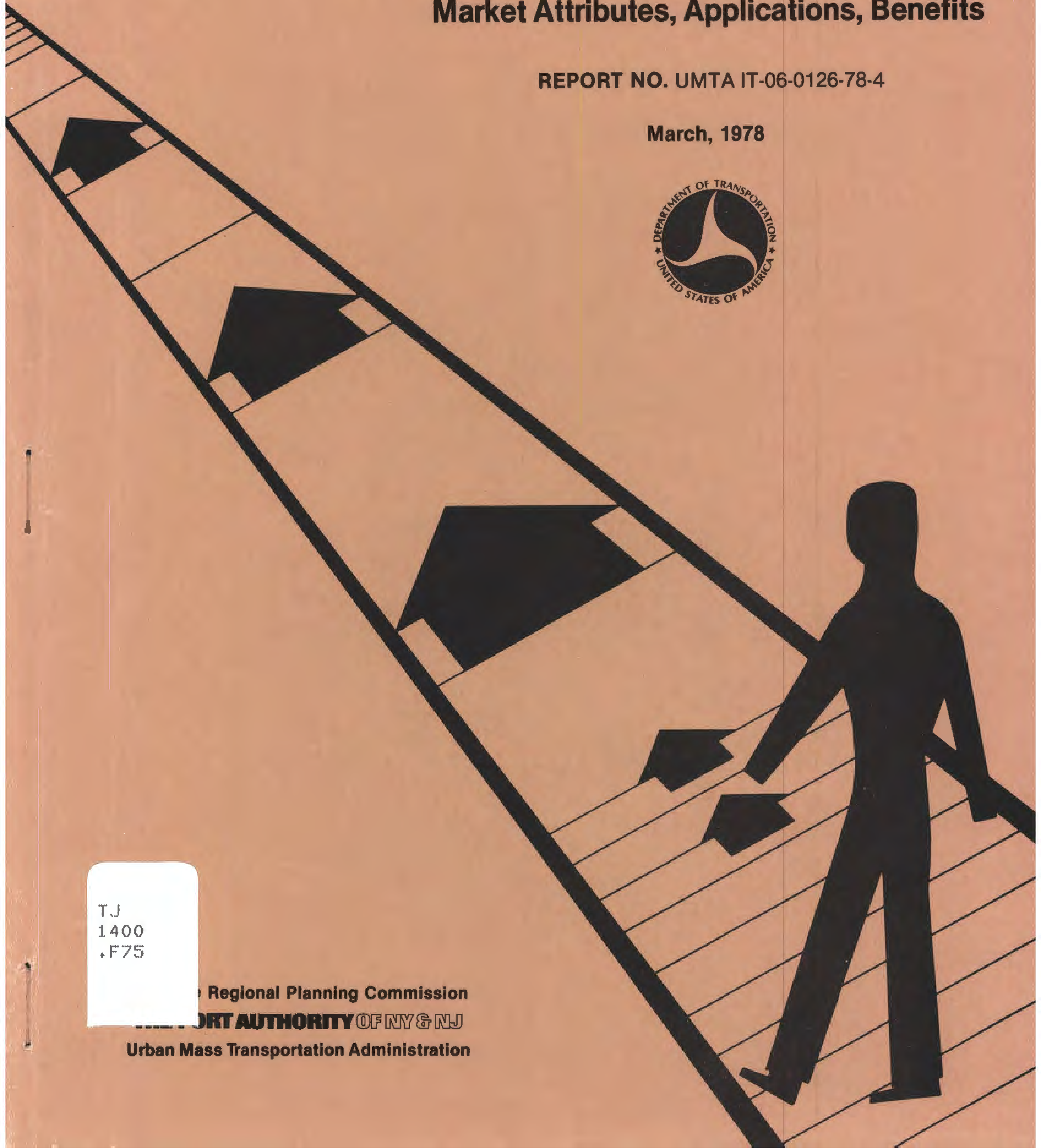
ACCELERATING MOVING WALKWAY SYSTEM

Market Attributes, Applications, Benefits

REPORT NO. UMTA IT-06-0126-78-4

March, 1978



Regional Planning Commission

ORT AUTHORITY OF NY & NJ

Urban Mass Transportation Administration

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-IT-06-0126-78-3		

4. Title and Subtitle	5. Report Date
Accelerating Moving Walkway Systems - Market, Attributes, Applications and Benefits	MARCH 1978
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Fruin, J., Marshall, R., Perilla, O.	
9. Performing Organization Name and Address	10. Work Unit No.
Port Authority of New York and New Jersey One World Trade Center New York, New York 10048	11. Contract or Grant No. No. IT-06-0126
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address U. S. Department of Transportation Urban Mass Transportation Administration 400 Seventh Street, S. W. Washington, D. C. 20590	
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An Accelerating Moving Walkway System (AMWS) is a pedestrian assist device having the capability through changing treadway configuration to accelerate pedestrians to 4 to 5 times normal entrance speeds after boarding and to decelerate prior to discharge. Time savings resulting from these systems make deployments over longer distances more feasible than with conventional moving walkways. Potential applications include a wide spectrum of possible short range passenger movement situations including feeders to transit, as a substitute for AGT, bus, or rail transit under some circumstances, as an airport movement system, as urban land use integrator, and as a vehicle free zone support system. Benefits accruing from AMWS systems include improved transit connectivity, improved pedestrian convenience, security, and safety, upgraded urban land use, reduced pollution and energy use, and improvements in urban quality of life.

17. Key Words	18. Distribution Statement
Accelerating Moving Walkways, Moving Way Transit, Pedestrians, Passenger Conveyors	Available to the Public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

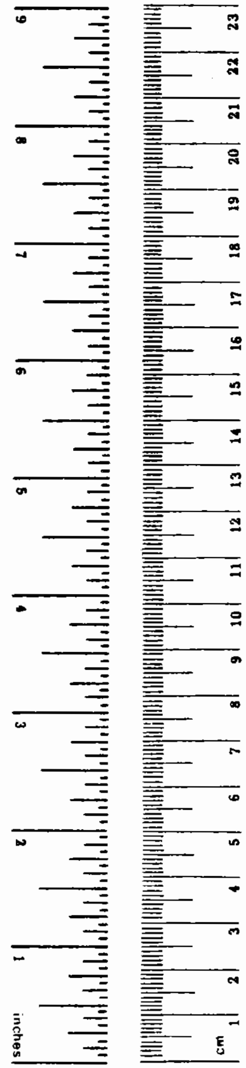
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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

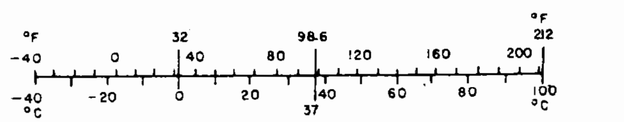


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 THE AMWS TRANSPORTATION MARKET

1.1 GENERAL DISCUSSION

The market potential for Accelerating Moving Walkway Systems will determine the extent of their application and use. This potential may be compared to a degree with the development of the reliable passenger elevator by Elisha Otis in 1853. The elevator made high rise construction feasible, and its invention came at a time of increasing demands for limited urban space. Accelerating Moving Walkway Systems would fill gaps in horizontal movement which exist in many urban areas and specialized activity spaces. These systems come at a time when there is a recognition that internal pedestrian movement within cities is not always convenient, that vehicular transportation does not function well on congested urban streets, that vehicles pollute and are energy intensive, and that our central cities are in need of revitalization, strengthening and improvements in their quality of life. Effective, convenient, economic, human scale horizontal movement systems are seen as an important means of fulfilling many of these objectives.

1.2 AMWS FOCUS

Walking trips comprise the largest single passenger transportation demand segment. If the total trips within, in and out or of any region are related to distance, it can be demonstrated that trip activity for each transportation market segment increase as trip distances decrease. For example for a large metropolitan region, such as New York, daily air trips may be measured in the tens of thousands, suburban rail commuter trips in the hundreds of thousands, intra-city transit trips in millions, and walking trips approaching the hundreds of millions. Figure 1 following is a generalized schematic conceptualization of this relationship.

Transportation technology development has concentrated largely on the longer distance transportation demand segments with relatively little attention being given to the largest segment, the pedestrian trip. The emergence of the automobile has in fact decreased pedestrian trip mobility by pre-empting increased street space for vehicular movement and introducing pedestrian trip delays due to traffic signalization. Because pedestrian trips are characteristically short, these delays are relatively more significant than they might be for the typical vehicular trip. The automobile has also introduced the threat of injury to pedestrians, as well as noise, fumes and visual pollution, all of which have had deleterious affects on walking.

Walking has a singularly important role in the urban Central Business District, acting as the feeder and distributor for all other transportation modes. More than ninety percent of the internal trips in most CBD's are made by pedestrians. The practical human walking distance range determines the effective service area, convenience and utility of public transit systems, and controls the configuration of most airports and activity centers. As a transportation mode, walking is continuously available, travel times are predictable, routes ubiquitous and easily maintainable, service reliable, free, non-polluting, and non-fossil energy consuming.

The constraints on increased utility and wider use of walking as an urban transportation mode are related to the limits of human energy and time expenditure. Pedestrian assist devices such as the accelerating moving walkway offer the prospects of improving average pedestrian speeds and trip times, and reducing human energy expenditure. This would effectively extend the pedestrian range, providing for increased urban development opportunities now constrained by the limits of acceptable walking distance.

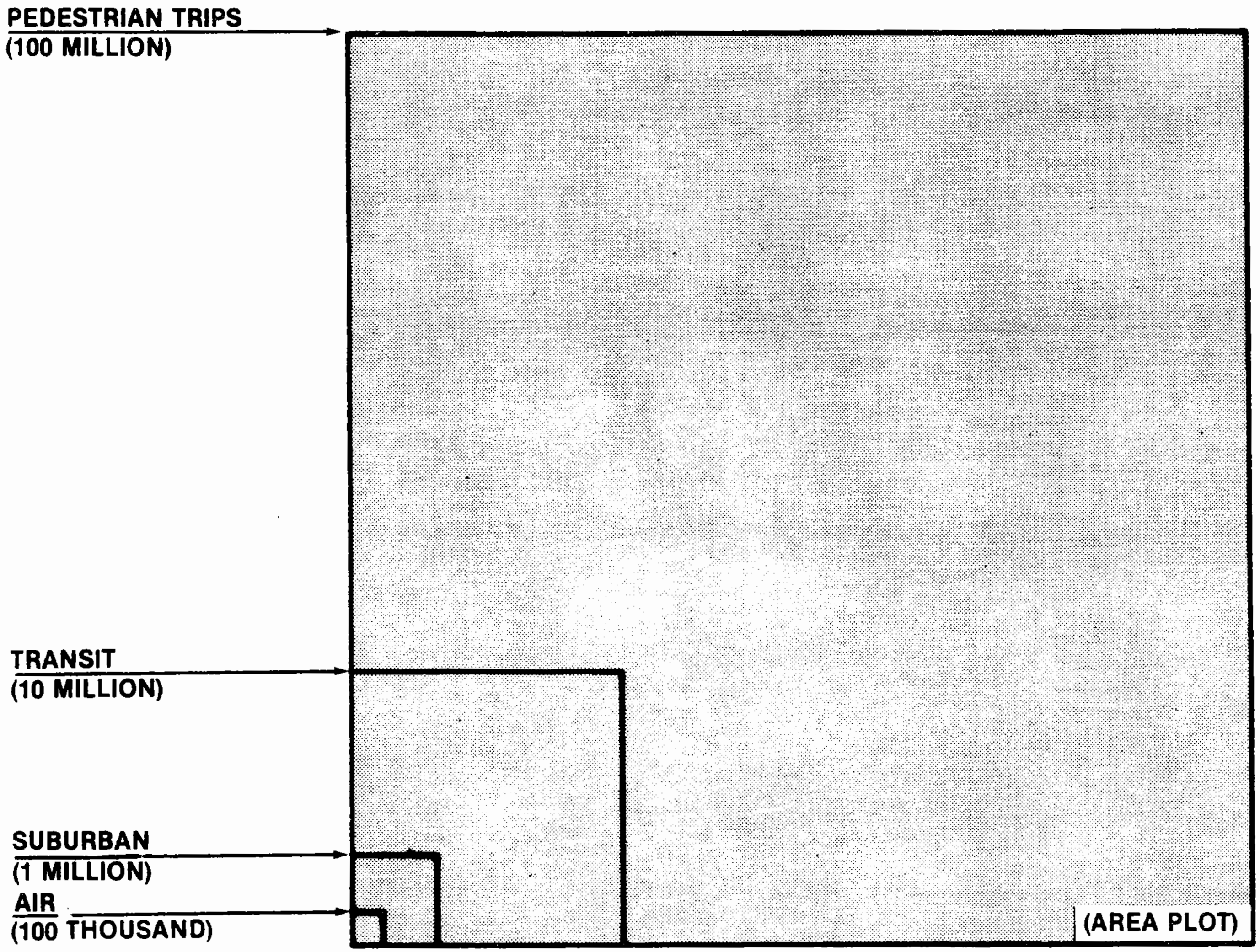


FIGURE 1 RELATIVE DAILY TRIP DEMANDS LARGE METROPOLITAN AREA (10 MILLION POP.)

1.3 THE PEDESTRIAN WALKING RANGE

It is fairly obvious that walking has practical limits. The greater the distance, the lower the percentage of people who will walk, until the point is reached where transfer to another mode becomes necessary to complete the desired trip. It is also likely that many trips are temporarily deferred, or not made at all, because they involve long walking trip linkages, or walking trips exposed to unfavorable weather, safety or security problems, or other inconveniences.

The results of a number of surveys of walking trip distances, related to trip purpose and the percentage of the population willing to walk that distance is shown on Figure 2. This plot is actually a family of curves demonstrating that pedestrian walking distance is strongly influenced by trip purpose and travel mode. For example, 50% of auto riders appear unwilling to walk more than 200-300 ft., whereas 50% of subway riders and other public transit users appear willing to walk 1000 ft. or more. This is readily understandable since the auto user has the means available to reduce his walking distance by selecting a parking facility near his destination, whereas the public transit system user on a fixed route system can only select the nearest transit stop.

The broad range of pedestrian performance shown in Figure 2 is to be expected considering the many factors that influence walking in addition to trip purpose. These factors include available transportation alternatives, the health and inclination of the individual, weather conditions, the nature of the terrain, area security, perceived safety, vehicular conflicts and vehicular threat, and the visual and

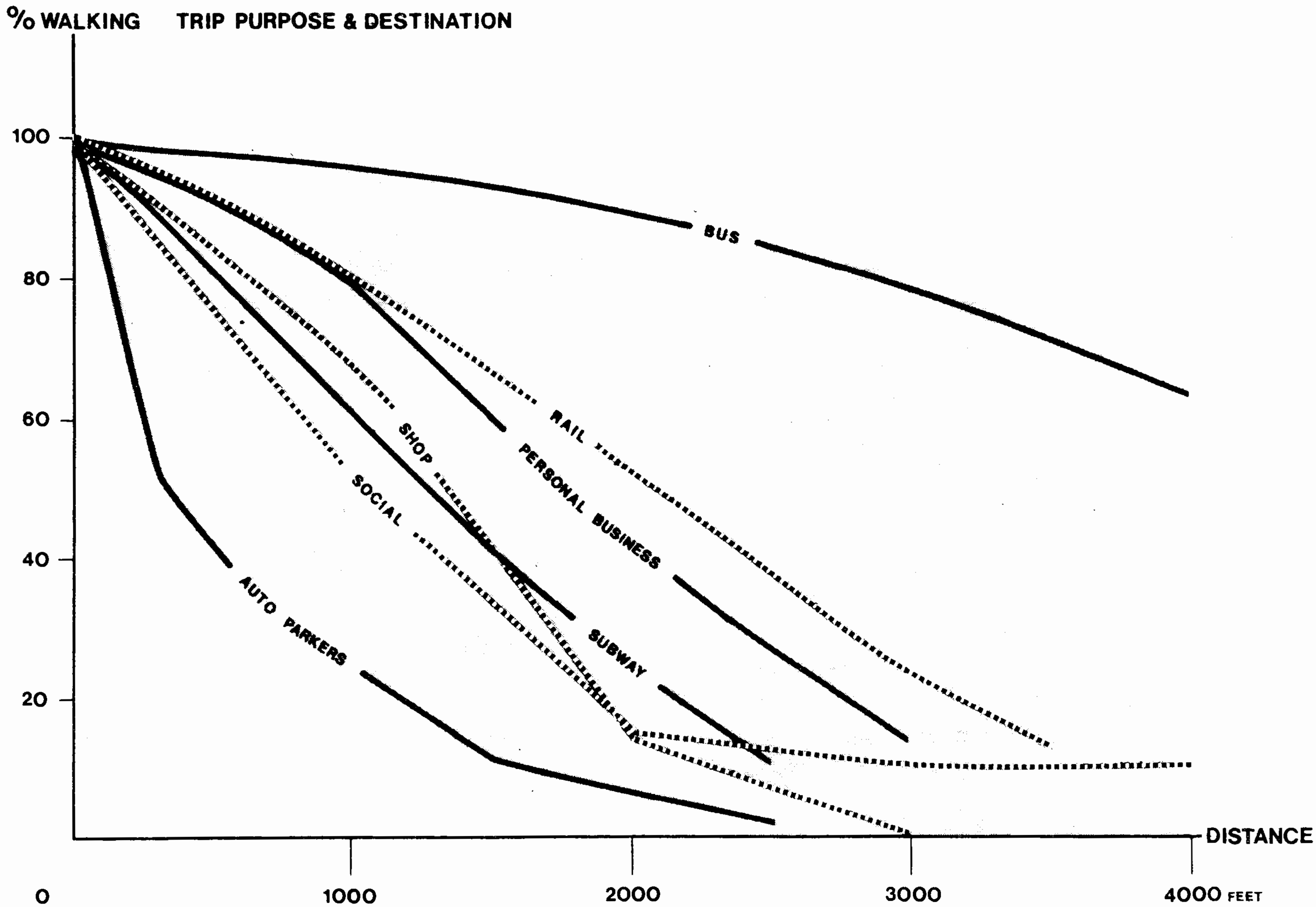


FIGURE 2 WALKING RANGE OF URBAN PEDESTRIAN

social interest along the pedestrian path. Pedestrian support systems provide the basis for expanding the lower levels of walking distance performance by a factor of ten, from a few hundred feet up to a few thousand.

