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OVERVIEW OF ESCALATOR APPLICATIONS IN RAIL TRANSIT

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PREFACE

This report is an overview of the research and development needs for escalators in U.S. rail transit operations. Of the many transit agencies and manufacturers who cooperated in providing information for this report, we would like to acknowledge the contribution of the following individuals and their organizations:

John Fruin, Howard Silfin, and Charles Culp, The Port Authority of New York and New Jersey

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METRIC CONVERSION FACTORS

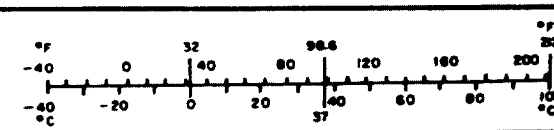
Approximate Conversions to Metric Measures

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

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

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



CONTENTS

FIGURES

TABLES

1. INTRODUCTION

This report is one product of a project titled, Study of Research and Development Planning for the Rail and Construction Technology Program of UMTA. It is the only part of the project that deals exclusively with escalators. Other sections of the study develop a general method for identifying and prioritizing research and development projects, and conduct an overview and a systems analysis of rail transit fare collection methods.

1.1 Background

Escalators play a major role in the efficient handling of rail transit patrons at the stations. By moving large number of patrons to and from the platform in a short time, they allow for patron convenience, resulting in an attractive rail transit system.

Escalators in subway stations have been part of the design requirements for newer systems such as the BART, WMATA and MARTA systems. A sufficient number of escalators to handle the peak hour demand is a common feature of these newly built systems. Escalators are not only a major capital cost item, but also a major contributor to operations and maintenance cost. There are about 18,000 escalators in use in the United States and nearly 1000 of these are at transit properties. At an average service contract cost of $6000 (1979$) per year, it costs $6 million annually to maintain transit escalators. An average height of 30 feet for a typical transit escalator and an installed cost of $5000 per foot represents an investment of $150 million for transit properties.

There have been several technological improvements in escalators in recent years. These include reversible escalator use, mat-operated escalators, use of extended flat steps at the top and bottom, and modular escalators. Some of these innovations, such as modular escalators, show promise of reducing initial cost for higher rise units. Modular escalators have equal sized driving motors located at regular intervals in the truss, whereas a conventional escalator has one motor at the top landing; the size of this motor and strength of the drive chain increases for higher rises.

Several of the U.S. properties have experienced significant escalator problems. Properties such as CTA, which have several older units, and even newer properties such as WMATA, which have modular units have had frequent service interruptions. It is becoming difficult to get spare parts for the older escalators because of long procurement lead times resulting in long downtimes.

As an initial effort to more clearly define these issues and problems, JPL has prepared this document. It has been funded as a part of UMTA's STARS (Subsystem Technology Applied to Rail Systems) program and is being managed by the Transportation Systems Center.

1.2 Study Objectives

The objectives of this study were to determine:

(a) The differences in environment and performance between escalators in transit use and escalators in non-transit use.

(b) The impact of recent escalator innovations on cost and performance.

(c) The areas which would benefit significantly from research and development.

1.3 Scope

The information developed in this study was based primarily on interviews with operators and manufacturers. Existing data made available by the operators and manufacturers were used in the analyses presented in this report.

1.4 Organization of the Report

Section 2 of the report discusses major findings of the study. Section 3 describes conventional and modular escalators. Section 4 is an analysis of operational data. Section 5 reviews institutional factors such as market and escalator procurement practices and Section 6 discusses issues in escalator research and development.

2. SUMMARY OF FINDINGS

The prime motivation for the analysis of escalators is the concern expressed by several properties regarding escalator availability and the seemingly high escalator maintenance costs. Based on data from operating properties and manufacturers and from results of analyses, our findings are as given in the following paragraphs.

2.1 Differences in Transit versus Non-Transit Escalator Applications

Transit escalators are subjected to a more severe environment than non-transit escalators. Major differences between the transit and non-transit types are: (a) rises of transit escalators tend to be higher; (b) transit escalators operate continuously for more than 20 hours a day, whereas department store escalators usually operate for a maximum of 12 hours a day; (c) transit loading is also comparatively heavier, especially when trains unload during the peak hours, leading to many persons on the escalator at the same time. The vertical alignment of the transit escalators is a problem because of the high rises, and the sway of the structure of elevated stations during train braking. The ability to maintain alignment in a severe transit environment that is contaminated by brake dust, subject to intermittent heavy loading, conditions of high humidity and temperature changes imposes strenuous operating requirements on transit escalators not found in other commercial environment.

In spite of these strenuous demands imposed on transit escalators, no differences in hardware exist between transit and non-transit applications. This is exemplified further in the design of the modular escalators, which have in recent years been used at several properties. The principal motivation for the modular concept is that it allows manufacturer to provide higher rise escalators for transit without any special tooling. The net effect is that modular escalators for transit with rises over 20 feet are comparatively economical to procure compared with conventionally designed escalators.

Vandalism encountered in the transit environment is a contributing factor to increased maintenance cost and lower availability of transit escalators. This is a critical problem for escalators in certain neighborhoods. Increased security with closed circuit television (CCTV) and surveillance could potentially reduce vandalism.

Although the objectives of this project concentrate on the technological aspects of escalators, some mention must be made of their interaction with the elderly. Many elderly persons and young children have great difficulties in using an escalator. In response to increasing retirement ages and federal policies promoting accessibility for the elderly, the importance of this problem is expected to grow.

2.2 Impact of Recent Innovations

Innovations in recent years include modular escalators, outdoor escalators used at several WMATA and BART stations, extra flat steps on top and bottom of the escalators, and automatic operating escalators. Each of these is described below.

2.2.1 Modular Escalators

A conventional escalator has one drive unit located outside the main truss, consisting of an electric motor and a gear reducer which drives the step chain and handrail. A modular escalator consists of several drive units (one for every 20-ft rise, 48-in. width), which share the load, and are located within the truss. These units drive the step rack and provide friction drive to the handrails. Modular escalators have lowered the capital cost of high rise escalators but, based on initial operating experience, they may have resulted in increased maintenance cost and lower availability.

Increased maintenance costs, especially on the high rise units, occur because of increased number of drive units, time required for the removal of steps to access the drive units, and increased wear of several components associated with modular design. For example, handrails in a conventional escalator in transit environment last about eight years, but at BART, modular escalator handrails have been lasting only two years. Several modifications are being made to components used in modular escalators to improve their performance. One of these has been to change the welded stub shafts, containing the pinion that drives the step chain, to a stronger forged design. Modular escalators, according to the manufacturer and operating properties are still in a shakedown period. More frequent failures are expected in the initial operation. Modular escalator performance should generally improve in years to come. Purchasers of modular escalators would best be protected by accepting bids only in conjunction with long-term maintenance contracts (15-30 years). Short-term contracts could lead to unanticipated price increased for contract renewals, particularly after 5 years when escalator components begin to wear out more rapidly.

2.2.2 Outdoor Escalators

Outdoor escalators provide access to a subway station from the street level. They give a pleasant appearance and are a great convenience to the user. However, the escalator is subjected to extreme temperature variations, water, snow, salt, and direct sunlight. Escalators used in this environment at WMATA use electrical heaters, which aid in melting the snow on the steps. These escalators are also provided with gutters for the flow of water. However, some moisture does get in and results in breakdowns. BART reports a requirement for more frequent lubrication and extended downtimes to dry weather-tight electrical switches for outdoor escalators. NYCTA reports accelerated deterioration of handrails due to sunlight. Based on our discussions with operators, it is not clear what proportion of the breakdowns of these escalators is due exclusively to weather. Further investigation is required as how to best locate and specify outdoor escalators.

2.2.3 Extra Flat Steps

Conventional escalators had 1.75 flat steps at each landing. WMATA uses two to four flat steps on several of their escalators, the high risers having the most flat steps. These increase the initial cost substantially (up to 30% depending on number of steps). These steps are located at the top and bottom landing of the escalators. They can help the patron when boarding a high rise escalator but can lead to confusion when the passenger alights from the escalator and expects to step onto the ground. The cost effectiveness and utility of extra flat steps is not clear, and requires further evaluation.

