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# ACCELERATING WALKWAY SYSTEM TIMES SQUARE-GRAND CENTRAL STATION ANALYSIS

DECEMBER 1978

PREPARED FOR:
U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
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16. Abstract

An Accelerating Walkway System (AWS) is a high capacity, continuously available mode of public transportation. The Times Square-Grand Central Station AWS study analyzes the economic feasibility of an AWS in an urban application with a high existing passenger demand. Both of the two types of AWS analyzed, a one-directional reversible linear AWS and two-directional loop AWS, are capable of satisfying the demand and providing good level of service.

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Accelerating Walkway System
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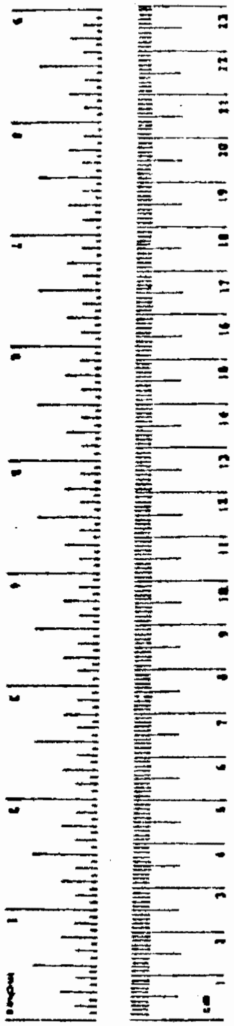
## METRIC CONVERSION FACTORS

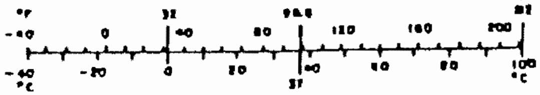
### Approximate Conversions to Metric Measures

| 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 |



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## 1.0 INTRODUCTION

An Accelerating Walkway System (AWS) is a high capacity, continuously available mode of transportation that has the potential of filling the level of service gap between walking or conventional moving walkways and conventional vehicular transit systems. The purpose of the Times Square-Grand Central Station case study is to analyze and determine the life cycle cost of an AWS in an urban application with a high passenger demand. It is not the intention of this study to examine the feasibility of replacing the existing rail shuttle system with an AWS.

### 1.1 Existing Times Square-Grand Central Shuttle System

The New York City subway system started the operation of its Interborough Rapid Transit (IRT) lines in October, 1904.* When the system extended its north-south operations on 1 August 1918, the subway leg between the Times Square and the Grand Central terminals became a shuttle operation. The Times Square-Grand Central Shuttle system has since then serviced the Midtown Manhattan cross-town traffic and is a major transfer link between various subway lines.

The shuttle system presently carries an average of about 90,000 passengers per weekday. The maximum peak hour one-way ridership which occurs between 8 and 9 AM, is approximately 6,500. The shuttle

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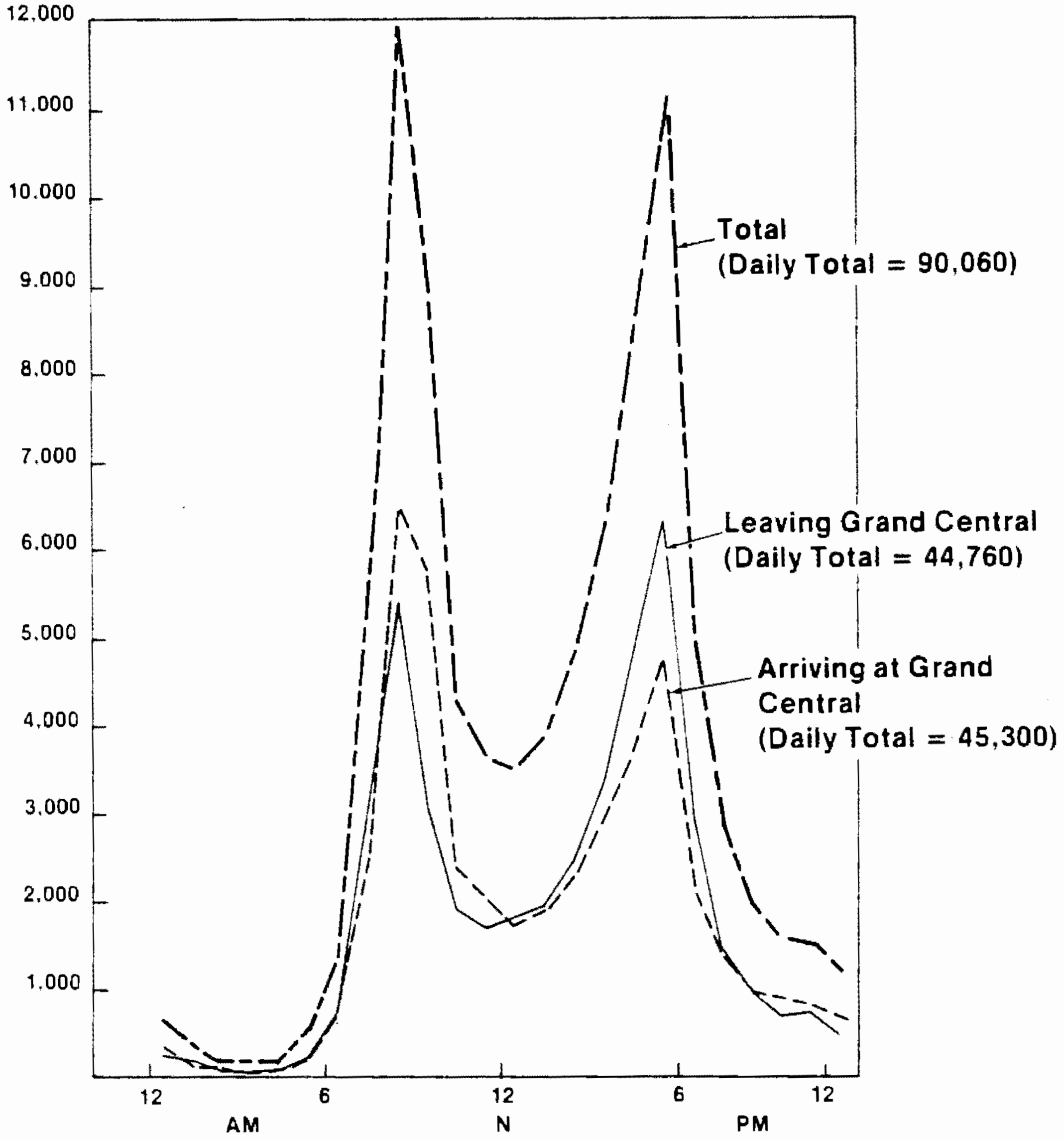
*"The New York Subway, Interborough Rapid Transit," New York Interborough Rapid Transit Company, 1904.

ridership hourly distribution is shown in Figure 1. The average travel time of the shuttle system is two minutes and the trains operate every four minutes during peak hours (approximately 7 to 9:30 AM and 4 to 6 PM), every five minutes during non-peak hours, and every ten minutes during the night hours (1 to 6 AM).

The length of the existing underground shuttle system between the two stations is approximately 732 meters. Figure 2 shows the general layout of the system. The tunnel between the terminals is a typical four-track, flat roof, "I" beam construction with a total width of approximately 15 meters and a vertical clearance of 3.9 meters. A cross section of the tunnel is shown in Figure 3. Only three tracks are currently in service: track number 1 runs a 3-car train, track number 3 runs a 4-car train, and track number 4 has a 3-car train as back-up. Track number 2 at the stations has been covered to make room for wider platforms. The maximum grade in the tunnel is 1.0 percent at the base of the rail, occuring between 6th Avenue and Broadway. One motorman and one conductor are required on each running train. Several "platform conductors" are also required, including the "handle operators" who operate the sliding platforms at the Times Square station and the attendants at the announcer's booth.