1.4 SPEED AND PEDESTRIAN TRIP DISTANCES

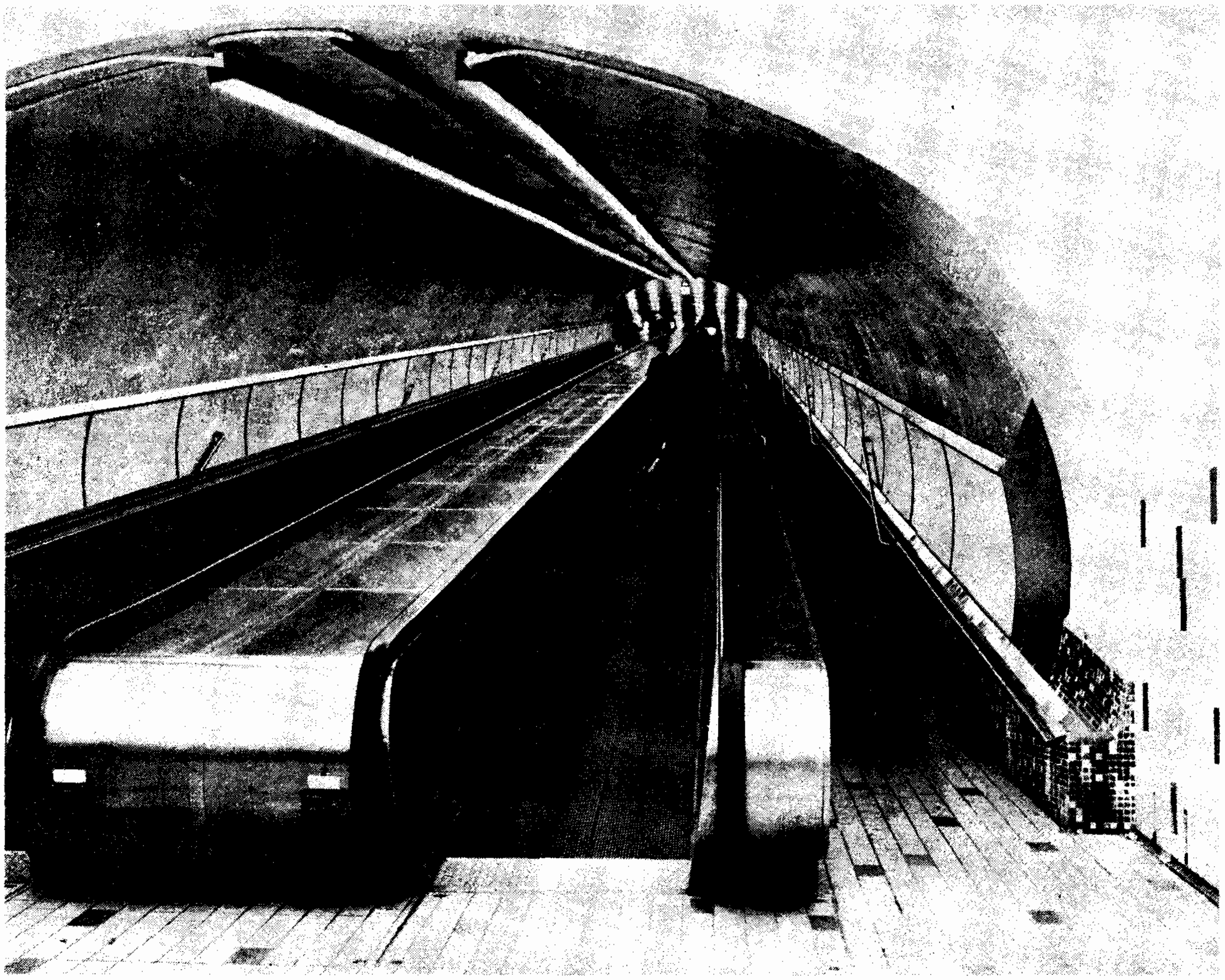
Pedestrian walking speed probably has as much influence on walking trip distances as human energy limitations. Walking speeds of pedestrians have been found to vary over a wide range depending on personal physical condition, age, sex, and many other variables including trip purpose, environmental conditions and traffic density. Normal walking speeds unrestrained by pedestrian crowding vary between 150 and 350 ft. m/min. (45-110 m/min.), with the average at about 270 ft./min. (83 m/min.) Pedestrian walking speeds in Central Business Districts are reduced by sidewalk crowding and traffic signal interruptions.

Relatively small increments of time have been found to be of significance to pedestrians, particularly for work related trips and intermodal transfers involving connections with other services. Minor delays in such situations can result in censure from employers or a missed transit connection, with possibly greater delay and inconvenience penalty. A study of queuing behavior of commuters at escalators by the New York Regional Plan Association showed that some pedestrians would climb flights of stairs as high as five stories, (50 ft.) (15 m) to avoid queing delays of less than one minute. [1]. At lower rises of 20 feet or less, almost 50 per cent of the pedestrians were observed to use nearby stairs rather than wait 60 seconds in a queue. It should be noted that other pedestrians preferred to wait rather than climb stairs.

Average stair climbing speeds have been found to approximate the speed of an escalator (i.e. 100 fpm ±), but significant variations have been observed, particularly for elderly and handicapped pedestrians. [2].

Similar pedestrian waiting time vs. energy trade-offs have been observed at airport moving walks where the percentage of pedestrians bypassing mechanical walkways increased with increased use of the walk. [3]. When moving walkways were first introduced, it was intended that pedestrians would walk on them, thus saving time and energy over walking. However, it has been found in United States practice that pedestrians will stand on the mechanical walkway, effectively blocking those seeking the walking time advantage. Since the common mechanical walkway speed of 120 fpm (37 mpm) is actually less than half of the normal walking speed of 270 fpm (83 mpm), use of the walk actually results in a loss of time over the equivalent walking distance. European practice differs in that the popular convention is to walk on the mechanical walkway, with standees being advised to keep to the right. This mode of use results in 44 per cent increase in average pedestrian walking speed and a significant speed advantage of more than 3 to 1 over simply standing on the walk.

It is therefore not surprising that in Europe mechanical walkway systems are more heavily utilized by pedestrians and appear to be more commonly considered for urban applications. For example, the Montparnasse Station of the Paris Metro has an installation of 3 parallel rubber belt walkways, 600 ft. long (183 m), 47 inches (120 cm) wide, operating at a speed of 160 fpm (50 mpm), accommodating a very heavy demand of walking commuters. [4]. These belts are operated in a 2 to 1 directional configuration based on the tidal flow.



CONVENTIONAL MOVING WALKWAYS HAVE BEEN INSTALLED IN PARIS, MONTREAL AND LONDON SUBWAY TRANSIT SYSTEMS. PHOTO ILLUSTRATES MONTREAL, CANADA, METRO SUBWAY INSTALLATION OF 2 · 295' FT. (90 M) LONG, 36 INCH (910 MM) WIDE UNITS AT 11.5° SLOPE.

Paris Metro also has 2 - 433 ft. (132 m) belts at its Chatelet Station. Another heavily used European transit installation exists at the Bank Station of the London Underground. This two unit, 295 ft. (99 m) long installation is of interest from a number of standpoints. It is an Otis "Travolator" system utilizing a treadway of finished metal pallets similar to escalator treads, it is sloped at 8° (14 per cent), the pallets are 40 inches (102 cm) wide, and it can be operated at speeds ranging from 90-180 fpm (28-54 mpm). The Montreal Metro Subway System also has an installation of 2 moving walks 295 ft. (90m) long at an incline of 11.5°. (See Photo Figure 3).

The continuing interest in the use of mechanical walkways in urban planning applications in Europe is evidenced by the recent plan for Charles DeGaulle Airport, outside Paris. When the airport reaches full development, it will employ 14 - 570 ft. (173m) Travolator moving walkways connecting the main airport passenger concourse with seven satellite passenger lounges. [5]. These units will operate at a speed of 148 fpm (55 mpm), sloped in a compound vertical curve configuration in their central sections to pass beneath airport runways.

Higher speed mechanical walkway systems are considered to have much greater potential for urban applications because of the attractiveness of the increased speed, and the concomitant prospects of greater deployment length. A five minute ride on a 120 fpm system equals the generally accepted 600 foot length limit for conventional walkways. A five minute ride at 500-600 fpm (150-180 mpm) expands the range of a pedestrian conveyor to 2500-3000 feet (.8-1 km), thus opening up a realm of many more applications, and even competing with vehicular systems.

Figure 4 is a graphic comparison of trip time and distance relationships for conventional walkways, walking, accelerating walkways and transit. For purposes of this comparison, average transit system

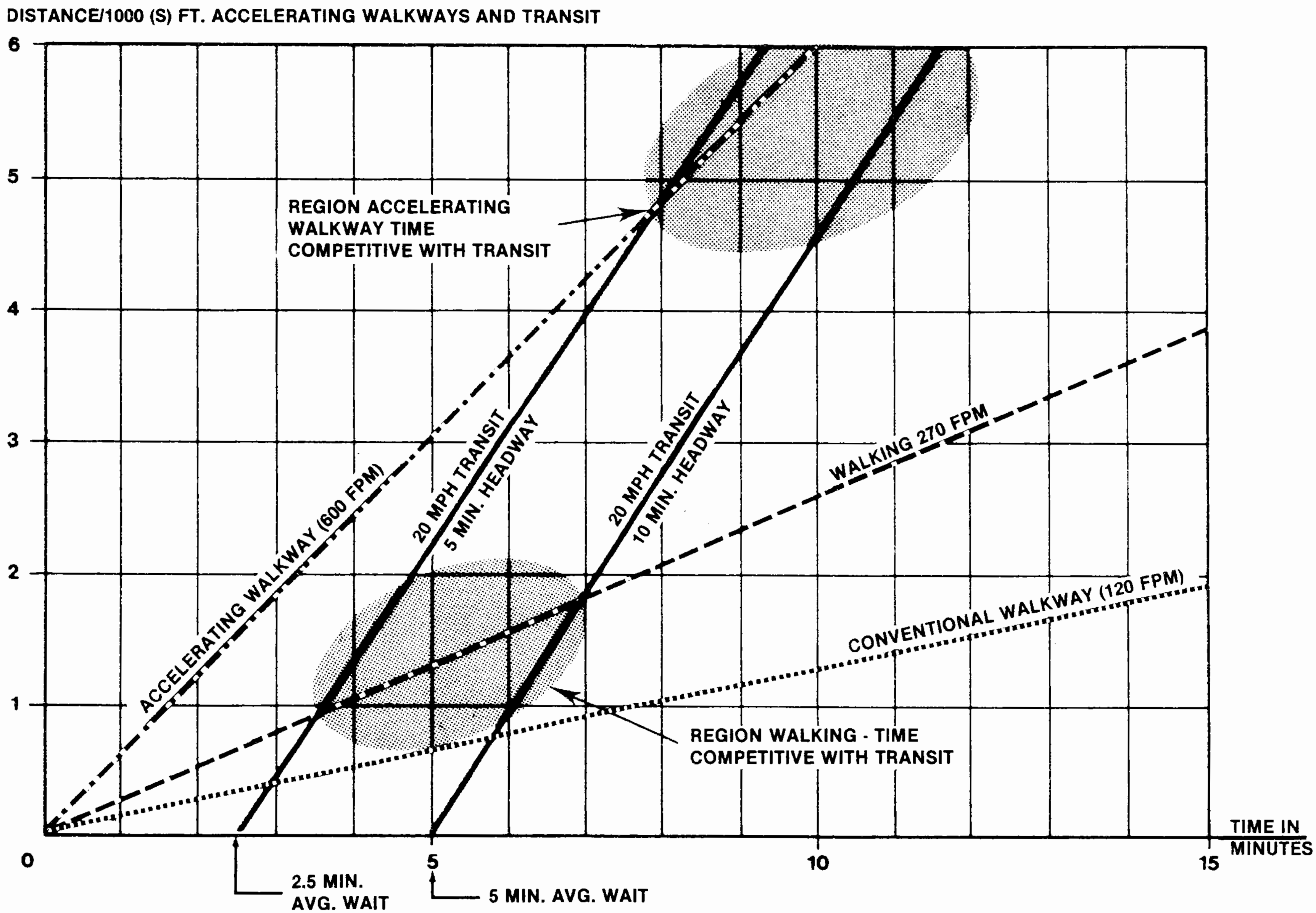


FIGURE 4 TIME DISTANCE COMPARISON

speeds were assumed at 20 MPH (32 KMH), and average headways at 5 and 10 minutes, a reasonably good level of service. Average transit passenger waiting times have been plotted at 2 1/2 and 5 minutes, respectively assuming uniform passenger arrivals. Walkway modes are shown at a "zero headway" because of the continuous service characteristic. Based on the assumptions of the graph, walking is seen to be time competitive with transit in a boundary region of about a 1000 to 2000 feet trip distance, (305-610 m). This coincides with walking trip distances at the Port Authority Midtown Manhattan Bus Terminal, where virtually all terminal patrons were observed to walk 1000 feet, (305 m), with surface and subway transit beginning to attract beyond this distance. At one mile, more than 50% of bus terminal patrons used transit rather than walking [6]. Figure 4 also illustrates that the most significant benefit of accelerating walkways is not savings in time, but expansion of the urban pedestrian trip range, as previously noted.

1.5 AMWS TRIP PRICING PERSPECTIVE

The AMWS focus discussion in section 1.2 illustrated the fact that the pedestrian trip market within a region is many times that of any other transportation mode. As trip distances decreased, the number of trips increased. With regard to trip pricing, the converse is of course true, fares and perceived trip value decrease with distance. The value of an AMWS trip may be put into perspective by comparing with the pricing of other trips within and in and out of a large metropolitan area. Figure 5 shows the relative pricing trend by distance for subway and bus transit, taxi, automobile, suburban commuter rail, intercity bus, air shuttle, intercity and transcontinental air. This trend indicates that in terms of trip pricing, the AMWS fits into a value range of approximately $.10 to .30 per trip. Placed in pedestrian trip corridors

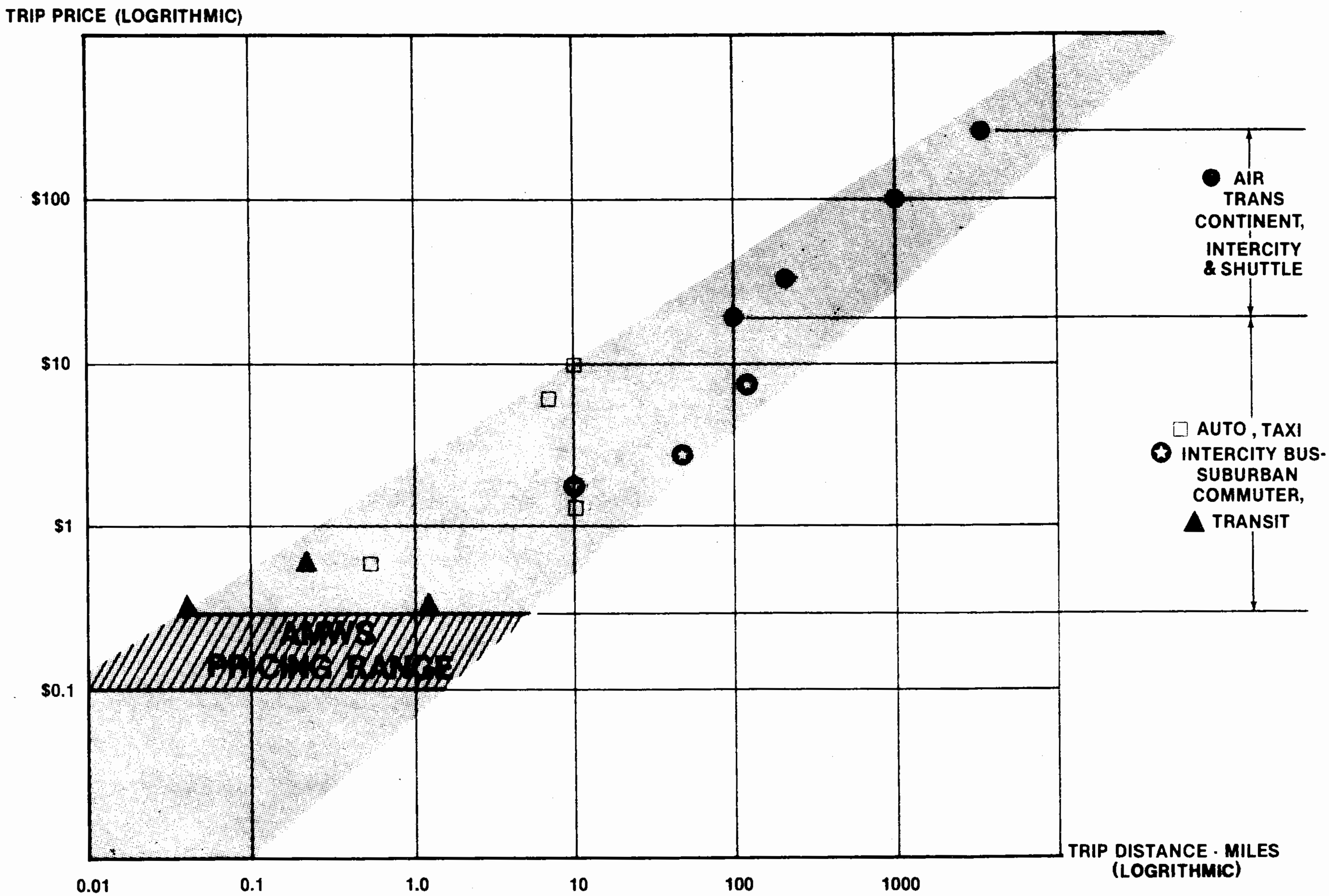


FIGURE 5 AMWS TRIP PRICING PERSPECTIVE

with daily use in the 10,000 to 50,000 volume range, the value of an AMWS would range from a low of $300,000 annually based on the minimum use and price to $4.5 million annually on the assumption of the higher use and price. The wide spread in total trip values emphasizes the importance of placing an AMWS in corridor settings with maximum perceived utility by its users, as well as with high daily pedestrian use.