2.2.4 Automatic Operation (Tredles, Mats)

The stated purposes of automatic escalator operation are to achieve bidirectional flow when there is room for only one escalator, lower maintenance costs, and lower energy costs. These objectives are not always achieved. Automatic, tredle or mat operation can lead to increased maintenance due to hard starts. If the escalator motors can be stopped and started gradually by use of power conditioning circuits, mechanical wear may be reduced. Some automatic escalators can be started by a patron stepping on a mat switch in front of the escalator. NYCTA uses this feature on 29 of their escalators and is planning to introduce this feature on other escalators. BART is experimenting with this feature using gradual starts on a bidirectional escalator at the Bayfair Station. Use of this feature is desirable during the off peak hour. CTA uses automatic operation to achieve bidirectional flow. Based on our conversation with the operators it was not clear whether the savings in energy are offset by increased maintenance resulting from tredles. NYCTA uses this feature only if less than 8 starts of the escalator are made hourly.

2.3 Recommendations for Escalator Research and Development

Analysis of the data on escalators indicates that there is considerable variation in the escalator procurement process and escalator specifications among various rail transit properties. Modular escalators, purchased by several properties are going through a "burn-in period" with all the associated problems. Several of the properties with older escalators are having difficulty in procuring adequate spares resulting in longer downtimes.

Based on our contacts with operators and manufacturers of escalators and analysis operating data, the following potential R&D projects have been identified.

2.3.1 Development of Escalator Specification and Procurement Guidelines

Escalator manufacturers are responding to the transit industry's practice of selecting the supplier with the lowest bid. They have utilized standardization with non-transit escalators in an effort to reduce manufacturing cost. However, as escalators are expected to last for about 30 years, operation and maintenance costs are as important as the first cost in determining total escalator cost. Recognizing this, some properties such as PATH, request optional bids for 30-year maintenance in the RFP (request for proposal).

There appears to be much that can be gained from improved escalator procurement procedures. An effort to specify and deploy these procedures is required. One problem associated with contractor maintenance which requires careful handling is the sometimes conflicting objectives of lower cost to the contractor and restrictions on interrupting service during peak hours.

If properties were to utilize life cycle costs in supplier selection, there would probably be an improvement in the quality of the escalators produced. There would be an inducement on the part of the manufacturer to design for reduced cost of escalator maintenance.

Technical specification guidelines are required to ensure that the product meets the unique transit requirements. This has become necessary especially with the recent use of outdoor escalators. The locations of controls and machine rooms require adequate consideration for access and ease of maintenance. Guidelines are also required to make escalator designs vandal resistant and safer. Enforceable specifications of reliability and availability of escalators are needed to reflect the unique transit requirements. Specification for flat steps based on human factor engineering considerations is required.

2.3.2 Development of Guidelines for Operating Policy

There are issues of operating policy for which there is little agreement among the various properties. These include: trade-offs between time clock direction controls, hours of operation, operating speed, automatic operation by mat switch and in-house versus contract maintenance. Guidelines in these areas could be of potential use to all transit properties.

Increased escalator surveillance could also have an impact in reducing vandalism and accidents. The effectiveness of closed circuit television (CCTV) used with loudspeakers should be examined. Operational policy guidelines could also develop criteria as to when and where to install an escalator.

2.3.3 Modular Escalator Performance Review

Modular escalators at BART and WMATA are being maintained presently by the manufacturer under contracts with the properties. At WMATA this contract expires in 1983. Under the terms of the contract, it is not possible for anyone other than the manufacturer to make any hardware changes.

The manufacturer is making design changes to the equipment to improve the operations at WMATA. However, a performance review based on the analysis of operational failure data and maintenance requirements of modular escalators is needed to establish the adequacy of modular escalator technology for transit usage.

3. ESCALATOR TECHNOLOGY

3.1 Types of Escalators

There were no significant changes in basic escalator technology for 50 years until Westinghouse introduced the modular escalator in the early seventies. Modular escalators have been used at the BART, WMATA, MARTA, NYCTA, and Montreal systems. BART has only 10 modular escalators out of a total of 163 escalators, whereas all of the WMATA and MARTA system escalators to date are modular. NYCTA has three modular escalators in use.

Although there are no design differences between an escalator used in transit and non-transit, there are several important functional differences. The most critical is the higher rises in transit applications. Most non-transit escalators will rise one story or less than 20 feet. Many transit escalators will rise several levels with rises of over 40 feet being common. Recently, escalators have been built with rises over 90 feet. Transit escalators are subject to a more dense passenger loading of the steps (e.g., after a train arrival) than a non-transit escalator. The physical environment of a transit escalator is more severe. One end can be indoors exposed to air laden with brake dust, and the other end may be at a different temperature and exposed to the weather.

3.2 Operational Characteristics

Most escalators are capable of operating at either 90 or 120 feet per minute (ft/min) and are reversible. The rated or nominal hourly capacities of escalators based on various available widths are:

Rated Escalator Capacity (Passengers per hour)

	Escalator Width			
Speed ft/min	24 in.	32 in.	36 in.	48 in.
90	4000	5000	6000	8000
120	4800	5750	7300	9300

Traffic counts indicate that actual transit use capacity is about 65 to 85 percent of the rated capacity.(1) Escalator capacity increases at a slower rate than speed increases since passenger density decreases with increasing speed. Higher speeds can also lead to increased accidents especially for the elderly.

3.3 System Elements of a Conventional Escalator

The basic components of an escalator consist of the truss, tracks, steps, step chains, drive, handrail and balustrading. Figure 3-1 shows the cross sections of conventional and modular escalators. Major features of these components based on escalators used at NYCTA (described in Reference 2) are as follows:

3.3.1 Truss

The escalator is constructed around the skeletal framework called the truss. It is a latticed steel box consisting of two main side trusses, cross-braced to form the boxed truss. The truss contains the tracks, drive pulley, tension pulley and all electrical and mechanical equipment below the steps as well as the handrail and panels above the steps, which are bracketed to the truss.

Each end of the truss is fastened to a steel beam which transmits the load to the structure. Intermediate supports are also provided under the truss at points no more than 20 feet apart.

3.3.2 Tracks

There are four sets of steel tracks which are bolted to the truss. They provide running surfaces for step chain and step wheels. Sections of track are bolted together at splice points to facilitate replacement.

The tracks curve at the upper landing to allow the step chain and wheels to start the return trip. The radius of a segment of this upper curve track is kept to a minimum of 14 feet. This prevents undue loading of wheels and strain on the tracks.