Figure 4 shows the existing Times Square Shuttle Station, Figure 5 shows the existing Grand Central Shuttle Station, and Figure 6 is a view of the existing tracks.



Source: New York Metropolitan Transportation Authority

**FIGURE 1**
**TIMES SQUARE-GRAND CENTRAL STATION SHUTTLE**
**TYPICAL WEEKDAY RIDERSHIP, 1976**

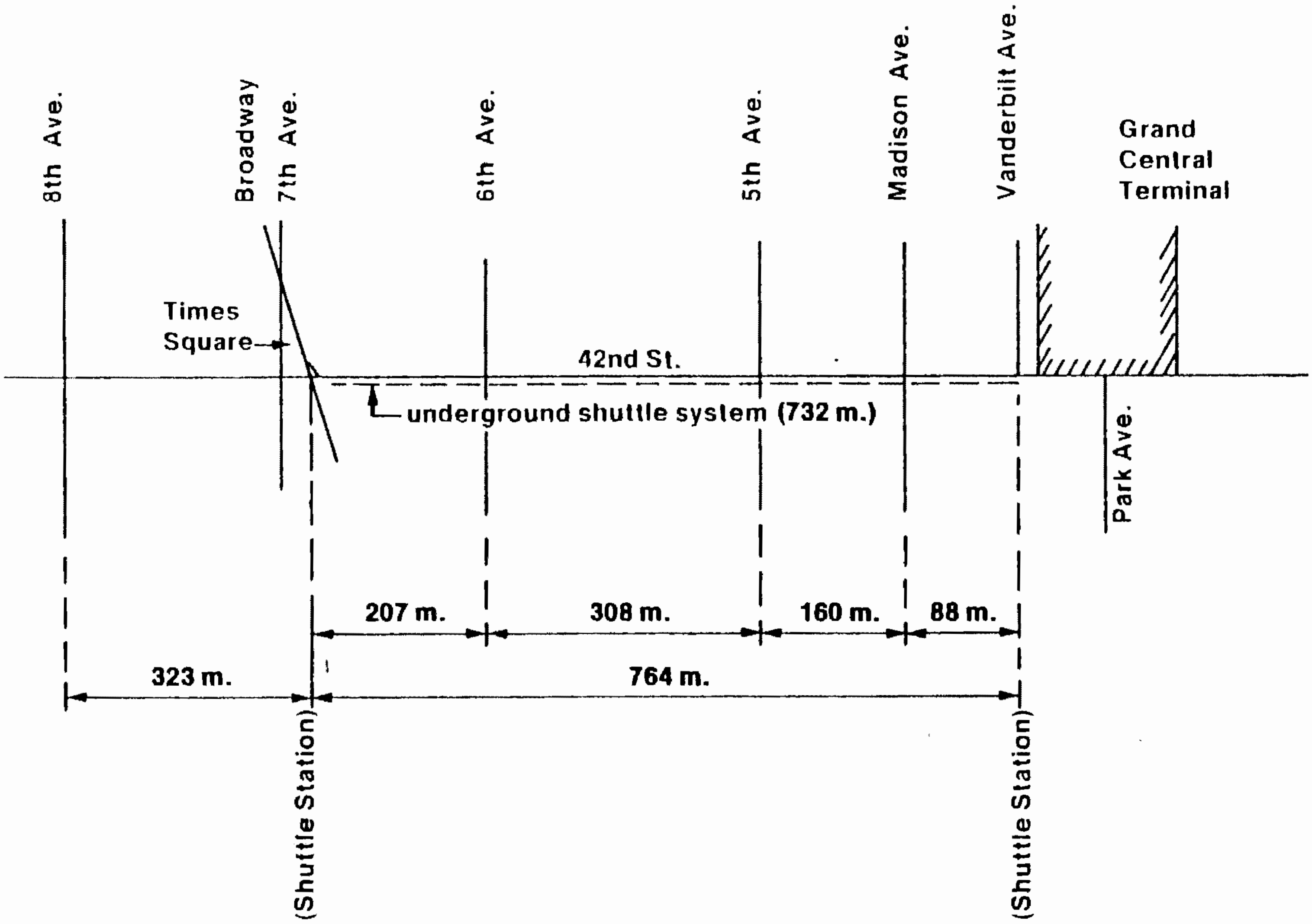


FIGURE 2
TIMES SQUARE-GRAND CENTRAL STATION SHUTTLE SYSTEM LAYOUT

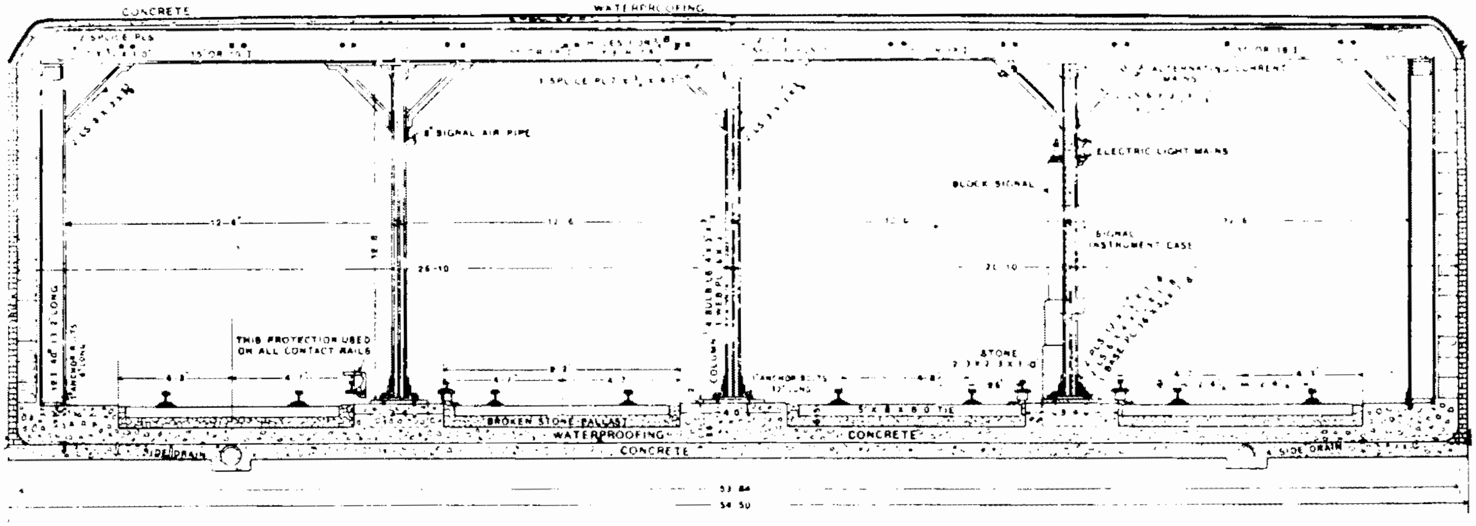


FIGURE 3
TYPICAL CROSS SECTION OF SUBWAY TUNNEL BETWEEN TIMES SQUARE AND GRAND CENTRAL TERMINALS

**FIGURE 4**
**TIMES SQUARE SUBWAY SHUTTLE STATION**

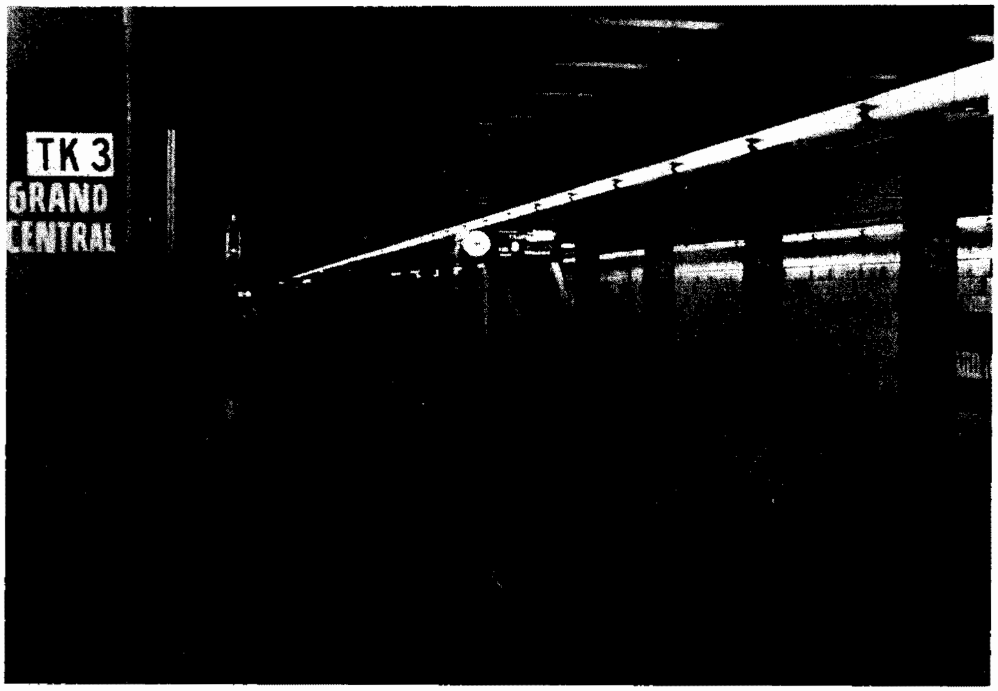


**FIGURE 5**
**GRAND CENTRAL SUBWAY SHUTTLE STATION**

FIGURE 6
A VIEW OF EXISTING SHUTTLE TRACKS

## 1.2 Other Existing Transit Services

Other transit services are presently available between Times Square and Grand Central Station. The Flushing Subway Line is located one level below the shuttle and two bus lines are on the street level.

The Flushing subway line (designated IRT 7) provides service between Manhattan and Queens, with the terminal stations at Times Square and Main Street, Flushing. The Flushing line between Times Square and Grand Central Station is located underneath the shuttle subway with an intermediate stop near 5th Avenue. Express service is provided between Flushing and Times Square during rush hours and local service is available at all times.

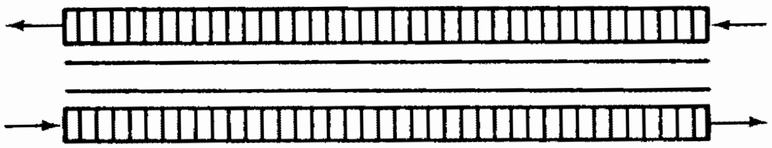
Two bus lines offer service between Times Square and Grand Central Station: Routes M106 and M104. M106 is an east-west (cross-town) route serving midtown Manhattan along 42nd Street between 1st and 12th Avenues. M104 is a mostly north-south route with its southern terminal at 42nd Street and 1st Avenue and the northern terminal at 129th Street and Amsterdam Avenue. It runs along Broadway for the majority of its length and turns to 42nd Street at Times Square. M106 buses operate every 2 minutes during morning and afternoon rush hours, every 3 minutes around noon time, every 10 minutes after 9 PM, and about every 40 minutes from 2 AM to the beginning of morning rush hours. M104 buses operate every 2 minutes during the day, every 4 minutes after 9 PM, and every 45 minutes from 2 AM to the beginning of morning rush hours.

## 2.0 DESCRIPTION OF ACCELERATING WALKWAY SYSTEMS

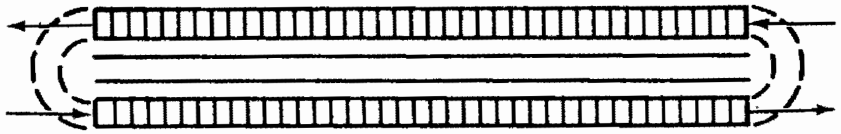
Conventional single speed moving walkways have been installed in many locations including airports, transit terminals, and other urban activity centers in order to extend the effective trip range of the pedestrian. These conventional mechanical walkways have operating speeds of approximately half walking speed (average normal walking speed is 4.9 km/h) and a maximum system length of approximately 183 meters. In order to extend the system length for longer moving walkway applications, higher speeds are needed. A version of an accelerating walkway system was proposed to New York City for Manhattan as early as 1904.

