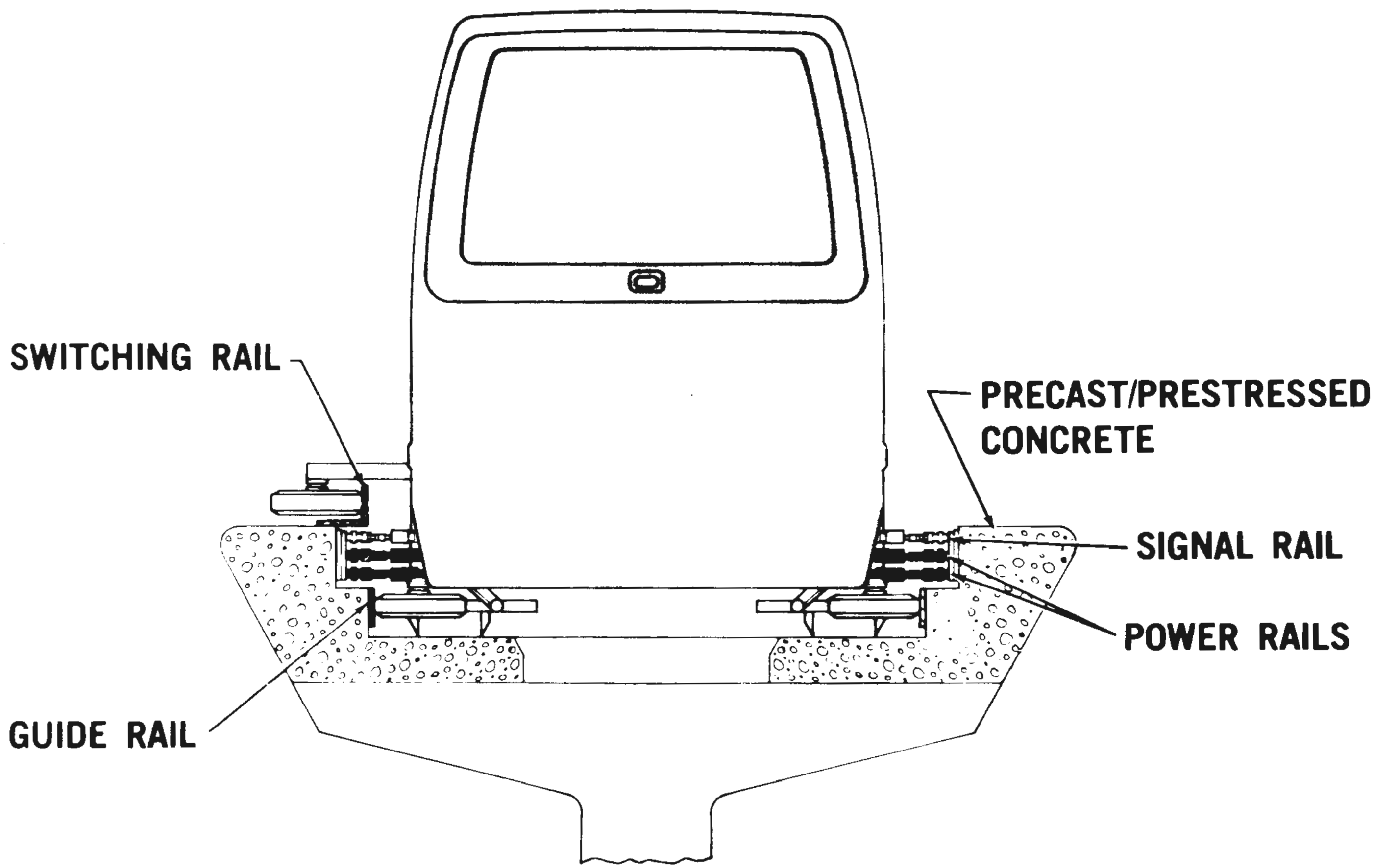


FIGURE 3-6 VEHICLE GUIDEWAY INTERACTION

in all respects. Fundamentally, switch position must be determined far enough in advance to allow the approaching vehicle to stop safely if a malfunction or error is detected. In both cases, the vehicle approaches the guideway junction with a given speed and characteristic stopping distance and time. As the vehicle passes the closest point allowing a safe stop, the switch elements must be in position, locked, and verified, whether on the vehicle or on the guideway.

It is clear that the loss of lateral control in the switch area would be a serious occurrence.

The Ford system checks the position of each switch element with electronic sensors on the vehicle and magnetically senses the presence of the switch arms at checkpoints on the guideway. Once the switch arms are in position, they are mechanically locked by a toggle mechanism. Loss of actuating power will not cause them to retract.

There is little possibility of a vehicle, once correctly set for a switch, having a mechanical failure in the switch area. It is the responsibility of the control system to be certain that an incorrectly set vehicle will not be cleared to proceed into a switch area.

3.6 Propulsion

Ford uses two separate identical drive systems incorporated in the bogies at each end of the car. A single drive system can operate the vehicle at a reduced speed if one fails.

The propulsion controller is a solid-state device designed to control torque through the conversion of 480 Vac three phase power to a variable dc voltage and to switch the motor circuitry to produce regenerative braking during stops. The thyristor controller receives an armature current command from the onboard computer and converts the ac power to chopped dc using a full-wave rectifier. During regenerative braking, the unit switches the motor to a generator that inverts dc voltage back to 480 Vac, 3 phase, for return to the power rails.

The propulsion motor has the following characteristics:

Type	Shunt wound dc
Nominal voltage	500 V dc
Number of poles	4 poles
Horsepower	60
Rpm	2,500

The motors are blower cooled and have built-in overheating sensors. Each motor is mounted above the axle and drives the wheels through a transfer case and chain drive of standard automotive design. The output sprocket drives a short drive shaft which is linked to a truck-type differential assembly. A disc brake and a tachometer are mounted on each drive shaft. The overall reduction is selected for 30 mph at 2,500 rpm.

3.7 Suspension

The Ford suspension system is a straightforward automotive design. The basic truck axle is constrained to the chassis with rubber-bushed radius rods. The upper, A-shaped, radius rod is on the centerline of the vehicle, with its base attached to the vehicle chassis and the tip attached to the axle. The lower radius rod is a single link from the axle to the chassis. This combination establishes in a direct manner the pivot center for the axle, the roll center, and the vertical deflection path.

The vertical load is transmitted to the axle through coil springs. When the axle pivots for curve negotiation, the coil springs simply deflect to a slight S-shape. This arrangement has been used on other forms of guided ground transportation with good success when properly designed.

The Ford vehicle is provided with a lateral suspension system as well because of the way the guide wheel preload is achieved. Each guide wheel is mounted so that it can slide laterally with respect to the truck axle. The guide wheels are sprung outward by leaf springs which, when the wheels are compressed inward about 1 in. to the track gauge, provide the 550-lb preload to the guideway. Minor lateral irregularities move only the guide wheels and have no noticeable effect on the chassis and passengers until the axle begins to respond to a change in guide wheel forces and steers to a new equilibrium position. This particular arrangement differs from other guided vehicles in that the lateral springing is usually between the running gear (axle or bogie) and the chassis. The Ford arrangement considerably reduces the laterally unsprung mass and makes use of the tendency of the load-carrying tires to roll in a laterally smooth path.

3.8 Guideway

The Fairlane guideway, which is entirely elevated, is arranged in the shape of a giant reversed "S," curving through the large surface parking areas separating the shopping areas and hotel. A station is located at each end, and a vehicle bypass, characteristic of the ACT guideway, is provided near the center. The total length of the guideway is approximately 2,600 linear feet including the 600 ft bypass section.

The geometric layout used at Fairlane has resulted in a guideway with very gentle grades and large horizontal curves. The bulk of the system has a 0.5% grade; the section approaching the hotel station is flat. Approaching the shopping center station, the guideway grade increases to 2.5% as the system enters the mall structure. The plan geometry employs a typical horizontal curve of 275 ft radius, with appropriate geometric transitions from tangent (straight) sections to curved and between curved sections of different radii. The majority of the length of the guideway is curved and thus requires superelevation. Superelevation transitions from zero at the tangent sections to 10% for the 275 ft radius curves.

3.8.1 Guideway Structure

The Ford ACT aerial guideway is a concrete structure composed of cast-in-place foundation elements, precast columns, and channel-shaped prestressed concrete guideway beams. In order to minimize the number of troublesome transverse joints, the structure has been divided into seven independent continuous units by means of expansion joints employing sliding bearings between column and beam ends. A typical unit consists of a series of up to eight continuous beams between expansion joints, giving a maximum continuous length of approximately 360 ft. Longitudinal forces and volume change effects result in bending of the relatively slender columns between expansion joints. Several of the continuous units that are supported by relatively short columns have additional sliding connections for the purpose of diminishing forces in the columns. Structural continuity is obtained by an arrangement of longitudinal, overlapping, posttensioning tendons. In addition to serving as continuity reinforcement, the posttensioning was designed to control both live and dead load deflections.

3.8.2 Guideway Beams

In addition to vehicle support and traction, the guideway beams provide horizontal guidance, vehicle entrapment, and mounting surfaces for electrical hardware. This heavy systems reliance on the beams, together with the largely curved plan geometry, makes the beams the key element of the structure. The guideway beams used at Fairlane are channel-shaped precast/prestressed concrete elements 2.5 ft deep and 12.2 ft.* width into which the vertical and horizontal geometry of the system has been molded. The horizontal web of the channel contains pretensioned longitudinal reinforcing together with mild steel transverse reinforcing. The vertical flanges of the channel house the longitudinal cross-tendon posttensioning. Blockouts in the upper inside corner of the vertical flanges provided access to tendons for anchorage and jacking. After tendon jacking and grouting was accomplished, these blockouts were filled with concrete and faired to match the inside surfaces.

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* Approximate guideway envelope dimensions, cosidering the height of the vehicle and about 2 ft extra margin on each side will be 16 ft wide and 12 ft high.

Vehicle guidance is achieved by means of T-beam guidance rails, which are fastened to the vertical flanges of the guideway channel with threaded fixtures to permit adjustment to exact alignment. An upper switch guidance rail is fastened to the top side of the vertical flange of the beam for use in the merge/diverge areas. Power conductors are mounted inside the guideway just above the lower guidance rails.

The tractive surface was applied after erection. Drains are provided at each column to carry water away from the guideway. The original design included a valley in the tractive topping slab leading to each drain. This feature was omitted in the actual installation, however, with the result that there is rather poor drainage in some locations.

3.8.3 Guideway Heating

The Ford Fairlane system is located in the Detroit Metropolitan area. The climatological chart on page 3 shows the general weather conditions of the area; mean snowfall is 39 in. per year, and accumulations average 3 in. with occasionally heavier accumulations. The Fairlane system has a guideway heating system that can prevent accumulation of snow and ice on the running surface to maintain operational performance and safety. Heated water drains are provided. A 30% loss of speed or acceleration performance while operating on a snow-covered guideway has been experienced at Fairlane.

The guideway has imbedded in the topping layer a mineral insulated heater wire, which is an electric resistive heating element within a copper tube filled with a heat-conducting mineral compound. The wire is within 1 in. of the running surface and winds across the running surface so that there are straight sections of heating element spaced 8 in. apart perpendicular to vehicle travel direction. Operating on 480 V ac, the wire uses 60 W/ft^2 to heat the guideway. Power used in heating the guideway is not separately metered.

Ford's original operational criteria for heating the guideway was to initiate the guideway heating 6-8 hours before an anticipated snowfall. However, many times the 6-8 advance forecast did not prove to be reliable. It was therefore decided to start the heating about 2 hours before an anticipated storm or snowfall or not use the heating at all but to remove the snow mechanically.

If the guideway were to be heated after a snowfall, icing of the power rail and steering surface would result from the vehicles splashing the water from the melted snow onto these surfaces. Therefore, if snow or ice has accumulated, the guideway is not heated. It is cleaned manually and methyl alcohol is used for ice removal on the power rail and steering surface.

Approximately 3,200 linear feet (including the bypass section) × 7.6 ft width, or about 24,500 ft^2, of guideway contain heating coils with a design capacity of 60 W/ft^2. Heating is used only when weather conditions are severe. Two heating modes are possible: (1) 100% heating of entire guideway, and (2) 50% heating implemented by alternating heating among the different track sections. Mode (1) requires about 1,470 kW, and mode (2) requires 735 kW.

3.8.4 Station

Inherent in the Ford ACT design is the ability to fit system stations into existing buildings. This ability is demonstrated to a large degree at the hotel station but not at the shopping center station.

At the hotel station, guideway is so constructed that it lines up with the side of the building so that a lobby of the hotel is used as a station through a pair of specially designed doors. Personnel of Ford's Transportation Systems Operations (TSO) claim that such a design requires the vehicle to be capable of making controlled station approach and precision stops. This is a reason given for the development of a sophisticated operation control near station areas as described in Section 3.2. Naturally, the space required in the lobby area for passengers, the lobby itself, and building structure are the basic ingredients required by all AGT stations.

Since the ACT maintenance facility is located in the shopping center, the ACT system must have the right-of-way into the shopping center complex to reach this facility. A station area is further designated just in front of the maintenance facility on the right-of-way. The space needed to accommodate the right-of-way in the shopping center essentially constitutes a station space requirement. Although the requirement of precision station approach and stop remain the same as the hotel station, the idea of space saving is less obvious.

3.9 Power Distribution

The Fairlane system is supplied by two substations which are dedicated to the ACT system. Each substation is equipped with a 13,200 V/480 V transformer, a motorized circuit breaker, and a contactor.

Two feed points on the guideway are approximately located at one quarter and three quarters of the guideway lanes. Although each point is fed by one substation, the power rails are commonly connected throughout. In case of failure of one substation, the other substation can sufficiently supply the system.

The power rails are made by Insul-8; the substation equipment is made by Allis Chalmers and Westinghouse. Special cast-iron shoes are used for their long-wearing properties. Power distribution on the guideway is of three-phase, delta-connected ac.