2.0 AMWS ATTRIBUTES

2.1 General Discussion

The attributes of a transportation system determine the number of its potential applications and prospective utilization. System attributes fall into five general categories including: (1) physical - the dimensional envelope, alignment, grade, structural, and right-of-way requirements; (2) operational - the speed, capacity, reliability and maintainability of the transportation mode; (3) public acceptability - deployment context, ride quality, safety, security, convenience, comfort; (4) costs - equipment, installation, operation, maintenance, insurance; (5) environmental - noise, air, visual pollution.

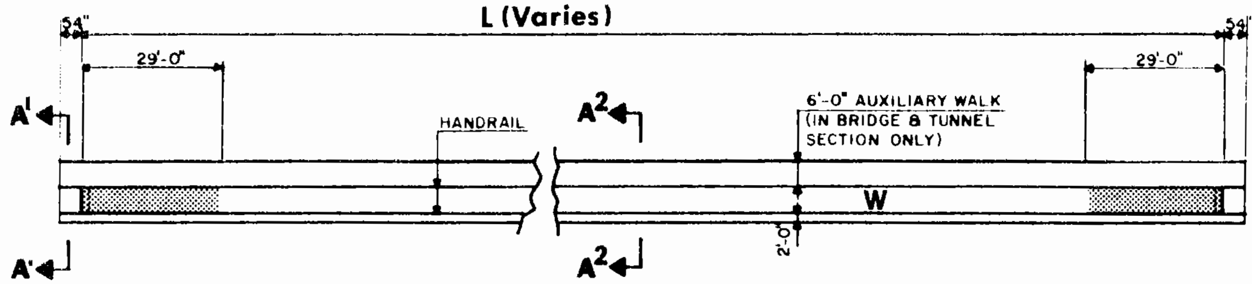
2.2 Physical Attributes

Accelerating moving walkways are basically linear transportation systems providing continuous point to point service without intermediate access. Figure 6 (A, B) shows three basic configurations for these systems, **straight line**, as manifested by the Johns Hopkins University Applied Physics Laboratory and Dean Research Systems; "S" shaped, as with the Dunlop Speed-away System; and, Loop, as represented by the RATP Trax and Boeing Systems. The first two systems provide only one-directional service but are reversible, whereas the latter two systems provide continuous two-directional service. System configuration and the basic cross-sectional envelope determine site adaptability. System directionality affects the applicability of the system to the specific passenger demands at the site.

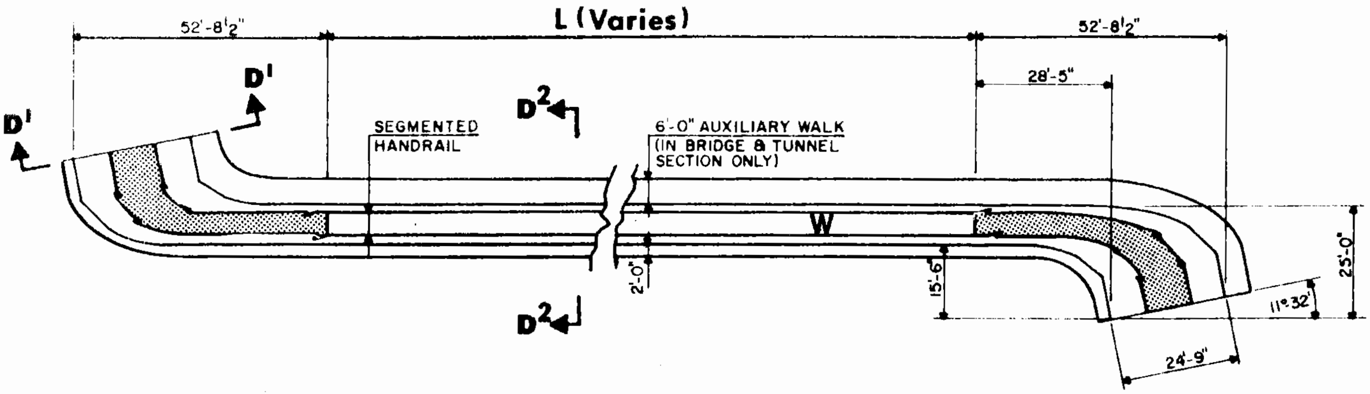
As indicated in the B Report, Technology Assessment, the dimensional envelope of the APL System is rectangular, consisting of subgrade depth requirement of 15 inches (380mm) in the central high speed section and 24 inches (610 mm) at entry and exit sections. The overall

PLAN VIEWS CANDIDATE AMWSS

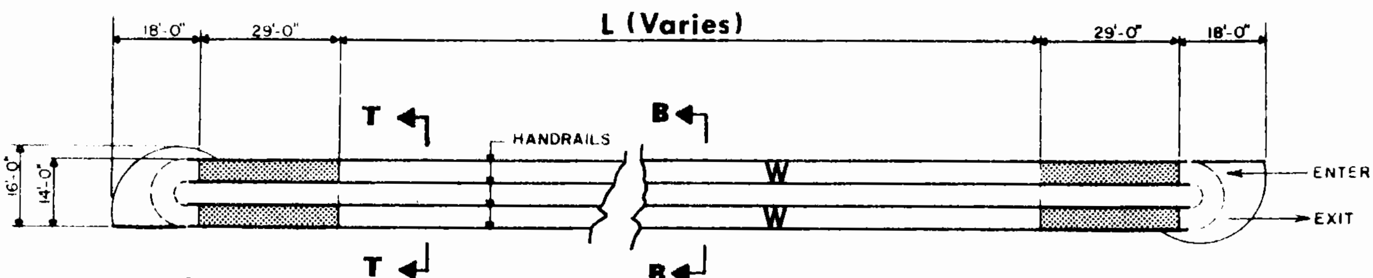
ALL DIMENSIONS APPROXIMATE - SUBJECT TO CHANGE



APPLIED PHYSICS LABORATORY - DEAN RESEARCH SYSTEMS



DUNLOP SPEEDAWAY SYSTEM



W = 40" ±

TRAX - BOEING SYSTEMS

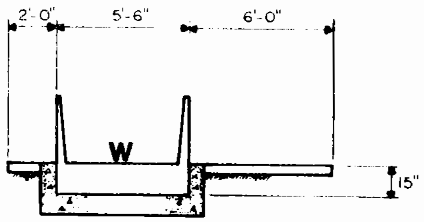
0 20 40
SCALE IN FEET

ACCELERATION
DECELERATION SECTIONS

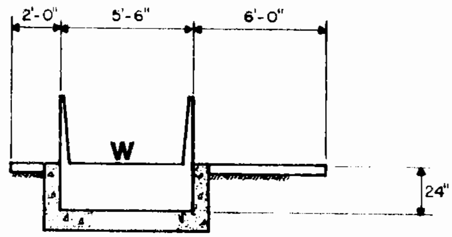
FIGURE 6A

SECTION VIEWS CANDIDATE AMWSs

ALL DIMENSIONS APPROXIMATE - SUBJECT TO CHANGE



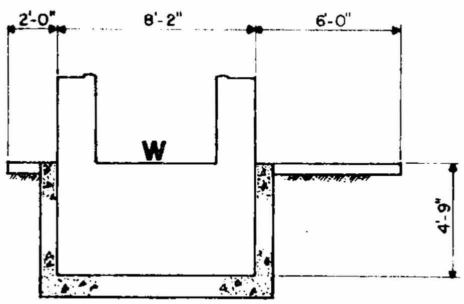
SECTION A^2-A^2



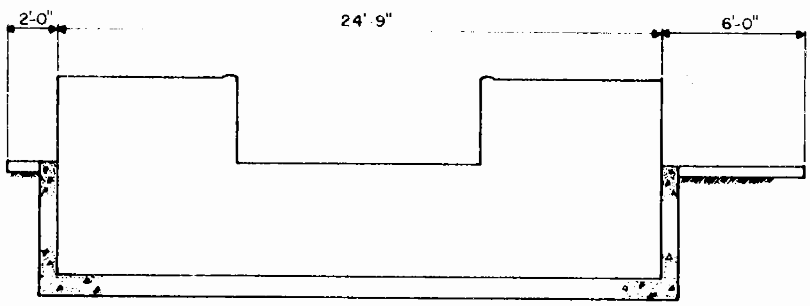
SECTION A^1-A^1

APPLIED PHYSICS LABORATORY - DEAN RESEARCH SYSTEMS

(FLOOR LEVEL MOUNTING THESE SYSTEMS POSSIBLE)

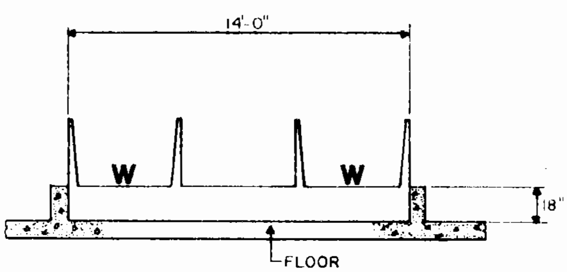


SECTION D^2-D^2



SECTION D^1-D^1

DUNLOP SPEEDAWAY SYSTEM

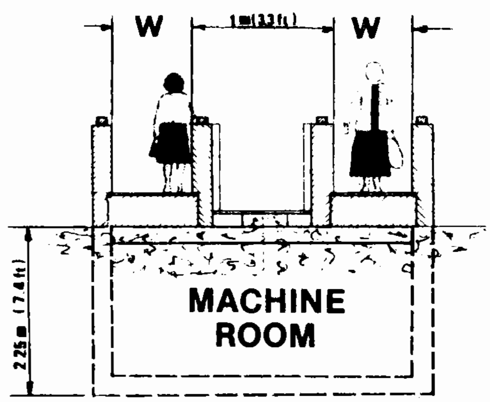


SECTION B-B

BOEING SYSTEM

FLOOR LEVEL MOUNTING POSSIBLE
(TWO-WAY)

W = 40" ±



SECTION T-T

TRAX SYSTEM

(TWO-WAY)

FIGURE 6B

width of a two lane system would be the same as that currently required for conventional passenger conveyors, or about 6-7 feet, (1.8-2.1 m). The APL system which exists as an engineering laboratory prototype can be installed on an incline of up to the 13-15% slope recommended as the practical maximum in current practice. Lower inclines would be desirable for AMWS because of their higher speed characteristic. Because of its physical similarity to current passenger conveyor systems, APL is considered to have favorable site adaptability, and it could be used to retrofit existing conveyor installations.

The Dean Research system, available in a short test section prototype, is a one-directional linear system similar to APL in its dimensional envelope. The Dean System utilizes a treadway surface comprised of a series of abutting one inch (25.4 mm) diameter steel rollers. Rollers in acceleration and deceleration sections are programmed to produce gradually increasing or decreasing speeds, if the concept proves feasible, it would have favorable site adaptability because of its shallow depth

The Dunlop Speedaway system which exists in production unit form has a linear central section with tangentially curved entry and exit sections. The dimensional envelope of the system is a constant 8'-2" (2.5 m) width along the central constant high speed section flaring out to a 30 ft. (9.1 m) width for a 5 to 1 speed ratio unit at the variable speed entry and exit sections (Figure 6 A & B). The centerline offset for the curved section is about 17 ft. (5.3 m) in an opposite direction at each end. The subgrade depth requirement of the system is 57 in. (1448mm.) The cross sectional envelope curved alignment and grade restrictions of the Speedaway system limit its site adaptability, except in new construction or open areas with minimal dimensional constraints.

The Trax and Boeing systems are both two-directional systems generally similar in their general plan configuration, but varying in their subgrade depth requirements (Figure 6 A & B). The Trax system exists as an operating prototype which is scheduled for trial public use in the latter half of 1978. The Boeing System, which has not yet progressed to the detailed design and operational prototype stage of development, can be installed on grade with ramped approaches, or at grade level with an 18 inch (457mm) subgrade depth. The subgrade requirement for the Trax system, which is advanced to the operational prototype stage is 14-20 in. (35-500mm) along the central constant speed section, with a 7.4 ft. (2.3m) deep, 13.3 ft. (4.1 m) long machine pit, handrail and tread return chamber, at each end of the dual unit. The Trax system can be installed on an incline of up to 15%, in a horizontal curve configuration of 164 ft. (50 m) radius and a vertical crest or sag curve radius of 82 ft. (25 m). The 15% incline may be too steep for high speed sections.

A physical characteristic of all transportation systems installed on grade including the AMWS, is the frontage or barrier affect. Unless an AMWS is located on an elevated overpass or in a subway underpass, the system blocks intersecting pedestrian pathways that are not parallel to the alignment path. The system also acts as a funnel for movements along their installation line, speeding up and preventing users from stopping at intermediate points. This may have adverse impacts on activities along the length of the system depending on their type and location relative to the entry and exit ends of the system. Depending on trip end locations and system length, grade level installation of an AMWS would improve travel times for some, be increased for others, in some cases trip links would be severed. The funnel affect, which speeds up users and prevents them from slowing down or stopping at intermediate locations along their travel lines, will be of mixed value in streets or passageways along retail and similar service frontages. Store entrances and windows towards the middle of system will have sharply decreased pedestrian exposure while at the ends will gain by being exposed to greater pedestrian concentrations.

2.3 Operational Attributes, Public Acceptability

The operational attributes of a transportation mode are closely associated with its public acceptability. System speed, capacity, and operating headways determine total trip times, waiting times, crowding, and other passenger level of service factors. System reliability and maintainability affect its availability and performance. Comparative total trip times for AMWS were discussed in Section 1.4 of this report.

The Accelerating Moving Walkway, like a conventional escalator or constant speed moving walk, provides continuous flow transportation. In contrast, vehicular transportation (including the elevator) provides batch movement of people, since vehicles must dwell at one place for the loading and unloading sequences, and must accept time delays to accommodate headway separation between vehicles when operating upon a common track or guideway. In continuous flow transportation systems patron waiting and queuing is minimized and will not occur when passenger volumes are below normal practical operating capacity. This is not the case with individual vehicle or batch movement systems where there is, inherently, always some waiting and queuing for the user, which may vary from being a relatively minor inconvenience to one involving long delays and dense crowding. User tolerance of waiting and queuing time is, understandably, related to the journey time and distance. The shorter the journey, the more magnified a given waiting time appears. For example, a 5-10 minute wait for vehicle arrival in which to accomplish a 5-10 minute ride is considered unreasonable by most users. The inference for the short distance pedestrian trip demand being considered is that continuous flow transportation is appealing to users and offers advantages over batch movement transportation.

The practical passenger carrying capacity of an AMWS will be largely dependent upon entrance or portal width of the system and the effects of human reaction times and psychological preference. Additional capacity effects may develop related to adaptability of the user population to the increased speed and other characteristics of the system, but this can only be determined by a public demonstration. A photographic study of approximately 800 pedestrians boarding escalators and a smaller number boarding moving walks, related the practical carrying capacity of these units to human reaction times and psychological preferences to avoid contact with others. [Ibid 6] Capacity was found not to increase linearly with increased speed due to these human restraints. Portal width also significantly affects system capacity. If there is insufficient step level and shoulder clearance for only one person, pedestrians must develop time consuming, and capacity reducing behavior patterns at the system entrance. As portal width is added to the system, it facilitates the entrance process and results in some increases in capacity, but it is necessary to provide sufficient step level and shoulder clearance for two persons abreast, to double the practical system capacity.