Several accelerating moving walkway concepts have been developed in which entry speeds of 1.6 to 2.4 km/h are gradually increased 4 to 5 times, resulting in line speeds about twice that of normal walking. Gradual deceleration occurs at the discharge end of the system to provide safe exit speed comparable with that of conventional moving walkways.

Modern accelerating walkway systems are of basically two different types; namely, one-directional linear and two-directional loop as illustrated in Figure 7. Among the five AWS manufacturers which have been identified by the Port Authority of New York and New Jersey as being sufficiently advanced in system development to be considered as prospective candidate suppliers, three are of the linear type: Dunlop



One-directional, usually reversible, linear AWS



Two-directional loop AWS

FIGURE 7
BASIC TYPES OF ACCELERATING WALKWAY SYSTEMS

Speedaway, Applied Physics Laboratory (APL), and Dean Research Corporation; and two are of the loop type: TRAX and Boeing Corporation.*

## 2.1 Early Accelerating Walkway System Proposals for New York City

The earliest proposal of a "continuous moving platform" system was submitted to New York City in November, 1904 by a group of leading railroad engineers and officials. The proposal was to build a multiple moving platform subway across Manhattan under 34th Street, between 1st and 9th Avenues. The proposed system consisted of four moving platforms with operating speeds ranging from 4.8 to 14.5 kilometers per hour.

The second "moving platform" system for New York City was proposed in 1923 by H.S. Putnam and supported by the chief engineer of the New York City Rapid Transit Commission. The proposal was to build an endless moving platform system in the shallow subway under 42nd Street, between Grand Central Station and Times Square to replace the existing subway shuttle service. The proposed system consisted of three parallel and continuous moving platforms with operating speeds of 4.8, 9.7, and 14.5 kilometers per hour, powered by linear induction motors. The fastest platform was to be wider than the others and fitted with seats. Although a complete demonstration installation was constructed and tested in Jersey City, the proposal was not adopted.

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*"Accelerating Moving Walkway Systems Technology Assessment," Report B of Series (Draft), J. Fruin, et al., Port Authority of New York and New Jersey, 1978.

Between 1948 and 1951, a pedestrian conveyor system called "Carveyor" was proposed for New York City jointly by the Goodyear Tire and Rubber Company and the Stephens-Adamson Manufacturing Company. The Carveyor was a system of wheelless cars carried on conveyor belts which would move slowly through stations at a speed of about 2.4 km/h and accelerate to a high speed of about 24 km/h between stations. Several working models and test units were built and the Carveyor shuttle proposal in the Times Square-Grand Central subway under 42nd Street was approved by the New York City Transit Authority and passed on to the Board of Estimates. The system, however, was not built for various reasons including finances and union considerations.