The substations are located at the shopping center guideway tunnel entrance and at the hotel area. Each substation is housed in a special shed. These substations may be used to supply the shopping center and hotel in case of power shortages in either location. Power for heating the guideway is drawn from the power rails.

4 SYSTEM OPERATIONAL PERFORMANCE

4.1 Operational Characteristics

The Fairlane ACT system has a fleet of two vehicles. Each vehicle has a normal rated capacity of 24 (10 seated and 14 standees), with a crush capacity of 30. The vehicle operates at a maximum speed of 20 mph, though initially this system was designed for a maximum of 30 mph. The observed round-trip time is 5.8 min, which includes two 50-sec dwells and two 123-sec travel times. The operational speed is 9.8 mph, which is calculated from the 5.8 min round-trip time and the distance between the stations. The line capacity for one-vehicle operation is calculated to be 250 passengers/hr with normal loading, and 312 with crush loading in each direction. The observed round-trip time is used for this calculation.

The system has been operating every day since it began on February 28, 1976, except for three days when the shopping center was closed and three days when heavy snow shut down the system. The system is scheduled to operate for 12.5 hours a day.

The ACT system is designed for two modes of operation: on-demand and scheduled. In the on-demand mode, the vehicle remains at the station with the doors closed until service is requested by a passenger. In the scheduled mode, the vehicle shuttles back and forth, remaining at each station with the doors open for a predetermined dwell time before moving. In case of any problems with the automatic operation, the vehicle can be operated manually via a special control panel within the vehicle.

The operation strategy being used is the request mode. This strategy is common for both one-vehicle and two-vehicle operations. The mean headway under one-vehicle operation is the same as the round-trip time: 5.8 minutes; under two-vehicle operation it is 2.9 minutes. Currently, the system operates approximately 93% of the time with two vehicles.

4.2 System Performance

The vehicle miles of travel (VMT) of the system in the first 12 months of operation (February 28, 1976-February 27, 1977) were calculated to be 60,262. This calculation was based on the number of trips made (information given in the weekly operating reports) in the same time period with a trip length, from station to station, of 2,492 ft.* The amount of energy consumed for vehicle operation in the first year of operation was estimated to be 1.0 million-1.2 million kWh. This includes vehicle operation and guideway heating. This estimate is based on the given energy cost and the given unit energy cost of $0.05/kWh. The annual vehicle hours of travel (VHT) in the first 12 months of operation were reported to total 6,239, whereas the total system operation hours in the same time period were reported to be 3,980 hr, indicating that the system was operated with two vehicles 56.8% of the time.

The patronage in the first 12 months of operation was estimated to be 2,434,076 passengers, on the basis of rough observations of daily passenger volumes by the operator. The number of passenger miles of travel per year (1,150,000) was found by multiplying the patronage by the trip length. The average ridership was 19.1 passengers/trip, which was calculated from the reported annual vehicle trips and the annual patronage. The average ridership of 19.1 and the normal capacity of 24 give a load factor of 0.80.

The ACT operations record, which covers the first 12 months of operations, is given in Table 4-1.

4.2.1 System Productivity

Four measures were adopted to describe system productivity: employee-to-vehicle ratio, system man-hour to VHT ratio, vehicle productivity, and labor productivity. The productivity measures of the first year of operations are calculated below. The total number of employees, including one supervisor, is ten. The employee-to-vehicle ratio is 5.0 for a two-vehicle operation and 10.0 for a one-vehicle operation. The employee-to-vehicle ratio with mean number of vehicles operated (1.57) is 6.4. A possible

* Station center to station center distance, excluding some end portions of the guideway.

Table 4-1

ACT SYSTEM OPERATIONS RECORD: FAIRLANE TOWN CENTER

Month	Percentage of Two-Vehicle Operation	Number of Inter-ruptions	Percentage of Downtime	Vehicle Operating Hours	Downtime Hours	Vehicle Trips	Estimated Ridership
March 1976*	63.7	127	3.7	308:53	2:07	10,207	237,689
April	77.0	147	5.4	343:55	18:26	12,516	235,988
May	47.0	116	5.9	357:21	21:01	11,449	199,168
June	75.4	53	3.2	350:40	11:41	13,532	228,237
July	68.3	61	5.0	344:17	17:21	12,139	250,633
August	58.2	107	6.3	313:27	19:36	10,089	216,668
September	37.2	136	7.2	335:46	24:09	8,777	185,222
October	44.4	67	4.5	352:45	15:45	11,377	209,744
November	65.6	56	3.8	325:28	12:22	11,787	216,389
December	60.5	62	12.3	337:54	41:51	10,189	186,432
January 1977†	33.6	53	13.0	294:06	38:14	7,446	131,737
February	56.9	39	6.0	322:00	19:25	8,475	140,329
Cumulative total	58.2	1,028	6.3	3,986:32	250:52	127,983	2,438,276

*Includes February operations data.

†Reduced operation was requested and a blizzard occurred during this period.

interpretation of these rather high values is that the small size of the ACT system does not fully utilize the work hours of all employees.

The system man-hours to VHT ratio is estimated to be 3.2; that is, 3.2 man-hours are needed to operate one vehicle for 1 hour. In calculating this, 20,000 man-hours per year were assumed based on the number of employees (10).

The vehicle productivity, which is expressed by the ratio of annual patronage to annual VHT, was obtained from the operating record. Its value is 390.1.

The labor productivity, which is expressed by the raio of annual place miles of travel to annual total man-hours, is 72.3 (1 hour of labor produces 72.3 place miles of travel).

4.2.2 Comparison of System Specifications and System Performance

The Ford ACT system went through an intensive modification process from the time it opened to the public in March 1976 until the middle of November 1976. The level of effort spent by TSO entailed more than a debugging of the system. The modification process, in TSO staff's opinion, is part of the development process of the Fairlane ACT system. At present, the Fairlane system is upgrading two-vehicle operations and conducting less intensive system modifications. This process is planned to be completed by the end of 1977.

TSO representatives and the system's maintenance and operations staff expressed their satisfaction with the system's performance. Some major performance changes have occurred--namely, the system's 25 mph maximum operating speed in the initial period was reduced to 20 mph when it became apparent after public operations that the system throughput was limited more by station dwell times than by system speed. Furthermore, it was felt that a reduction of speed would reduce the wear-and-tear problems of the mechanical subsystems and increase ride comfort.

The operational performance requirements specified for the system cover operating modes, line capacity, dwell time, travel time, system speed, and system shutdown. The requirement for relevant operational measures and the existing performance levels are compared in Table 4-2.

4.3 System Assurance

4.3.1 General

Ten employees are engaged in operations and maintenance at the Fairlane ACT system. At the time of this assessment, the system was maintained by TSO personnel who are in the process of being transferred into a new entity (Ford's Aerospace and Communications Corporation) for the same function (see Appendix C for details). Many of the on-site personnel have experience with the ACT system since its development stage. As the shopping center complex belongs to the Ford Land Development Corporation, the transition of personnel and maintenance responsibility is expected to be smooth. However, a reduction in the ten-man on-site labor force may be in effect after the reorganization is completed.

The maintenance and operating staff of ten consists of one supervisor, six electronic technicians, and three vehicle mechanics. The supervisor works a standard Monday through Friday day shift. The technicians and mechanics work on two rotating shifts of 7:00 a.m.-3:30 p.m. and 3-00 p.m.-11:00 p.m. to provide seven days full coverage a week. At least two persons are on duty at all times; the normal crew is three.

The operations console does not require continuous monitoring, but an operator must be nearby. If a system malfunction occurs, an audible tone of sufficient loudness to be heard throughout the maintenance area is sounded. One maintenance crew member assumes command of the console and notifies the passengers that assistance is on the way. The remaining two crew members are dispatched to recover the failed vehicles.

4.3.2 Maintenance Strategy

Ford was required to make the system operational and open for public use within a very tight schedule. Therefore, sufficient time was not available for durability testing of the Fairlane system including certain debugging activities that could otherwise be fully conducted. This

Table 4-2

COMPARISON OF ACT SYSTEM SPECIFICATIONS AND SYSTEM PERFORMANCE: FAIRLANE TOWN CENTER

	Specified	Existing
Operating modes	Three modes; automatic, request, and manual	As specified
Line capacity	Two-vehicle automatic mode has a crush line capacity of 676 passengers/hr, with an average dwell time of 50 sec in each direction. System capacity with a single vehicle is one-half the above numbers.	Somewhat lower than this value: 624 with crush-loading; 50 sec dwell time
Dwell time	Variable, the range is from 10 to 70 sec.	The system can be adjusted as specified (nominal 50 sec)
Travel time	At full system speed, travel time is 78 ± 5 sec, including the time from vehicle start to vehicle stop.	Approx. 123 sec due to the reduction of speed (see system speed)
System speed	Vehicle speeds of 0, 15, or 30 mph to be selected by the central operator.	The system now operates at 0, 11, and 20 mph.
Acceleration	With crush-loaded vehicle 0.0175 g (1.57 mph/sec)	1.36 mph/sec
Deceleration (Service)	With crush-loaded vehicle 0.0175 g (1.57 mph/sec)	1.36 mph/sec
(Emergency)	0.25 g (5.49 mph/sec)	4.1 mph/sec
Jerk (acceleration and deceleration)	With crush-loaded vehicle 0.10 g/sec (2.2 mph/sec^2)	2.1 mph/sec^2
System shutdown	System to be capable of restart in a convenient and expeditious manner. In the event the system cannot be restarted, capability must be provided to move both vehicles (without electrical power) to their respective stations and unload all passengers within 15 min	System restarts as specified; movement unpowered (accomplished with gasoline powered tug in the event of power failure)

Source: Fairlane Shuttle System Specification, No. TSO-SE-1010D (1974) situation is not unusual for deploying a prototype system, and it is not peculiar to Fairlane. Certain "wear-in" problems are expected in the initial operating period of any system, and Fairlane has anticipated such problems in their ACT Support Plan.[6]

However, in order to provide service during operating hours, the analyses of subsystems or component problems can only be done during nonoperational hours. Because of this constraint, Ford has only modified or upgraded components to remain operational, but has not analyzed intermittent failures. (Experience with other AGT systems has shown that intermittent failure problems may not be resolved in a short period, such as a year or so, of operation.)*

The first year of operation was therefore a combination of maintaining service, bringing systems up to service goals, and modifying necessary components. This situation is no different from many other AGT sites in their initial period of operation. Having this year of record (1976-1977) as the only presently available record for Fairlane ACT makes it difficult to conduct an assessment in its usual sense, for it does not represent a typical period of normal operations.

The maintenance strategy at Fairlane is based on both preventive and on-line maintenance. The emphasis is on preventive maintenance, which is conducted regularly on a daily, weekly, and monthly basis. The maintenance personnel use a standard checklist for each scheduled maintenance operation, and work is carried out while items on the lists are being checked (see Section 4.3.3).

Daily preventive maintenance can be separated into prepublic service check, with emphasis on system/passenger safety, and systems inspection for engineering subsystem integrity. The daily maintenance list covers four subcategories: electric, hydraulic, guidance, and guideway. Daily maintenance emphasizes items such as signal and power collection, brake assembly, tachometers and electric connections, and switch assembly that may have been fatigued or failed during the accumulation of daily operation.

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*For example, the Satellite Transit System at Seattle-Tacoma International Airport.

Weekly preventive maintenance covers the same four subcategories of daily maintenance, but with deeper and more detailed emphasis. Items such as alignment of all collectors and shoes, propulsion controller, switching cylinders, and motor assembly are covered on weekly maintenance. All counter and meter display readings are done during weekly maintenance. Monthly preventive maintenance calls for yet a more detailed examination, which covers almost three times as many items as the weekly maintenance list.

The two-vehicle operation at Fairlane has made on-line maintenance less critical since the failure of one vehicle would not interrupt service, especially during low demand period. However, the preventive maintenance program has been very effective, as evidenced by the fact that two-vehicle operation increased from an average 58% in March 1976 to 93% in August 1977, as estimated by Ford personnel.

4.3.3 Record Keeping

Records are kept of the system for operations and maintenance. The operation record contains four levels of reports:

- System log
- Daily operations report
- Weekly operations report
- Monthly operations report.

The system log is a running record from the start to the close of operations each day. In it are recorded start-up time, opening time for public service, and shutdown time. The log also records service interruptions, the time at which they occur, some information on the nature of the interruption, and the time the system is restarted. A service interruption is any interruption that causes loss in service. The causes of reported interruptions range from a foreign object in the door path to unauthorized personnel on the guideway.

From the system log the daily operations report is constructed. The information contained in this report is number of service interruptions, total downtime, net operating time, number of vehicle trips, and estimated ridership. This record is kept for two-vehicle operations and for each vehicle. There is also a section for summary information on the nature of the interruption and corrective action taken. This information is then compiled into the weekly and monthly reports.

The weekly report contains such statistics as vehicle operation hours, vehicle trips, ridership, and total downtime. The monthly report contains additional operational statistics calculated on the basis of the weekly report. Information in the monthly report is divided into technical performance data and total systems downtime figures.

The reports are prepared for operational reference. They do not provide failure information. The summary information recorded in daily report is not summarized in the later reports. Except for total system downtime, the failure information source is the system log.

The maintenance records kept have four preventive maintenance records and one failure/maintenance record. They are:

- Daily prepublic safety check record
- Daily system inspection record
- Weekly system inspection record
- Monthly system inspection record
- Separate failure/maintenance record.

The prepublic safety check is performed just before system operational start. An operator is required to check brakes, door safety edges, and communications to ensure that vehicle and station safety devices are operating.

The daily system inspection requires a visual inspection of 22 items in the general subsystem categories of electrical system, hydraulic system, guidance, and guideway. The weekly inspection requires a more extensive inspection of the same subsystem components such as collector shoe alignment and heights and hydraulic system check. Recording switch arm cycles, door cycles, vehicle odometer readings, and hours of CC&Cs use is also performed at this time. The monthly system inspection involves a more intense level of inspection.