Anthropometric studies have shown that the upper range of human shoulder widths, representing larger, fully clothed human males is 22.8 inches (58.0 cm). It has also been observed that during human locomotion the body sways from side to side requiring additional space if contact between pedestrians is to be avoided. The theoretical capacity of pedestrian conveyors as narrow as 36 inches (92 cm) has been sometimes calculated on the basis of two persons abreast, even though this is only possible with a small proportion of the user population. Treadway widths of 40 inches, (102 cm) commonly provided on the standard 48 inch escalator unit accommodate a larger proportion of the user population on a two abreast basis, but observations show that only 60-70 percent of the possible step positions are occupied, even under the most crowded heavy demand situations. Practical capacity of AMWS systems are estimated to be 3600 persons per hour per 24 inches (610 mm) entrance portal width measured over the handrails. The wide entrance portal width of the Dunlop Speedaway system (9.75 feet. 2.98 m) suggests that it would have potentially more capacity than the other basically two lane entrance systems. However, it is not yet understood how this wide entrance would function under a dense queue since pedestrians entering the system through the center of the portal would not have an accessible handrail.

An operating characteristic of moving way transit systems that could affect passenger acceptability of AMWS is that the whole unit is put out of operation if major maintenance is required or there is a system malfunction. In comparison, multiple unit transportation systems can sometimes sustain a limited amount of malfunctions or maintenance downtime on individual units without the total system being put out of service. It is anticipated that AMWS operational reliability and maintainability will be on a par with existing escalators and moving walks. The walking alternative would always be available for a system outage.

2.4 AMWS Costs

Total system cost is an important attribute affecting the decision to install an AMWS. Costs would include the furnishing and installation of the AMWS unit, generally included in the manufacturers price, the cost of structural and architectural site preparation by the owner, insurance, operation and maintenance expense and property acquisition costs where necessary. Conventional moving walkways currently cost about $1000-1200 per lineal foot ($3280 - 3940/m) for furnishing and installation of the unit. This cost is based on established manufacturing and installation procedures. It is expected that an AMWS will cost from 50 to 100 percent more for furnishing and installation than conventional systems depending on system complexity, manufacturing plant set up requirements and manufacturer experience and capabilities. Longer systems will have slightly lower lineal unit costs because of the greater base over which the higher costs of the acceleration and deceleration sections are spread. The remaining major cost item for an AMWS is the structural and architectural preparation required at the specific installation site, as well as site acquisition costs.

A wide variation in preparation costs can occur depending on the system dimensional envelope, as discussed in Section 2.1, whether the system is installed in existing or new structure and whether it is to be installed at grade, elevated on a pedestrian bridge or in tunnel. At grade installations would be the most economical but provision of weather protection, lighting, heating, ventilation and air conditioning (HVAC) could add to cost. Elevated installation costs would depend on bridge spans, width including standby walkway if needed, and weather protection, lighting and HVAC. Pedestrian tunnel installations would depend on subgrade conditions such as ground water, nearby utility and foundation locations, interior finishes, lighting and HVAC. The range of approximate estimated preparation costs for typical conditions for the Dunlop, APL and Boeing systems is shown on Table 2.1.

Operation and maintenance costs will depend on power costs, which is directly related to the length and passenger utilization of the system, and the maintenance experience with the system. Candidate AMWS suppliers have specified power requirements for their systems as detailed in the Technology Assessment Report (B). Power varies according to the width and length of the system, the weight of its moving treadway components, and mechanical design. Because Boeing and Trax are two-way systems, direct power comparisons are difficult. For a 1000 foot (305 m)-2 lane system, Dunlop rates its maximum design power requirements at 200 hp (150 kw), APL single lane unit at 100 hp (75 kw), and Trax and Boeing double lane loop systems at 120 hp (90 kw). Actual running power consumption of each of these units would vary according to passenger utilization, and would be very likely drawing less than 50 percent of the maximum design power load on the average for even heavily used units.

Power costs vary according to locality, the total power consumption of the user, and demand rate factors. Based on Federal Power Commission statistics the 1976 national average rate for commercial users in a 40 kw demand, 10,000 kw hour per month category, was 4.05

TABLE 2.1

COMPARATIVE AMWS ARCHITECTURAL AND STRUCTURAL PREPARATION COSTS (1)

SYSTEM	GRADE LEVEL (2)	ENCLOSED ELEVATED PEDESTRIAN BRIDGE (3)	PEDESTRIAN SUBWAY (3)	COMMENTS
	$/FT.	$/FT.	$/FT.	
DUNLOP SPEEDAWAY	1860	2580	4250	One Direction
APL	1360	2240	3330	One Direction
BOEING	1430	2650	4020	Two Way Loop

NOTES: (1) Assumes "average" conditions, no unusual sub-grade problems, includes heating, ventilating and air conditioning, 35% for Engineering Administrative and Financial costs.

(2) Protective canopy included.

(3) Includes adjacent 6 ft. (2 m) wide walkway, assumed cut and cover construction.

cents per kw hour. Regional 1976 averages varied from 2.70 cents kw hour, in the east south central U.S. to 6.35 cents kw hour in the middle Atlantic area.(see Appendix Table A-1).

For purpose of the cost benefit analysis contained in Section 5 of this report, it is necessary to develop a baseline system cost for the furnishing, installation, operation and maintenance of an AMWS. It should be recognized that wide variations in the baseline cost are possible depending on the system selected, specific building conditions at the site, site acquisition costs, local utility rates, maintenance workers costs and other similar variables.

The baseline system assumed for later cost benefit analysis consists of a 1000 ft. (305 m) long linear one-directional system, elevated on a pedestrian bridge section, weather protected, plus heating and air conditioning, with an installed power of 200 hp, operating in a reversible "tidal flow" commuter demand situation, 16 hours per day, 300 days per year. The assumed furnishing and installation cost of the system is $1500 per lineal foot ($4920/m) or $1.5 million, and the structural preparation or bridge cost $2240 per foot ($7350/m) or $2.24 million. The capital write off for the baseline system would be based on a 25 year life cycle for structure and 15 year life cycle for equipment, at 7 percent interest (capital recovery factors 0.086, 0.11 annually - Table 2.2 following). No site acquisition cost has been assumed on the basis that the system is installed on public right-of-way, over sidewalks and streets.

Annual operating cost for the baseline system would include an estimated insurance cost of $10,000. Power cost with an installed capacity of 200 hp, power draw averaging 50% of capacity, 80% electrical efficiency, a power cost of $.05 per kilowatt hour, is $4.70 per operating hour. In a commuting environment, 16 hours daily operation would equal $75 and for a 300 day year $22,560. Around the clock 365 day operation would equal an annual power cost of $41,172. Heating, ventilating and air conditioning costs, which would depend on location, have been assumed at $10,000 annually. Maintenance costs for the baseline AMWS would be based on system location and such factors as maintenance experience and costs of replacement parts. Where the AMWS would be part of a larger system of moving way units, such as with a transit property or airport, operation and maintenance would be significantly less than a single installation. Bergmann's compartive study of AMWS vs. People Mover systems at SEATAC Airport developed a prospective maintenance cost of about $20,000 per 1000 feet for an AMWS.[7] This would be equal roughly to about one mechanic man year for the baseline system and appears reasonable. An additional $20,000 would be added for overheads, contingencies and supplies. Table 2.2 following summarizes the cost assumptions for the baseline system.

2.5 Environmental Considerations

Accelerating Moving Walkways are expected to have minimal detrimental environmental impacts in comparison to possible alternative transportation modes including buses and automatic guideway transit systems. The dimensional envelope of an AMWS is much smaller than the vehicle alternative, producing less visual intrusion. Unlike vehicular systems, where separation of vehicles and pedestrians is mandatory for safety reasons, the AMWS becomes an integral part of the pedestrian environment. The noise level of an AMWS would consist of a constant

TABLE 2.2

AMWS COST ANALYSIS - BASELINE SYSTEM (1)

ITEM	ANNUAL COST	DAILY COST (2)	NOTES
1. FIXED CHARGES			
a. furnishing and installation	$165,000	$550	CRF = 0.11 per annum (15 yrs. 7%) F & I $1.5 Million
b. structural preparation	193,000	643	Structural prep. $2.24 Million CRF = 0.086 (25 yrs. 7%)
2. OPERATIONS AND MAINTENANCE			
a. maintenance	40,000	133	
b. power (running)	22,560	75	
c. insurance	10,000	35	
d. HVAC	10,000	35	
TOTALS	$440,560	$1471	

(1) Linear reversible unit, 1000 feet long, elevated on covered pedestrian bridge, 200 installed hp. one-directional commuter demand situation, reversible, including HVAC.

(2) Based on 16 hours daily operation, 300 day year.

muffled machine noise, possibly coupled with some low level contact noise of treadway and other system parts similar to escalators, in contrast with the higher acceleration and operation noise of the vehicular alternative. No atmospheric pollution, with the exception of minor heat losses from electrical machinery, will be produced. This would be a significant consideration in urban core areas where pedestrian densities are greater and atmospheric pollution from vehicles tends to be the worst.

The relatively unobtrusive operation of an accelerating moving way transit system might be compared on a capacity equivalency basis with an urban bus or automatic guideway transit operation. In order to duplicate the passenger capacity of a two lane AMWS, 100 to 140 hourly bus trips would be required, at close 25-35 second headways depending on whether only seated, or seated plus standee passenger loads are considered for the bus. Automatic guideway transit systems using smaller vehicles would have to be close to, or exceed, their practical capacity limits to equal moving way transit system performance. Table 2.3 following is a comparative summary of the environmental aspects of an AMWS, transit bus operation and an AGT system.

COMPARISON OF ENVIRONMENTAL ASPECTS

	AMWS	Bus	AGT
Construction	Light - to support 300-500 lb./ft.	Medium - to support 1000 lb./ft.	Medium - to support 1000 lb./ft.
Noise	Low expected - of same order as escalator plus air conditioning	Relatively High - diesel bus	Low expected - based on Tampa AGT operation
Smell	Negligible - electric	Pronounced - diesel	Negligible - electric and rubber
Heat Generated	Low/Medium - principally from air conditioning	Medium - diesel engine and air conditioning	Low/Medium - principally from air conditioning
Air Quality	Good - electric	Poor - from diesel operation	Good - electric

3.0 IDENTIFICATION OF AMWS BENEFITS

3.1 General Discussion

The benefits accruing from the installation of an AMWS form a complex matrix depending on the goals and objectives of the prospective sponsors of the system, its users, and non-users. In some instances the goals and objectives of all will overlap, in others they will not. It is also possible that something viewed as a benefit by one of the system actors would be considered as a dysbenefit by another. For example the sponsor's ability to charge a fare to offset the costs of installation and operation of an AMWS would be viewed as a benefit by him, but as a dysbenefit by the user. The non-user may be neutral in this case. Benefits may be direct, such as time savings by users, or indirect, such as the benefits that might be derived by merchants due to improvements in the utility and viability of the urban core, or even more difficult to determine, the offsetting of possible urban decay. Figure 7 following is a Venn diagram which schematically illustrates the interaction of the AMWS actors, the prospective coincidence of their respective goals, and the potential for direct and indirect benefits for all.

3.2 AMWS Benefits

The benefits accrued from an AMWS installation are site specific and dependent upon the application for which it is used. A number of potential applications are described in Section 4 of this report. A general review of prospective benefits follows.

Time savings would result from pedestrians using an AMWS as discussed in the preceding Section 1.3. These savings can be measured against a walking alternative, and with shorter trips, against a transit alternative. However, the order of magnitude of these time savings is

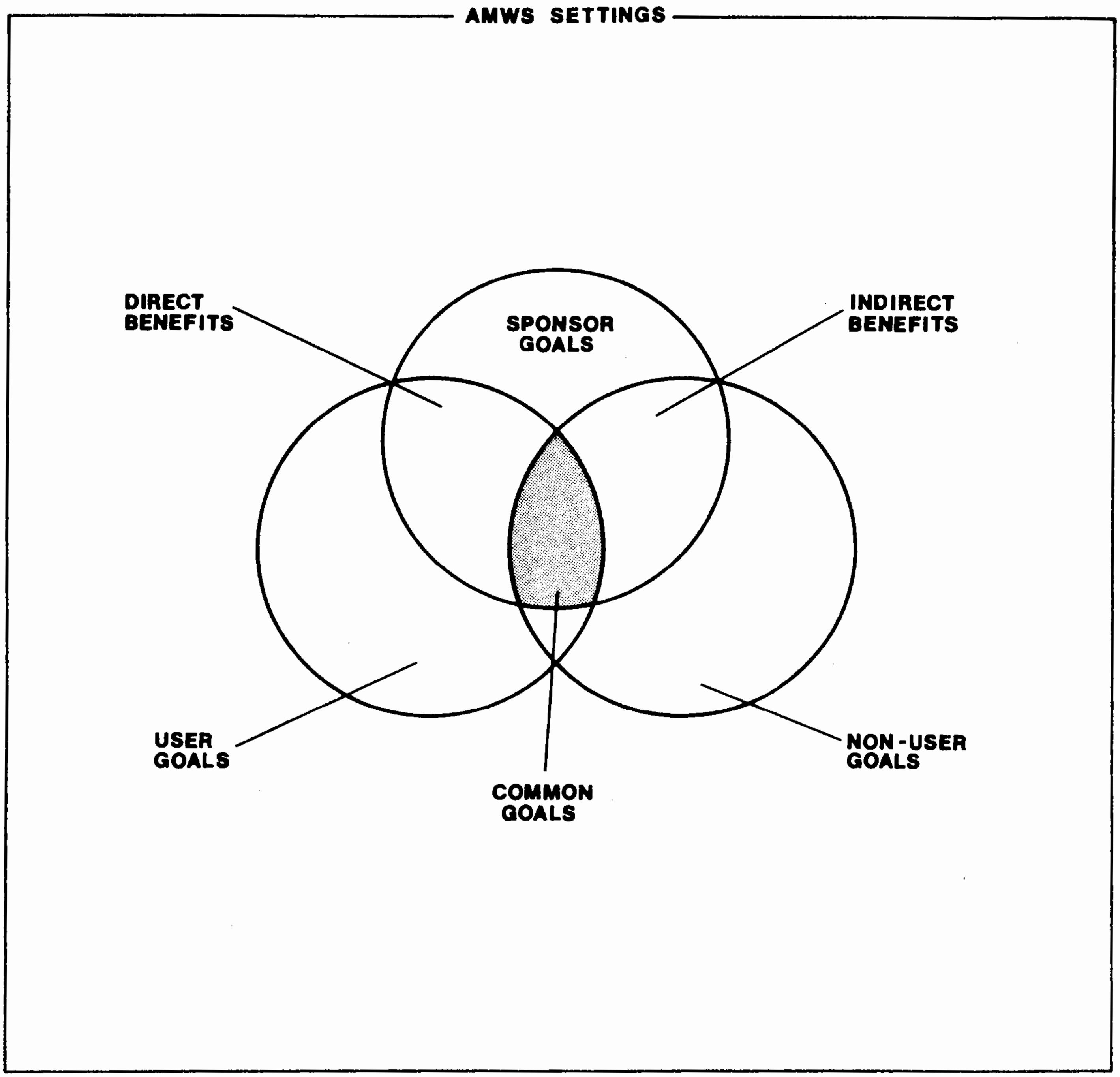


FIGURE 7 AMWS BENEFITS CONTEXT

relatively small, for example about 2 minutes for a 1000 foot (305 m) walking or transit trip. (Fig.4) Time savings for urban core walking trips would be slightly greater where an AMWS eliminates grade crossing traffic signal and sidewalk congestion delays for pedestrians. Although these time savings are a significant proportional reduction in total time for the typical walking or short transit trip, they represent a relatively small base upon which to determine system value as is traditionally done in cost benefit analysis. Interestingly, despite their widespread use, neither escalators or constant speed moving walks offer any time advantage for their users unless they walk on them. Obviously such criteria as user convenience, human energy savings, the developmental advantage afforded by the system, or criteria other than time savings, were used to justify their installation.

A commonly applied method of valuing time savings is to use an assumed average employee wage rate. When this is done within a job related context, say savings in a production workers time, there is no question of its validity. This method of valuing time would appear to have less validity when applied to time savings by public transportation users because there is no resultant increase in work productivity. However, when used in this context, it is a fair approximation of what the individual perceives as the relative worth of his time, and should represent a reasonable means of assessing the societal value of such time savings. At an assumed average annual wage of $10,000, the value of an employee's time equates to $4.80 per hour for a 40 hour week or $0.08 per minute. If it assumed that a commuter used an AMWS daily for 500 trips each year, and saves a minute for each trip, total time savings for the year would equal 8.3 hours, or approximately one work day, and an equivalent annual wage value of $40 per single trip minute saved.

Expansion of the pedestrian trip range is the key benefit of accelerating moving walkway systems, but one that is difficult to value, except for specific development opportunities. This horizontal movement development advantage was compared to that of the invention of a reliable elevator, which made vertical hi-rise construction possible. The economic benefit of the elevator accrues from the fact that the high cost of land can be averaged over a larger area of rentable space, There are economies in high rise construction that can be realized over the low rise alternative, and simply that the demand is there, with many businesses preferring central city locations. Improved horizontal movement systems offer similar, albeit not as spectacular, or as universal, developmental advantages, some of which are discussed in Section 4.0 of this report.