## 2.2 One-Directional Linear Accelerating Walkway Systems

The three linear accelerating walkway systems: in approximate order of development, are: Dunlop Speedaway, Applied Physics Laboratory (APL) of the Johns Hopkins University, and Dean Research Corporation.

### 2.2.1 Dunlop Speedaway System

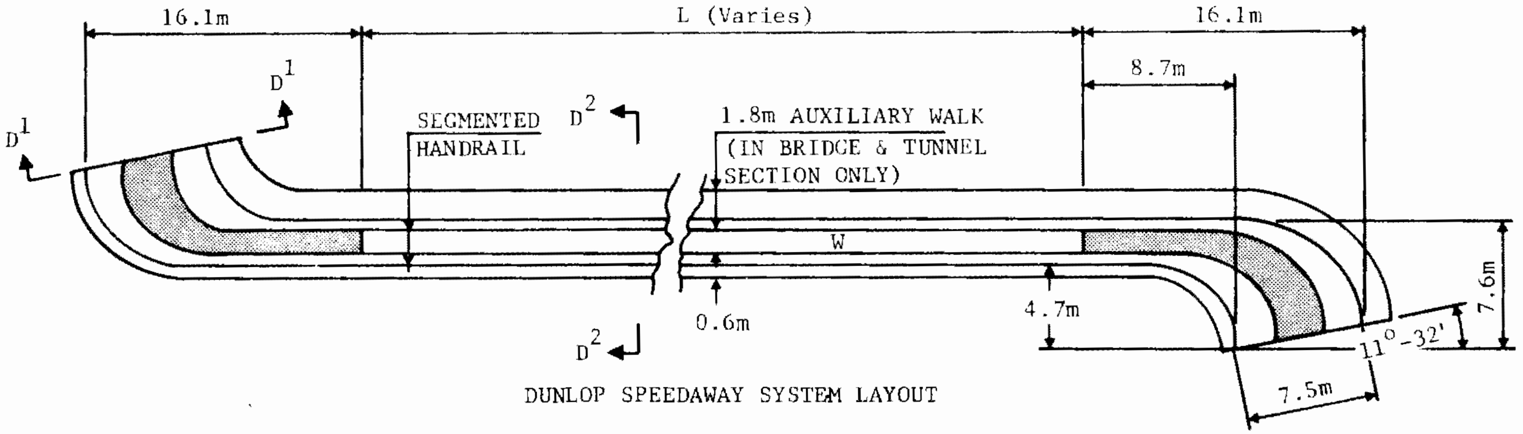
The Dunlop Speedaway system is a one-directional, reversible, variable speed moving walkway developed by Dunlop Limited, a well established manufacturer of escalators and conventional moving walkways in Britain. The system takes an elongated "S"-shaped configuration with curved acceleration and deceleration areas at both ends. The gradual shifting in both a forward and lateral direction of the aluminum pallets produces the variations in speed. Conventional balustrades are fitted to both sides of the walkway with a sequence of conventional constant speed handrails to match the mean speed of the platform for that zone. Currently, a full scale pre-production model of this system is operating.

Figure 8 shows the Dunlop Speedaway system layout and the cross sections at acceleration/deceleration and high speed sections. Two views of the Dunlop Speedaway model are shown in Figure 9.

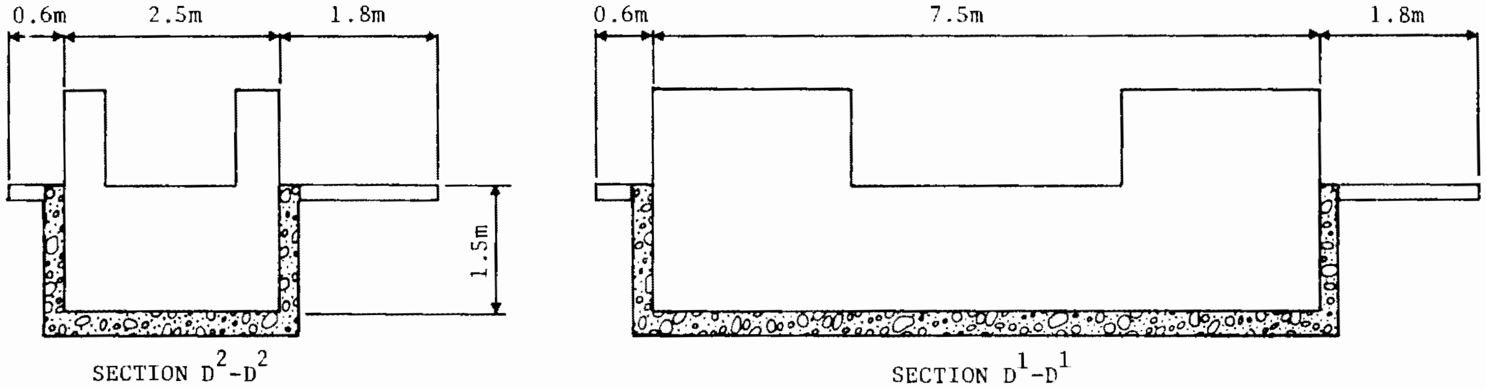
### 2.2.2 Applied Physics Laboratory System

This accelerating walkway system, developed by the Applied Physics Laboratory (APL) of the Johns Hopkins University, is of a linear one-directional, reversible design that uses a treadway comprised of overlapping and intermeshing leaves. Two variable pitch screws, rotating at constant angular velocity beneath the treadway, change the treadway leaf angle and produce the elongation and contraction of the walkway surface to provide acceleration and deceleration of the system. The double comb shaped interconnecting leaves forming the treadway are curved such that the composite surface remains practically level at all times. The system employs a concept of a compressible accordion type handrail which is also driven by a variable pitch screw and whose speed matches that of the walkway. The APL system presently exists as a laboratory prototype with stationary handrail.

Figure 10 shows the APL system layout and cross sections and Figure 11 shows the APL laboratory model.