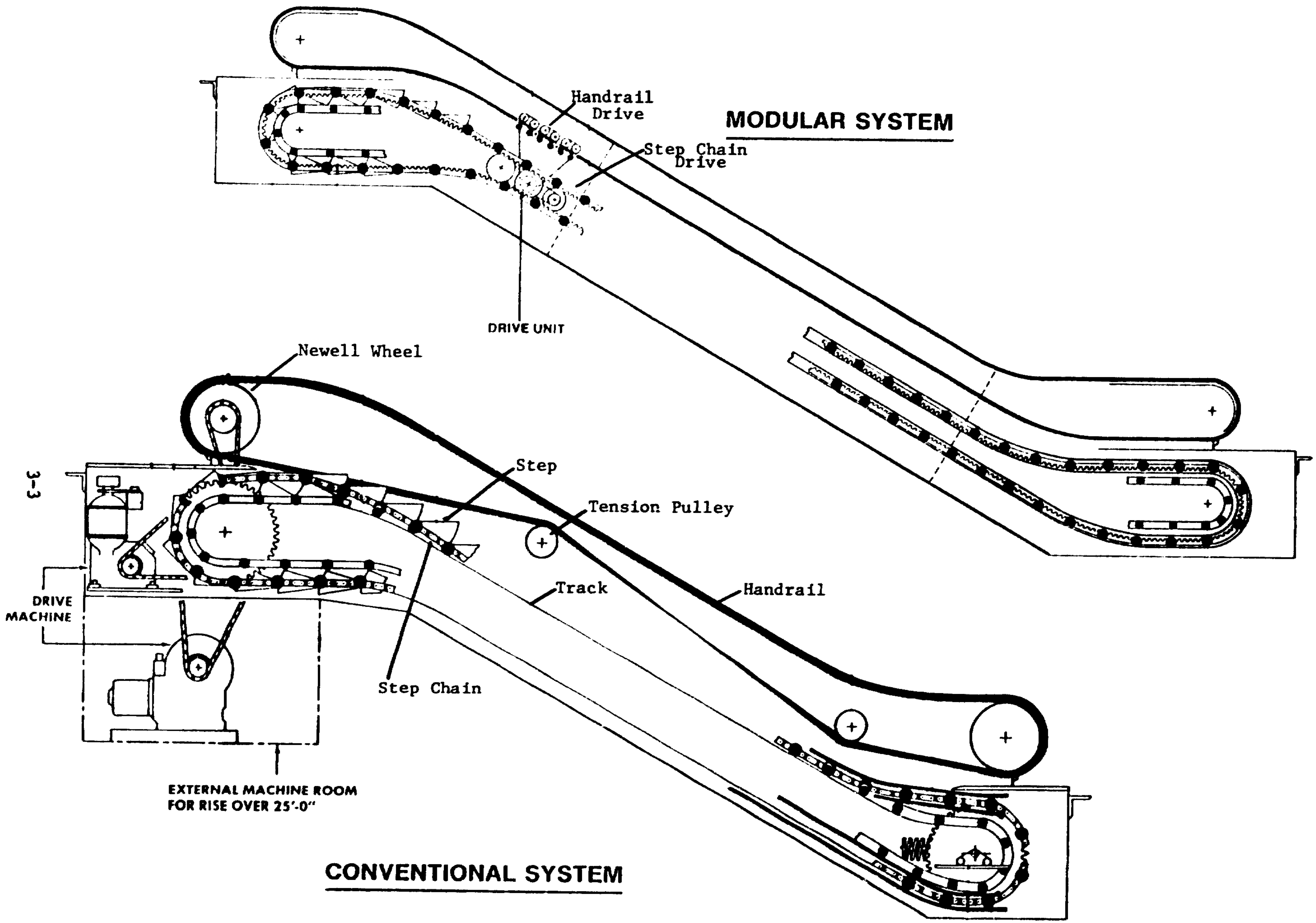


Figure 3-1. Westinghouse Escalator, Modular System (above) and Conventional System (below)

Source: Westinghouse

3.3.3 Step Chains

Two continuous steel chains are used to drive the steps around the loop and maintain proper spacing of steps. There is one chain on each side of the escalator. Each chain is attached to opposite ends of a step. Hardened rollers on the chains ride around the drive sprocket and plastic wheels which support the step chains' ride on the step chain tracks.

3.3.4 Steps

Each step has two sets of wheels. One set is fastened to each end of a shaft which supports the step at the point where the step and step chain join. These wheels are guided by two tracks - one at the top and one at the bottom of the wheel. The tracks provide a defined path for the chain and steps to travel around the loop from floor to floor. These are the load wheels and load tracks.

Another set of wheels is provided at the back of the step, at the end of the step riser. These are the trailer wheels which ride in a separate set of tracks. The trailer wheel tracks set the orientation of each step and insure that the tread will always be level through the usable area and guide the step around the pulleys on the return travel.

Steps are made of substantial metal frames and have curved risers. The step treads are made of die cast white metal with cleats about 1/8 inch wide. The treads are fastened to the steps.

Clearance between steps is kept to a maximum of 1/8 inch to prevent boots and other foreign objects from being caught between steps.

At the top and bottom landings, where the steps disappear into the floor, a comb plate fitted with comb teeth that fit into tread recesses is installed. The comb guides the shoes of passengers from the moving step to the stationary landing plate without hazard.

3.3.5 Drive

The escalator drive motor is a 208 volt, three-phase induction motor in the 35 HP range (the exact size depending on width and rise of the escalator). The motor is designed for two speed operation and is directly coupled to a worm and worm gear.

A chain sprocket wheel is mounted on the worm gear shaft. The drive chain loops between the sprocket wheel and the main upper drive pulley which is located within the truss at the upper landing. The main drive pulley drives the step chains. A pulley at the lower escalator landing is held against the chains by springs to remove any slack from the step chains. A brake and speed governor are also part of the drive assembly.

The entire drive assembly (except the main upper drive) and motor controller is located in a machine room just below the upper landing. The assembly is mounted on a steel bedplate which is securely anchored to the machine room floor. This prevents the drive machine from being pulled off the floor by the tension in the drive chain between the machine and escalator. The tension pull for a 4-foot wide escalator with a 30 foot rise is about 7,000 pounds.

To control the escalator at slow speed for maintenance inspection purposes, an auxiliary slow speed drive is provided. This drive moves the escalator at 10 feet per minute and permits maintenance men to closely examine the running gear when in motion. The drive is electrically powered. Manual operation is also possible, but at a much slower speed.

From the machine room, a maintenance personnel can lubricate the machine and escalator, inspect all equipment, and check for malfunction (sometimes without interrupting escalator operation). For safety reasons, the escalators would be barricaded if it were operated at inspection speeds or if it was going to be started and stopped. Machine rooms make it possible to provide 24-hour service. This would not be possible with the department store type installation, where the motor is usually located in a pit accessible by lifting a landing plate.

The escalator can be controlled from three locations. A set of start, stop, speed, and direction buttons are located on the control panel in the machinery room and in the upper and lower ends under a locked deck panel. Inside the panel the direction switch is key-operated. On newer escalators, an additional switch has been added to select automatic control.

Automatic safety devices that stop the escalator or activate an alarm are also provided. These include sensors to detect a human's limb or shoe caught in the combplate or by the handrail, brakes to prevent motion when power fails, and smoke detectors at some properties. The safety devices are sometimes intentionally activated by mischievous children.

3.3.6 Handrail

The handrail is made of neoprene on laminated dacron with steel tape imbedded in the neoprene. The handrail slides on brass guides fastened to the top deck of stainless steel panels. It rides over a large pulley (newel wheel) at the top and bottom landings. At the point where the handrails enter the newel panel near the floor, a stiff brush closure prevents accidental entrance of a child's finger or a foreign object. This brush closure is located so that normal accidental entry of a hand is impossible.

The handrail pulley is chain driven from the drive shaft below. The handrail receives its motion by friction contact with the upper handrail pulley. Tensioning devices are used to maintain pressure and friction contact between the handrail and pulley.

3.3.7 Balustrading

This comprises all interior and exterior panels, skirt panels, deck covers and mouldings. It is supported on brackers which are mounted on the truss. All panels are fireproof. Interior panels are sheet steel faced with a colored vitreous porcelain enamel. Exterior panels are stainless steel.

The balustrading is streamlined with extended newels at upper and lower landings. Certain portions of the balustrading are removable to permit access to the interior for inspection, lubrication, and adjustment of safety devices. The panels are held in place by aluminum and/or stainless steel moldings.

3.4 System Elements, Modular Escalators

The modular escalator is functionally similar to the conventional escalator. The major difference is in the number and location of the drive units. The truss, steps, and balustrading are essentially similar to a conventional escalator with single drive.

In a conventional escalator, the steps and the hand rails are driven by a motor located at the upper landing. The drive motors for a modular escalator are located along and within the truss. This feature reduces initial costs even for a 20 to 30-ft rise escalator since it eliminates the need for construction of a machine room and the loading of the step chain is reduced. However, maintenance procedures are more complex for modular escalators. Description of system elements of a modular escalator (3) follows.

3.4.1 Drive Unit Assembly

The number of individual drive assemblies used in an escalator is proportional to the escalator rise. For a 32-in. wide escalator a drive unit is used for each 30-ft rise and a 48-in. wide escalator requires a drive unit for each 20-ft rise.

Each drive unit is a self-contained assembly, enclosed within the truss. The unit consists of two drive sprockets and two idler sprockets which support a triple strand driving chain. The outer strands are made of steel rollers, the center strand of polyurethane rollers. The AC motor drives the shaft-mounted helical spur gear speed reducer via a drive belt. Motion to the steps is transmitted from the drive unit through the driving chains engaging the step link assemblies.

In the escalator models observed, the speed of each motor is determined by the same power input and load on the particular motor. The motor power supplies do not provide feedback or control mechanism to coordinate the speed of the individual motors or respond to different loads. Slight variations in motor speed can lead to increased stress on the chain and drive assembly.