Development advantage analyses compare the cost of alternative actions with the least cost, or most profitable action, or combination, being determined. A horizontal movement system provides the basis of connecting low and high valued land uses, affording the opportunity to increase the value of the lower, or to shift secondary land uses such as parking or even transit from high valued locations to low. This value transfer characteristic will be the most likely basis for private commercial uses of an AMWS. Other forms of development advantage redounding from the availability of a convenient longer range horizontal pedestrian movement system could be obtained at an airport, say in comparison with maintaining and operating a mobile lounge fleet; or as an alternative to constructing an on airport AGT system. Developmental advantage could come in transit system construction by making more alternative, and possibly less expensive alignments possible. Additionally, land made inaccessible by barriers such as rivers, highways or transit right-of-ways could be made useable by means of an AMWS.

Improved pedestrian convenience is a tangible but non-quantifiable benefit of an AMWS. Increased pedestrian mobility in the urban core can make it more attractive for shopping, recreation, business and cultural trips. Improved accessibility to public transportation would increase its use for these trips. An example of this secondary type of benefit occured when the Washington Metro Transit System opened its first short downtown section, and also when the Seattle Bus Transit System instituted its free-fare magic carpet service within the CBD. These services generated pent-up demands for longer restaurant and shopping trips which previously did not occur during limited lunch periods. Pedestrian traffic movement via an AMWS would be more comfortable, with less conflicts and signal interruptions than walking on crowded urban sidewalks. Improved urban mobility of this type can increase gross retail sales, sales tax receipts and eventually lead to upgraded property values and increased property taxes.

Improved Safety and Security would also accrue from AMWS installations where they would substitute for street level movement of pedestrians, eliminating the conflict with vehicles and accident hazard connected with street crossings. A recent study established a pedestrian accident avoidance value at about $8 per 1000 pedestrian crossings in 1975 dollars. [8]. This value is based on the cost of medical treatment and/or death for a pedestrian casualty as well as lost wages and other costs. Enhancement of security cannot be accurately valued, but in some CBD's improved security could increase core area use, and improve area image and business potential.

Reduced pollution and energy use compared to the vehicle transport alternative would result where an AMWS could be substituted for bus and taxi movement in core areas. Environmental impact studies for the proposed Madison Avenue pedestrian mall in New York City showed that the concentration of atmospheric pollution was the greatest where pedestrian traffic volumes were the highest. Insertion of an AMWS in high volume corridors of this type would reduce surface transit bus and taxi traffic, and in cases where an enclosed system was provided, reduce exposure of pedestrians to the fumes, noise, dust and danger of street traffic as well as to the vagaries of the weather.

The energy required to operate an AMWS might be compared with other modes such as the transit bus and automatic guideway transit systems. Buses with total seated and standee load of 72 persons would have to make 100 trips per hour to equal the capacity of a two lane AMWS. For a 1000 ft. (305 m) loop, at an assumed average speed of 20 miles per hr. (32.2 km/hr), this would require 8 buses operating continuously if it is assumed that passenger unloading and loading takes 2 minutes at each trip end. For a 100 passenger AGT vehicle similar to the Tampa airport type, 5 vehicles operating at an average speed of 20 MPH would be required if it is assumed the larger door capacity of this type of system permits passenger unloading and loading in 80 seconds at each end. Table 3.1 following compares energy use and cost for the three modes. The reasons for the outstanding energy economy of the AMWS over the Bus and AGT systems is attributed to the lower equipment weight/passenger that is propelled, the lower resulting drag to be overcome and the continuous motion of the AMWS system which substantially reduces the energy required for acceleration and that lost in braking.

TABLE 3.1

ENERGY COMPARISON

1000 FOOT (305 M) SHUTTLE OPERATION
ONE DIRECTION PASSENGER VOLUME 7200/HR.

MODE	SERVICE ASSUMPTION	UNITS REQUIRED	INSTALLED HORSEPOWER	HOURLY ENERGY CONSUMPTION (3)	HOURLY ENERGY COST $(4)
AMWS	Continuous	1	200	75 KW	$ 3.75
Transit Bus	20 MPH (32.2 KMH) Avg.	8 (1)	(8 @ 250) 2000	22 Gal.	$11.00
AGT (Tampa Type)	20 MPH (32.2 KMH) Avg. 80 Sec. Dwell	5 (2)	(5 @ 200) 1000	373 KW	$18.70

(1) 5 minutes round trip including 2 minute dwell, 75 passengers per bus.
(2) 3.67 minutes round trip including 80 second dwell, 100 passengers per vehicle.
(3) All modes assumed operating at average 50% maximum installed capacity.
(4) Electric $.05 KW hr., diesel $.50 gallon.

Urban quality of life improvements would result from reductions or elimination of the vehicle dominance that now exists in most urban core areas. The form of future urban development could be reshaped according to the scale and needs of the pedestrian, rather than that of the vehicle, as is currently done. Traffic signals, regulatory signs, parking meters and other similar urban design features could be removed to create a more human environment.

3.3 AMWS Sponsors

The identification of possible AMWS sponsors and the determination of their relative interests in the benefits described in the previous section, is of value in determining the likelihood of potential AMWS applications.

Federal, state and municipal governments are prospective AMWS sponsors. Goals would include improved accessibility to public transit, reduced urban pollution and energy use, urban renewal, improved public safety and security.

Transit operating agencies would also be interested in improved accessibility to transit to increase patronage, in developmental advantage to increase transit route options, and as a potentially less costly public transportation mode for some locations.

Airport operators are likely to be one of the primary sponsors of AMWS installations because of the horizontal separation of most airport facilities. Goals would include time savings for airport personnel and patrons and developmental advantage stemming from the ability to consider alternative airport configurations that are possibly more effective or less expensive.

Commercial developers are potential AMWS sponsors from the standpoint of developmental advantage in value transfer situations, and improving urban mobility and pedestrian convenience, comfort, convenience and security for the purpose of increasing business patronage.

Recreational enterprises, amusement parks, athletic stadiums and racetracks are possible AMWS users where long walking distances limit convenience and accessibility to parking, transit or other facilities. Since such traffic is very often directional, maximum use could be made of a one-way reversible unit.

Cultural centers - public educational, performing arts, museums, zoos, and parks might be prospective sponsors or co-sponsors of an AMWS installation, probably more likely in conjunction with others where connection to such activity centers would enhance other land uses such as transit or commercial development.

3.4 Sponsor/Benefits Matrix

Table 3.2 on the following page is an array in which prospective AMWS sponsors are listed in conjunction with associated benefits. The benefits have been scored on the basis of their approximate relative interest to the sponsor; H=High, M=Medium, L=Low.

TABLE 3.2

AMWS BENEFITS MATRIX

SPONSOR	Time Savings	Development Advantage	Urban Renewal Value Transfer	Human Energy Convenience	Improved Pedestrian Mobility	Improved Area Safety	Improved Area Security	Reduce Pollution	Reduce Energy	Improved Urban Design	Pedestrian Weather Protection
GOVERNMENT Federal, State Municipal	H	M	H	M	M	H	H	H	H	M	L
Transit Operator	H	H	M	M	M	M	M	M	H	M	L
Airport Operator	H	H	L	H	M	M	M	L	L	L	M
Commercial Developer	L	H	H	M	H	M	M	M	M	H	M
Recreational Enterprise	L	H	L	H	M	M	M	L	L	L	M
Cultural Centers	L	M	L	H	H	H	H	M	M	H	H

<u>Relative Interest</u>

(H) High (M) Medium (L) Low

4.0 AMWS APPLICATIONS

4.1 General Discussion

Potentially there are a wide range of possible applications for a short range small scale horizontal movement system such as an AMWS. Many opportunities exist in cities, airports and activity centers, where the installation of such systems would substantially improve pedestrian mobility and convenience. The constraints on installation, including system cost, site adaptibility, public acceptability and other factors discussed in the Attributes Section (2.0) of the report will determine the degree of actual future use in these applications. For purposes of this report section, five generic classifications of AMWS use have been identified and are discussed along with some potential variations within the category. Where possible, some examples of known situations fitting the application category have been cited as a point of reference. The five general categories include: (1) Transit, (2) Airports, (3) Urban Development, (4) Vehicle Free Zones, and (5) Bus or PRT System Alternative.

4.2 Transit Applications

Transit uses for an AMWS include utilization as a transfer element between transportation terminals and adjacent transit stations, as a feeder and distributor for transit lines, connecting with peripheral parking or nearby activity centers. While these roles may appear to be basic, the ramifications of an efficient small scale support system for mass transportation systems could be quite significant.

For example, one of the criticisms of the BART system resulting from impact studies is that the relatively long distance separating stations limits pedestrian accessibility to the system. This limited accessibility reduces total system connectivity, or the ability of the system to efficiently serve the maximum number of regional origin and destination trip pairs. Connectivity is an important factor affecting transit patronage and is directly related to the ability of transit to compete with the automobile. The AMWS also opens up the possibility for a number of other benefits as well. For example, commuter parking could be remote from the station itself, allowing for the location of parking in less valuable locations, or in several smaller lots rather than one large capacity lot surrounding the station. (See Figure 8). The former application provides the opportunity to cluster valuable commercial land uses close to the station proper, rather than sterilizing commercial potential around stations by dedicating this area to grade level, blacktop parking. The latter application of the AMWS also would allow dispersed, less concentrated auto access to the transit system, reducing the heavy traffic and environmental impacts associated with the larger station lot.

Perhaps one of the most intriguing potential applications of a short range pedestrian scale AMWS system is the development of alternative alignment options for new mass transit systems. It is the practice to align new transit systems beneath the most densely developed urban streets. While this is desirable from the standpoint of proximity to passenger demand, construction of the system under these streets is usually more expensive because of concerns for disruption of economic activity at the surface, foundation and utility problems, and other factors. Deep tunnel subway construction is usually selected

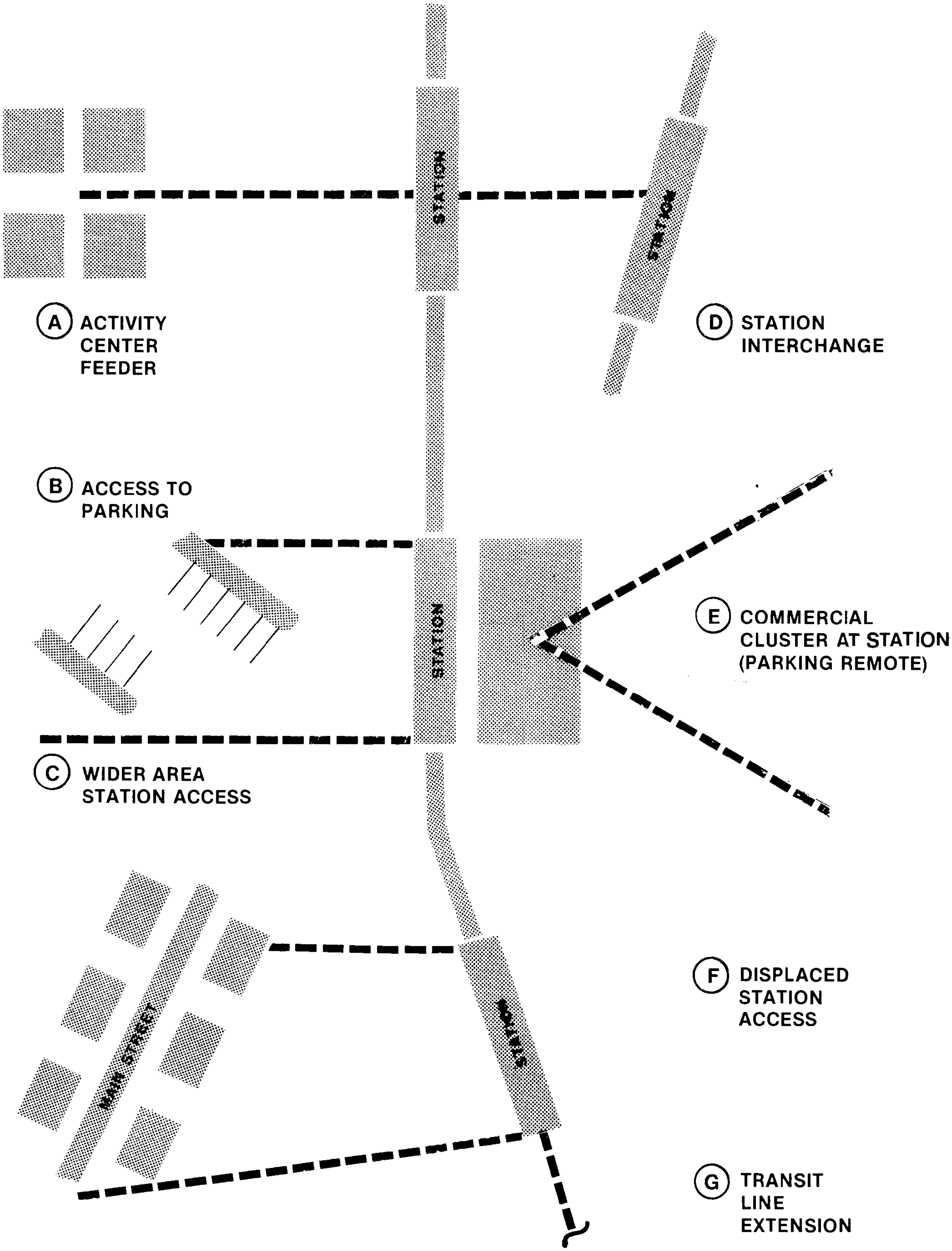


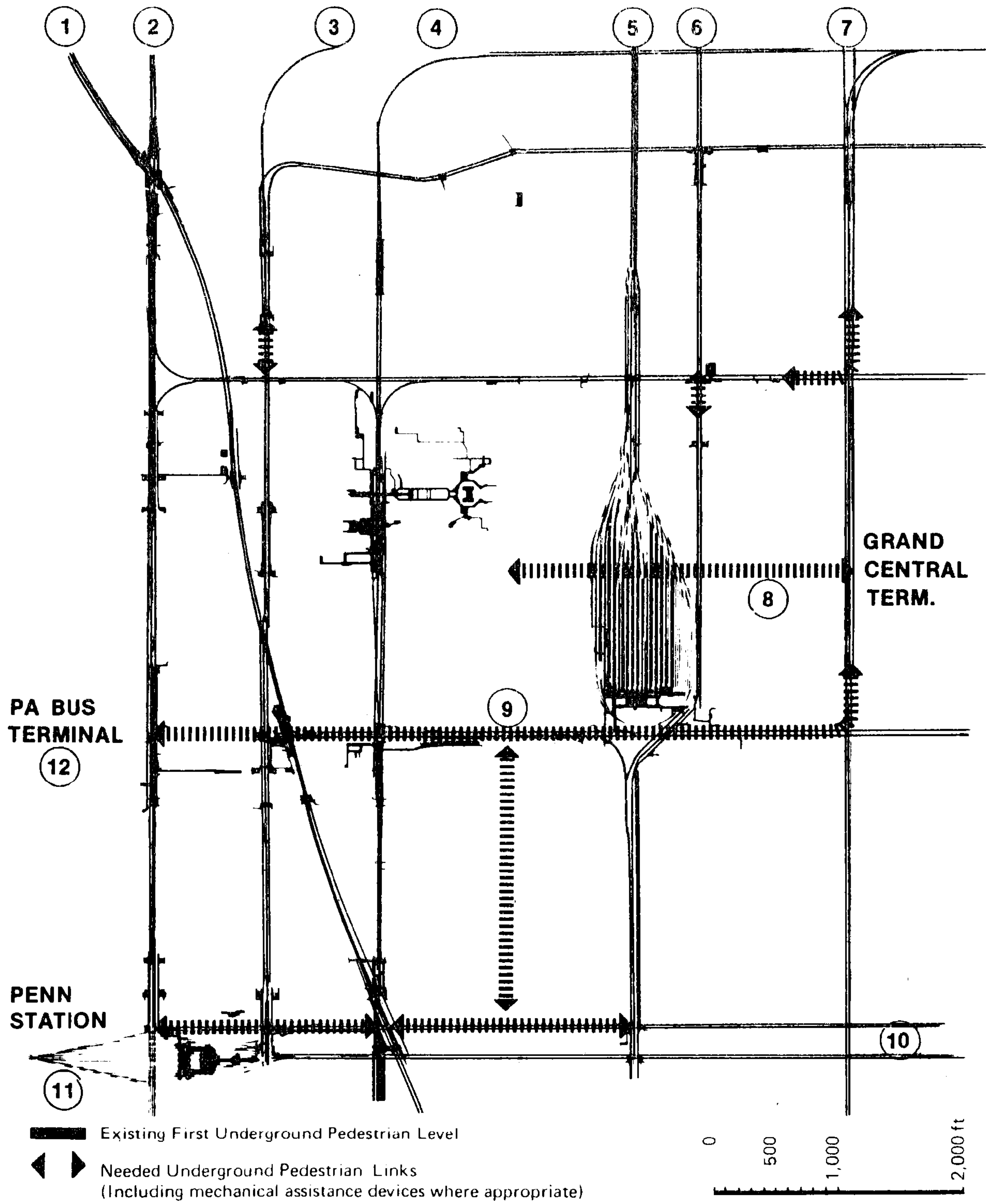
FIGURE 8 AMWS TRANSIT USES

in these situations. AMWS feeders connecting to main street access points would allow displacement of transit stations to less densely developed streets, reducing construction impacts and possibly allowing less expensive alternative construction methods such as "cut and cover" trenching. Station access time for the transit passenger would be no greater in the horizontally displaced station than it would be vertically in the deep station. Displaced alignments of this type would have the advantage of spreading accessibility and the potential economic benefit resulting from proximity to transit over a wider urban area.