DUNLOP SPEEDAWAY SYSTEM LAYOUT



SECTION $D^2$-$D^2$

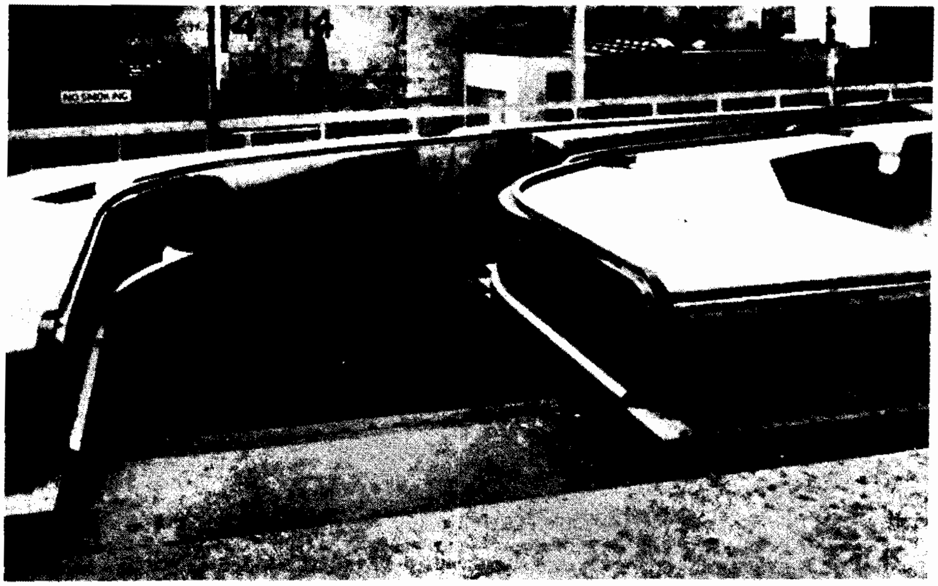
SECTION $D^1$-$D^1$

DUNLOP SPEEDAWAY SYSTEM CROSS SECTIONS

▨ Acceleration/deceleration sections

W = 1m ±, All dimensions approximate and subject to change

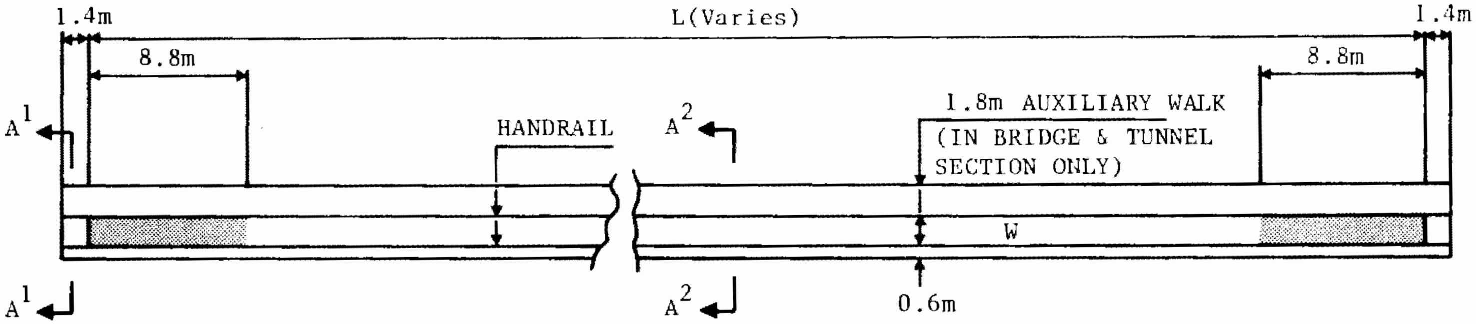
**FIGURE 8**
**DUNLOP SPEEDAWAY SYSTEM**



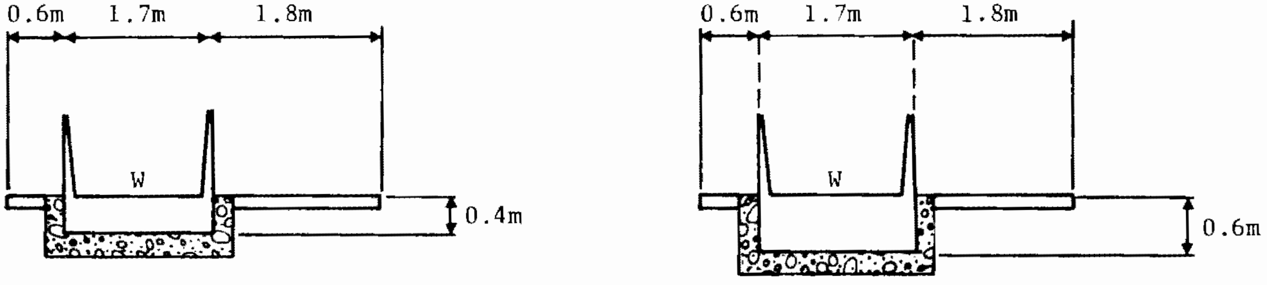
(a) Entry/Exit Section

(b) High Speed Section

FIGURE 9
DUNLOP SPEEDWAY MODEL



APPLIED PHYSICS LABORATORY & DEAN RESEARCH SYSTEM LAYOUT



SECTION $A^2$-$A^2$

SECTION $A^1$-$A^1$

APPLIED PHYSICS LABORATORY AND DEAN RESEARCH SYSTEMS CROSS SECTIONS
(Floor Level Mounting These Systems Possible)

▨ Acceleration/deceleration sections

W = 1m ±, All dimensions approximate and subject to change

FIGURE 10
APPLIED PHYSICS LABORATORY AND DEAN RESEARCH SYSTEMS

**FIGURE 11**
**APPLIED PHYSICS LABORATORY SYSTEM MODEL**

### 2.2.3 Dean Research System

The Dean Research Corporation, a manufacturer of specialized industrial conveyor systems based in Kansas City, has developed a linear one-directional, reversible accelerating walkway system with the trade names of SPEEDEMON. The treadway of the system is comprised of fine steel alloy rollers independently driven at different speeds to produce gradual acceleration or deceleration. Presently, a short prototype of the walkway exists, but no operational handrail has been developed. The manufacturer has proposed a roller driven handgrip which could be synchronized with the treadway.

The system layout and cross sections of the Dean Research system are similar to those of the APL system and are shown in Figure 10. The Dean Research system prototype is shown in Figure 12.

## 2.3 Two-Directional Loop Accelerating Walkway Systems

The following two-directional loop accelerating walkway systems, in the order of development, are discussed: TRAX system and Boeing system.

### 2.3.1 TRAX System

The TRAX system is a linear accelerating walkway configured in a two-directional loop. The system, developed by RATP (Paris Region Transit Authority), has a continuous treadway which consists of grooved overlapping plates sliding over and combing each other through the action of deformable quadrangular links underneath the plates. An outgoing and a return walkway are connected at both ends

**FIGURE 12**
**DEAN RESEARCH SYSTEM PROTOTYPE**

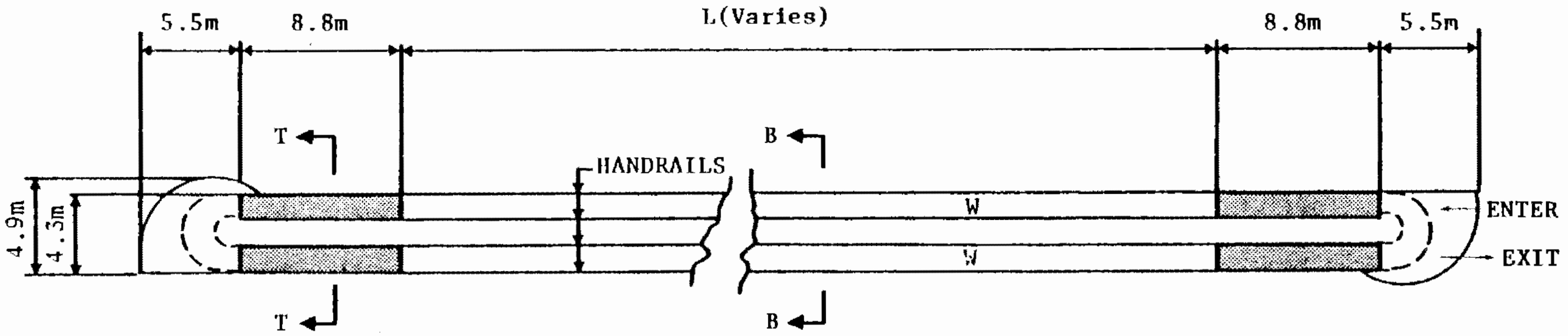
by two half-turnarounds to form an endless loop. The TRAX handrail consists of individual handgrips superimposed upon a continuous vertically articulated handhold and moves at the same speed as the walkway. A full scale prototype of the TRAX system has been built and a public demonstration is scheduled in Paris for late 1978.

The system layout and a cross section are shown in Figure 13. Two views of the TRAX prototype are shown in Figure 14.