The drive unit also consists of a disc brake on the input shaft of the reducer. In addition, the drive unit consists of six roller handrail drives mounted above each side of the main drive and are driven by a timing belt from the main drive shaft.

3.4.2 Link and Shaft Assembly

The step link and shaft assemblies are an endless loop chain. They form the rigid link between axles and prevent the steps from coming in contact with each other. The link assembly is a toothed track. These teeth mesh with drive chains transmitting the motive power to move the steps. Self-lubricated bronze bearings are used between racks and axles. Polyurethane rollers are used to guide the steps between the skirts, tracking both vertical and horizontal movement.

3.4.3 Handrail Drive

The handrail drive consists of drive rollers which engage the inner fabric surface of the handrail. The idler pressure rollers engage the external side of the handrail. The handrail is driven in synchronism with the steps.

Handrails are driven at each motor location. This is a more complicated process than in a conventional escalator where the driving force is supplied by the same large radius pulley that reverses the handrail direction at each landing. At a mid-escalator drive point, the modular handrail is passed through several closely spaced small radius drive rollers to achieve the proper frictional driving force.

3.5 System Characterization

Other differences exist relating to the modular and conventional escalators. These differences, based on data supplied by Westinghouse, are shown in Figures 3-2 and 3-3.

(a) Figure 3-2 shows the need for a machine room for a conventional escalator which rises more than 25 feet. The modular escalator does not require a separate machine room because all drive units are enclosed within the truss.

(b) Figure 3-3 shows the design load requirements for the step chain of conventional and modular escalators. Because of the modular concept, the load ideally being shared by each drive unit, the maximum load is proportional to the load on the section of the escalator between two drive units, which is 20 feet for the 48-inch wide escalator. Thus, maximum load, irrespective of the escalator rise on the step link of the modular escalator is ideally about 3000 lbs.

The step chain design load of a conventional escalator increases with the rise and hence the requirements of strength and chain size. Thus, in the past, high-rise escalators (conventional) were usually limited to rises up to 50 feet due to dramatic increases in their load and cost with rise.

(c) Some power savings could be achieved with the use of modular escalators by shutting off some of the drive units and sharing the load by running the motors at peak efficiencies.

3.6 Operation and Maintenance Requirements

There are considerable differences in maintenance requirements for the modular and the conventional escalator. Maintenance requirements for modular escalators are generally higher than those for the conventional escalator due to the multiple drive units.

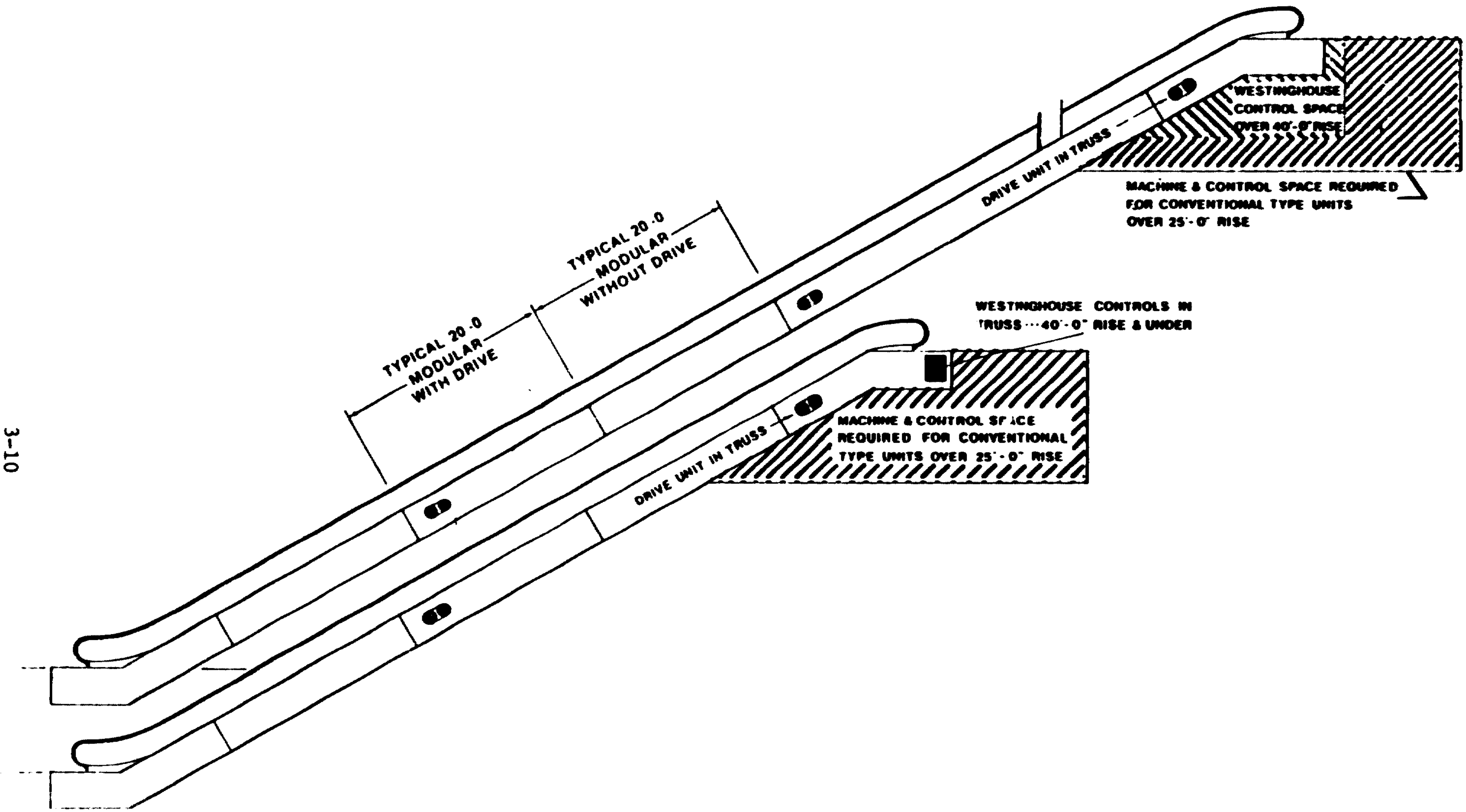
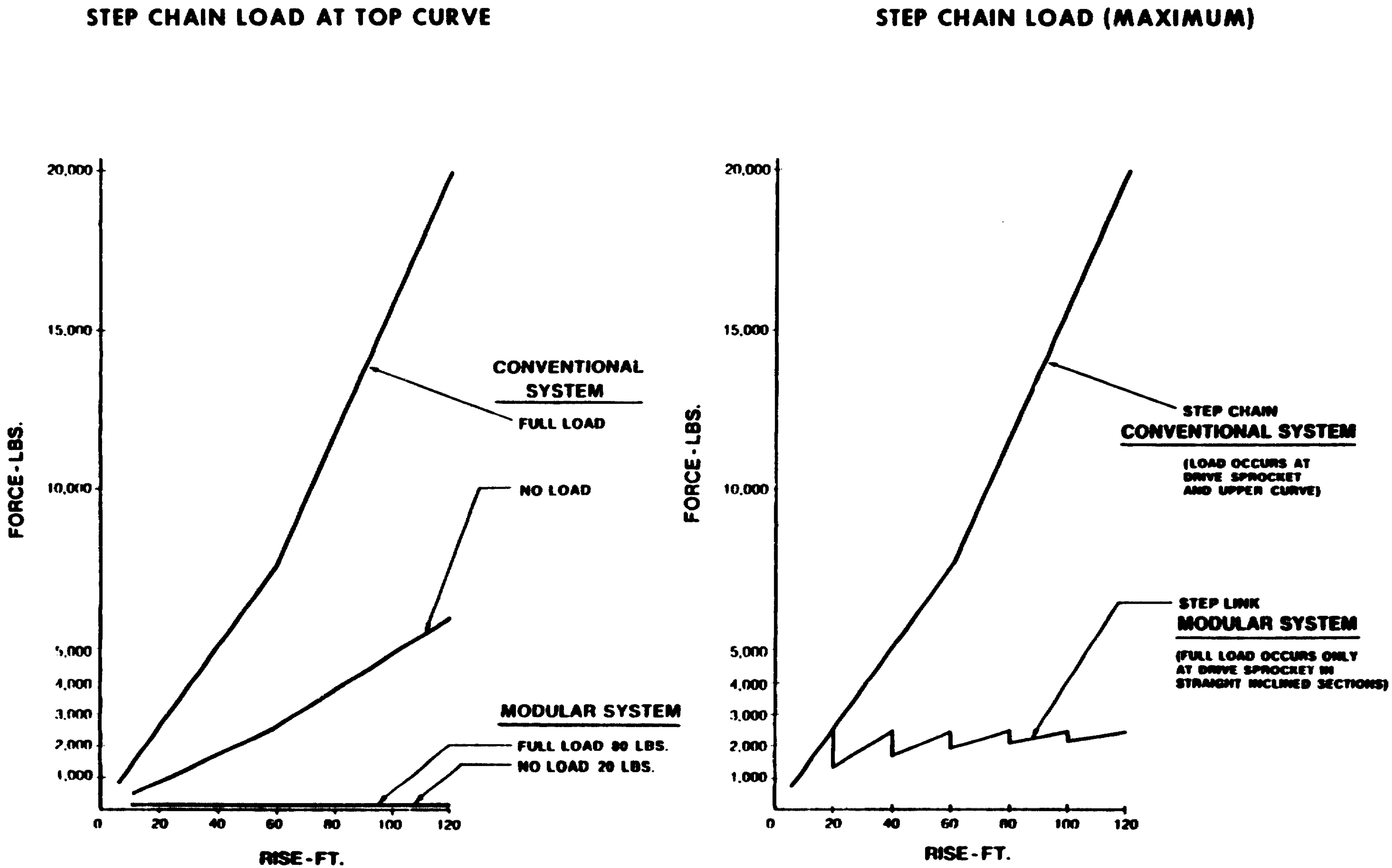