The failure/maintenance report is a separate record containing three parts: Part A, General Records, describes the failure or the nature of the failure; Part B, Adjustment, records whether or not corrective action taken was successful. It also records parts, numbers of parts replaced, and the number of hours the repair took to complete; Part C, Engineering, covers the work done on site or by vendor. The report is used to record both preventive maintenance and failure repair. The report is made at the time of each occurrence.

Failures are recorded on an occurrence basis whether they are corrected by on-line maintenance or preventive maintenance. The location, description, and action taken of the failure are recorded. No attempt is made to determine the cause or subsystem origin of the failure on the failure/maintenance report. One of the goals of recording failure is to enable the improvement of the system on this initial operational period.

4.3.4 Failure Characteristics

Intensive modifications were made to the Fairlane ACT system during its initial stage of operation (see shaded areas in Figure 4-1). Therefore, as discussed in Section 4.3.3, the emphasis was to upgrade performance and to perform adjustment rather than to carry out an in-depth failure analysis. The general decreasing trend of failures is shown in Figure 4-1.

Several component failures have been recognized as causes of repeated failures. These failures are power collectors and shoes due partly to the limited space for accommodating them. Wearing of shear pins at the bogies led to false computer alarm. However, by and large, there is no failure analysis in the traditional sense of subsystem reliability and maintainability. In some cases, the failures were induced by the process of testing and modification in the initial period. For example, contacts for the onboard computer frequently failed due to the removal of the computer for accessing to the control cabinet for equipment modifications.

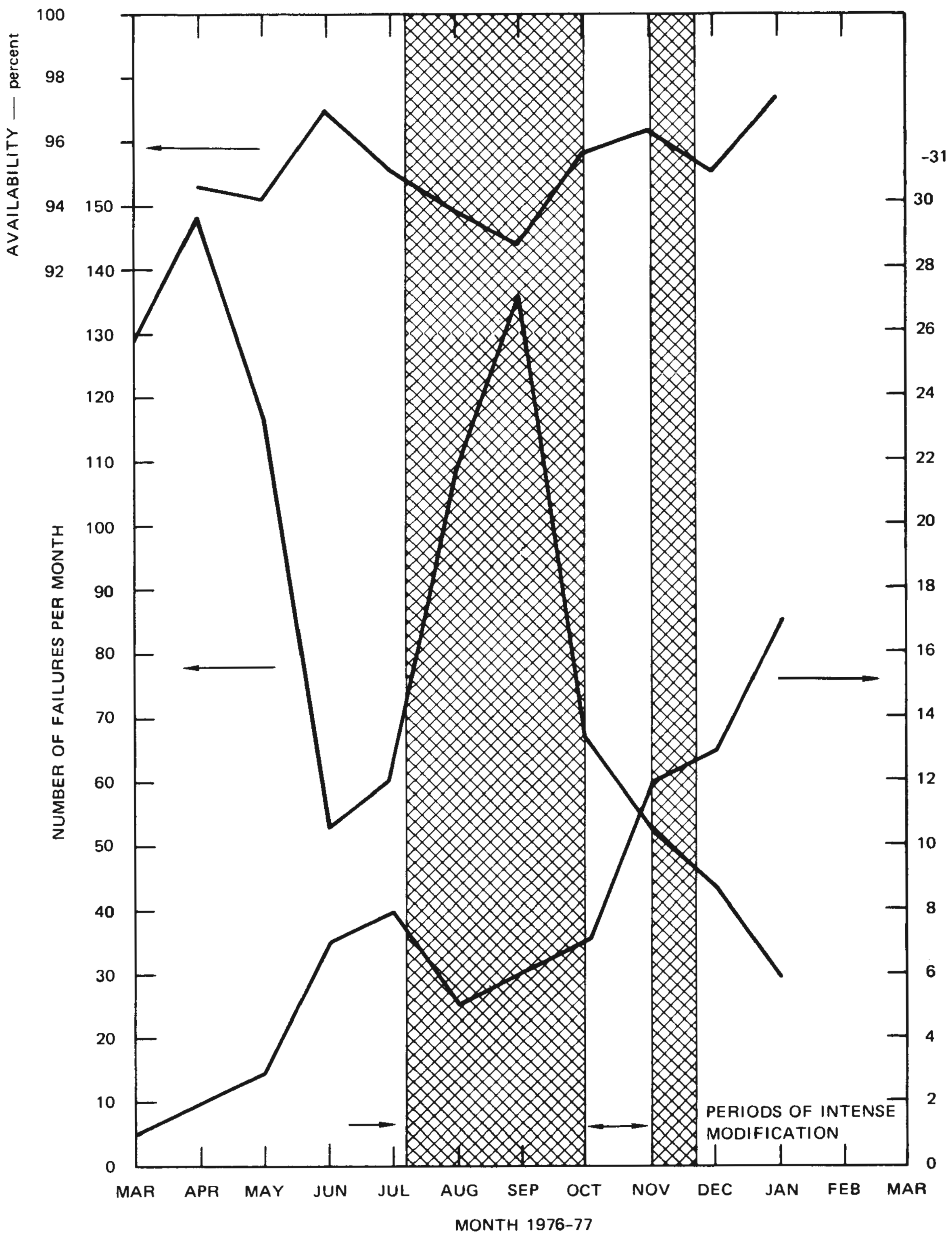

FIGURE 4-1 FAIRLANE SYSTEM OPERATIONAL FAILURES (EXCLUDING ICE AND SNOW)

A failure analysis in its true sense cannot be performed because of the modification process. The reliability measure of MTBF and the maintainability measure of MTTR, which are traditionally used, will not represent the Fairlane system because at the time of assessment it was not in a normal operational phase. Major modifications of failures adopted during this period are more representative of the system's operational experience of the past year and these are provided below.

Modification 1

Problem--Siemens relay contact failed to conduct on occasion even though physically closed (CC&CS failure). This was the cause of most of the failures at one time.

Solution--Raised contact voltage from 5 V, 15 V, and 24 V to 60 V.

Modification 2

Problem--Reed relays occasionally failed to transfer and sometimes welded (CC&CS failure).

Solution--Replaced with solid-state devices designed by Ford.

Modification 3

Problem--Power and signal shoe and rail needed frequent maintenance and adjustment; temperature extremes caused excessive expansion and contraction.

Solution--Redesigned the shoe assembly and cut short segments of the same rail to allow for expansion.

Modification 4

Problem--Connector reliability problem due to frequent component removal for testing during the test and modification phases.

Solution--Replaced connectors. Conclusion of testing resulted in increased reliability.

Modification 5

Problem--Inadequate capacity of vehicle power supplies. In the circuit arrangement, two batteries were directly across the power supply output, which cause batteries to draw current when low.

Solution--Increased the capacity of power supply and corrected the circuit.

Modification 6

Problem--Excessive usage of wayside power substation breakers in the test phase resulted in breaker failure.

Solution--Replaced breakers and added additional contactors.

Modification 7

Problem--Signal noise generated because of the proximity of solid-state command and control equipment to relays and an onboard electric motor.

Solution--Suppressed noise by using capacitors, suppression diodes across relay coils, and improved grounding, and by increasing cable size.

Modification 8

Problem--Signal rail impedance variation due to (1) ice on rail; (2) ice grounding the rail; and (3) use of urea and ethylene glycol for de-icing.

Solution--(1) Used methanol to de-ice rails, (2) replaced insulators that exhibited poor insulation when wet, and (3) redesigned rail jackets in some areas.

Modification 9

Problem--Premature failure of tire carcass and excessive wear.

Solution--Worked with the tire manufacturer and improved tread design and manufacturing technique.

Modification 10

Problem--Mechanical sensors that sensed the position of doors at station malfunctioning, prohibiting vehicle movement.

Solution--Changed the sensor type.

Modification 11

Problem--Air conditioning system noise.

Solution--Replaced the worn bearings and reduced belt tension.

Modification 12

Problem--Design problem with lateral guidance arm.

Solution--Reinforced the arm.

TSO management reports that the mechanical components of the vehicle are relatively failure free, CC&CS problems have been corrected, and the remaining irritant is occasional halts by the onboard computer. Correction of this problem is proceeding.

In retrospect TSO representatives stated that they would have preferred to have more durability testing before placing a system into operation and they would have redesigned some system features, such as the vehicle collector shoe (there are too many collection functions in a small area).

4.3.5 System Availability*

The manner in which the ACT operational records are kept does not lend itself to the traditional measurements of subsystem or component reliability and maintainability, i.e., MTBF and MTTR# Furthermore, the Fairlane system does not have a need at this time for subsystem or component reliability measures. The records identify the service interruptions as opposed to subsystem failures. This is in concert with Fairlane's major goal, to achieve 100% system availability as opposed to subsystem or component reliability. In the failure/maintenance record, where a failure is identified, it cannot always be determined whether the origin of the failure, such as a subsystem or component, was included in the problem. If subsequent analysis proved another component or subsystem was at fault, the original record would remain.

System availability, on the other hand, can be calculated from system uptime and downtime. Table 4-3 illustrates the availability of the ACT since the system began operation in late February 1976. System availability for the 12 months--February 1976 to February 1977--was 0.937 based on 3,986.53 hr of operation.

The rather high availability of the system in the initial stage (as shown also in Figure 4-1) is said to be mainly due to having an operator on board. (The system was operated with an operator on board for the initial six-week period.) The most intensive modification program took place in July, August, September, and November. This situation explains the high failure records during the summer.

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* $$\text{System Availability} = \frac{\text{System uptime}}{\text{System uptime} + \text{System downtime}}$$

\# MTBF = Mean Time Between Failures; MTTR = Mean Time To Restore.

Table 4-3

ACT SYSTEM AVAILABILITY: FAIRLANE TOWN CENTER

Month	Percent System Availability	Total System Uptime	Total System Downtime
March 1976*	0.963	297.45	11.43
April	0.946	325.49	18.43
May	0.941	336.33	21.02
June	0.968	338.99	11.68
July	0.950	326.93	17.35
August	0.937	293.85	19.60
September	0.928	311.62	24.15
October	0.955	377.00	15.75
November	0.962	313.10	12.22
December	0.877	296.05	41.85
January 1977†	0.870	255.87	38.23
February	0.940	302.58	19.42
Total	0.937	3,735.06	250.87

*Includes February operations data.

†Reduced operation was requested and a blizzard occurred during this time.

Note: The availability record for the second year of operation is not complete, but Ford indicated that system availability is expected to be higher than it was in the first year.

4.3.4 Maintenance Facility

The maintenance facility is located at the shopping center end of the system. The facility contains approximately 2,690 ft^2, which includes a maintenance room, a control room, and a storeroom. The maintenance room has a pit that is long enough to accommodate two vehicles.

A gasoline-powered retrieval vehicle is stored in the maintenance room. TSO representatives state that this vehicle was originally planned to retrieve vehicles but in reality is not often used, as manual mode operation of the vehicles results in a shorter recovery time. The maintenance facility is fully equipped to perform maintenance and modification work.

4.3.5 Training

The ACT representatives state that all the maintenance technicians must go through a training program that covers the theory and practice of wayside control, onboard controller, mechanical system, power collector, door, and guideway. The duration of the training is about 10 or 11 weeks, including 4 or 5 weeks of classroom sessions given by Ford engineers.

4.3.6 Comparison of Achieved System Assurance with System Specifications and Employees' Assessment

The availability and maintainability of the system as specified by the TSO of Ford Motor Company are shown in Table 4-4.

The TSO management reported that the system has already met the performance level required in the system specifications. However, because the system has been in the modification process up to now, it was not possible to assess the system performance in a strict sense. What was learned instead was the level of effort spent during the test and modification process and the length of time needed to bring an advanced prototype system to an operationally acceptable state.

A less intensive modification process is planned to be completed by the end of 1977. The TSO staff's goal is to attain a system availability of 0.998 by that time.

Table 4-4

SPECIFIED AVAILABILITY AND MAINTAINABILITY
OF THE ACT SYSTEM: FAIRLANE TOWN CENTER

	Availability (%)	Average Outage/Month† (hr)
Availability*		
One-half capacity (1 vehicle)	99.7	1.2
Full capacity (2 vehicles)	99.3	2.7
	Mean Time to Restore‡ (hr)	95 Percentile‡ (hr)
Maintainability‡		
Electronic component	0.5	1.5
Mechanical component	2.0	4.0

*The numbers shown will apply when averaged over a sufficient time to be statistically significant. Individual months can be of greater or lesser value.

†Based on 720 hr of operation.

‡These times do not include retrieval of the vehicle or travel time required in addition to the basic repair time.

4.4 Human Interface

4.4.1 General

The shopping center terminal is centrally located in the enclosed mall, so access time could range from zero to several minutes, depending on the shop the passenger is coming from or going to.

With two vehicles in operation (typically Thursday through Sunday) the mean wait time is 1.5 min. With one vehicle in operation, usually at the beginning of the week if preventive maintenance on one of the vehicles is indicated, mean wait time is a little less than 3 min.

Line-haul travel time is about 123 sec, including the time required for door closing. The vehicle does not travel excessively fast, but some teenagers and young adults have indicated they would prefer to have the vehicle move faster.

Little information on using the ACT system is provided for the passenger; however, little is needed because the system is so easy to use. A sign on the window of each station says "Automatically Controlled Transportation" to the hotel or to Fairlane Town Center and gives the hours of service. At the shopping center, one of the two doors has a sign for exiting passengers only, although many passengers, including the system operators (due to the short access route from the maintenance facility), enter from that side. At the hotel, a sign states the policy of priority access for hotel guests.

4.4.2 Communications from Passenger to System

Passengers can affect the operation of the system in three ways. A button to the right of the doors can be pushed to indicate that service is requested. When the button is pushed, it lights up, like an elevator button; however, it does not do anything except light an indicator on the operator's console when the system is in automatic mode, as it usually is. In the rare event that the system is switched to demand activated, usually as a test by one of the system operators, it is necessary to request service to keep the system operating. If this mode of operation is selected during the day, enough service requests are usually made to keep the system operating continuously.

Two "door open" buttons are located in the vehicle, each 35 in. above the floor. The doors may be kept open by pressing the button or by holding them, like an elevator.