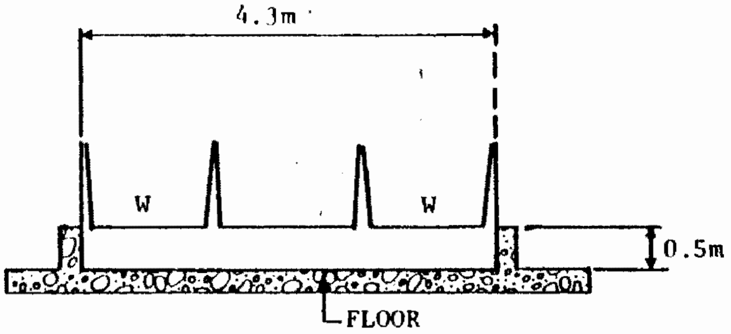
### 2.3.2 Boeing System

The Boeing system, presently being developed by the Boeing Company, is also a linear system of the two-directional loop type configuration. Although this system has not yet reached the operational prototype stages of development, it resembles the TRAX system in many respects. Its treadway also consists of grooved overlapping and intermeshing sliding pallets, which would be mounted on rollers running in flanking tracks. Changing the overlay of the intermeshing pallets produces the variable speed. A variable speed matching handrail has also been proposed. A prototype of the Boeing system is scheduled for completion in late 1978.

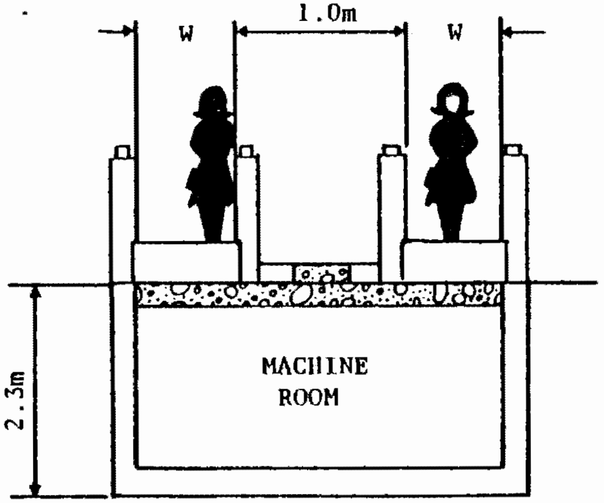
Figure 13 also shows the Boeing system layout and a walkway cross section. Depth requirements at the ends of the Boeing system as presently proposed are less than those for the TRAX system.



TRAX & BOEING SYSTEM LAYOUT



SECTION B-B
BOEING SYSTEM CROSS SECTION
FLOOR LEVEL MOUNTING POSSIBLE
(TWO-WAY)



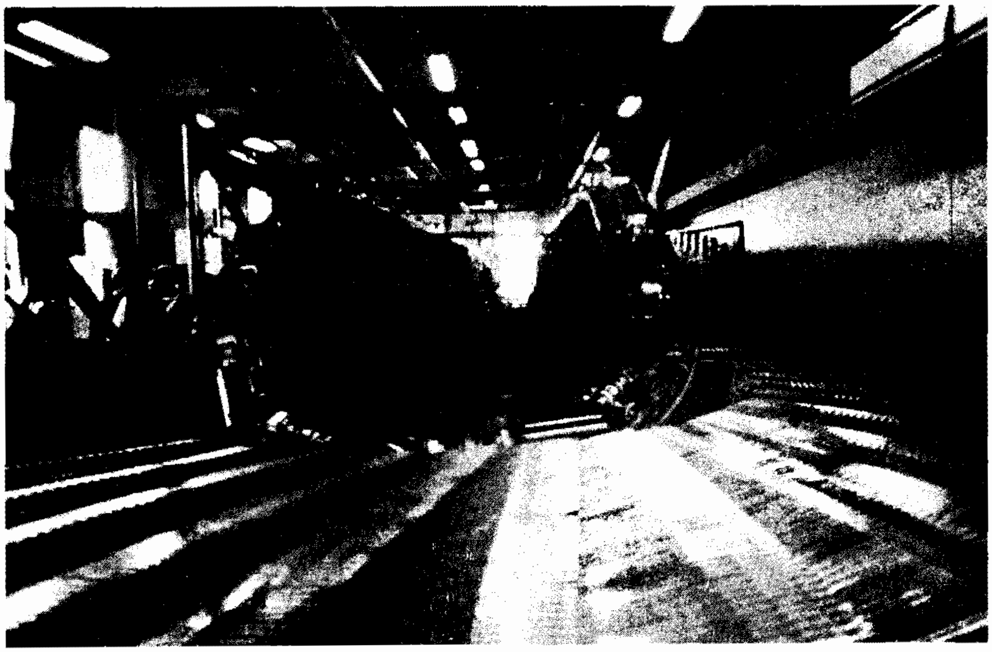
SECTION T-T
TRAX SYSTEM CROSS SECTION
(TWO-WAY)

▨ Acceleration/deceleration sections

W = 1.0m ±, All dimensions approximate and subject to change

FIGURE 13
TRAX AND BOEING SYSTEMS

(a) A View of the TRAX Prototype



(b) A View of the TRAX Loop End

FIGURE 14
TRAX SYSTEM PROTOTYPE

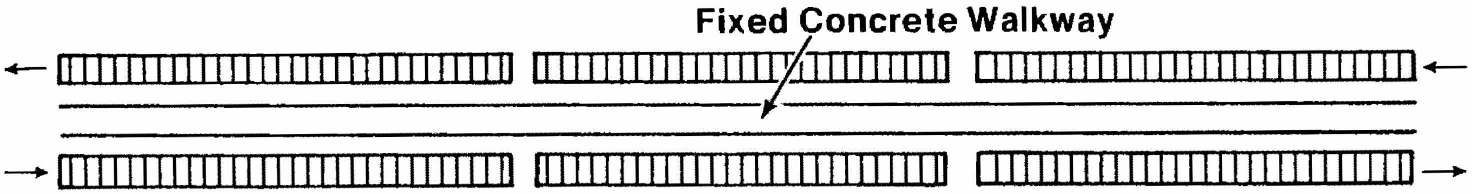
## 3.0 ACCELERATING WALKWAY SYSTEM COST ANALYSIS

One major concern in the design and implementation of a new mode of transportation for public use is the system reliability and maintainability. The economic analysis of an accelerating walkway system at the Times Square-Grand Central Station site is based on all the AWS options having three segments of approximately 244 meters each, as illustrated in Figure 15.

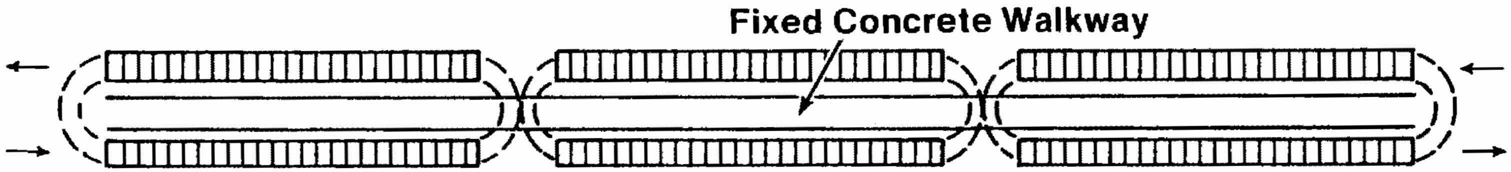
Both basic types of AWS, i.e., the linear one-directional type with three candidate systems (Dunlop, APL, and Dean) and the loop two-directional type with two candidate systems (TRAX and Boeing) are examined. There is no intermediate access to the accelerating walkway system, i.e., the only accesses are at the Times Square and Grand Central Stations. Dividing the total length of 732 meters into three equal segments increases the system reliability and maintainability. When any one segment needs to be shut down for service or repair, the remaining segments of the system can remain open requiring passengers to walk only 244-meter distance on the fixed concrete walkway.