Figure 3-2. Westinghouse Escalator Modular System - Machine and Control Space Requirements, Modular vs Conventional

Source: Westinghouse



Source: Westinghouse

Figure 3-3. Westinghouse Modular Escalator System - Step Chain Load

Normal maintenance, such as drive unit inspection and periodic lubrication of the drive chain, can be accomplished in a conventional escalator from the machine room and does not require stopping the escalator. A modular escalator, by design (drive units in the truss), requires not only stopping the escalator, but also prevents the use of the escalator as stairs since a step must be removed to access the drive unit. The effect of routine maintenance on the modular escalator availability can be reduced by scheduling the routine maintenance at off-peak or non-operating hours.

3.6.1 Escalator Maintenance

Otis provided the following information on maintenance of escalators (4). The time spent maintaining an escalator is comprised of four basic functions. The first two consist of scheduled services and the last two of unscheduled services.

1. Examination hours
2. Repair hours
3. Call backs, regular time
4. Call backs, overtime

Examination hours are used to lubricate, adjust and clean the escalator and its components. This work is traditionally performed during regular working hours.

Repair hours are comprised of time spent in replacing worn or damaged parts such as handrails, drive chains, step chains, etc. Escalators generally last for about 30 years. Components such as handrails, drive chains, and step chains are replaced periodically or when they wear out.

Call-back hours consist of time spent returning the escalators to service following interruption of service caused by activation of safety circuits or overload protection. Since interruption of service may occur at any time of day or night, this work might be performed during regular working hours or after hours.

The number of examination hours is determined by planned lubrication frequency and preventive maintenance practice. This work is traditionally performed during regular working hours and its frequency increases as the use of the equipment is increased beyond a base of 60 hours per week.

Repair hours can be determined by past experience in replacing major components of the escalator. For example, an escalator handrail is expected to last approximately 8 years before it requires replacement. The time to replace a pair of handrails is estimated to be approximately 16 hours for a team of two men. Therefore, 16 hours is pro-rated over 8 years and two hours per year is estimated into the maintenance for replacement of handrails. Similar calculations are performed for other major components of the escalator such as step chains, drive chains, rollers, and bearings. Naturally, the more use an escalator gets the sooner these components will require replacement. Repair labor is then pro-rated over a shorter period of time.

Call-backs are difficult to predict and may occur at any time, day or night. Escalator manufacturers indicate that all escalators average over four call-backs per year. Escalators under the best operating conditions will exhibit an average of one call-back per year based on 60 hours of use per week. Greater use of the escalator will result in increased overtime hours per week and a greater number of call-backs per year. Since overtime call-backs are paid at a premium rate, there will be a disproportionate increase in call-back hours with an increase in the use of equipment (3).

The escalator industry partially describes the environment of an escalator by usage factors which are based on the average numbers of hours per week that equipment is in use. Table 3-1 shows a list of usage factors and building types which exhibit each factor. Usage factors generally determine the maintenance requirement. Expected call-backs are proportional to the usage factor.

Table 3-1. Usage Factors and Building Types

Usage Factor	Hours Use per Week	Building Type
1	60	Office
2	60-80	Retail Store
3	81-100	Buildings
4	101-130	Hotels
5	131-168	Transportation Facilities

Transportation facilities have the highest usage factor and also the greatest peak passenger conditions. This leads to shorter component life, more frequent examinations, and more costly maintenance since major component life must be pro-rated over a shorter time period. In order to control the time spent on a given escalator for examinations, repairs, and call-back, the escalator is generally designed with major components readily accessible. Four to five callbacks per year per escalator would be required at most transportation facilities.

For a conventional escalator, the machine and controller are located at the upper end of the escalator. Access is gained through a machine room access door which functions as the upper landing floor plate. Lubrication can be performed from the upper and lower landing without removing steps from the escalator. For adjustment of the handrail tension, skirt board clearance and chain tension, several steps must be removed. The step assembly is easily removed at the lower landing and adjustments are not performed frequently after the "run in" period of the equipment.

BART personnel supplied in-use data on maintenance of conventional escalators. This is summarized in Table 3-2.

Table 3-2. Estimates of Scheduled Maintenance Requirements for Conventional Escalators (Rise 40 ft)

	Frequency per year	Hours per Operation	Hours/ Year
1. Inspection and Preventive Maintenance including cleaning, lubrication, replacing broken comb plates and adjust chain tension	12	1	12
2. Annual Maintenance Inspection, cleaning, lubrication and oil changes (all components)	1	24	24
3. Major Overhaul			
Replace step chain	1/8	60	8
Replace handrails	1/8	12	2
Replace handrail drive bearings	1/10	20	2
Replace sprockets and step rollers	1/10	20	2
Total Scheduled Maintenance			50 hours/year

Modular escalators used at BART and WMATA are going through a "burn-in" period, according to the operators. Initial data indicates that replacement of certain parts for modular escalators occurs more frequently than that for conventional escalators. These items include handrails, stub shaft and bearing, handrail drive bearings, and polyurethane rollers on a link chain. The stub shafts are being retrofitted with forged ones expected to last for 30 years.

Based on data supplied by BART personnel the replacement rates for these items impose additional pro-rated annual maintenance requirements shown in Table 3-3.

Table 3-3. Estimated Difference Modular and Conventional Scheduled Maintenance

	Frequency		Hours per	(Modular)	Difference
	Modular	Conventional	Operation	hrs/yr	Modular vs Conv. hrs/yr
1. Polyurethane rollers on link chain	1/3 yrs	1/20 yrs	24	8	7
2. Handrail drive bearings	1/2 yrs	1/10 yrs	24	12	10
3. Handrail	1/2 yrs	1/8 yrs	8	4	3
					20 Total

These items together impose an additional annual requirement of 20 hours per year due to faster wear on a pro-rated basis. The effect of stub shaft replacement has not been included.

Thus, if the present replacement rates continue the annual maintenance requirements of a modular escalator are about 70 hours compared to about 50 hours for a 40-ft rise conventional escalator. However, with design changes under investigation these additional requirements might be cut by at least 50%, resulting in an annual maintenance requirement of about 60 hours for a modular escalator compared to 50 hours for a conventional escalator.

4. ANALYSIS OF OPERATIONAL DATA

Because of the limited extent of this project, data collection efforts on escalator operations were restricted to that provided by WMATA and a telephone survey of transit agencies.