A "call operator" button located on both sides of the vehicle 31 in. above the floor triggers an alarm (call request) on the console and in the entire maintenance shop (so an operator will know that there is a problem even while the console is unattended). The operator then activates the microphone in the vehicle so he can hear what is being said and, when necessary, can speak to passengers in the vehicle through the console microphone. Almost all the operator calls are false alarms, so the operators plan to change the sign near the button indicating that it is for emergency use only.

4.5 Comfort and Convenience

4.5.1 Comfort

A number of passengers interviewed informally remarked that, overall, the system was comfortable. With its current top speed of 20 mph, the system has good ride quality, although some of the older passengers are a bit apprehensive about the sharp turns near the entrances to the two terminals. Some of the younger passengers, in fact, would like to see the system operate considerably faster. When initially opened, the system operated for about 11 months with a maximum speed of 25 mph, but this speed was reduced to increase ride quality and reliability. Several passengers remarked about the smooth ride quality and deceleration.

The seats are comfortable. They are individual (not bench type), soft, contoured seats, 19 in. to 20 in. wide, 17 in. above the floor, and with backs 17.5 in. high. Three seats face in the direction of travel and three face backwards. The remaining four seats have access to grab-rails and are transverse to the direction of motion. The seats are staggered so no passenger sits directly opposite another.

Temperature inside the vehicle is comfortable even when it is cold outside. Air circulation and lighting levels are good.

The average load is more than ten, so usually some of the passengers must stand; typically all the seats are filled. During the weekday lunch hours, when the car becomes fully loaded with 25 to 30 passengers, additional riders frequently wait for the next vehicle. With two vehicles in service, passengers do not mind the additional wait because, although the next vehicle is not always visible, they know that as soon as one vehicle leaves a station, the other vehicle is heading for their station. On Saturdays and Sundays, demand for use of the ACT is so high that attendants from the shopping center and from the hotel have been present to ensure that the passengers wait in an orderly line within the ropes that are in place during those periods. Hotel guests may wait on a separate queue at the hotel station and are given priority use of the system from the hotel station only. For these reasons, some of the passengers interviewed would prefer to have a larger vehicle on the system during the peak hours.

The noisiest components of the trip are the air conditioner and the conversations of other passengers in the vehicle. Although announcements can be made in either vehicle or either station, they occur infrequently and are usually made only in response to a "call operator" button request. The noise levels are typically 72 to 76 dBA inside the vehicle.*

4.5.2 Convenience

Ford's ACT is essentially a horizontal elevator operating in a continuous shuttle service. It can be placed into a demand mode by throwing a single switch on the operator's console, which makes it truly a horizontal elevator, used in exactly the same way as a vertical elevator. It can accommodate baby strollers, baggage, and packages without problem.

Ford ACT cars are accessible to handicapped individuals. The vehicle is within 3/8 in. of the station, at exactly the same level, thus eliminating any steps or barriers. Wheelchairs, crutches, and seeing-eye dogs can be fully accommodated. When a wheelchair is brought onto the car, it restricts access to one of the ten seats.

The shopping center terminal is located right at the center of the building. With the facility for exiting from either side of the vehicle at that station, it is extremely convenient for shoppers and employees at the center. The hotel station is located one floor above the lobby, directly above the pedestrian and motor vehicle entrance.

ACT is in operation from 9:30 a.m. to 10:00 p.m. Monday through Saturday, and noon to 5:30 p.m. Sundays. It stays open one-half hour after stores in the shopping center have closed. The proprietors of movie theaters, lounges, and bars in the Fairlane Town Center would like to

* Measured by SRI team using a Noise Meter.

have ACT operate until 2:00 a.m., but this wish has not been fulfilled because it would require operations to be expanded from two to three shifts.

4.5.3 Appearance and Cleanliness

The ACT system is a major drawing card of the Fairlane Town Center. Many local residents bring their out-of-town visitors to Fairlane so they can ride on the system. The guideway and vehicle are an integral part of the hotel and center, having been designed and built simultaneously. The graphics are clear, attractive, and easy to read. The consistency of typefaces and logo with that of the Fairlane Town Center provides an easily followed visual identity for a total system.

The use of dark window glass in the vehicles provides privacy for passengers from the exterior, and yet the large window area allows excellent visibility from the interior and gives a feeling of openness from within the vehicle. The vinyl and plastic materials used on interior surfaces provide good durability and an attractive, colorful effect that is consistent with that of the exterior.

The scale of the guideway and vertical supports is unobtrusive and blends in with the surrounding structural environment.

The vehicles, guideway, and station areas are well maintained. Occasionally papers or litter are left in the vehicles and may not be cleaned until the end of the day. The glass paneling in the stations is cleaned only once every two weeks. Between washings, some dirt and grime accumulate on the windows, but overall the stations have an appearance of cleanliness.

4.6 Safety and Security

4.6.1 System Safety Philosophy

The safety philosophy at Fairlane can be categorized in terms of how it relates to operations, safety procedures, and safety-related equipment checks. All three aspects are much in evidence.

The operating safety philosophy at Fairlane is to rely primarily on the automatic control safety features to the maximum extent possible. The philosophy has evolved because the control system has caused no accidents during the period of operation, while there has been damage to lobby screens due to operator failure to retract switch arms when the vehicles are operated in the manual mode.

Safety procedures are well established for all aspects of operation, from morning start-up to placing maintenance personnel on the guideway. Signs are much in evidence and well placed, with lights to show when the power rail is energized. Two safety bumpers, one at each end of the guideway, are used for additional overshoot protection. The safety bumper at the shopping center must be removed to allow vehicles to enter the maintenance area. When this bumper is removed, an electrical interlock turns off guideway power, preventing vehicle movement. The central control operates five cameras. Two cameras used to monitor any point on the guideway, one camera monitors the hotel station, and two cameras provide coverage of the shopping center's station boarding and exit areas.

Regular (daily) safety checks are made to ensure that equipment is operating properly. Such things as sensitive edges on doors and car communication equipment are checked daily. The guideway contains marks for checking braking rates of the vehicles.

In short, the safety philosophy is to maintain a high level of safety primarily through reliance on equipment, with regular checks to ensure proper operation.

4.6.2 Emergency Stops

Four injuries have resulted from three emergency stops in one year of operation. The injuries have been to a chest, wrist, elbow, and leg as the passenger in each incident was pushed forward when the vehicle made the emergency stop. A stroller inside the vehicle was destroyed during one of the emergency stops. Two of the emergency stops were caused due to random errors in information transmission and one was caused by a mechanical problem in the differential gear of the vehicle.

4.6.3 Emergency Evacuation

If a vehicle becomes disabled outside a station and the damage cannot be repaired quickly, the vehicle will be pushed or towed to the station by the internal-combustion engine tractor available in the maintenance shop for this purpose. Passengers can then leave the vehicle at the station in the normal manner. Meanwhile, if another vehicle is in service and not disabled, it can proceed to its intended station under manual control by one of the maintenance personnel, and the passengers can be discharged in the normal fashion. Recovery time is typically 6 to 8 min. (If both vehicles have entered the bypass prior to the failure, the nondisabled vehicle will normally proceed automatically to its destination and unload its passengers prior to recovery.)

In the unlikely event that both the ACT vehicles and the tug are inoperative, it is possible to evacuate passengers along the guideway. Guideway power is automatically shut off when the emergency exits are opened, and the passengers will be evacuated through either of the end canopy windows and escorted along the guideway to a station. This procedure was never required in the system's first year of operation.

There have been no fires on the system, except for one minor act of vandalism at the beginning of system operation. No power blackouts, serious crime, or medical emergencies have occurred.

4.6.4 Passenger Perception

Only one of the passengers interviewed was apprehensive about an automated vehicle, but he did not really fear a collision with the other vehicle or an object on the guideway. However, at the moment just before the vehicles switch onto the passing tracks, as they are approaching each other, some passengers are slightly apprehensive. Some passengers are afraid of heights and are uneasy about the elevation of the guideway surface above the parking lot.*

Overall, the vast majority of the passengers enjoy the system, like to ride it, and feel safe when doing so. Some of the passengers inquired as to whether the system was actually automated.

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* About 25 ft above ground level.

4.6.5 Security

There have been very few acts of vandalism on the system (the most serious was the theft of two walkie-talkies) despite the fact that there have been several acts of vandalism and thefts in the parking lots at the Fairlane Town Center.

There are no regular police patrols of the ACT although the stations and the guideway including the vehicles are under television surveillance. Both Town Center and Dearborn police are available on call if needed.

Police are not visible and the television cameras are not obvious. Even if the cameras are observed, the passengers do not know that each image is displayed separately in the system's control room. Therefore, the feeling of security that most passengers seem to have must be due to the large number of other passengers present in the vehicles and at the stations. The system is hardly ever vacant, except occasionally shortly after opening or before closing. Even at these times each vehicle is highly visible, never more than two minutes from a station, and has two "call operator" buttons. If the troubled passenger cannot speak into the microphone after pushing the button, the system operator can still listen in on the conversation or other activity taking place in the car and dispatch aid as necessary.

4.7 Public Attitude Survey

4.7.1 Introduction

The comments in the above sections were based on observations and interviews, at random, with a small number of passengers. To ascertain more clearly the public perception of an AGT system a public attitude survey was undertaken at the Ford Fairlane Town Center.* AGT riders and nonriders were interviewed, so that the reasons for using or not using

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*Authorized by the Office of Management and Budget, No. 04-S77011. Approved questionnaire is attached as Appendix E.

the system might be solicited. The riders' perception of comfort, ride quality, convenience, safety and security, appearance, and information was analyzed, based on 70 questions asked. A number of socioeconomic identifiers were also obtained from those interviewed.

The survey was conducted over a four-day period in May 1977 during system operating hours. Individuals interviewed were selected randomly at points about 100 ft removed from the stations at both ends of the guideway. Over 400 individuals agreed to be interviewed and over 60% had been a passenger on the AGT.

4.7.2 Reasons for Using or Not Using AGT

Those who had not been a passenger on AGT were presented with a number of possible reasons for not using the system. Seventy-five percent of the nonriders said that they had no particular reason for making the trip. Among those who make the trip by car, on foot, or by bicycle and do not use the AGT, 40% stated that they anticipated a long wait to ride the AGT and therefore did not use it.

Of the riders interviewed, 52% had taken the trip four or more times and the rest were taking the trip to try out the system. When asked about paying a hypothetical 25¢ fare, those who were taking the trip because they had some desired destination rather than just to ride AGT were more willing to pay the fare.

4.7.3 Using AGT

To assess comfort, ride quality, convenience, safety and security, appearance, and information, a number of issues in each category were put forth to the riders.

In the comfort category, 95% said that the vehicle temperature was comfortable, 99% said that the lighting inside the vehicle was adequate, and 52% said that the stations were crowded. Thus, it would appear that the only comfort problem relates to crowding.

The answers to ride quality questions were most favorable--97% said that the ride was quiet, 98% said that the ride was not bumpy, 98% said that the ride did not have objectionable sudden stops and starts, and 92% said that the vehicle did not sway much from side to side.

The convenience of the system was not rated as highly as the ride quality. Twenty-seven percent said that they had to wait too long for AGT. When asked about space in the vehicle for carry-on items, a number of individuals could not answer, but of those who did, 55% said that space was inadequate. Again, long wait times, need for more space in the vehicles, and crowding at stations paint a picture of queues exceeding vehicle capacity, which was observed during peak hours. Responses about the convenience associated with the vehicle layout and boarding areas were quite favorable.

Questions about the vehicle size and directions for seating were also asked. Passengers can sit in any of the four directions on the Fairlane vehicle. Fifty-five percent of those interviewed had no preference about seating direction, and 35% preferred facing to the front. A number of individuals stated that, because of crowds, it was often impossible to get a seat in any direction. Fifty-four percent of those interviewed said that the vehicle was too small, and this answer correlated strongly with comments about crowding.

Ninety-eight percent of all of the riders interviewed said that the speed of the vehicle was not too fast or too slow, but among the small subpopulation who use public transit, there was a tendency to feel that the vehicle was too slow. Several other safety and security issues were addressed. Ninety-seven percent of the riders said that the doors had never closed on them. Only 2% expressed any unsafe feeling during the day in the station or vehicle.

Among the riders who have tried AGT but no longer use it, 50% said they would feel more secure with police located at various places in the system. They also expressed a much stronger feeling that there should be an attendant on board than those who continue to ride AGT. The need for police and/or attendants was particularly expressed by women in the sample, including those who continue to ride AGT.

Among all riders, 43% also expressed the need for a closed circuit television monitor in the vehicle. Many passengers are not aware of the camera which monitors the guideway and can be zoomed to take a closer look at the vehicle.

As far as an explanation for these views, the data did not support any hypothesis about system safety or fear of crime, but rather a matter of controlling rowdy passengers.

The appearance of the system was generally rated favorably. Ninety-nine percent of the riders said that the vehicle and station areas were clean and well maintained, ninety-six percent said that they liked the architecture of the stations, and 93% said that the vehicle interior was attractive. While ratings were high, there was some diversity according to age. Riders under 30 tended to respond less favorably to questions about appearance.

Riders and nonriders were asked about their preference for elevated guideways. Seventy-two percent said that they liked the AGT guideway as it was, elevated; 11% said that they would prefer it at ground level; 2% would prefer underground, and 11% had no preference. The answers to this question were correlated with public transit use of the individual and further with ridership--those who continue to use AGT at Fairlane had the highest preference for an elevated guideway.

Few instructions are given about using the AGT at Fairlane, and 32% of the riders said that the information was inadequate. This points to a definite problem with respect to instructions for system use.