### 3.1 Accelerating Walkway System Characteristics and Unit Costs

With a treadway width of one meter, the practical one-way capacity of the five candidate AWS systems is approximately 7,200 passengers per hour.



Six one-directional Linear AWS



Three two-directional Loop AWS

FIGURE 15
ACCELERATING WALKWAY DEPLOYMENT OPTIONS FOR THE TIMES-SQUARE
GRAND CENTRAL STATION SHUTTLE CASE STUDY

AWS unit costs of the five manufacturers examined in this study are shown in Table I. These costs are the best estimates the manufacturers could make at this time. Site preparation costs include structural and architectural preparations of the installation site and would vary according to existing site conditions and whether the installation was at-grade, elevated, or underground. A fixed 1.8 meter concrete walkway is included in each AWS option to provide an alternate path in the event of AWS failure. The costs presented in the table assume favorable site conditions (i.e., no relocation of utilities, etc.) and include costs of finishing the existing concrete walls and ceilings, installing partitions, and providing additional lighting inside the tunnel. The AWS unit operating costs are shown in Table II.

### 3.2 Analysis

The total operating, capital and life cycle costs, total cost per place provided, and total cost per passenger for the two AWS options (linear and loop) and the five candidate manufacturers (Dunlop, APL, Dean Research, TRAX, and Boeing) are established. One linear one-directional AWS in each direction or one loop AWS will be sufficient to carry the existing demand of 6,500 passengers in the peak hour. This would require six 244-meter one-directional moving walkways or three 244-meter two-directional loop moving walkways.

## TABLE I

## AWS UNIT CAPITAL COSTS (FOR 244-METER DUAL LANE AWS)

| TYPE OF SYSTEM | DUNLOP | APL | DEAN | TRAX | BOEING |
|---|---|---|---|---|---|
| Estimated Equipment Cost (1) (furnishing and installation --25 year life) $/Lane-Meter | 5,707 | 4,166 | 5,248 | 5,576 | 2,821 |
| Estimated Site Preparation (2) Cost At-Grade (25 year life) $/Lane-Meter | 3,214 | 1,574 | 1,574 | 902 | 902 |

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(1) "Accelerating Moving Walkway Systems Technology Assessment," J. Fruin, et al., Port Authority of New York and New Jersey, hardware costs interpolated from those for 152 meter and 305 meter accelerating walkways.

(2) Based on Port Authority Engineering Department estimates of site preparation without cover, assuming favorable site conditions. All sites include 1.8 meter concrete walkway and 35 percent overhead and contingency charges. Also include furnishing existing walls and ceilings and adding extra lighting to provide 323 Lumen/sq. meter (30-foot candles) illumination.

## TABLE II

## AWS UNIT OPERATING COSTS (FOR 244-METER DUAL LANE AWS)

| | DUNLOP | APL | DEAN | TRAX | BOEING |
|---|---|---|---|---|---|
| Electric Power Consumption(1) Loaded, KW/Running Hour | 336 | 214 | 192(3) | 118 | 134 |
| Maintenance, Incl. Overhead and Contingencies ($/Year)(2) | 80,000 | 80,000 | 80,000 | 80,000 | 80,000 |
| Insurance ($/Year)(2) | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |

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(1) Data from "Accelerating Moving Walkway Systems Technology Assessment," J. Fruin, et al., Port Authority of New York and New Jersey.

(2) Based on figures from "Life-Cycle Costs and Application Analysis for New Systems," M. Lenard, The MITRE Corporation, presented at the Conference on Automated Guideway Transit Technology Development, Cambridge, MA, February 28 - 2 March 1978.

(3) Data from Dean Research Corporation in September 1978. Power requirements for 152 m and 305 m walkways are 60 kw and 120 kw per running hour per lane, respectively.

The capital costs of the AWS options are shown in Table III, while the O&M costs which include power consumption, maintenance and insurance are shown in Table IV.

The capital costs of the AWS options do not include any station modification or modernization costs because the existing stations are wide enough to accommodate the accelerating walkways. Total capital costs range between $5.4 million and $13.1 million.

Total O&M costs are calculated assuming 24 hours operation of AWS a day for 365 days a year. These costs are higher than would be expected in real operations because the power consumption rates were based on a full load of passengers on the accelerating walkways.

The life cycle cost analysis assumes an average interest rate of 10 percent and a service life of 25 years for the AWS. With the two AWS options designed to carry the existing demand, the life cycle cost per passenger ranges between five and eight cents for the linear one-directional AWS option and between four and five cents for the loop AWS option (Table V). If the system were operated at capacity load at all times, the life cycle cost per place provided or per passenger would be between one and two cents.

# TABLE III

## CAPITAL COSTS OF AWS OPTIONS* (THREE 244-METER DUAL LANE SEGMENTS)

| | DUNLOP | APL | DEAN | TRAX | BOEING |
|---|---|---|---|---|---|
| Equipment Cost ($ 000)<br>(Furnishing & Installation) | 8,352 | 6,096 | 7,680 | 8,160 | 4,128 |
| Site Preparation Cost ($ 000) | 4,704 | 2,304 | 2,304 | 1,320 | 1,320 |
| Total Capital Cost ($ 000) | 13,056 | 8,400 | 9,984 | 9,480 | 5,448 |

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*All costs in 1978 dollars

## TABLE IV

## AWS O&M COSTS (THREE 244-METER DUAL LANE SEGMENTS)

| | DUNLOP | APL | DEAN | TRAX | BOEING |
|---|---|---|---|---|---|
| Power Consumption Cost* ($000/yr.) | 442 | 281 | 252 | 155 | 176 |
| Maintenance Cost (Including Overhead and Contingencies) ($000/yr.) | 240 | 240 | 240 | 240 | 240 |
| Insurance ($000/yr.) | 60 | 60 | 60 | 60 | 60 |
| Total O&M Cost ($000/yr.) | 742 | 581 | 552 | 455 | 476 |

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*Assumes operations of 24 hours a day, 365 days a year, $0.05 per kwh, and full load power consumption rates; all costs in 1978 dollars.

## TABLE V

## AWS LIFE CYCLE COSTS (THREE 244-METER DUAL LANE SEGMENTS)

| | DUNLOP | APL | DEAN | TRAX | BOEING |
|---|---|---|---|---|---|
| Annualized Capital Cost ($000/yr.)(1) | 1,436 | 924 | 1,098 | 1,043 | 599 |
| Total Annual Cost (Annualized Capital and Annual O&M Costs) ($000/yr.) | 2,178 | 1,505 | 1,650 | 1,498 | 1,075 |
| Total Cost Per Passenger ($)(2) | 0.08 | 0.05 | 0.06 | 0.05 | 0.04 |
| Total Cost Per Place ($)(3) | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |

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(1) Assumes 25 yr. life, 10% interest rate, capital recovery factor = 0.11; all cost in 1978 dollars.

(2) Total Annual Ridership = 28,099,000 passengers.

(3) Total Annual Capacity = 126,144,000 places.

## 4.0 ANALYSIS OF SERVICE LEVELS OF AWS AND OTHER OPTIONS

The levels of service of the accelerating walkway system, existing subway shuttle, Flushing subway line, and buses are analyzed in this section.