4.1 WMATA Data Base

Operational data were provided by the WMATA staff for their escalators for the time period of July 1978 through January 1979. The data consist of maintenance calls for each month. The data is further classified according to the subsystem failure.

The monthly maintenance call data is summarized below.

WMATA ESCALATOR UNSCHEDULED MAINTENANCE DATA

Month	Maintenance Calls
July 1978	119
August 1978	137
September 1978	116
October 1978	142
November 1978	203
December 1978	141
January 1979	200

Increased maintenance calls after October reflect expanded WMATA service. The WMATA system operating at about 20 hours a day reflects a usage factor of 5 acording to Table 3-1. Best operating conditions would reflect a call-back (maintenance call) for a 60 hour week at the rate of 1 per year. Thus, WMATA escalators would have under best operating conditions about five escalator failures per year per escalator or about 1500 per year for approximately 300 escalators or 125 maintenance calls monthly. The maintenance call frequency is expected to be reduced once the system overcomes the initial period of installation problems. It was not possible to verify the portion of these calls caused by equipment malfunctions.

Analysis of unscheduled out-of-service conditions by subsystem failure data supplied by WMATA is shown in Table 4-1 reflecting the monthly call-back analysis record.

Table items B through J are essentially safety related items. The switches used in skirts, brakes and push button assembly encountered significant failures. This has also resulted in some modifications to the equipment.

Data for handrail drive unit, handrail, and handrail guide indicate that they are a problem. Maintaining handrail in alignment for a high rise escalator is a technically difficult problem considering the maintenance of constant tension along the entire length of the handrail.

Combfingers also accounted for substantial number of failures. Broken combfingers have to be periodically replaced. "Other" failures (items X, Y and Z) totalling 274 seem to be predominant. There are several identifiable causes for the majority of the "other" failures. On nearly 50% of these calls, the escalator is found to be running or starts when the key is inserted or the station gate switch adjusted. The escalator start keys are in an inconvenient location and station attendants will sometimes report an out-of-service escalator rather than attempt to turn it on. The station gate switch shuts off power to the escalators when the station is closed. It frequently fails to restore power when the station and gate are open. Since this is not part of the escalator system, this type failure is charged to "other."

Escalators are on the transit systems' non-essential power circuit. Interruptions in this circuit will sometimes cause circuit breakers in the escalator to trip requiring manual resetting. Accidents are also reported under "other."

WMATA has had the escalator controls at two test stations moved to a more convenient location. They report a much lower incidence of other escalator call backs for these stations.

Table 4-1. WMATA Callback Analysis Record, July 78 - January 79

MONTH		July	Aug	Sept	Oct	Nov	Dec	Jan	Sub Totals	Percent
Controller	A	1	2	2	7	5	-	4	21	1.99
Skirt Switches	B	19	9	11	8	16	13	13	89	8.43
Brake Switch	C	4	6	7	6	15	5	9	52	4.92
Underspeed or Overspeed Switch	D	2	2	4	6	9	1	7	31	2.94
Broken Drive Belt or Broken Drive Chain	E	1	4	-	2	3	2	2	14	1.33
Broken Step Rack Switch	F	1	-	-	-	-	-	-	1	0.09
Interlock	G	4	9	6	-	10	4	7	40	3.79
Step Upthrust Switch	H	-	4	1	-	-	1	2	8	0.76
Push Button Assembly	J	17	15	19	24	23	27	11	136	12.88
Conduit & Wiring	K	-	-	-	-	-	-	-	-	
Drive Unit Reducer or Shaft	L	2	3	1	2	5	1	4	18	1.70
Brake	M	-	3	1	-	1	1	-	6	0.57
Escalator Drive Chain or Sprocket	N	4	2	1	2	8	4	15	36	3.41
Combplate Lights	P	-	-	-	-	-	-	-	-	
Handrail Drive Unit	Q	15	13	5	11	17	9	6	76	7.20
Handrail or Handrail Guide	R	10	9	5	13	17	10	42	106	10.04
Track or Turnaround	S	-	-	-	2	1	1	2	6	0.57
Step or Pallet	T	1	-	-	-	2	-	-	3	0.28
Step, Pallet or Rack Guide Roller	U	-	-	-	-	-	-	-		
Guide Roller (at Combplate)	V	-	-	-	-	-	-	-		
Skirt, Panel, Deck or Glass	W	-	-	-	1	-	1	1	3	0.28
Escalator V-Belt or Walk Drive Chain	X	-	-	-	-	2	-	-	2	0.19
Combfinger	Y	8	17	16	13	20	15	19	108	10.23
Other	Z	27	34	32	41	46	39	55	274	25.95
Power	AA	3	5	4	3	3	7	1	26	2.46
Smoke Detector	BB	-	-	-	1	-	-	-	-	
Totals	-	**119**	**137**	**115**	**142**	**203**	**141**	**200**	**1056**	**100.0**

Subsystem failure data highlights the critical elements in a escalator. Further analysis of the exact nature of work done for each failure is necessary to reach any conclusion in identifying the failure prone items.

4.2 TSC Data Base

Data supplied by TSC on the preliminary assessment of WMATA escalator reliability and associated maintenance experience as a part of WMATA Technical Assessment (5) was analyzed. The summary of a telephone questionnaire from nine transit properties on escalator experience is shown in Table 4-2.

The TSC supplied data was analyzed to understand the extent of escalator problems encountered by properties other than WMATA. Several properties including WMATA, CTA, MBTA and PATH indicated vandalism and unauthorized stops as major causes of failures of escalators.

Consequences of failures are not serious at WMATA, CTA, and BART because of multiple units at WMATA and steps at CTA and BART. Escalator failures result in serious crowd control problems at NYCTA and SEPTA.

Among the components requiring improvement handrails were frequently mentioned at several properties. Several of the properties indicated a need for relocating controls at more accessible locations. The problems of unauthorized stops led the respondent at PATCO to suggest hiding the stop button, a change not permitted due to safety requirements of American National Standards Institute (ANSI) escalator standards.

Only four properties, CTA, TTC, NYCTA, and SEPTA, have in-house maintenance; remaining properties have contract maintenance. Almost all properties have preventive maintenance programs either in-house or under contract.

Failure rate data was available only at WMATA, CTA, TTC, BART, and PATH. CTA experiences higher failure rates per escalator on a daily basis due to a large number of older escalators.

Table 4-2. Summary of Answers to Questionnaire

	TRANSIT PROPERTY								
	WMATA	CTA	TTC	BART	MBTA	NYCTA	SEPTA	PATCO	PATH
City	Washington D.C.	Chicago, IL	Toronto, Ontario	San Francisco, CA	Boston, MA	New York, NY	Phila., PA	Phila., PA	Jersey City, NJ
No. of Units	279.	78.	215.	164.	65.	120.	19. plus 6 not in use	11.	26.
Manufacturer Type	All West. Modular Type	N.A.	N.A.	50-Montgomery 98 - West. 16 - Otis	28 - Mont. 31 - Otis 3 or 4-West. 2 or 3-Others	N.A. N.A.		8 - Mont. 2 - Otis 1 - West.	19 - Otis 2 - West. 5 - Others
Failure Rate: from all causes down 8 hr	7/day 1/mo.	5 to 7/day 2 to 3 day	10/day 2/week	2 to 3/day 2/mo.	N.A. not reported	N.A. 2/mo.	N.A. N.A.	N.A. 1/mo.	2/day 1/mo.
Major Causes of Failures	Vandalism & Mechanical Failures	Unauthorized stops, minor adjust., Handrails	Handrails on older units Houghton	Otis: Hand-rails, bearings West.Modular: Handrails Main Drive Shaft	Vandalism	"Misuse"	Initial align. maint., weather	Handrail, bearings, micro sw.	Not sure, except for unauthorized stop at Grove St.
Consequences of Failures	Minimal, since 3 to 4 escal. at each station	Not serious (stairs available)	Serious at busiest station, not serious in suburbs	Not serious (stairs plus reverse other units)	Minimal (older units) are very slow	Some station platform crowding at busiest sta.	Some station platform crowding at busiest sta.	Complaints by riders	Minimal
Desired Improvements	Change controls, protect from weather, improve design	Retrofit segmented handrails	Redesign, make less compact for easier maint.	Should be run slower West. mod: should relocate controls	Replace older Montgomery units (hardest to service)	Better accessibility to moving parts	Want to replace 6 units with West. mod.	Replace access covers w/alum.covers hide 'stop' buttons	Improve combs of old west. design-caught a sneaker
Escalator Availability	98%	N.A.	N.A.	93% avg. (incl. maint. & repairs)	95%	95.8% avg.	N.A.	99%	N.A.
Avg. Time to Restore	2 hr.	N.A.	N.A.	N.A.	N.A.	1 hr - vandal. 1 hr - other causes	1 day or less	N.A.	0.5 hr-stop button 4 hr - other causes
Maintenance In-house vs. service contract	Service contract w/West.	in-house	in-house	in-house, except for 10 West. mod. units.	service contracts	in-house, plus contract. rebuilds 2/yr.	in-house	service contracts	service contracts (Otis & West.)
Preventive Maint. Program? If so, describe	Yes Done by West.	Yes Basic Lube. Done at night	Yes 6 units out for 6 hr over-haul at all times	Yes Scheduled at weekly, monthly, 6 mo. & yearly intervals	Yes Inspect 2 x daily, inspect weekly inspect monthly	Yes Inspect & lube twice/week, major inspec. 3 to 6 mo.	No (no staff)	Yes Monthly hand-rails insp. 6 mo. - Micro-SW	Yes Monthly & yearly (by Otis & West.)