The displaced alignment concept might also be applied to older transit systems, or even new transit use of unused railroad right-of-ways, in places where the centroid of urban activity has shifted away from these lines and is now beyond reasonable walking distance. This could offset the need for new transit lines or extensions in the case of the older systems, or allow the more economic use of existing railroad right-of-way for new systems. An AMWS might also be selected as a less expensive alternative in terms of construction and/or operation to a segment of a transit line, by substituting it for a branch or shuttle rail line operation.

Several such shuttle operations exist in New York City, the most notable being the "Time Square Shuttle" which operates between the Grand Central Terminal and Times Square Areas of Manhattan. This 2300 foot (700 m) line provides for east-west distribution and free transfer for a number of major transit lines in Midtown Manhattan. Daily use is about 90,000 riders. Although Manhattan offers the largest single

SOURCE: N.Y. REGIONAL PLAN ASSOC.



INDEX

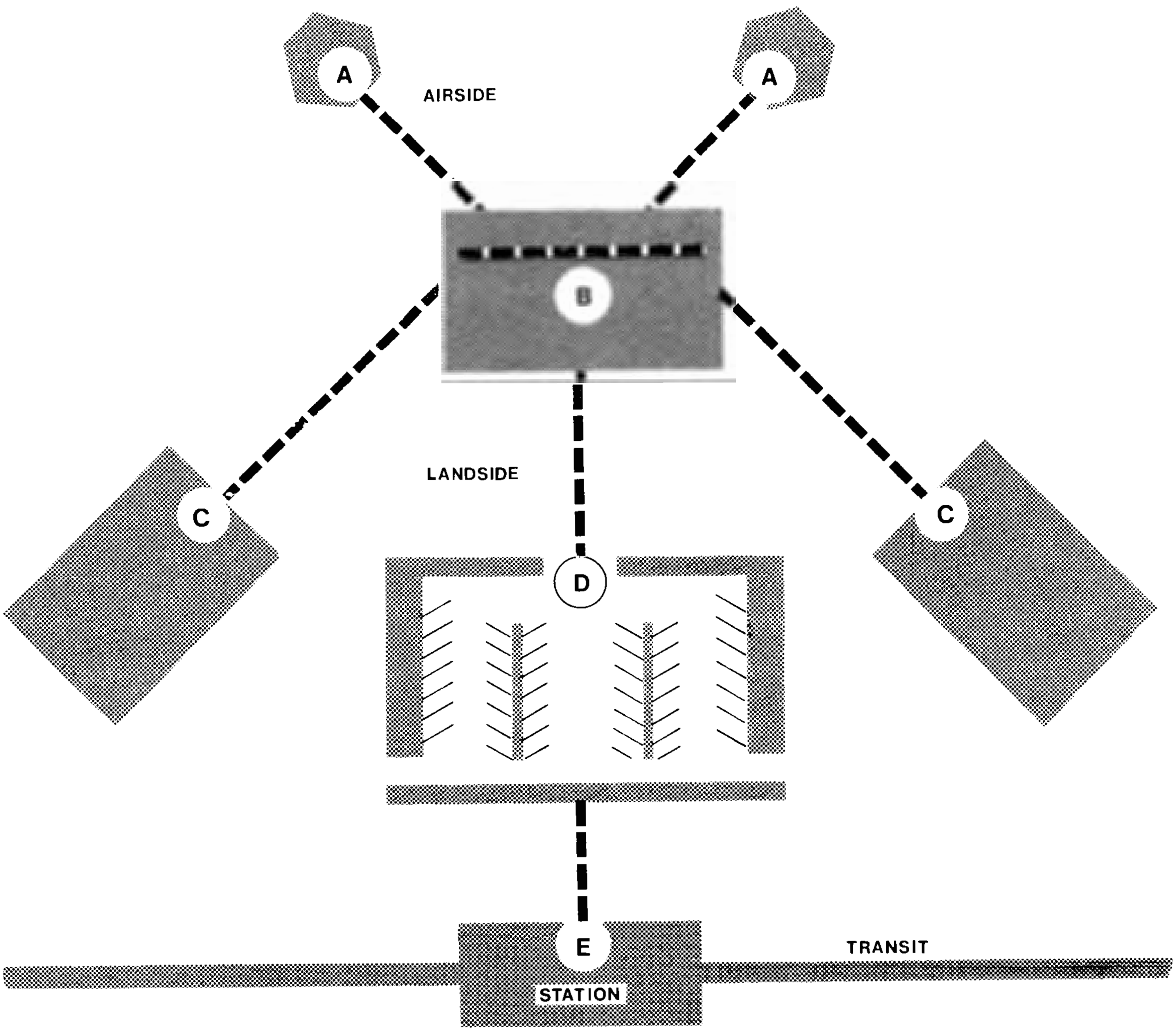
1. BROADWAY BMT SUBWAY
2. 8TH IND SUBWAY
3. 7TH AVE. IRT SUBWAY
4. 6TH AVE. IND SUBWAY
5. N.Y. CENTRAL SUBURBAN
6. IRT LEXINGTON AVE.
7. 2ND AVE. (UNDER CONST.)
8. GRAND CENTRAL TERM.
9. TIMES SQUARE SHUTTLE
10. LONG ISLAND SUBURBAN
11. PENNSYLVANIA STA. AMTRAK, LIRR, PENN RR
12. PA BUS TERMINAL N.J. AND INTERCITY BUSES

FIGURE 9 MIDTOWN MANHATTAN TRUNK TRANSIT LINES AND UNDERGROUND PEDESTRIAN PASSAGEWAYS concentration of major trunk subway lines in the world, these lines run basically north-south. East-west circulation has always been a significant passenger movement deficiency in Manhattan which could potentially be ameliorated by pedestrian assist systems. The possible extension of the Time Square Shuttle operation further to the west would be a desirable transportation planning objective to connect with an additional major trunk subway and the Port Authority Midtown Bus Terminal, an interstate bus facility serving 200,000 daily suburban passengers. Ideally, the three major passenger terminals in Manhattan, Pennsylvania Station serving 200,000 daily suburban passengers, Grand Central Station serving 130,000, and the Bus Terminal should be interconnected. (See Figure 9.)

A pedestrian assist network serving these three major terminals, which are within a 3200 ft. (1000 m) radius of each other, would also intercept all the major transit trunk lines. Of added interest in this area is the large number of unconnected passageways which would offer the possibility of creating an underground network similar to the 6 km system in Montreal, Canada. This system connects the major transit stations in the downtown area with most of the major hotels and retail establishments.

4.3 Airport Applications

Airport applications for an AMWS include use as a landside connector between individual terminals, as an intra-terminal movement system within a main terminal building, or connecting to airside satellite lounges or as an on airport connector to landside transportation elements such as a nearby transit or bus system, centralized parking or other auxiliary passenger processing sub-systems. (See Figure 10).



Ⓐ SATELLITE LOUNGE CONNECTORS

Ⓑ INTRA-TERMINAL MOVEMENT

Ⓒ CONNECTOR BETWEEN UNIT TERMINALS

Ⓓ CONNECTOR TO PARKING—AUXILIARY PASSENGER FACILITIES

Ⓔ TRANSIT SYSTEM CONNECTOR

FIGURE 10 AMWS AIRPORT USES

Conventional moving walkways have been introduced into many airports in recognition of the functional limitations imposed by the restraint of acceptable pedestrian walking distances. The expansion of landside requirements with its concomitant increase in parking area, curb frontage, etc., has led to growing separations in terminal facilities and the demand for ancillary on-airport transportation systems. The effective range of accelerating moving walkway systems, smaller scale, continuous service aspect, simplicity of use, and other similar features make it particularly well suited to on-airport transport problems. Prospective benefits include greater functional freedom in developing airport expansion plans based on landside-airside separation concepts, increased convenience to the air traveler where long interline transfer distances are required, and a potential lower cost alternative to the on-airport AGT and bus connector systems presently being utilized and proposed.

An AMWS system might be introduced as an alternative to a mobile lounge fleet operation such as exists at Dulles International Airport where the costs of the operation might be weighed against the development of satellite lounges served by underground connectors such as presently done at Seattle-Tacoma (SEATAC) Airport. In addition to the possible low cost, passenger convenience might be improved by elimination of the plane/vehicle/terminal transfer sequence inherent in the use of mobile lounges. An after the fact economic analysis of possible use of a network of AMWS units as an alternative to the AGT system at SEATAC Airport showed that the AMWS network would be more economic in terms of initial construction cost and operation and maintenance. [Ibid 7].

4.4 Urban Development

A characteristic of many older central business districts is a shift in the location of active retail and commercial development, leaving areas containing many sound structures, which cannot be fully rented, and therefore tend to deteriorate. Such shifts may be caused by a number of factors, including physical separation from transit systems, cultural facilities, restaurants, retail stores, or other types of complementary land uses that affect commercial development and viability. Isolation of potentially valuable land in relatively close proximity to the commercial core can also be caused by the spatial interruption of rail and highway rights-of-way or natural topographical barriers. AMWS(s) would provide a means of bringing the complementary activities conducive to commercial development within an effective range of these depressed areas, improving their place utility and prospects for potential redevelopment and more productive use. The potential benefits of improved pedestrian circulation within the core include revitalization of declining central business districts, increased CBD employment, increase in transit system utilization, increases in gross retail sales, sales and property taxes.

Additional possibilities for urban development include "remoting" of parking now occupying high value land space within the core, releasing core areas for other high value uses and enhancing the value of the core by integrating other activity spaces with it. As an example of the latter, the City of Cincinnati found that the construction of a pedestrian bridge over a highway landlocking its riverfront sports' stadium substantially increased CBD restaurant and shopping patronage on game days at the stadium. Mutual enhancement of this

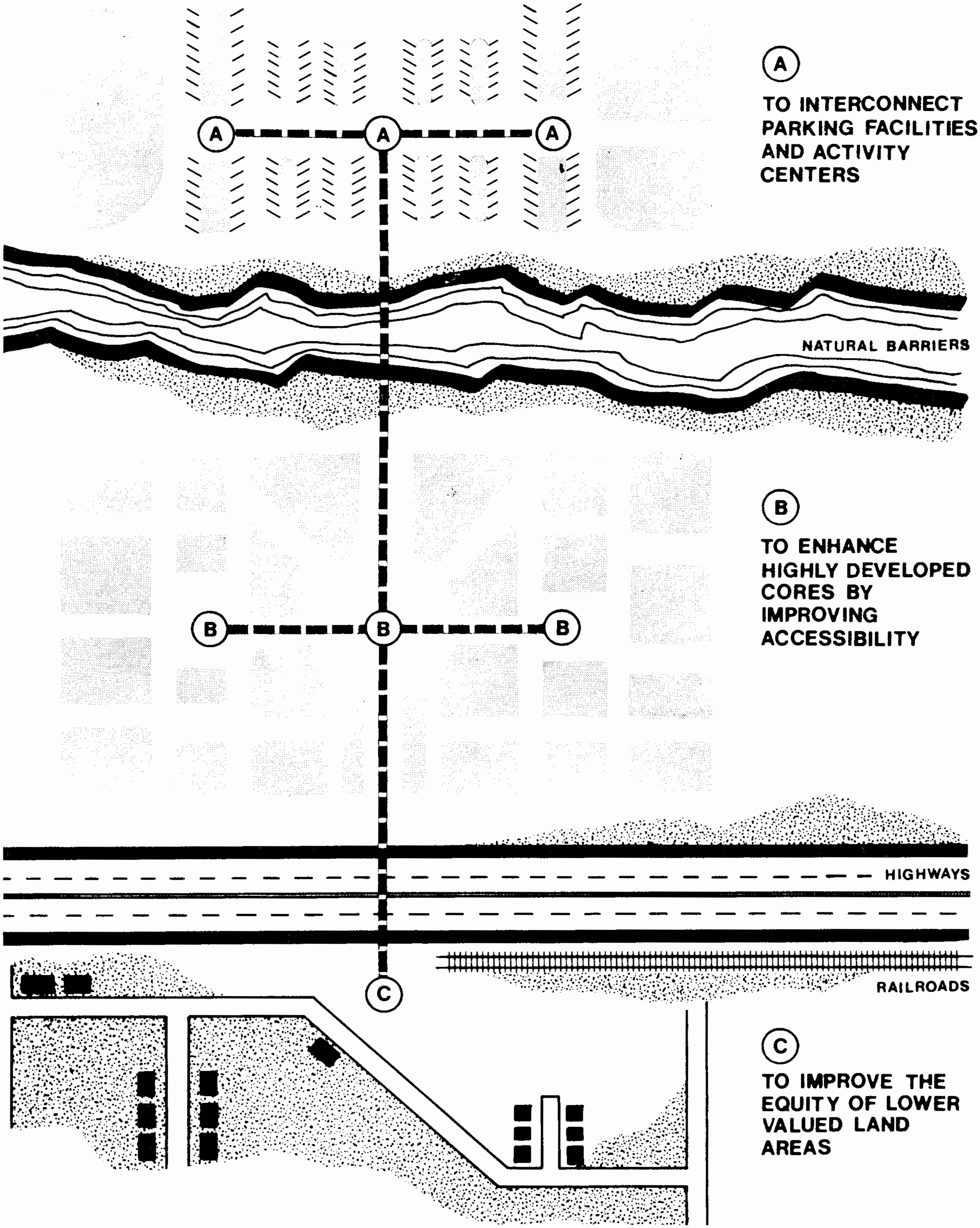


FIGURE 11 AMWS USES FOR URBAN DEVELOPMENT

type, integrating different types of land uses in and surrounding the CBD core, are considered significant in maintaining downtown vitality. Similar opportunities exist in many older cities where land use changes leave relatively large tracts of land just "out of reach" of the core. New York City conducted studies for a proposed Convention Center on several alternative sites which would involve large areas of such land on the West Side of Manhattan. The Convention Center would be expected to increase tourism and bolster the city's faltering economy. The large area required for the Center, coupled with high property values, precluded its location at the core center. An AMWS connecting the core with an activity center of this type would improve accessibility to core area hotels and retail establishments. (See Figure 11)

4.5 Vehicle Free Zones

Vehicle Free Zones (VFZ) or pedestrian only precincts, have been advocated as a means of reducing atmospheric pollution, visual and noise pollution, and energy use in urban areas. A significant restraint on the size, utility and potential future viability of VFZ's is the acceptable pedestrian walking distance range. AMWS's would permit increases in the area restricted to vehicular operation within the VFZ by expanding the effective trip distance range of the pedestrian. The AMWS would provide access capability to transit and peripheral parking which would allow more alternative VFZ configurations.

The AMWS would also provide a "radial" service alternative to a Shuttle Loop Transit (SLT) system where such a system might be proposed around the periphery of the VFZ. It has been suggested by some planners that radial systems provide wider coverage than peri-

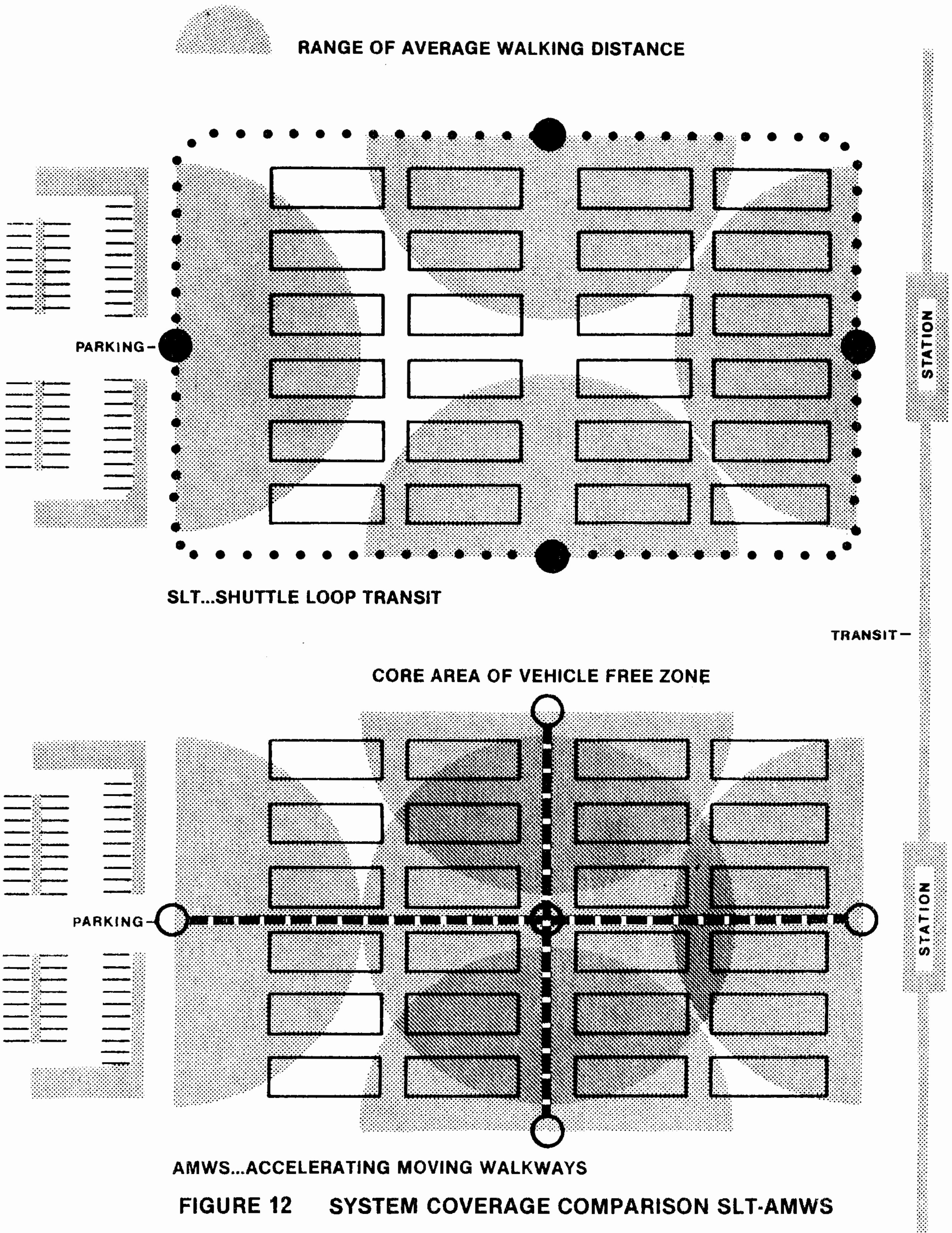


FIGURE 12 SYSTEM COVERAGE COMPARISON SLT-AMWS

pheral systems in activity center applications. The continous service aspects of AMWS, smaller deployment profile, lighter structural load, and other similar benefits of scale make it ideal for core applications of this type. Additionally the route miles of an alternative radial system compared to a loop system would be up to 50 percent less despite its wider area coverage. (See Figure 12)

4.6 Bus or PRT System Alternative

A short range, continous service transport system, such as an AMWS would present many opportunities for considering it as an alternative to taxis, bus, automatic guideway transit, light rail transit, or in some cases even heavy rail transit. As compared to these vehicular systems, an AMWS would provide continuous rather than intermittent batch service, would require less manpower to operate and would be relatively simpler to deploy because of its scale. It would not require exotic control systems, or a fleet of vehicles to be maintained, or maintenance garage facilities. Environmental impacts would be considerably less than vehicular systems, and there would be lower energy consumption per passenger. User accessibility to the smaller scale system should be superior, because the added height required for grade separating vehicle systems results in a greater vertical access penalties for users.