4.7.4 Overall Impression of AGT

Riders were asked about their overall impression of the AGT transportation system. Their answers were:

47%	Excellent
42	Good
7	Satisfactory
3	Poor
1	Totally unacceptable
100%	

Since a number of questions were asked about each of the categories (comfort, ride quality, convenience, safety and security, appearance, and information), an overall rating for each aspect of the system was derived, using all of the questions. The proportion of answers in each category that were favorable were used to rate the six aspects of the system. The percentage of respondance that selected these attributes were as follows:

Ride quality	96%
Appearance	94%
Safety and security	92%
Convenience	88%
Comfort	85%
Information	74%

Ride quality had the highest proportion of favorable answers, information the least. The proportion of favorable answers for each of the six categories correlated with the overall system rating of excellent to totally unacceptable. This indicates that each category plays a role in one's overall impression of the system.

Riders were also asked to select two of the six categories that were the most important to them. They were cited in this order:

Convenience (most important)
Safety and security
Comfort
Ride quality
Appearance
Information (least important).

Comfort was most frequently mentioned and information was mentioned the least. Note that convenience, while most frequently mentioned as important, did not receive one of the better ratings. Information, while not rated well, was not considered by a majority to be important either.

4.7.5 Characteristics of the Sample

Only 14% of the riders regularly (at least twice a week) use some public transit modes or paratransit instead of or in addition to a car. Eighty-four percent use a car only for transportation, and 2% use neither a car nor other modes. In this survey, opinions about AGT did correlate with public transit use. The overall system rating was dependent on public transit use, preference about guideways, and opinions about desirable speeds.

Income for this sample was higher than U.S. average:

3%	less than $ 5,000
5%	$ 5,000 - $ 9,999
35%	$10,000 - $19,999
33%	$20,000 - $29,999
18%	$30,000 - $50,000
6%	more than $50,000.

There were no questions or category of questions the answers to which had a statistically significant relationship to income. Since this was one of the more sensitive questions asked, it might be suggested that this question be eliminated from further attitude surveys.

In the sample, 53% were female and 47% male. The only opinion which was sex-related was the previously mentioned opinion about safety and security. While no other opinions in the survey were correlates, this is a rather important one.

The age distribution of the sample was as follows:

15%	10-19
24%	20-29
22%	30-39
14%	40-49
17%	50-59
8%	60 and above

The overall system rating was age dependent as was the selection of the two most important factors out of the six categories. Additionally, the previously mentioned opinions about the AGT appearance was correlated with age.

5 SYSTEM ECONOMICS

In this section Fairlane ACT system costs, which include capital cost estimated both in actual year and in 1976 dollars and annual operating and maintenance costs (O&M) for 1976, are presented. Total equivalent annual costs--capital plus O&M--are computed for appropriate service lives and discount rate. Average unit costs of service are computed for vehicle miles, passenger trips, passenger miles, and capacity miles, or "place miles," for seated and standing passengers. Methods of analysis are discussed in Appendix B, Historical cost data, analyses conducted to fill data gaps, and results are discussed below.

5.1 Capital Cost

The ACT system at Fairlane Town Center was designed and manufactured by Ford's TSO. Construction of the guideway and stations was performed by contractors under the management of Ford Motor Company Construction Division. One station is in a shopping mall that was constructed with space to allow penetration of the guideway into the building and to accommodate the station, control room, office, maintenance shop, and storage. The second station is at a hotel and was built as an integral part of the building.

5.1.1 Estimates of Capital Cost

The estimated capital cost of the ACT system was given by a former executive of TSO to be about $5.5 million total (± 10%). Supporting details for the estimate are in storage and cannot be recovered without excessive effort.

The total cost of $5.5 million reportedly excludes the nonrecurring cost of developing the basic system. It includes site-specific adaptation costs which are likely to be incurred in one or the other form at other sites as well. Thus the costs reported are said to be the best estimates of "recurring" cost. The Ford spokesman acknowledged, however, that separation of recurring cost from development costs for the first installation is a difficult problem.

The system cost used in this report was estimated by the research team based on information from the following sources:

- Construction drawings of the Fairlane ACT System.
- Information on construction method.
- Rough estimates of capital costs by TSO executive.
- Cost estimates for a similar ACT system at Bradley International Airport, Hartford, Connecticut, captured from the management of that system.
- Information on guideway costs supplied by ABAM Engineers, Inc.

Two breakdowns of estimated capital expenditures for the ACT system are shown in Table 5-1, which compares the research staff estimate and the Ford-supplied data. All costs are in 1974 dollars. While differing in detail, the research staff estimate of total capital cost is well within the ± 10% accuracy limit attributed to the Ford-supplied cost estimate. The research team estimate of capital costs is used as the basis for computing the equivalent annual cost of capital and unit cost of service shown later in this section.

Right-of-way cost was estimated by the allocation method at $20,000 on the basis of $22,000 per acre and 0.9 acres. However, most of the area beneath the guideway is useable for parking and other functions. Thus, the marginal cost of land is much smaller than the allocated cost. For this reason right-of-way cost is zero.

Cost of construction engineering, architecture, and administration is estimated by the study team based on 15% of total construction cost. Guideway cost, including installation of power rails# was estimated as follows:*

Single guideway, prestressed concrete:	1430 ft x $594 =	$849,420
Transition Guideway sections near bypass:	4450 sq ft x $50 =	222,500
Double guideway, prestressed concrete:	500 ft x2x$594 =	594,000
Single Guideway, steel/concrete:	220 ft x $380 =	83,600
Total		$1,749,520 (≃ $1.75 million)

* Costs per ft or per square ft of different types of guideways was estimated using the data provided by TSO.

Excludes hardware.

Table 5-1

ESTIMATED CAPITAL EXPENDITURES FOR THE ACT SYSTEM:
FAIRLANE TOWN CENTER

	Research Team Estimate (millions of dollars)	Ford-Supplied Data (millions of dollars)
Construction		
Right-of-way	Zero	N.A.
Engineering, architecture, and administration	0.33*	N.A.
Guideway	1.75*	N.A.
Stations	0.35*	N.A.
Maintenance shop	0.10*	N.A.
	\$2.53	\$3.60
Hardware		
Engineering and administration	0.60*	N.A.
Vehicles (2)	0.60†	0.60
Command, control and communication	0.60†	0.60
Power and miscellaneous	0.79†	0.70
	\$2.59	\$1.90
Total capital cost	\$5.12	\$5.50 ± 10%

*SRI estimate, using allocation method.

†Ford TSO estimate.

Cost of the station at the shopping center was estimated at \$180,000 and includes access space for the guideway from the exterior face of building to the boarding area. Cost of the station at the hotel was estimated at \$170,000 and includes the portion of guideway paralleling the station. These costs have been obtained by using unit construction costs of \$33/ft^2 for unfinished areas, \$50/ft^2 for completely finished areas at the shopping center, and \$60/ft^2 at the hotel.

Cost of hardware engineering and administration is related to the design and implementation of the hardware and has been assumed in the same order of magnitude as that quoted for the ACT system at Bradley International Airport.

Vehicle cost was furnished by senior staff members at TSO and is assumed to include some testing and engineering costs at the site.

Command, control, and communications cost is an estimate provided by TSO staff. The total cost of $600,000 averages to $1.0 million per mile. This compares with values ranging from $0.6 million to $1.0 million per mile for other automated systems and appears reasonable.

The cost of power supplied and miscellaneous hardware is an SRI estimate based on information provided by TSO staff. It includes hardware for guideway power rails, two power substations, power distribution, and probably miscellaneous equipment for testing and maintenance of the system.

5.2 Operations and Maintenance Costs

TSO furnished O&M costs without substantiating details. The costs for 1976 are given in Table 5-2.

Table 5-2

ESTIMATED OPERATIONS AND MAINTENANCE COSTS FOR THE ACT SYSTEM: FAIRLANE TOWN CENTER

	Cost (1976 dollars)
Operations	
Labor (included below)	
Electricity @ 0.05/kWh	$55,000 ± 5,000
General and administration	--
Maintenance	
Labor (10 people)	300,000
Material	40,000
Total	$395,000 ± 5,000

The system is operated and maintained by a three-man crew at any given time, and it takes two crews to operate the system for a whole day. Thus six people are required to operate this system for a day. If one adds vacation, sick leave, and supervisory manpower to this figure, the total number of employees required becomes 10.

High wearout items include the foam-filled traction tires with a service life on the order of 17,000-20,000 miles, and collector shoes (16 per car) with an average service life on the order of 1.5 months. The study team was unable to obtain cost information for spare parts beyond the lump sum estimate.

Ford personnel indicated that the electricity cost estimate of $55,000 was based on a rate of about $0.05/kWh for peak demand and total energy consumption. Ford indicated that, based on summer consumption, about $15,000 of this cost was consumed by vehicle operation and maintenance facility consumption.* The balance of electricity cost, about $40,000, or about 800,000 kWh, was used for guideway heating in 1976.

No estimates of general and maintenance expenses are available.

5.2.1 Unit Costs of Operations and Maintenance

The system started operation in 1976. Consequently, O&M costs were not obtained for the full year. The cost figures used here are estimates given by the TSO representatives for "normal" operating conditions after shakedown--when modifications are not required.

The unit O&M cost measures for 1976 are estimated as follows:

Operations and maintenance per vehicle miles of travel (VMT)	$6.55
Operations and maintenance per passenger miles of travel (PMT)	0.34
Operations and maintenance per passenger	0.16

*Although the Ford vehicles have regenerative braking, no credit is given for power returned to the system.

Operations and maintenance per capacity miles of travel (CMT)	\$0.27.

These figures represent operations and maintenance cost performance for a small-scale installation. Although an exact estimate is not possible, the operations and maintenance cost performance is likely to improve with increases in scale. For example, a total of ten people are employed at Fairlane to maintain and operate two vehicles and a half-mile of route. A small increase in the number of employees might be sufficient to maintain and operate a much larger fleet and a longer route or several shuttles at a single site.

5.3 Escalation

The estimated construction and hardware costs are separately escalated to 1976 dollars by using indexes adopted for all sites studied (see Appendix B). The resultant costs in 1976 dollars are \$3,115,000 for hardware and \$2,992,000 for construction. The total capital cost in 1976 dollars is \$6,107,000.

5.4 Equivalent Annual Cost

The equivalent annual cost of capital was computer based on the formula shown in Appendix B. A 10% discount rate was employed.

The service life of AGT components depends on many factors and must be estimated by planners for each new site. To achieve comparability among systems we have employed the same basic service lives for all sites: 15 years for hardware and 35 years for construction. We have also made calculations for optimistic service lives--20 years for hardware and 50 years for construction--to illustrate sensitivity of equivalent annual costs to service life estimates.

Equivalent annual costs or capital for two service life assumptions are given in Table 5-3.

Table 5-3

ACT SYSTEM EQUIVALENT ANNUAL COSTS OF CAPITAL:
FAIRLANE TOWN CENTER

	Service Life (Years)		Equivalent Annual Cost of Capital (1976 dollars)
	Hardware	Construction	
Basic estimate	15	35	$719,800
Optimistic estimate	20	50	667,600

5.4.1 Total Equivalent Annual Cost

The total equivalent annual cost of capital and operations and maintenance, for the basic service life assumption and in 1976 dollars, is given as the sum of the equivalent annual cost of capital and the cost of operations and maintenance. Thus, total equivalent annual cost is $1,114,800 in 1976 dollars, based on operating experience after the shakedown period.

5.5 Unit Cost of Service

The unit costs of service, which include capital and operations and maintenance costs, are given below:

Unit cost per VMT	=	$18.50
Unit cost per PMT	=	0.97
Unit cost per Passenger	=	0.46
Unit cost per CMT	=	0.77.

Uncertainties regarding the inputs used in these estimates suggest that the results should be used with caution.

5.6 Recapitulation

The inputs and results of the economic analysis are given in Tables 5-4 and 5-5. Table 5-4 shows the major cost data in 1976 dollars and the equivalent annual cost of capital. Table 5-5 shows the unit cost of service.

Table 5-4

ACT SYSTEM CAPITAL, OPERATIONS AND MAINTENANCE COSTS:
FAIRLANE TOWN CENTER
(1976 dollars)

	Capital Cost (Actual Year)	Escalated Capital Cost	Equivalent Annual Cost	Annual Operations and Maintenance Cost	Total Annual Cost
Construction cost	$2,530,000[*]	$2,992,000	$310,200	N.A.	
Hardware cost	2,590,000[†]	3,115,000	409,600	N.A.	$1,114,800
Operations and maintenance cost	N.A.	N.A.	N.A.	395,000	

N.A. = Not applicable

[*] In 1974 dollars. Station costs were estimated by SRI based on allocation method.

[†] In 1974 dollars. Estimated by SRI based on Ford supplied data.

Table 5-5

ACT SYSTEM UNIT COST OF SERVICE:
FAIRLANE TOWN CENTER
(1976 dollars)

	Per VMT*	Per PMT†	Per Pass.‡	Per CMT§
Operations and maintenance cost	$6.55	$0.34	$0.16	$0.27
Equivalent annual hardware cost	6.80	0.36	0.17	0.28
Equivalent annual construction cost	5.15	0.27	0.13	0.21
Total equivalent** annual cost	18.50	0.97	0.46	0.77

*VNT = Vehicle miles of travel.

†PMT = Passenger miles of travel.

‡Pass. = Passenger.

§CMT = Place miles of travel or unit capacity miles of travel.

**Total equivalent annual cost does not necessarily equal the sum of the three items above because of rounding off.

6 SYSTEM DEVELOPMENT PROCESS

6.1 Role of AGT

The AGT system at Fairlane Town Center in Dearborn, Michigan, is a shuttle with midroute bypass to allow simultaneous operation of two vehicles. The route is elevated, is about 2,600 ft long, and links a large shopping mall with an 800-room hotel.

No fare is charged, and the AGT service is not essential to the functions of either the hotel or the shopping mall. However, it has commercial value to both. The substantial patronage experienced since the system began operations suggests that its novelty and visual appeal attract additional people to the center. Also, a number of the people who come primarily as hotel guests, shoppers, or employees use the AGT system to visit the other facility and make purchases while there. For example, it is said that revenues in the hotel restaurants drop appreciably if the AGT system goes out of service at lunchtime. It is also said that some people bound for the mall prefer to park near the hotel and use the AGT system. However, the value of any profits and benefits attributable to the AGT system appear small in comparison with the capital and operating costs of the system.