N.A. - not available

An overview of this data across several properties indicates that there are some common problems such as vandalism, handrails, and relocation of controls as needing attention. Older escalators experience higher failure rates and longer time to repair due to parts availability.

4.3 Escalator Reliability

The data from the various properties indicate that estimates of availability vary from 93% to 99%. The WMATA data supplied to JPL indicate that an availability of 99.7% was met for the six months between July 1978 and January 1979.

However, this availability of 99.7% based on a formula in the maintenance contract is not a true reflection of escalator breakdowns and maintenance at WMATA. For example, 203 escalator failures occurred during the month of November 1978. However, only one of these failures lasted for more than 18 hours and was included in the availability formula. Including the downtime to all failures would show a lower availability. Precise estimates of availability could not be made because of lack of detailed data on failures. This example illustrates one of the potential problems when specifying reliability criteria in purchasing contracts.

However, Table 4-3 shows the mean time between failures (MTBF) where data was available with the following results for July 1978 to January 1979.

Table 4-3. Mean Time Between Failures, July 78 - January 79

Month	No. of Escalators	Failures	MTBF*(hours)
July 1978	280	119	1312
August 1978	280	137	1140
September 1978	280	116	1303
October 1978	280	142	1110
November 1978	299	203	795
December 1978	299	141	1183
January 1979	299	200	834

*Based on 18 hr/day for entire month

An earlier analysis (5) of WMATA escalator reliability for quarterly data ending in June 1978 showed an MTBF of 600-900 hours. The MTBF shown above based on daily operation shows only marginal improvement since the state-of-the-art MTBF of 3000 hours is possible (5).

The effect of reliability on operations and patron delays due to escalators has been minimal. This is because there are multiple units in operation at most stations. The WMATA operating personnel indicate that they are satisfied with Westinghouse maintenance.

It should be noted that availability depends on reliability and the mean time to repair. Many breakdowns, especially those caused by passenger activation of safety devices, can be corrected quickly if an attendant is aware of the problem and is able to go to the escalator and restart it. Also, escalators are sometimes taken out of service for crowd control purposes. This can give a misleading impression to the casual observer as to escalator availability.

5. INSTITUTIONAL FACTORS

5.1 Background

Escalators have a long life, lasting up to 30 years. Escalator maintenance costs are largely a function of load and annual distance traveled (speed x time). As escalators age, the annual maintenance costs go up due to more frequent breakdowns. Major overhauls are sometimes needed to prevent frequent breakdowns.

Properties can have some control over the escalator maintenance cost by specifying in detail the exact equipment requirements during the procurement process. Escalator buying practices vary among properties. The market for transit escalators is small compared to other escalator uses. The two institutional factors of market size and procurement practices for transit escalators have a major impact in controlling the long term escalator performance and cost.

5.2 Escalator Market

Escalators in use at transit facilities are subjected to severe service requirements. They have rises up to 100 feet and operate up to 20 hours daily, seven days a week. Some escalators are unsheltered and exposed to rain, snow, sunlight and temperature variations between the top and bottom landing. In addition, steel dust and moisture present extraordinary environmental conditions. There are also problems with vandalism and passengers using escalators to transport bulky and heavy materials.

These conditions are unique to transit. The department store escalators are in a temperature controlled environment, with loadings that are much lighter than those in transit use. The department store escalators are used, at the most, only 12 hours a day and have rises lower than 20 feet.

Thus, escalators for transit have unique requirements. NYCTA (2) in the past has procured heavy duty escalators. They achieved this by specifying an upper track radius of 14 feet as opposed to 6 feet for a department store escalator. As the step wheels ride up the incline and pass from the inclined plane to the horizontal plane, they must support the entire load on the chain. If the radius between the two planes is small, few wheels support the load. A large radius will divide the load among a greater number of wheels reducing the load per wheel which decreases both track and wheel wear.

Other unique escalator requirements for transit consist of an exhaust fan to remove brake dust in the machine room, heaters for outdoor escalators at WMATA, and extra flat steps at both BART and WMATA on the high rise escalators.

There are four major manufacturers of transit escalators in the U.S.: (1) Westinghouse, (2) Otis, (3) Montgomery, and (4) Haughton (Ornestein & Koppel AG). Westinghouse produces only modular escalators for all markets. Other manufacturers produce conventional escalators with a single drive.

The design construction, installation, operation, inspection, testing, maintenance, alteration and repair of escalators are governed by the American National Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks. These standards are set by the American National Standards Institute (ANSI) A17 Committee. This committee continually revises the code to keep it up to date with the state-of-the-art. The membership of the committee consists largely of manufacturers, operators, insurance companies, consultants and representatives of various cities.

Transit escalators represent a small segment of the escalator market in the U.S. Escalator manufacturers generally consider transit escalator as an extension of their commercial product line, not as distinct product line. The majority of escalators sold for transit consist of rises of only 20 feet. A breakdown of the escalators rises at WMATA is shown below.

WMATA ESCALATORS

Rise	No. of Units
20 feet	224
40	95
90-100	21
Total	340 (514 modules)

Thus, nearly 2/3 of the escalators at WMATA are similar to escalators in other markets. Costs of conventional escalators and modular escalator for rises up to 20 feet are almost the same based on bids received at PATH (3). However, the cost of the high rise conventional escalator goes up dramatically due to larger drives and stronger chain. The modular escalator initial cost is generally proportional to the rise.

Use of modular escalators allows more standardization of components used in escalators and thus, a lower cost when compared to a conventional escalator. Table 5-1 shows the extent of standardization achieved for the drive units, rises, and escalator widths. Various rise escalators can be constructed by repeated use of similar parts rather than use of specialized heavy duty parts.

Table 5-1. Drive Unit and Motor Application

Escalator Width	32 in.	48 in.
Speed, ft/min	90 or 120	90 or 120
Motor H.P.	10	10
One Drive Nominal Max. Rise	30 ft	20 ft
Two Drives Nominal	60 ft	40 ft
Three Drives Nominal Max. Rise	90 ft	60 ft

The number of drive unit assemblies is a function of rise, speed and size of the escalator. Table 5-1 shows a few examples of the flexibility of the modular concept where the same sized motor and drive assembly is used in escalators of varying heights and widths (3).

5.3 Procurement Practices

Transit Properties procuring escalators generally specify the functional requirements of escalators in their RFP. Properties also require the manufacturers to bid on one or two years of extended maintenance. The major reason for short term maintenance agreements is to insure that major problems with escalator installation will be corrected by the manufacturer.

The WMATA procurement process for first escalator buy resulted in bids shown in Table 5-2. The total cost of the 74 modular (60-ft rise or less) (Westinghouse) escalators along with 24-month maintenance agreements was $8,887,312 compared with a conventional escalator (OTIS) of $10,292,556.

After modular escalators were selected for the first three bids, WMATA made the decision to purchase only modular escalators for the remainder of the system. Quotations were requested from only Westinghouse.