5.0 AMWS COSTS AND BENEFITS

5.1 General Discussion

Cost benefit analysis may be described as a procedure by which the range of benefits resulting from a prospective course of action are identified, translated in dollar terms and quantified where possible, and measured against the costs or other penalties associated with the action. If the benefits developed from such an analysis exceed the costs, the action can be considered a favorable one from the standpoint of the decision maker establishing the benefit/cost parameters. The larger the ratio of benefits to costs, the more favorable the action may be considered by the decision maker. This basic description of cost benefit analysis is a reasonable model of how many decisions are made, including such simple things as everyday personal purchases.

The most accurate and effective uses of cost benefit analyses occur when it is used as a management decision procedure involving such things as the purchase of new equipment with easily identifiable productivity improvement capabilities. Although cost benefit analysis has been applied to public transportation decision processes, it has been the subject of debate because of the inability to completely identify the benefits, (and dysbenefits) associated with transportation improvements. In particular, difficulties have been experienced in valuing passenger time and convenience, since passengers themsleves may vary in their perception of this value under differing circumstances. [9].

Four different ways of viewing the possible cost benefits of an AMWS installation are discussed in this section. One or more may apply to the prospective types of applications developed in the previous section. It should be recognized that the cost and potential use, and/or value, of an individual AMWS installation is extremely site specific, and difficult to generalize. Cost/benefit as developed in this section include: (1) Time Energy Value, the possible worth of time/energy savings associated with AMWS use; (2) Least Cost Alternative, a comparison of the cost of an AMWS as an alternative to use of another transportation mode; (3) Value Transfer, the use of an AMWS in a context in which an increase in property value, rentals or other values will result, and, (4) Developmental Advantage, where an AMWS allows a potentially lower cost development plan, or one with superior advantages.

5.2 Time Energy Value

A representative dollar value of an individual AMWS user's time savings based on an assumed yearly worker's wage of $10,000 is $0.08 per minute, as developed in Section 3.2. A user of a 1000 feet (305 m) baseline AMWS would save two minutes over an equivalent walking or transit trip or a single trip value of $0.16. Time savings would be more where the walking alternative involved at grade street crossings and movement on congested sidewalks or where the transit alternative speed was less than 20 MPH, (32.2 KMH), or headways longer than 5 minutes. Values of walking time from a number of sources summarized in a study by Rutherford and Schofer showed a range of $0.03 to $0.24 per minute. [10] (Appendix Table A- 2).Based on these studies, the two minute savings on the baseline system would equal to a value of between $0.06 and 0.48 per trip. This study also compared riding time with walking time indicated that passengers valued the latter at 3 to 7 times greater than that spent in vehicles. The possibility of an AMWS user walking on the system for additional time savings is not considered.

AMWS users not only save time, but also human energy, a factor that is not represented in the above analysis. Some indications of the value of the time/energy combination may be derived from "walking avoidance" values that parkers place on parking facilities nearer to their destinations, or by the fares paid by bus or taxi users. The validity of the bus and taxi fare comparison is colored somewhat by the fact that such trips generally involve distances longer than 1000 feet (305 m), but the majority of such trips are under one mile (1.6 KM)in most CBD's.

A study by the New York Regional Plan Association (RPA) comparing the prices paid for long term parking versus distance to destination, found a one directional walking avoidance cost for parkers in Manhattan of $0.65 per 1000 feet (305 m) in 1969 prices. [Ibid 1] RPA reported the results of a similar study for Los Angeles indicating walking avoidance values ranging between $0.36 and $0.48. The RPA study found walking avoidance values for transit users in Manhattan varying between $0.03 to $0.50 per 1000 feet (305 m), with a value of $0.11 to $0.13 being representative of the typical cross town transit bus trip in Midtown Manhattan. This latter value is reasonably close to the assumed wage rate value of time savings of $0.16.

Taxi cab users in Manhattan currently pay $0.70 for the first seventh of a mile (750 ft., 230 m) and $0.10 for each seventh of a mile. Most of these trips in Midtown Manhattan average less than one mile in length. Without gratuities, a one mile trip equals to $1.30 or $0.25 per 1000 feet (305 m). A multiple unit AMWS weather protected network could capture a vast majority of such core area trips, but it is difficult

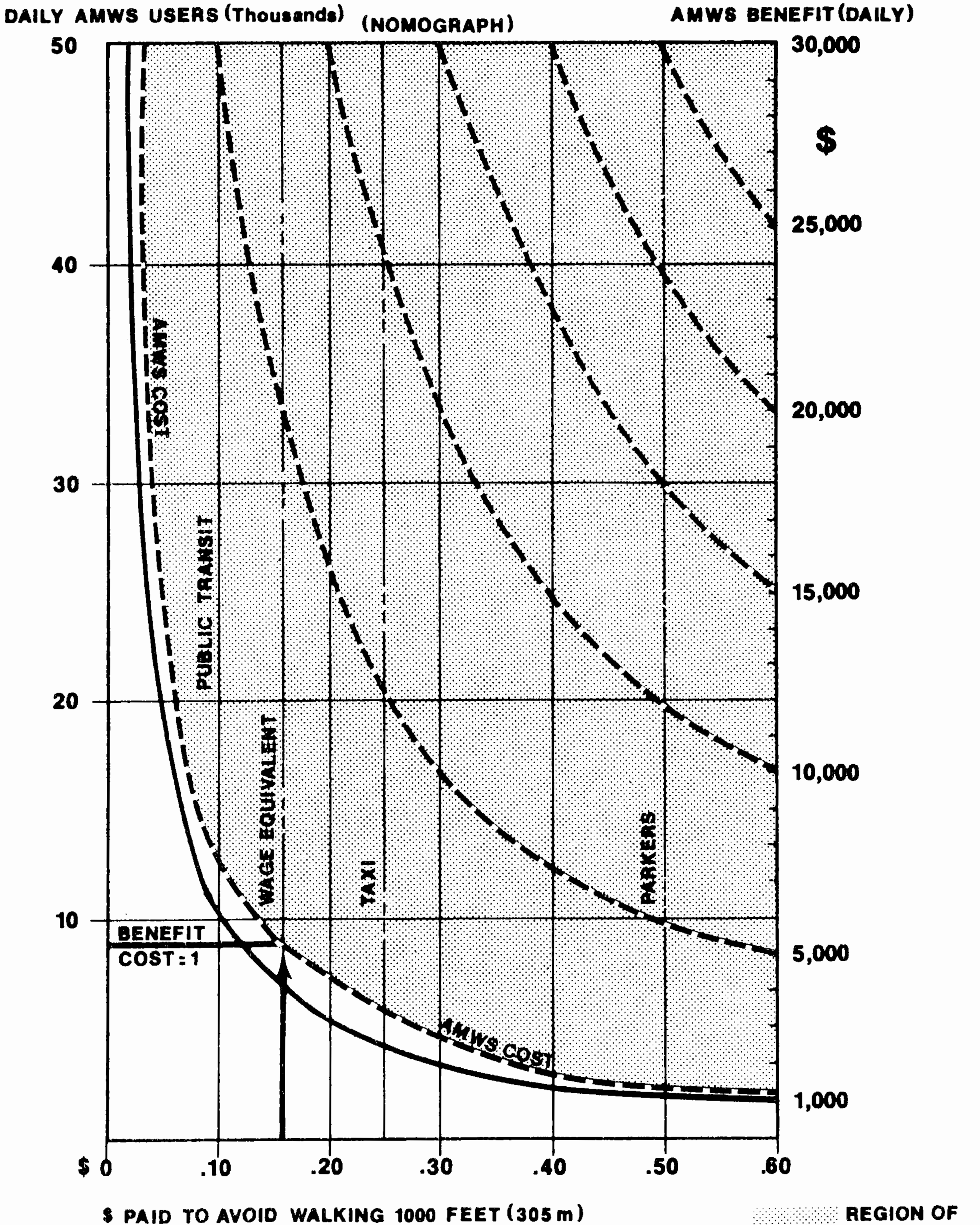


FIGURE 13 AMWS COST BENEFIT

to estimate what the insertion of a single 1000 foot unit would divert from taxis. Depending on location, it could capture corridor oriented trips now in the 2000-3000 ft. (610-915 m) range.

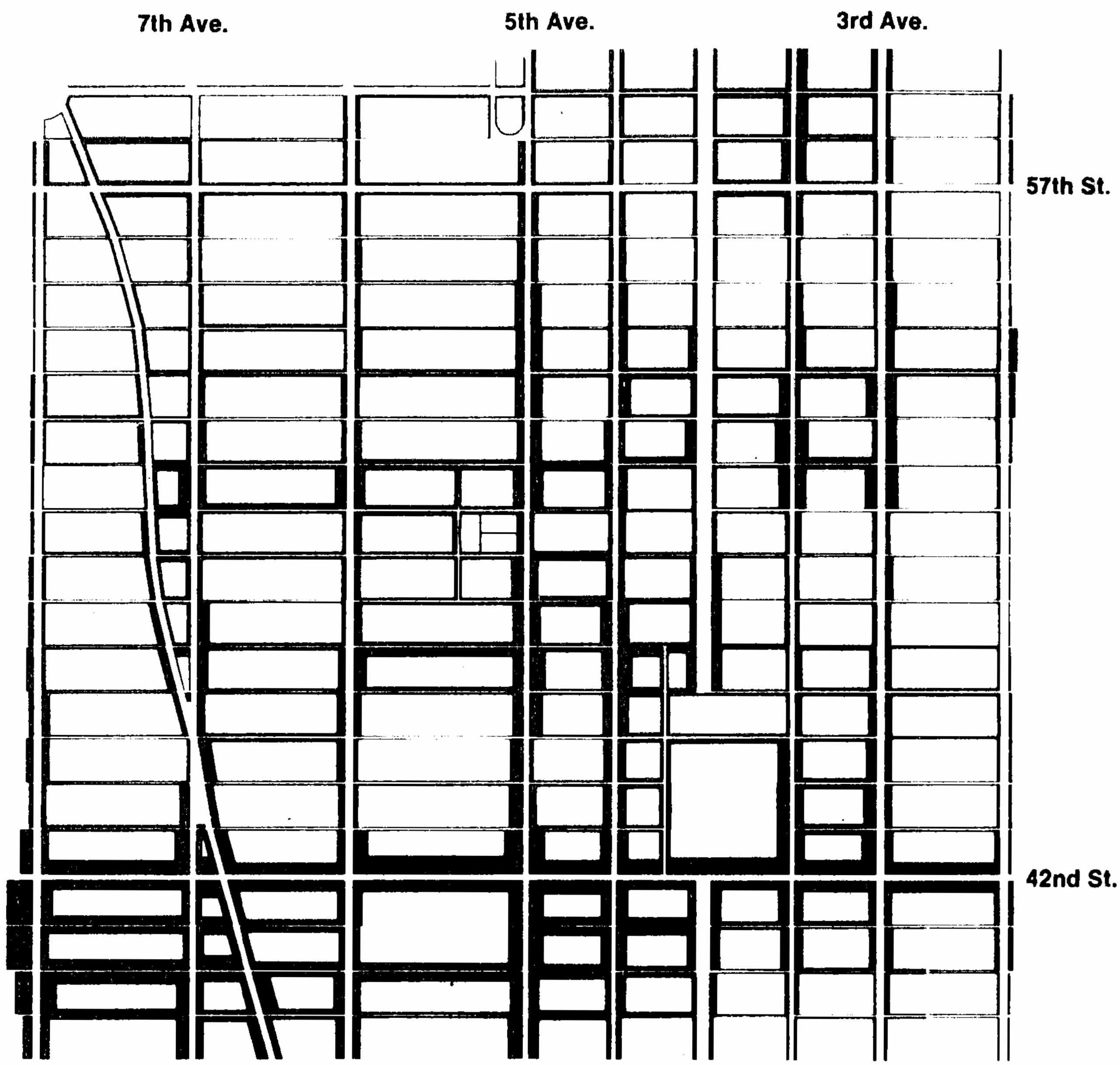
Because of the many variables, system cost, daily user volume and the perceived system value, (or potential fare), it is difficult to establish a definitive cost benefits ratio for an accelerating moving walkway, unless these data for a specific site are determined in detail. However, the range of these parameters can be developed in such a manner as to establish the region of AMWS economic feasibility in terms of system cost, use and perceived value, (or fare), and cost. Figure 13 is a nomograph developed on this basis. The horizontal plot on this nomograph is the value placed on either the avoidance of walking or savings in time. The left side vertical plot is daily AMWS use in thousands of trips. The curved lines on the nomograph are the resulting product of use and value in increments of $5000 daily revenue and/or system cost. Also illustrated as a curved line of this nomograph is the $1471 daily cost of the baseline system as developed in section 2.4 of the report. The nomograph may be entered in various ways depending on available data, or the assumptions of the user. For example, the total daily cost of $1471 for the baseline system, at the wage equivalent time savings value of $0.16 per trip, requires about 9,000 daily users to offset costs, or the cost benefit value of one. Either doubling system use or doubling the users perceived time energy value is required to bring the cost benefits ratio up to two. As noted previously, an added accident avoidance value of $8 per 1000 users could be assumed for each pedestrian grade crossing eliminated by the system. A baseline system eliminating 5 such grade crossings would add 25 percent to the wage equivalent value developed above, raising the cost benefits ratio to 1.25 with 9,000 daily users.

The cost benefit analysis shows that the region of economic feasibility for a baseline one directional elevated Accelerating Moving Walkway System begins at about 9,000 daily users based on typical economic indicators. This does not include values for pollution or energy reduction or other benefits that could result from such a system. A number of corridors in excess of this level of pedestrian activity exist in Midtown Manhattan based on studies of the New York Regional Planning Association. (See Figure 14)

5.3 Least Cost Alternative

The AMWS can also be considered as a possible least cost alternative for parts of larger transit systems, or as a substitute for short shuttle like operations either bus, rail, or automatic guideway transit (AGT). In this case the cost benefit lies in comparing alternate costs and services, with the assumption that some form of transport is necessary. The cost advantage of the AMWS is mainly in its simplicity and lower cost of operation as compared to the other modes; bus, AGT, light or heavy rail. Table A3 of the Appendix shows the relative capital costs of rail and guideway transit as compared to the AMWS. This table does not include the cost of vehicles for the AMWS alternatives because this is a system variable depending on car capacities, route lengths, headways, (etc.). All the alternative transit systems, with the exception of the bus, require sophisticated control systems, and all are more labor intensive.

In the 1000 foot (305 m) range, the AMWS is cost competitive with buses operating non-exclusive right of way on grade, but as distances increase, the bus has the advantage in energy consumption,



Evening hourly pedestrian flow rate
in Midtown Manhattan

Hourly flow rate

15,000	1,000
10,000	500
5,000	100

SOURCE: N.Y. REGIONAL PLAN ASSOCIATION

FIGURE 14 MIDTOWN MANHATTAN PEDESTRIAN VOLUMES

atmospheric, visual and noise pollution, pedestrian safety and passenger service factors are not considered. The energy analysis in Section 3.2 of the report showed that it would require 8 buses to equal the peak period passenger capacity of an AMWS in a 1000 feet (305 m) long shuttle operation. The capital cost of these units is minimal, say $500,000, but as many as 24 drivers would be necessary to provide equivalent service on a 16 hour, 300 day year basis, as assumed in the AMWS cost analysis in Section 2.4. The bus system would also require garage and repair facilities. This analysis showed that 5 AGT vehicles would be necessary to provide the AMWS shuttle service equivalent.