Undoubtedly, one purpose of the installation was to demonstrate Ford's AGT system to prospective buyers. However, the explanation for the construction and operation of the system and for curtailment of plans for a larger system are related to past programs and program changes of the Ford Motor Company and the Ford Land Development Corporation.

6.2 History and Initiation

The Ford Land Development Corporation owns the Fairlane Town Center site, which includes 2,360 acres surrounding the Ford Motor Company World Headquarters. The center is said to be the largest parcel of urban land in the United States owned by a single company. The entire area will be developed according to a long-term comprehensive plan. Early construction, which began in 1970, included two 15-story office buildings, the 800-room hotel, and the first stage of the shopping mall. The structures occupy only a small fraction of the site, and the entire development program will require many years.

The Ford Land Development Corporation owns the hotel building and shares ownership of the shopping mall with a land development group that includes Taubman Company, and others. Certain major buildings in the mall are owned by their occupants. Details regarding other buildings and plans for future construction were not found.

Early plans for the development of the center called for the construction of an extensive network of AGT routes. Total length would have been either 4 or 9 miles according to accounts by Ford executives. Originally the one half-mile route now in place was regarded as the first stage of the larger network. However, Ford has withdrawn from the AGT business, so it is now expected that no additions will be made to the existing route.

Impetus for the use of an AGT system at Fairlane Town Center came from Ford Motor Company and was related to an ongoing development program that is described below under Planning and Design. The Fairlane AGT project was initiated in 1973 under a contract for the installation and operation of the AGT system by Ford. However, in an economy campaign during 1974, Ford considered eliminating the project. Participants in the land development project opposed the cancellations of the AGT project because availability of AGT had been emphasized in promoting the mall to tenants, in the design of the buildings, and in the placement of the mall and hotel on the site. Consideration was then given to reuse of the Transpo '72 cars at Fairlane. That was not done because it was found that building two new cars for Fairlane similar to the two cars Ford was committed to build for the Bradley International Airport installation would be less costly. In the end, the installation was made according to the first stage of the initial plan. A chronology of events is included in Appendix C; a list of major participants is given in Appendix D.

6.3 Planning and Design

The Ford Motor Company's AGT program was an outgrowth of a broader program initiated in 1968 when a unit called the Transportation Research and Planning Office was created. That group had a "futures" orientation and a broad charter to look for important changes in the transportation of goods and people, including changes that would generate new opportunities for the company. The group tended to specialize in urban public transportation and made studies of dial-a-ride, dual mode, and AGT systems.

In 1971, the staff groups joined forces with a Ford line organization to build a vehicle chassis and a short guideway at Allen Park, Michigan, for test purposes. Later that year, the company responded to UMTA's invitation and entered competition to demonstrate an AGT system at Transpo '72. In May 1971, Ford was selected as one of four firms to demonstrate AGT systems. Responsibility at Ford was assigned to a new Special Purpose Vehicle Unit. The $1.5 million budget under the UMTA contract was matched by an equal amount from corporate funds. The system was designed and installed on an extremely tight schedule. It was successfully demonstrated at Transpo '72 in May 1972 where it transported 25,000 people during ten days. It was further tested under an UMTA-designed program later that year.

Market studies made by Ford in the spring of 1972 were encouraging, and at Transpo '72, Henry Ford II announced Ford Motor Company's entry into the AGT business as a supplier. In September 1972, responsibility for AGT work was assigned to a new Transportation Systems Operations (TSO). The organization was established as a profit center with a deadline--a date when it should become profitable. It assembled a staff of 120 employees including systems engineers, vehicle engineers, control specialists, a marketing staff, and financial analysts.

A new test facility at Cherry Hill in Washtenaw County, Michigan, was opened in February 1974. It contained a test track, control center, maintenance shops, and a reliability laboratory. It was used for development and test work on components, subsystems, vehicles, guideway structures, and operating techniques. Tests were first conducted with the Transpo '72 cars and a prototype of the Fairlane CC&CS, and later with the four second-generation cars designed for Bradley and Fairlane and the Fairlane CC&CS.

Between 1972 and 1974 the company participated in numerous AGT competitions:

- In August 1972, Ford received an invitation to propose on a system to be installed in Toronto for the 1974 exposition. Early in 1973, after careful study, Ford decided not to bid because of insufficient time to develop a product that would meet the specifications.
- Early in 1973, Ford was asked to bid on the Bradley International Airport and won the contract. The system was installed and accepted by the customer but has not been placed in operation.
- The Fairlane commitment was made in 1973.
- Extended negotiations were conducted for an international installation between El Paso, Texas, and Juarez, Mexico. The project would have required development of a large vehicle capable of operating in two-car trains. (That product would probably have had capacity and speed competitive with the Westinghouse Transit Expressway.) Ford was selected, but the project was aborted for lack of financial support.
- Ford competed for an AGT installation in a permanent exposition and park called Interama near Miami, Florida. That project also would have required additional design work. Proposals were evaluated, but an award was not made because the buyer found it impossible to sell revenue bonds to finance development of the entire facility.

In 1974 Ford was committed to two projects--Fairlane and Bradley--and had few prospects for other work. A new study was made of the outlook for the AGT program. It assessed AGT as an alternative to buses, examined financing of AGT, and assessed UMTA's interests in the AGT field. The results were discouraging and the company began gearing down its AGT program. The commitment to complete the Bradley project was firm. As mentioned above, consideration was given to aborting the Fairlane project and to reuse the Transpo '72 cars, but it was decided to complete the first phase project as planned.

By mid-1974 the die was cast--Ford would leave the AGT business. Outsiders might have reached that conclusion when Ford declined to bid on the Duke University project later that year. In early 1976, Ford representatives, responding to an inquiry, indicated that the company was not a potential AGT supplier for the new Atlanta air terminal. In April 1976, Ford announced to UMTA that it was no longer in the AGT business. The company would not bid on new projects but would be willing to sell the system design to another firm. In 1976, the staff of TSO was cut from 100 to 20 employees. By April 1977, the staff had been further reduced to 9 employees, and by late summer, operations ended.

Ford will continue operation of the Fairlane system until 1986 under a 10-year contract. Responsibility has been assigned to Ford's Aerospace and Communications Corporation. The Engineering Services Division within that corporation will provide the staff.

6.4 Acquisition

The decision to make the installation was made in 1973 and most of the work on equipment fabrication and guideway construction was performed in 1973 and 1974. The system began transporting passengers in March 1976.

Because of the close relationship between Ford Motor Company and Ford Land Development Corporation, the acquisition process for the Fairlane AGT system is a special case. Details of the agreements are not known.

A joint venture including Ford Land Development Corporation and Taubman Company was responsible for the development of the mall and for planning site development and land use in areas surrounding the mall and hotel. Charles Luckman Associates participated in the design of the mall and hotel, and in the integration of the AGT system routes and stations.

Ford Motor Company was responsible for the design, fabrication, installation, testing, and operation of the AGT system. ABAM, a consulting firm in Seattle, Washington, designed a special steel form that could be adjusted to shape a variety of horizontal guideway structures and prefabricated guideway members. The horizontal structures were fabricated in Tacoma, Washington, and shipped by rail and truck to Dearborn.

6.5 Finance

The Fairlane AGT system was financed as part of the entire project. Details regarding sources of funds are not available. The Ford Land Development Corporation owns the site, the hotel building, and 75% of the shopping mall. Other members of a joint venture own the remainder of the mall. The ownership of the AGT system was said to be divided between the two Ford companies as follows: Ford Motor Company owns the hardware, and Ford Land Development Corporation owns the fixed installations.

Ford Motor Company has a long-term financial obligation because of its contract to operate the system until 1986.

Current costs of operation, said to be about $395,000 per year, are shared by Ford Motor Company, the hotel, and tenants of the shopping center. Tenants make payments in direct proportion to the area of rented space. Therefore receipts from that source will increase as the mall expands. Receipts from the hotel and tenants are expected to cover only one-third to one-half of operating costs. Thus, Ford's losses on operation of the system for ten years could total $1.3 to $2.0 million or more.

7 CONCLUDING REMARKS

The Ford system deployed at Fairlane Town Center is characterized by sophistication and potential beyond the immediate needs of the application. Most, if not all, of the engineering design is excellent. The following three areas are most outstanding:

- Modular command, communications and control system
- Onboard switch
- Guideway design and construction.

As we have described in the text, the command and control system is well suited for expansion to more complex applications. The modular approach, with provisions for modification of performance levels, switching positions, and other vehicle control through software changes, contributes to expansion potential. The onboard switch has considerable advantages in reduced headway and off-line repair.

The system's reliability and maintainability must be considered in light of the developmental and demonstrative nature of the installation. The figures presented in this report are not representative of a more mature system. It is difficult to separate failures, which are related to malfunction, when the system is still undergoing modifications. The trends of increasing two-vehicle operations and decreasing number of failures in the initial period of operation gave excellent indication of early system maturity.

The public attitude survey of the Fairlane system indicates that the passengers perceive it to be comfortable, safe, and enjoyable. Passenger demand often causes queuing. Obviously a large number of people would rather wait in line to ride the system than walk or drive approximately 1/2 mile across the parking lot.

The actual value of the system is bringing shoppers to the Fairlane complex has not been measured. Based on preliminary observations, the aesthetic appeal and technological interest of the system appear to create positive public response.

A special feature of the Fairlane system is that the owner, manufacturer, and operator are all part of the same company. Therefore, comparisons of the development process with other AGT deployments are probably inappropriate.

Appendix A

AGT ASSESSMENT MEASURES: FAIRLANE TOWN CENTER

This appendix provides a detailed check-list of assessment measures associated with the description and performance of the Fairlane Town Center AGT System. The descriptive measures essentially provide the basic facts about the design of the system. The performance measures provide data associated with system operations. The statements under the column heading "user" are qualitative descriptions about the system from user's point of view. The statements or numbers under the heading "operator" reflect the operational features of the system generally in quantitative terms. These were either provided by the system operators or were calculated by SRI team using some basic data provided by the operators. Much of the information presented in this appendix has been extracted from the main body of the report. Some of the information presented in this appendix may not be found in the main body of the report. Such information was either gathered independently or was inferred from the data in the main body of the report.

Appendix A

AGT ASSESSMENT MEASURES: FAIRLANE TOWN CENTER

Descriptive	User	Operator
1. System sizing		
Fleet size		
Total		2 vehicles*
Peak-hour operating		2 vehicles*
Off-peak operating		2 vehicles*
Number of vehicles per train		
Maximum		1 vehicle*
Peak hour		1 vehicle*
Off peak		1 vehicle*
Number of stations	2 stations*	2 stations*
Guideway configuration		
Closed loop or others		Bypass shuttle
Length at grade, elevated, etc.		2600 ft elevated*
Bidirectional service		Car is bidirectional
Station occupancy		1 vehicle maximum number queued at station
Employees		10 employees*
2. System costs		
Capital costs		(1974, based on data in Table 5-1)
Engineering, architecture & administration (construction/hardware)		930,000
Guideway		1,750,000
Stations		350,000
CC&CS		600,000
Power		790,000‡
Vehicles (2)		$600,000
Maintenance facility		$100,000‡
		Total = 5.12 Million
3. Technical description		
System description		
Gradeability		0.5 - 2.5%
Line Capacity		500 passengers/hr/lane‡ (normal)
Seat		208 passengers/hr/lane‡
Standee		291 passengers/hr/lane‡
Crush		624 passengers/hr/lane‡
Degree of automation		
Employee-to-vehicle ratio		6.5 employees/mean # veh. op. (1976) (5.4-1977)‡
System man-hour ratio		3.2 man-hours/vehicle-hrs.* 2.6 m/hrs (1977)
Fare collection		None
Existing automated operation		
Strategies		
Peak hour		Automatic shuttle; two vehicles*
Off-peak hour		Demand responsive; one vehicle
Elderly and handicapped accommodations		Doors 41 in wide, 80 in high; no steps
Operational speed	Satisfactory	9.8 mph average speed including stops
All-weather capability	Service suspended in extremely bad weather	Guideway heated by imbedded electrical cables, water drains through normal storm drains in guideway (which are also heated)
Subsystem description		
Vehicle		
Weight (empty and maximum design)		12,500 lb. empty, 4,500 lb. capacity*
Dimensions (length, width, height wheelbase, etc.)		24.7 ft × 6.67 ft × 8.67 ft
Design life (with average mileage/year)		Unavailable (10-year operating contract)
Capacity		
Seated passenger	10 seats/vehicle	10 seats/vehicle
Standee passenger	14 standees/vehicle‡	14 standees/vehicle*
Crush	30 passengers/vehicle‡	30 passengers/vehicle*

*Data supplied by the manager or operator.

†Estimate by the operator.

‡Calculated result based on given information.

§Estimate by the manufacturer.