Table 5-2. WMATA Escalator Bids - 24 Month Maintenance

Station	No.	Westinghouse Cost Modular	OTIS Cost Convent.	Maintenance 24 months Modular	Maintenance 24 months Convent.
1. Arlington Cemetary	4	579,612	858,264	32,640	39,456
2. Arlington Cemetary	4	467,424	455,548	25,056	33,696
3. Crystal City	6	615,414	622,212	38,880	47,664
4. Crystal City	6	579,690	597,366	33,408	46,368
5. National Airport	4	375,688	405,208	25,920	31,776
6. Federal Triangle	3	280,269	295,860	17,424	21,888
7. Federal Triangle	3	219,177	255,282	16,414	20,448
8. Federal Triangle	3	293,814	294,339	17,064	24,048
9. L'Enfant Plaza	3	383,175	548,637	22,896	26,784
10. L'Enfant Plaza	3	503,673	687,724	27,864	33,624
11. L'Enfant Plaza	3	539,199	769,476	29,808	36,072
12. L'Enfant Plaza	10	979,320	1,002,010	57,000	76,800
13. L'Enfant Plaza	12	1,274,232	1,245,852	73,440	100,224
14. Stadium Arm.	3	452,955	643,809	25,632	31,104
15. Stadium Arm.	2	354,178	486,170	18,768	22,560
16. Stadium Arm.	2	196,422	196,492	11,376	15,696
17. Stadium Arm.	3	295,014	287,985	17,064	24,048
		8,382,000	9,644,000	490,567	632,170
Capital plus 24 Month Maintenance Cost	74	$8,883,000	$10,276,000		

Another approach taken by PATH is to require the manufacturers of escalators to bid on the acquisition cost and an optional 300 month (25 year) maintenance agreement with appropriate escalation for inflation. For a recent buy of 53 escalators for the PATH terminals, the bids received are as shown in Table 5-3.

Table 5-3. PATH Escalator Bids - 300 Month Maintenance

Company	Base Cost ($)	Maintenance 300 month ($)	Total Cost ($)
OTIS	3,566,265	3,941,000	7,507,265
Westinghouse (Modular)	3,980,000	4,019,700	7,999,000
Haughton	3,8880,00	5,612,700	9,492,700

Based on the lower cost for acquisition and long-term maintenance, OTIS was selected to supply escalators at PATH. The procurement practice followed by PATH is different from other properties. The advantages of long term maintenance agreement is to provide an incentive to the manufacturer to reduce the maintenance. The PATH approach is very close to requesting life cycle cost for escalators for the procurement bid.

There are at least two areas of long term contract maintenance that require further investigation: To ensure that escalators are serviced on a schedule that produces minimum interruption to passengers, and to determine the effect of strikes in the escalator repair industry on transit escalator availability.

A contract such as a two year maintenance agreement will result in detecting early flaws which can be corrected by the manufacturer. Experience at BART has shown that modular escalators are still being retrofitted with new components after four years in use. The manufacturer has the choice to renegotiate the maintenance agreement after the initial period and can request higher fees. In this situation, Transit Agencies have little choice other than to continue with the manufacturer at the cost demanded. However, if rail transit agencies requested bids for long-term maintenance they are protected from this situation. In addition, the manufacturer has the incentive to improve his design by using materials that will require lower maintenance and hence provide higher availability.

6. RECOMMENDATIONS FOR ESCALATOR RESEARCH AND DEVELOPMENT

6.1 Issues in Escalator Research and Development

The escalator manufacturers in the U.S. have been in business for more than 50 years. Transit escalators comprise a small fraction of their business. High rise (greater than 20 feet) escalators have very few uses outside of the transit industry. An UMTA sponsored escalator research and development program should take advantage of the design expertise available in the escalator industry and be sensitive to the limited leverage transit properties have on the escalator industry.

In recent years, there has been an upsurge in the demand for escalators used in transit due to the construction of rail transit systems at BART, WMATA, MARTA, and Baltimore. Responding to the transit industry practice of buying the lowest bid escalators, efforts were made by manufacturers to reduce cost and still meet the transit escalator requirement. The modular escalator allowed standardization of components between both transit and non-transit escalators.

Standardization of equipment used in transit and non-transit use is generally beneficial to the properties. This assures long-term manufacturer support and competitive pressure in the marketplace to keep the costs at a reasonable level. However, in the case of escalators for the operating conditions in transit, some equipment may be different from the non-transit environment.

The escalator industry is financially healthy and capable of producing escalators to meet transit needs. One way to procure an escalator to meet the special transit requirements is to specify these requirements in the procurement process. These requirements would increase the capital costs but reduce the long-term operating and maintenance costs and result in higher availability. Use of similar specifications by all transit agencies would increase the incentive of manufacturers to provide special transit features.

Any program undertaken by UMTA in the area of escalators should meet the needs of properties that will procure escalators in the near future, and properties that already have escalators in place that need improvement. The first group includes several new properties such as WMATA, MARTA, Miami, etc., that have yet to complete escalator purchases and older properties, such as CTA and NYCTA that are replacing the older escalators.

Properties such as WMATA must rely on the equipment manufacturers to solve their present problems. The equipment is being maintained by the manufacturer under a contract which expires in 1983. WMATA escalators are being modified by the manufacturer to improve operating performance as a part of the routine maintenance effort.

Section 4.3 of the technical provisions of WMATA contract (6) with the manufacturer makes it clear that only the manufacturer may make alterations, additions, adjustments, repairs or replacements to the escalator equipment during the contract maintenance period.

WMATA staff indicated that they are satisfied with the maintenance effort of the manufacturer under the terms of the contract. The long term concern of WMATA is obviously the time perid beyond 1983, when they will either negotiate a new maintenance contract or switch to in-house maintenance. The R&D beneficial to properties under these circumstances would be to estimate long-term performance of the modular escalators.

A performance review coupled with analysis of failures and availability data would be helpful. An analysis of the retrofits being made is needed to evaluate their long-term performance. Study could also help WMATA to determine the feasibility of taking such a responsibility of in-house maintenance.

Our analysis of the escalator operating policies indicates that there is a variation among properties. Choices and trade-offs for operating policies need clarification. Areas to be considered include in-house maintenance versus contract maintenance, use of treadle operated escalators, operating speed and escalator surveillance. These operating guidelines could be developed under R&D efforts by UMTA.

The problems of properties with older escalators needs to be investigated. One of the problems was the difficulty of getting spare parts in time, some items taking longer than six months to receive. Studies under the sponsorship of UMTA regarding methods to achieve improved maintainability of these escalators are required. There exists the possibility of joint buys of escalator spare parts to lower costs for all the properties.

Other UMTA sponsored studies helpful to properties are needed in the area of station designs for efficient handling of the traffic. While escalators are capable of handling large volumes, there seems to be inadequate understanding of coordination with fare collection equipment processing rates. The specification of number of escalators to be used should be proportional to the expected traffic flow. Our observation leads us to conclude that at several stations in the WMATA system, the number of escalators were overspecified. There are tradeoffs between the train headways, time to clear the platform, and escalator costs which need to be investigated. The merits of one high rise escalator versus two shorter escalators with an intermediate landing should also be investigated.

One very useful role for UMTA in escalator R&D appears to be the development of procurement guidelines including realizable and utilitarian specifications. Hardware development is best left to the escalator industry. The escalator industry is skeptical of federal involvement in escalator hardware R&D. In the long run, manufacturers of escalators will be able to supply equipment for transit industry needs based on their corporate R&D. The initiative must come from UMTA and operating properties. This requires a closer look at the procurement practices and specifications of escalators by operating properties. Such an improvement could be supplied by escalator manufacturers if transit agencies use criteria other than low bid such as life-cycle cost in selecting suppliers.

The specification of reliability in terms of MTBF and availability of transit escalators needs to be standardized. The availability must be based on all failures as opposed to current practice of using failures that are not corrected within 24 hours. In addition, the transit industry could benefit from a more uniform method of collecting escalator data, and an information exchange of maintenance practices.

It is our conclusion that an UMTA sponsored program in escalator research and development, by assisting transit agencies in specifying and procuring escalators, could substantially improve performance and reduce life-cycle costs.

7. REFERENCES

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