Accelerating walkway systems provide passengers with continuous flow transportation service. Vehicular transportation systems, on the other hand, provide batch movement of people, and vehicles must dwell at the stations for loading and unloading passengers and must also accept time delays in accommodating headway separation between vehicles when using the same track.

With the existing subway shuttle system, there is, inherently, always some waiting time for the users. The average wait time is two minutes during peak hours (approximately 7 to 9:30 AM and 4 to 6:30 PM), two and one-half minutes during non-peak hours, and five minutes during night hours (approximately 1 to 6 AM) on a weekday. On Saturdays and Sundays, the average wait time is between two and one-half and five minutes. The average travel time on the trains is approximately one and one-half minutes. Total trip time is, therefore, between three and one-half and six and one-half minutes. Presently, the design capacity of the existing subway shuttle system is being exceeded during peak hours on normal weekdays. With a three-car train and a four-car train in operation, the average peak hour load factor (passenger demand divided by design capacity) is 1.03; with two three-car trains in operation, the average peak hour load factor is 1.20.

The Flushing subway trains traveling between Times Square and Grand Central Station arrive every 10 minutes during the day and every 20 minutes at night on weekdays, and on weekends they arrive every 15 minutes. The average travel time between Times Square and Grand Central Station, with an intermediate stop at 5th Avenue, is approximately two and one-half minutes. Since the Flushing subway between Times Square and Grand Central Station is located one level below the shuttle, an extra transfer time of approximately three minutes for descending and ascending the stairs and some extra physical effort are necessary.

Buses travel on the surface streets and with mixed traffic, so their speeds differ very much according to time of the day and number of intermediate stops. Based on the motor vehicle speeds on 21 midtown Manhattan streets,* the approximate average speeds of 8.1 km/h, 11.3 km/h, and 24.2 km/h respectively for peak, off-peak, and night hours are used for the two bus lines. The average travel time on the buses is between 1.8 and 5.5 minutes. Total bus trip time ranges between 5.4 and 21.8 minutes.

Passenger wait time and queue buildup on the AWS are minimized and are zero if the system is operating below capacity under relatively steady passenger flow. The average speed of the AWS is approximately 12 km/h and the overall average travel time on the AWS is 3.5 minutes

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*"Urban Space for Pedestrians," B.S. Pushkarev and J.M. Zupan, Regional Plan Association, 1975.

at all times. This level of service, in terms of total travel time, is similar to that provided by the existing shuttle during peak hours and much better than the shuttle during non-peak and night hours because of the relatively long wait times for the shuttle trains in those hours. Table VI compares the trip times between the AWS and the alternative transit modes.

With the relatively short distance between the Times Square and Grand Central Stations, the waiting times of the alternative modes are significant considering the fact that the average running times are all relatively short (between 1.5 and 5.5 minutes).

Although the alternative transit modes analyzed offer similar level of service in peak hours in terms of total travel time (waiting time plus travel time), most people place more value on waiting time than on time in motion. In addition, user tolerance of the waiting time usually decreases with decreasing journey time and distance. The accelerating walkway system provides a constant level of service throughout the day, and a much superior service over the other transit alternatives during off-peak and night periods.

## TABLE VI

## TRIP TIME COMPARISON (IN MINUTES)(1)

| | AWS | | | EXISTING SUBWAY SHUTTLE | | | FLUSHING SUBWAY LINE | | | BUSES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wait Time | Travel Time | Total | Wait Time | Travel Time | Total | Wait Time | Travel Time | Total | Wait(2) Time | Travel(3) Time | Total |
| Weekday | | | | | | | | | | | | |
| Peak | 0 | 3.5 | 3.5 | 2 | 1.5 | 3.5(5) | 5 | 2.5 | 7.5 | 1 | 5.5 | 6.5 |
| Off-Peak | 0 | 3.5 | 3.5 | 2.5 | 1.5 | 4.0 | 5 | 2.5 | 7.5 | 1.5 | 3.9 | 5.4 |
| Night | 0 | 3.5 | 3.5 | 5 | 1.5 | 6.5 | 10 | 2.5 | 12.5 | 20(4) | 1.8 | 21.8(4) |
| Weekend | | | | | | | | | | | | |
| Peak | 0 | 3.5 | 3.5 | 2.5 | 1.5 | 4.0 | 7.5 | 2.5 | 10.0 | 2.5 | 5.5 | 8.0 |
| Off-Peak | 0 | 3.5 | 3.5 | 2.5 | 1.5 | 4.0 | 7.5 | 2.5 | 10.0 | 4.5 | 3.9 | 8.4 |
| Night | 0 | 3.5 | 3.5 | 5 | 1.5 | 6.5 | 7.5 | 2.5 | 10.0 | 20(4) | 1.8 | 21.8(4) |

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(1) Extra transfer time of descending and ascending the stairs to the underground systems not included.

(2) Approximate average of the two bus lines.

(3) Uses 8.1 km/h for peak, 11.3 km/h for off-peak, and 24.2 km/h for night hours.

(4) These times could be reduced somewhat if buses operate according to published schedule.

(5) Existing shuttle system is overcrowded in peak hours.

## 5.0 SUMMARY AND CONCLUSIONS

The accelerating walkway systems analyzed at the Times Square-Grand Central site are capable of carrying the existing high passenger demand of approximately 6,500 per peak hour and 90,000 per day. The level of service in terms of total travel time provided by the 732-meter accelerating walkway system will be similar to that of the existing shuttle system during peak hours and better during off-peak hours. A major advantage of the accelerating walkway system is that it is continuously available and the waiting time is minimized.

Total capital and O&M costs, total cost per passenger, and total cost per place provided for the potential accelerating walkway systems are summarized in Table VII. With the existing passenger demand and using the existing tunnel and station facilities, the five candidate AWS systems (Dunlop, TRAX, APL, Boeing, and Dean Research) will have a total life cycle cost varying between four and eight cents per passenger carried and one to two cents per place provided. Total capital cost will be between 5.4 and 13.0 million dollars and total annual operating and maintenance cost will be between 0.46 and 0.74 million dollars.

# TABLE VII

## COST SUMMARY

| | LINEAR AWS | | | LOOP AWS | |
|---|---|---|---|---|---|
| | Dunlop | APL | Dean | TRAX | Boeing |
| Total Capital Cost ($ million) | 13.0 | 8.4 | 10.0 | 9.5 | 5.4 |
| Annualized Capital Cost ($ thousand/yr.) | 1,436 | 924 | 1,098 | 1,043 | 599 |
| Total O&M ($ thousand/yr.) | 742 | 581 | 552 | 455 | 476 |
| Total Annual Cost ($ thousand/yr.) | 2,178 | 1,505 | 1,650 | 1,498 | 1,075 |
| Total Cost Per Passenger ($) | 0.08 | 0.05 | 0.06 | 0.05 | 0.04 |
| Total Cost Per Place ($) | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |

# APPENDIX

## ACCELERATING WALKWAY SYSTEM MANUFACTURERS

Dunlop Speedaway System
Dunlop Limited, Passenger Conveyor Systems
Denbridge Industrial Estate
Oxford Road, Uxbridge
Middlesex, England

Applied Physics Laboratory System
The Johns Hopkins University
Applied Physics Laboratory
Johns Hopkins Road
Laurel, Maryland 20810, USA

Dean Research Corporation System
Dean Research Corporation
8100 N.W. 97th Street Terr.
Kansas City, Missouri 64153, USA

TRAX System
Regie Autonome des Transports Parisiens
53 ter, quai des Grands-Augustins
75271 Paris, Cedex 06, France

Boeing System
The Boeing Company
P.O. Box 3999
Seattle, Washington, 98124, USA