Descriptive	User	Operator
Speed		
Maximum		20 mph§ operating/(design maximum 30 mph†)
On-board heating	Satisfactory	9 kW electric‡
On-Board cooling	Satisfactory	4 tons of forced air cooling
On-board illumination	Very bright	Fluorescent overhead longitudinal lighting
Command, control, and communications		
Hardware		Failsafe relay logic wayside and onboard;* onboard PDP-8 computer
Software		Performance profiles and onboard functions (door open, etc.) controller in response to limited wayside signals
Vehicle control and management		Synchronized departure for each end of shuttle to coordinate bypass*
Operational control		On demand (schedule is also possible)
Headway protection		Fixed block way side control system
Merge strategy		Not applicable
Service policy		Demand responsive
Routing policy		Not applicable
Empty vehicle management strategy		Not applicable
Dispatching policy		Continuous demand responsive
Failure management		Failed vehicle is moved manually
Steering		Horizontal guidewheels, pivot axles about a vertical axis*
Switching (captive/noncaptive)		Onboard mechanical switch*
Propulsion		60 hp shunt wound dc motor* (two per vehicle)
Power		480 Vac, 60 Hz*
Suspension		Automotive type coil springs vertically; leaf springs for lateral guidewheels*
Guideway		Prestressed cast contrete; assembled on-site*
Stations		End of line stations; 1 single platform; 1 double platform*
Passenger information	Sufficient, good graphics	ID sign in each station, temporary traffic direction, signs and roped areas)*
Braking (normal, backup, emergency)		Regenerative; hydraulic friction; hydraulic friction*
4. Service characteristics		
Levels of service		
Comfort		
Temperature		72°F over outside ambient range of -20°F to +110°F*
Humidity		
Lighting		
Heating and cooling		
Air circulation		
Periods of operation		
Hr/Day	12 hr. Mon-Sat, 5 hr. Sun.†	12.5 hr/day†
Days/Year	360 days/year†	365 days year†
Accessibility or area coverage	Serves hotel and shopping center	
Patronage		2,434,076 in the first year of operation (since March 1976)

Performance	User	Operator
1. Sociological		
Levels of service		
Comfort		
Seating room area	Vehicles small but trip short	3.9 ft²/passengers seated*
Standing room area		1.93 ft²/passengers/standing*
Seat availability (Peak, off peak)	Seats full during peak hour	0.53 seats/average passengers‡
Lighting	Rather bright	
Heating and cooling	Comfortable	
Air circulation	Satisfactory	
Satisfaction	Very high	
Ride Quality	Good	
Convenience		
Transfers	None	None

Performance	User	Operator
Service quality		
Frequency of service (peak, off peak, policy, demand actuated)	21 departures/hr	(2 vehicles) 174 sec headway†
Mean wait time	Mean wait time without queuing 2§ min/1 vehicle; 1 min/2 vehicle	Mean wait time = 2§ min/1 vehicle; 1 min/2 vehicle without queuing
Average trip speed		13.8 mph‡
Maximum trip speed		30 mph† (designed) 20 mph (existing operation)†
Cruise trip speed (maximum)		20 mph†
2. Economics		
Capital costs		$5.12 million (1974); $6.11 million (1976 dollars)
Operating and maintenance costs		$395,000
Per Passenger		$0.16/passenger‡
Per passenger mile traveled		$0.34/passenger mile‡
Per vehicle mile traveled		$6.55/vehicle mile‡ (1976)
Per seat or place mile traveled		$0.27/place mile‡
Per passenger mile traveled under capacity condition		$0.27/passenger mile/capacity condition‡
Labor		$4.9/vehicle miles of travel‡
Materials		$0.73/vehicle miles of travel† (1976)
Energy		$0.92/vehicle mile†
Life cycle costs		$1,114,800/year; 35 years construction life, 15 years hardware life
Travel cost (fare)	None	
3. Environment, land use, energy, safety, and security		
Environment		
Impact	Diverts some auto trips†	
Noise (exterior)	Quieter than ambient level of parking lot†	
Air pollution		Virtually none
Aesthetics	Excellent, large window area	
Urban disruption	None	
Land use		
Guideway space requirements		0.9 acres
Stations		Not calculated
Maintenance and other facilities		2690 sq.ft.
Energy		18.25 kWh/vehicle mile‡ (includes guideway heating in winter)
Safety and security (on system versus off system)		
Accidents		3 Emergency stops in 1976
Fatalities		None*
Injuries		4 injuries in 1976
Assults		None*
Vandalism		Very little
4. Operational/technical performance		
System		
Elderly and handicapped factors	Fully accessible	
Accommodations	No barriers	
Ease of use	Simple	
Routing efficiency		Not applicable
Vehicle load factor		0.8
Vehicle productivity		390.1 passengers delivered/vehicle hour
Labor productivity		72.3 place miles/year/man-hours for all employees
Operating cost productivity		3.66 place-miles/operating and maintenance cost/year‡
Availability		
Subsystem availability		
Traditional availability		Not available due to extensive modifications to the system during the past year. See text.
Proportion of delay (vehicle based)		
Successful trip ratio vehicle-based)		
Total system availability		0.937

Performance	User	Operator
Subsystem		
Vehicle		
Acceleration	Satisfactory	1.36 mph/sec*
Deceleration (service and emergency)	Satisfactory	1.36 mph/sec (service)*; 4.1 mph/sec* (emergency)
Speed		
Line (Peak and off peak)	Satisfactory	20 mph; 20 mph*
Vibration (stationary vehicle)	Fine	
Noise		
Jerk		
Acceleration		2.1 mph/sec^{2*}
Deceleration		2.1 mph/sec^{2*}
Tire life (where applicable)		
Command and control		
Acceleration		1.36 mph/sec*
Deceleration		1.36 mph/sec*
Speed (maximum cruise)		20 mph
Stopping		Mean deviation = ±6* in
Headway		Not applicable
Steering		
Lateral ride quality	Fine	Not measured
Steering member wear		Negligible
Switching		
Response time		Nominally 1.5 sec*
Noise	No noise	
Vehicle vibration	Very little	
Propulsion and braking		
Tractive effort		0.062 lb. force/units weight‡
Power distribution system		
Power pickup wear		Unavailable due to modification*
Electronmagnetic interference		Negligible*
Voltage regulation		Not measures
Guideway		
Condition	Satisfactory	Satisfactory
Roughness characteristics	Not perceptible	
Maximum dynamic load		Not measured
Stations		
Dwell time		50 sec mean time
Throughput (assuming 30 departures/hr; annual average load factor .8)		1140 passengers/hr/station (onboard and deboard passengers)
Comfort		
Capacity	Queues in peak periods§	
Information/graphics	Clear and attractive	
Access/egress	10 sec †	
Train screens (doors)	Attractive	Clear glass doors
Fare collection		
Ease of use	None	No fare
Service capacity		
System and subsystem		
Maintenance requirements		
Equipment		All equipment necessary for system modification
Labor		3.2 man-hours/vehicle-hours
Operating requirements		
Labor		Included in maintenance
Reliability		Not available due to extensive system modifications during the past year. See text.
Maintainability		
Service life		20 ~ 25 years†

Appendix B

METHODS OF COST ESTIMATING AND ANALYSIS

Appendix B

METHODS OF COST ESTIMATING AND ANALYSIS

Objective

One objective of the assessment of six existing AGT systems was to collect and present cost information on these systems in a manner that would be useful to planners of new AGT systems in the Downtown People Mover program and in other urban settings.

Various Problems and Aspects Associated with Cost Analysis

To approach the objective, a number of problems and aspects--both practical and theoretical--had to be taken into account, as discussed below.

Historical cost data obtained from published reports and by inquiries addressed to owners and participants in AGT system development projects are often incomplete or otherwise unsuitable, as guidance or indicators, for planners of future systems. Costs of some items are incorrectly reported or omitted. Separate costs of some items are not obtainable because the AGT facility was built as an integral part of a multipurpose facility. Where necessary, cost estimates have been derived by SRI staff members and consultants.

Urban settings for AGT systems are the main focus of interest in this research but none of the six AGT systems studied is in a typical urban setting--three are in airports, two are in recreation parks, and one is in a multipurpose commercial development owned and operated by private interests. The research staff has taken various measures to recognize possible differences between the actual settings observed and typical urban settings. Planners of new AGT systems are urged to pay particular attention to the stated conditions associated with cost estimates prepared for each site, and to make needed changes in cost estimates to fit the actual conditions of local sites.

Price changes must be taken into account to make cost data from different years useful to planners. AGT systems and their components were purchased or constructed in different years and at different price levels. Escalation adjustments have been made to state all capital cost estimates at 1976 price levels. Capital costs for each system are stated in 1976 dollars.

Total equivalent annual costs is the most convenient format for presentation of cost data on the six systems. However, initial capital costs are incurred in lump sums, and long intervals pass between replacements of capital assets while operating and maintenance costs are incurred year-by-year. To make these estimates commensurate, capital costs have been restated as equivalent annual series amounts for assumed service lives and interest rates. The result is equivalent to the uniform annual payment that would be needed to repay a loan with interest by the end of the series life. Equivalent annual costs of capital and annual operating and maintenance costs can then be added to produce total equivalent annual costs.

Unit costs of service per vehicle mile, per passenger mile, etc. are quite useful in making comparisons. These are computed by dividing total equivalent annual costs by measures of service performed.

Growth or decline in costs of operation and in amounts of service rendered are likely to occur from year to year during the life of each AGT system. For example, patronage and costs may increase for many years, then level off, and finally decline as the AGT system or the entire facility approaches obsolescence. Growth and decline are site-dependent characteristics--the experience of an existing site will seldomly, if ever, apply at another. Therefore, growth and decline have not been treated in this research.

Discussion of Terms and Parameters Used in Cost Analysis

A discussion of several terms and parameters used in the cost analysis is presented below. Values of various parameters used in the study are also mentioned where applicable.

Joint-use and multipurpose refer to facilities and services shared by an AGT system and one or more additional functions. An example is an AGT station located within an air terminal building.

Free-standing and independent refer to facilities and services provided solely for an AGT system such as an AGT maintenance facility.

Conceptual design or duplicate facility refers to a hypothetical free-standing or independent AGT system designed solely for transit service. It is functionally equivalent to the transit portion of a system having joint-use or multipurpose characteristics. This concept allows estimation of costs of an AGT system without the need for division of costs among an AGT system and other functions.

Actual cost is the dollar amount paid for a specified asset or service.

Allocated cost is a division of the cost of a joint-use facility or multipurpose service among numerous functions and is usually based on some estimate of the percentage of use. For example, if an AGT station occupies 1% of the space in a shopping mall, one might say that the allocated cost of the station is 1% of the cost of the entire building complex. Allocation of costs is common in accounting practice, but cost allocations made for one site will seldom be well suited for decision making at another site. Therefore, allocated costs must be used with caution.

Marginal cost is an estimate of the additional cost or cost increment made necessary by the addition of an optional function, such as an AGT station, to an existing or planned facility, such as a hotel or office building.

Duplicate cost is an estimate of the cost of a hypothetical duplicate facility discussed above. In this study it is the estimated cost of duplicating the essential AGT functions observed in an existing joint facility at a hypothetical new site where the AGT system could be independent or "free standing."

Price indices are factors used to adjust estimates of costs of assets acquired in given years to the price levels of a common year--1976 in this research. Indexes and escalation procedures must be used with care to avoid introduction of serious errors. This is especially true when systems having dissimilar characteristics--such as buses and AGT systems--are to be compared. In this work separate indices are used for three cost categories:

- Hardware
- Construction
- Professional and administration services.

The selection of various indices was made in consultation with UMTA and its subcontractors. A brief description of various indices is given below.

Hardware--The Wholesale Price Index for Machinery and Motive Products is used to escalate all hardware costs including vehicles; command, control, and communications; power distribution system; station equipment; and power rails.* Commodities included in this index are:

1. 42%--Electrical machinery and equipment: wiring, integrating instruments, motors, transformers, switchgear, electronic components, and accessories.
2. 14%--General-purpose equipment: elevators, escalators, mechanical power transmission equipment, conveyor belts, monorail conveyors, valves, and bearings.
3. 14%--Tools: metal working tools and machine-shop products.
4. 8%--Heavy equipment: tractors, construction equipment.
5. 22%--Miscellaneous equipment: mining, textile, food, woodworking, printing industries.

Construction--The Engineering News Record (ENR) Construction Cost Index for 20 cities is used to escalate all construction costs including guideways, stations, utilities, maintenance, and support facilities. The components included and their relative weight in the index are (1) base price of structural steel shapes (38%); (2) consumer's net price of cement exclusive of bag (7%); (3) lumber (17%); and (4) common labor rate (38%).

*The selection of this index is based on MITRE letter to UMTA, # W24-3789, Subject: "Inflation Rates for AGT Socio-Economic Research Program," 27 July 1977.

Table B-1

COST INDICES FOR ESCALATING AGT CAPITAL COSTS

	Hardware (Wholesale Price Index for Machinery and Motive Products)		Construction (Engineering News Record Construction Cost Index for 20 cities)		Professional Services (Consumer Price Index for Urban Wage and Clerical Workers, U.S. City Average)	
Year	Index	Conversion Factor to 1976 Prices	Index	Conversion Factor to 1976 Prices	Index	Conversion Factor to 1976 Prices
1965	--	--	91	2.45	--	--
1966	--	--	95	2.35	97.2	1.75
1967	100.0	1.66	100	2.23	100.0	1.70
1968	103.0	1.61	108	2.07	104.2	1.63
1969	106.0	1.56	119	1.87	109.8	1.55
1970	110.6	1.50	130	1.72	116.3	1.46
1971	115.3	1.44	148	1.51	121.3	1.40
1972	118.2	1.40	164	1.36	125.3	1.36
1973	121.2	1.37	177	1.26	133.1	1.28
1974	136.3	1.22	188	1.19	147.1	1.16
1975	156.2	1.06	206	1.08	161.2	1.06
1976	165.8	1.00	223	1.00	170.3	1.00

Source: N. D. Lea and Associates, Inc.

Professional and Administration Services--The Consumer Price Index for Urban Wage Earners and Clerical Workers, U.S. City Average, All Items is used to escalate all costs for professional services such as A&E, design, project management, systems integration, and acceptance testing.

Service life is the period of service expected of an asset. Service life may be determined by wear or exhaustion of the asset or by obsolescence of the entire facility. Equivalence calculations start with the service life of the AGT subsystem having the longest expected life--usually the structures. Subsystems with shorter service life are assumed to be replaced at the same initial cost, stated in 1976 dollars. The selection of service life is based on experience and judgement.

Two sets of service life assumptions have been made for all systems. One, characterized as "basic," uses 15 years for hardware and 35 years for construction. A second, characterized as "optimistic," uses 20 years for hardware and 50 years for construction. In addition, a third set, characterized as "commercial", uses lives of 15 years for both hardware and construction and was applied to the two recreation parks--King's Dominion and Disney World. These short lives refelct the possibility that obsolescence, rather than use and deterioration, will determine the end of service.

Salvage value is the expected value of an asset at the end of the service life. Salvage values are neglected in this analysis.