In comparison with AGT systems, structural preparation costs for the AMWS would be about equal to the AGT if a standby pedestrian sidewalk is provided with the AMWS. AMWS stations would be much simpler than the AGT equivalent and thus less costly. Provision of AGT vehicles and control systems would be less costly than the AMWS, but added personnel with more sophisticated training and skills would be required to monitor AGT operations and maintain AGT equipment. An AMWS in an urban core or airport complex could be monitored and maintained by escalator mechanics as part of a larger maintenance operation.

Table 5.1 following is a comparison of AMWS, bus and AGT systems on the daily cost basis presented in report Sections 2.4 and 3.2. It shows that in a 1000 feet (305 m) shuttle operation that the AMWS is significantly cost competitive with the bus on the basis of savings in drivers wages. For purposes of the analysis guideway costs for an AGT system were assumed to equal that of the AMWS, but at least 5 skilled personnel are considered necessary to operate and maintain the AGT system. The AMWS is more economic on the basis of the lesser

TABLE 5.1

DAILY COST COMPARISON - AMWS, BUS AND AGT

(300 day year, 16 hours operation)

ITEM	AMWS (1)	BUS (2)	AGT (3)	NOTES
1. FIXED CHARGES				
a. Furnishing and Installation	$ 550	$ 147	$ 183	
b. Structural Preparation	$ 643	-	$ 643	Guideway and Pedway costs assumed equal.
2. OPERATIONS AND MAINTENANCE				
a. Operators	-	$1600	-	
b. Maintenance	$ 133	$ 333	$ 667	
c. Power, HVAC	$ 110	$ 400	$ 373	
d. Insurance	$ 35	$ 35	$ 35	
TOTALS:	$1471	$2515	$1901	

NOTES: (1) Re: Costs Analysis, Table 2.2, Energy Comparison Table 3.1.

(2) Eight buses 50,000 each, CRF 0.11, 24 drivers @ $20,000 per annum including overheads, bus maintenance, 2 mechanics plus supplies, (say) $100,000 per annum.

(3) Five AGT vehicles @ $100,000 each, CRF o.11, 5 employees @ $40,000 per annum including overheads.

personnel and power requirements. Bergmanns analysis of the AMWS alternative to the SEATAC AGT provides a more detailed analysis of this relationship. [Ibid 7]

AMWS installations would be even more cost competitive with comparable light or heavy rail operations where the AMWS was used as a substitute for branch line or shuttle rail services. Additionally, the AMWS would occupy considerably less space than these systems making it easier to place in the urban environment.

5.4 Value Transfer

A classic economic view of transportation is that it can create "place utility" by moving goods or people to locations where there is some type of increase in value. [11] A convenient short range horizontal movement system can provide improvements in place utility by connecting low valued development tracts isolated by natural or man made barriers, or by changes in land use. In most cities there are "high" and "low" rent districts. Often older, structurally sound buildings become separated from the centroid of new development, affecting their rentability. This can be the beginning of urban blight, a problem common to many major cities. A survey of office building rental rates in major United States cities shows that rental rates for new office space averages 65% higher than the old. (Appendix A-4) It is important to maintain the rentability of older office space to provide a balanced real estate market with lower rentals available to marginal businesses which might otherwise find it necessary to leave the core. AMWS installations connecting with the more viable core can help maintain communication with restaurants and retail establishments, providing for a more integrated and stable downtown.

Another aspect of the place utility potential of an AMWS is the possibility of using lower valued land for an improvement providing widespread benefits. Hospitals, urban universities, performing arts centers, convention centers and other similar public, or quasi-public developments require large tracts of land which are costly and often difficult to accumulate. High land costs can discourage the development of such projects, or cause them to be located on marginal land which limits their accessibility and potential success. A convention center has been proposed for New York City and received wide support from a broad range of commercial interests who would benefit from increased tourism. Major economic benefits projected for the center include 16,000 new jobs for the New York region, and $40 million annually in new state and city tax revenues. Estimated site area requirements for the center total approximately 2 million square feet. (186,000 sm)

Figure 15 shows crosstown variations in Manhattan real estate assessed valuations showing a range in value from $30 to $1100 per square foot. ($300 to $10000 sm). The high valued locations are in close proximity to transit lines, hotels, restaurants and other similar facilities considered desirable for a convention center. An AMWS connection from the center to these facilities not only makes the center economically viable, but in a sense has transferred value from a site that could cost one billion, to one that might cost $60 million. Cost benefit accrues from such an installation in terms of savings in site acquisition, an improvements in the economic viability and income potential from the center itself.

5.5 Developmental Advantage

The convention center example in the previous section is an illustration of developmental advantage, that is the availability of a

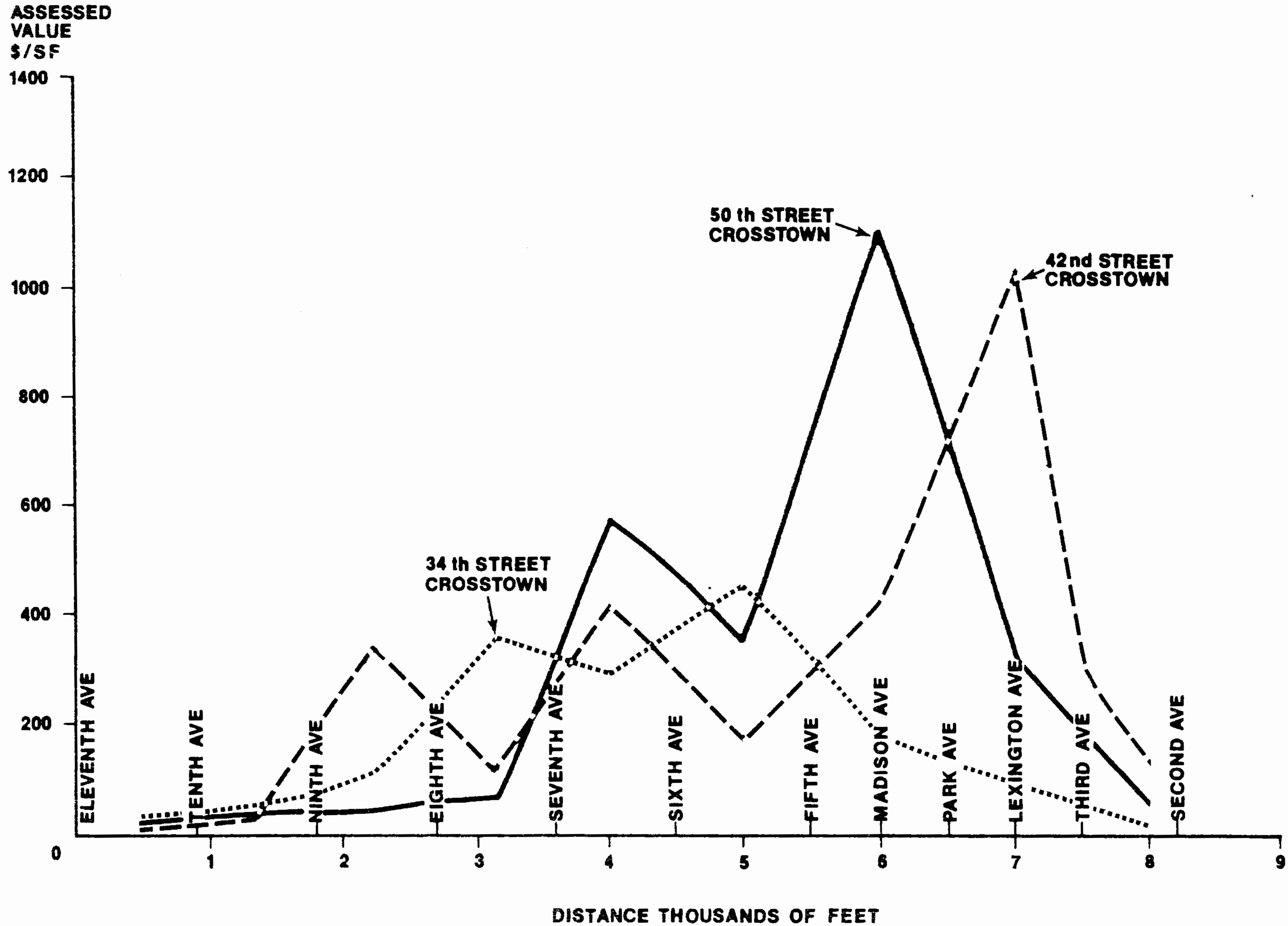


FIGURE 15 CROSSTOWN MANHATTAN ASSESSED VALUATIONS

short-range horizontal movement system making a prospective development more economically or functionally feasible where before it might not have been. Many different types of development advantage have been discussed in the applications center. The table 5.2 following is a listing of some examples along with possible economic benefits that could accrue from an AMWS installation.

Table 5.2

AMWS DEVELOPMENT ADVANTAGE COMPARISON

DEVELOPMENT TYPE	DESCRIPTION	ECONOMIC BENEFITS	NOTES OR COMMENTS
1. Transit			
a. Commercial cluster development around stations	AMWS provides remote parking and accessibility to station, allowing cluster of commercial or retail development around station	Value capture prospects, increased real estate taxes, employment, sales taxes	Most applicable suburban stations, opportunities to combine stations with shopping centers, separate parking shoppers and commuters
b. Branch line, shuttle operation substitute	Substitute for existing or proposed operations	Construction and operating cost savings, user time savings depending on distance, headways (etc.)	Manpower differentials significant, would offset AMWS costs in most applications
c. Lower cost alignment	Shifting of transit r.o.w. to lower cost alignment alternative	Construction cost savings spreading of economic benefit of transit over wider service area	Transit alignments now restrained, tied to high density locations, often with higher construction costs
2. Airports			
a. Mobile lounge replacement	AMWS connecting satellite lounge	Fleet purchase, replacement, operations and maintenance savings	Users would save time, avoid transfers
b. Auxiliary curb space	AMWS connecting to remote curb facilities	Avoid costly terminal expansion to produce additional load/unload curb space, reduce congestion at terminals	Allows more design alternatives, operating options, common use of facilities
3. Urban Development			
a. Value transfer	Use lower cost real estate for "high value" applications	Savings in site costs some types of development, increased employment, sales, income tax, enhancement, strengthening urban core, improved pedestrian safety, accident cost savings.	Better integrated CBDs, improved accessibility to retail and services more competitive with suburban regional shopping centers

APPENDIX

BIBLIOGRAPHY

APPENDIX

TABLE A-1

ELECTRIC POWER COST - GEOGRAPHIC VARIATIONS (1)

GEOGRAPHIC REGION	1976 COST PER KILOWATT HOUR (CENTS) (2)
New England	4.79
Middle Atlantic	6.35
East North Central	3.63
West North Central	3.28
South Atlantic	4.02
East South Central	2.70
West South Central	2.95
Mountain	3.19
Pacific	3.08
U.S. Average	4.05

(1) Source: "Typical Electric Bills--1976"
Federal Power Comission FPC R88

(2) Based on 40 kw demand, 10,000 monthly kw hrs.

APPENDIX

TABLE A-2

SUMMARY OF STUDIES OF THE VALUE OF WALKING TIME *

Source	Location	Description	Value of Time
Austin, 1973	Los Angeles CBD	From parking	16-24¢/min
Ergun, 1971	Chicago CBD	Work trips from parking; income $8000	8¢/min
STAC, 1970	South Suburban Chicago	Trips to transit stations	3¢/min
Talvitie, 1972	Chicago CBD	Work trips from parking and transit	7 times riding time
Lisco, 1967	Chicago CBD	Trips from parking	9-14¢/min; 3 times riding time
Quarmby, 1967	England	To work trips	2 to 3 times riding time
Lambe, 1969	Vancouver, B.C.	From parking	4-5¢/min
Regional Plan. Assoc., 1971	Manhattan	From parking From subway Low income Average all	16¢/min 2.5¢/min 3¢/min 3.5¢/min

*Source: "Analysis of Pedestrian Travel Characteristics", Ibid (10)

APPENDIX

TABLE A-3

COMPARATIVE TRANSIT SYSTEM CONSTRUCTION COSTS (1)

CITY/SYSTEM TYPE	PER MILE COST $ MILLIONS	COST PER FOOT (.305m)	NOTES
RAIL TRANSIT			
Buffalo	80	$15,200	81% Tunnel
Washington	50	9,500	58% Tunnel
Honolulu	20	4,000	At Grade
PATH	20	4,000	At Grade
LIGHT RAIL			
Buffalo	53	10,000	81% Tunnel
PEOPLE MOVERS			
New York City	25	4,700	Elevated
Detroit	24	4,600	Elevated
St. Paul	22	4,200	Elevated
BASE LINE AMWS	16	3,740	Elevated uni-directional (incl. sidewalk)
	24	4,150	Elevated bi-directional (incl. sidewalk

OFFICE RENT DIFFERENTIALS

OLD VS. NEW BUILDINGS*

(all figures in $ per sq. ft.)

CITY	OLD BUILDINGS	NEW BUILDINGS	OLD VS. NEW DIFFERENTIAL
ATLANTA	$4.50 - 5.75	$5.75 - 9.00	$1.25 - 3.25
BOSTON	6.00 - 7.00	8.50 - 13.00	2.50 - 6.00
CHICAGO	4.00 - 7.00	7.00 - 15.00	3.00 - 6.00
DETROIT	4.00 - 5.50	7.50 - 12.50	1.50 - 5.00
KANSAS CITY	4.50 - 6.50	6.00 - 9.00	1.50 - 2.50
NEW YORK CITY	6.00 - 8.00	8.00 - 12.00	2.00 - 4.00
AVERAGES	$4.83 - 6.63	$7.13 - 11.75	$1.96 - 4.46
MID RANGE AVERAGE	$5.73	$9.44	$3.21

*Source: Buildings Magazine, February 1977.

A. <u>Referenced Bibliography</u>

(1) Pushkarev, B. and Zupan, J. - "Urban Space for Pedestrians" - MIT Press, '75, 212 pp.

(2) Fruin, J. J. - "Designing for Pedestrians" - dis. Polytechnic Inst. N.Y., Jan. '70 135 pp.

(3) Horonjeff, R., Hoch, C. - "Some Facts About Moving Sidewalks at Airports" - Proc. ASCE Specialty Conf., NYC, May '74.

(4) J. Tough and C. O'Flaherty - "Passenger Conveyors" - Publisher Ian Allan 1971, 176 pp.

(5) "Charles De Gaulle Airport - Satellites Linked by Horizontal Transport in World's Largest Airdrome" - Elevator World, June '76, pp. 16, 17, 19.

(6) Fruin, J. J. - "Pedestrian Planning and Design" Pub. Maudep, '71 206 pp.

(7) Bergman, D. (et al) - "A Comparison of Automated People Mover and Accelerating Moving Walkway Costs and Effectiveness" GM Transportation Systems Div. '76, 40 pp.

(8) Braun R. L., Roddin, M.F. - "The Benefits of Separating Pedestrians and Vehicles" Stanford Research Institute, NCHRP 20-10.

(9) Transportation Research Board - "Value of Travel Time", TR record 587, 6 papers 1976, var pp. PB 259 - 556.

(10) Rutherford, S.C., Schofer, J.L. - "Analysis of Pedestrian Travel Characteristics" - TRB presentation Jan. '76 29 pp.

(11) Sampson, R.J., Farris, M.T. - "Domestic Transportation - Practice, Theory and Policy", pub. Houghton Mifflin, 1971, 493 pp.

B. Additional Relevant Bibliography

(1) "A Manual for Planning Pedestrian Facilities" U.S. DOT-FH-11-7966, Peat, Marwick, Mitchell, Co. June '74, 75 pp., bib.

(2) Boston Redevelopment Authority - "Feasibility of Moving Walks/Boston - Overview" Jan. '71 144 pp.

(3) Bouladon, Gabriel - "The Transport Gaps" - Scien. Journ. Apr. '67 pp 41 - 46.

(4) Bunting, P.M., - "Passenger Conveyor Economics-Costs, Capacity and User Benefits" - University Loughborough (U.K.), Oct. '74, - 107 pp.

(5) Kraft, L.S. - "Surface Transportation Systems for Pedestrian Traffic" - Bldg. Oper. Mgmt., Sept '72 pp 40 - 42 - 44.

(6) Levinson, H. "The Need for Moving Way Transportation Systems" - Proc. Moving Way Trans. Conf. Nov. '73, pp 24 - 47.

(7) Megas, I., Pickering, D., - "The Speedaway Cost Benefit Study" - Traffic Engineering and Control - Feb. '77 pp 52 - 57.

(8) Richards, Brian - "New Movement in Cities" - Reinhold 1966 - 96 pp.

(9) Rubenstein, A.M. - "Future Central Area Mobility" Nation's Cities Apr. '72 pp 18 - 23, 40.

(10) Tutty, E.B., "Airport Transit Systems - a Major Factor in Terminal Expansion" Airports Inter., Aug/Sept '75, pp 16 - 21.