Discount rate is the time value of money to the owner of an AGT system or the rate of interest that would be attractive for a given investment in an AGT system. A discount rate of 10% was used in the study, this being a typical discount rate currently prevailing. However, planners should use the rate predicted to be available for the specific case.

Equivalent annual cost of capital, R, is found by the following equation:

$$R = P\left[\frac{i(1 + i)^n}{(1 + i)^n - 1}\right]$$

where

P = capital cost

n = service life

i = discount rate.

Operating and maintenance costs are annual outlays for goods and services required by AGT systems.

Total equivalent annual cost is the equivalent annual cost of capital, R, plus the cost of operations and maintenance.

Cash flow analysis is not employed in this report but would be an appropriate tool for certain purposes. For example, cash flow analysis is required to determine fare structure adequate to repay capital and interest and to recover operating and maintenance costs. If a cash flow analysis is desired, all cash receipts and outlays must be estimated for each time period over the life of the system. For example, actual cash expenditures for interest must be used, rather than the discount rate used in equivalent annual cost calculations.

Some Specific Comments on Capital Cost Estimates

AGT systems include numerous items or groups of capital assets, and there is no uniformity among systems in the breakdown of systems into subsystems, components, and so forth. However, it has been possible, with fair accuracy, to classify assets under three headings--professional and administrative services, hardware, and construction.

Professional and Administrative Services--Detailed historical records of the cost of consultants and administration were usually not found. In such cases these costs were calculated as a fraction of the cost of major assets in consultation with the system designers.

Hardware--Estimates of hardware costs obtained from the AGT sites appear to be reasonably complete and dependable. AGT hardware was usually purchased for cash under one or a few contracts. It is noteworthy that published reports of hardware costs usually cite the price bid by the system supplier, rather than the final contract amount. Consequently, the published figure often omits such elements as the costs of change orders and items furnished by other suppliers. Data obtained from accounting records were usually considered dependable and were used.

Right-of-way was not purchased for any of the systems studied. In each case, the AGT system occupies a small part of a large parcel of land acquired to serve a broad variety of purposes. Right-of-way costs will differ greatly among urban sites, and may be quite substantial in certain cases. Where owners have used the allocation technique to estimate a right-of-way cost to meet accounting needs, that estimate is reported.

Site preparation costs are included in the analysis in those cases where historical data were found. However, where the data were lacking, estimates were not derived by the research staff.

Utility relocation was not encountered as a cost factor in any of the systems studied. Again, urban sites will differ greatly in this respect and gain little from the experience of the six AGT systems treated in this research.

Construction costs for civil works--mainly tunnels, elevated structures, and stations--have presented the most difficult cost-estimating problems. Available historical data of dependable quality were always used. In several cases the cost of major elements of the civil works had never been estimated by the owner (or anyone else) until the restudy stage of this research. This lack of data is understandable. In many instances an AGT facility element was incorporated into the design and construction of another, much larger facility. In such cases there is no theoretically correct way to identify the cost of the AGT facility and, in some cases, no need to make a cost allocation. Only a few owners treat AGT systems as profit centers and have a need to account for the cost of the AGT system.

To overcome the lack of historical data, special studies have been made to derive construction cost estimates. These estimates fill data gaps and present a complete--but qualified--cost picture for use by planners of future AGT systems. Three main approaches are available to estimate construction costs:

- Duplicate Cost Approach. Costs are estimated by assuming free-standing duplicate facility with appropriate dimensions.
- Allocation Cost Approach. Costs are estimated by allocating a suitable fraction of the total cost to AGT system.
- Marginal Cost Approach. Costs are estimated as the additional cost that must have been incurred because of the inclusion of the AGT system.

In the present study, one or the other approach was used where appropriate.

Appendix C

CHRONOLOGY OF EVENTS: FAIRLANE TOWN CENTER

Appendix C

CHRONOLOGY OF EVENTS: FAIRLANE TOWN CENTER

1968	Transportation Research and Planning Office was established.
1971	Short guideway and vehicle chassis were fabricated for test purposes.
1971	Ford started Transpo '72 project in May.
1972	Transpo '72 system was demonstrated and tested, carrying 25,000 people during the ten days at Transpo '72.
	Henry Ford II announced entry into AGT business.
	Transportation Systems Operation (TSO) was established in September with staff of 120.
	Received RFP from Toronto in August.
1973	Declined to bid on Toronto project.
	Bid and won Bradley International Airport Project.
1974	Awarded El Paso project in January (it was not built).
	Bid Interama project in May.
	Interama project was aborted for lack of funds in August.
	AGT business was reassessed and company began gearing down program in midyear.
	Declined to bid Duke University project late in 1974.
	Considered cost saving alternatives at Fairlane but made no change.
1973-75	Fabricated, constructed, and installed Bradley and Fairlane systems.
1976	In response to inquiry, stated that Ford was not a potential AGT supplier for Atlanta airport in January.
	Initiated operations at Fairlane in March.
	Announced to UMTA that company was no longer in the AGT business and indicated willingness to sell product in April.
	Transferred 80% of TSO staff to other departments by end of year.
1977	Will transfer remainder of TSO staff and terminate TSO.
	Reassigned responsibility for operation of Fairlane to Ford Aerospace and Communications Corporation.

Appendix D

MAJOR PARTICIPANTS: FAIRLANE AGT PROJECT

Appendix D

MAJOR PARTICIPANTS:
FAIRLANE AGT PROJECT

Owners: Ford Land Development Corporation
Ford Motor Company

Supplier: Ford Motor Company

Consultants and Subcontractors:

SMITH, HINCHMAN, and GRYLLS, Detroit, Michigan
ABAM, Seattle, Washington

Planners and Developments:

Ford Land Development Corporation
Taubman Co.
Charles Luckman Associates

Tenants: Hyatt Regency Hotel
Occupants of Town Center Shopping Mall

Appendix E

PUBLIC ATTITUDE SURVEY QUESTIONNAIRE: FAIRLANE TOWN CENTER

Hello. We are doing a study of the Fairlane Town Center Automated Transit System (known here as the ACT--Automatically Controlled Transportation) between the shopping center and the hotel. I'd like to ask you a few questions.

This survey is authorized by Section 6 of the Urban Mass Transportation Act of 1964 as amended through November 26, 1974, wherein the Secretary of Transportation is authorized to request and receive such information or data as he deems appropriate from public or private sources. While you are not required to respond, your cooperation is needed to make the results of this survey comprehensive, accurate, and timely.

1. How many times have you been to Fairlane Town Center before today?

   1☐ First time for me

   2☐ Once or twice before

   3☐ 3-5 times before

   4☐ 6-10 times before

   ☐ More than 10 times before

   [If more than 10, ask] Are you employed at Fairlane Town Center?

   6☐ Yes   7☐ No

2. Did the existence of ACT (that's the Automatically Controlled Transportation) influence your decision to come to Fairlane Town Center today?

   1☐ Yes

   2☐ No

   3☐ Not sure

3. Do you think ACT adds to the attractiveness of Fairlane Town Center?

   1☐ Yes, it adds attractiveness

   2☐ No, it detracts

   3☐ Makes no difference to me

4. Within the last year have you traveled between the Fairlane Town Center and the Hyatt Regency Hotel?

1 ☐ Yes 2 ☐ No [If No, go directly to Question 45.]

5. [If answer to 4 is Yes,] How do you usually make the trip?

1 ☐ ACT 2 ☐ Walk

3 ☐ Drive Auto 4 ☐ Other

6. [If not ACT, ask] Did you ever ride the ACT?

1 ☐ Yes 2 ☐ No [If No, go directly to Question 45.]

7. Would you have taken the trip if there were no ACT?

1 ☐ Yes 2 ☐ No 3 ☐ Not sure

8. Would you have taken the trip if there were a 25¢ fare to ride the ACT?

1 ☐ Yes 2 ☐ No 3 ☐ Not sure

9. What was the main purpose for taking your last ACT trip?

1 ☐ Sightsee, or try out ACT?

2 ☐ To kill time?

3 ☐ Shop at the shopping center?

4 ☐ Shop at the hotel?

5 ☐ Eat or drink at the shopping center?

6 ☐ Eat or drink at the hotel?

7 ☐ Other

10. How many times have you been a passenger on ACT?
Count a round trip as 2 trips.

1 ☐ Only once

2 ☐ Two or three times

3 ☐ Four to ten times

4 ☐ More than ten times

11. What is your overall impression of this transportation system?

- 1 ☐ Excellent
- 2 ☐ Good
- 3 ☐ Satisfactory
- 4 ☐ Poor
- 5 ☐ Totally unacceptable

12. Was the temperature inside the vehicle comfortable? 1 ☐ Yes 2 ☐ No

13. Was the lighting inside the vehicle adequate? 1 ☐ Yes 2 ☐ No

14. Was the station crowded? 1 ☐ Yes 2 ☐ No

15. Was the ride quiet? 1 ☐ Yes 2 ☐ No

16. Which way would you prefer to be seated during a trip on this type of vehicle?

- 1 ☐ Forward
- 2 ☐ Backward
- 3 ☐ Sideways
- 4 ☐ No preference

17. Was the ride bumpy? 1 ☐ Yes 2 ☐ No

18. Did the ride have any objectionable sudden stops or starts? 1 ☐ Yes 2 ☐ No

19. Did the vehicle sway much from side to side? 1 ☐ Yes 2 ☐ No

20. Are the boarding areas conveniently located? 1 ☐ Yes 2 ☐ No

21. Do you feel that the space in the vehicle for luggage or parcels is adequate? 1 ☐ Yes 2 ☐ No

22. Was the vehicle layout (seating arrangement, entry and exit provisions) satisfactory? [1] ☐ Yes [2] ☐ No

23. Did you feel that you had to wait too long to ride ACT? [1] ☐ Yes [2] ☐ No

24. Did the vehicle speed seem fast enough? [1] ☐ Yes [2] ☐ No

25. Did the vehicle speed seem too fast? [1] ☐ Yes [2] ☐ No

26. Did the vehicle doors ever close on you? [1] ☐ Yes [2] ☐ No

27. Did you think there should be an attendant on board? [1] ☐ Yes [2] ☐ No

28. Would you feel more secure if police were present at various locations in the system? [1] ☐ Yes [2] ☐ No

29. Do you think there should be a closed circuit television monitor in the vehicle? [1] ☐ Yes [2] ☐ No

30. Have you ever felt unsafe in the station or vehicle during the day? [1] ☐ Yes [2] ☐ No

31. Do you like the architecture of the station? [1] ☐ Yes [2] ☐ No

32. Was the guideway obtrusive? [1] ☐ Yes [2] ☐ No

33. Were the vehicle and station areas clean and well maintained? [1] ☐ Yes [2] ☐ No

34. Was the vehicle interior attractive? [1] ☐ Yes [2] ☐ No

35. Was information about the operation and use of the system adequate? [1] ☐ Yes [2] ☐ No

36-37. You have just answered several questions related to various factors.. These factors are listed on this card. Please indicate the 2 factors that are most important to you. Pick two only. (SHOW CARD).

- 1 ☐ comfort
- 2 ☐ ride quality
- 3 ☐ convenience
- 4 ☐ safety and security
- 5 ☐ appearance
- 6 ☐ information/instructions

38. Would you prefer this guideway to be:

- 1 ☐ underground?
- 2 ☐ at ground level?
- 3 ☐ elevated?

39. During the ride would you have preferred that the vehicle be larger, smaller or was it about the right size?

- 1 ☐ larger?
- 2 ☐ smaller?
- 3 ☐ right size?

40-44. In a typical week, for trips to work, school, shopping or other locations, do you usually (at least twice a week): (Check as many as apply)

- 40 ☐ drive your car alone or with family?
- 41 ☐ car pool or van pool?
- 42 ☐ take bus transit?
- 43 ☐ take subway or railroad?
- 44 ☐ take taxi?

GO TO QUESTION #58

45-51. Here are some possible reasons for not riding the ACT. Please tell me which are reasons why <u>you</u> do not presently ride the ACT. (CHECK ALL THAT APPLY)

45 ☐ You have no reason to travel between the hotel and shopping center.

46 ☐ The ACT does not run at the times you could use it.

47 ☐ You do not think the ACT is mechanically safe.

48 ☐ You think the ACT would be too crowded for comfort.

49 ☐ You think you would have to wait longer than is reasonable.

50 ☐ You think you might be stranded because of a stoppage.

51 ☐ You think it would be difficult to take packages or other bulky items on the ACT.

52-56. In a typical week, for trips to work, school, shopping or other locations, do you usually (at least twice a week):

(Check as many as apply)

52 ☐ drive your car alone or with family?

53 ☐ car pool or van pool?

54 ☐ take bus transit?

55 ☐ take subway or railroad?

56 ☐ take taxi?

57. Would you prefer the ACT guideway to be:

1 ☐ underground?

2 ☐ at ground level?

3 ☐ elevated?

58. What was your immediate family's income (before taxes) in 1976? (SHOW CARD)

1 ☐ less than $5,000

2 ☐ $5,000 to $9,999

3 ☐ $10,000 to $19,999

4 ☐ $20,000 to $29,999

5 ☐ $30,000 to $49,999

6 ☐ over $50,000

Thank you very much for your cooperation.

59-60. Age: ☐☐ 59 60

* *

61. Sex: 1 ☐ Male

2 ☐ Female

62. Site location:

1 ☐ Shopping Center

2 ☐ Hyatt Regency Hotel

63-64. Date May ☐☐ 63 64

65-68 Time completed ☐☐☐☐ 65 66 67 68

69. Interviewer ☐ 69

70. Day of week:

1 ☐ Monday

2 ☐ Tuesday

3 ☐ Wednesday

4 ☐ Thursday

5 ☐ Friday

6 ☐ Saturday

7 ☐ Sunday

Note: Leave all boxes blank for "no answer."

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3. "Automated Guideway Transit: An Assessment of PRT and Other New Systems," prepared by Select Committee on Appropriations, Transportation Subcommittee (June 1975).

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7. "Assessment of Operational Automated Guideway Systems--Jetrail," Final Report No. UMTA-06-0067-77-1, U.S. Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts (December 1977).

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