Applications for Intraairport Transportation Systems

FRANCIS X. MCKELVEY AND WILLIAM J. SPROULE

This paper presents the results of research undertaken to develop planning guidelines and unit cost estimates for the incorporation of intraairport transportation systems into terminal facilities. Procedures used for the development of cost estimates for the capital and operating and maintenance costs of such systems are outlined. Parameters are presented for evaluation of the unit and incremental costs of various types of intraairport systems being incorporated in various terminal applications. Techniques are presented to assess these, the unit and incremental costs, against the reduction in travel time and walking distance associated with such systems.

The process that was used in this research (*1*) to develop application guidelines for intraairport transportation systems is shown in Figure 1. A discussion of the essential elements of this process and an overview of the methodologies employed are contained below.

RESEARCH METHODOLOGY

Development of Schematic Terminal Systems

Generic terminals were developed using two basic modules for each of the four classical terminal concepts, namely, the linear, pier, satellite, and transporter. The first module was designed to contain eight aircraft gates for all four terminal concepts. It included a single terminal unit with the processing facilities necessary to serve the passengers using these gates. The second module was designed to contain sixteen aircraft gates for only the pier and satellite concepts. This module was developed to contain a single terminal unit containing the necessary processing facilities and was attached by two connectors, each with eight gates. Presumably the second module would accommodate twice the passenger demand of the first, but the terminal facilities would not be increased proportionately because of the inherent efficiencies in the latter module. As the passenger demand increased, modules were combined to form a configuration of terminal units necessary to meet the demand. By constructing terminal configurations in this fashion, it was possible to identify guidelines for intraairport transportation systems on the basis of passenger demand levels and the terminal concepts used. An approach similar to using modules was used in a 1973 study (*2*) to identify applicable terminal concepts relative to passenger demand levels.

Initial estimates indicated that an eight-gate module could accommodate approximately 1 million annual enplaned passengers. Estimates of typical levels of hourly passenger and aircraft activity associated with this level of annual demand were made so that terminal area requirements could be calculated using commonly accepted planning guidelines (*3*). It was necessary to lay out each of the terminal modules in sufficient detail to locate activities so that passenger walking distances could be approximated and the impact of passenger circulation in the module could be assessed.

For the eight-gate module, it was assumed that a single-level terminal and single-level curb would be required, all gate positions would be designed to accommodate Boeing 767 wide-bodied aircraft, aircraft would move to and from the gate complex in a power-in push-out mode, surface parking facilities would be provided, and passenger processing facilities would be arranged in a typical manner. The assumptions for the sixteen-gate module were similar except that a two-level terminal curb and structural parking were incorporated.

An analytical queuing model developed by the FAA (*4*) was used to verify the preliminary module layouts to ascertain that the passenger demands placed upon them could be accommodated at specified design levels of passenger processing time. For enplaning passengers, the average passenger processing time was not to exceed 20 minutes; for deplaning passengers, the average passenger processing time was not to exceed 30 minutes. Using these processing time limits as the control parameters, the layout of passenger processing facilities in each module was modified until the criteria were satisfied.

Terminal Module Combinations

The basic terminal modules were then combined in two fundamental configurations to form larger terminal units

F.X. McKelvey, Department of Civil and Environmental Engineering, Michigan State University, East Lansing, Mich. 48824-1212. W.J. Sproule, M. M. Dillon Limited, Consulting Engineers and Planners, 47 Sheppard Avenue East, Toronto, Ontario M2N 6H5, Canada.

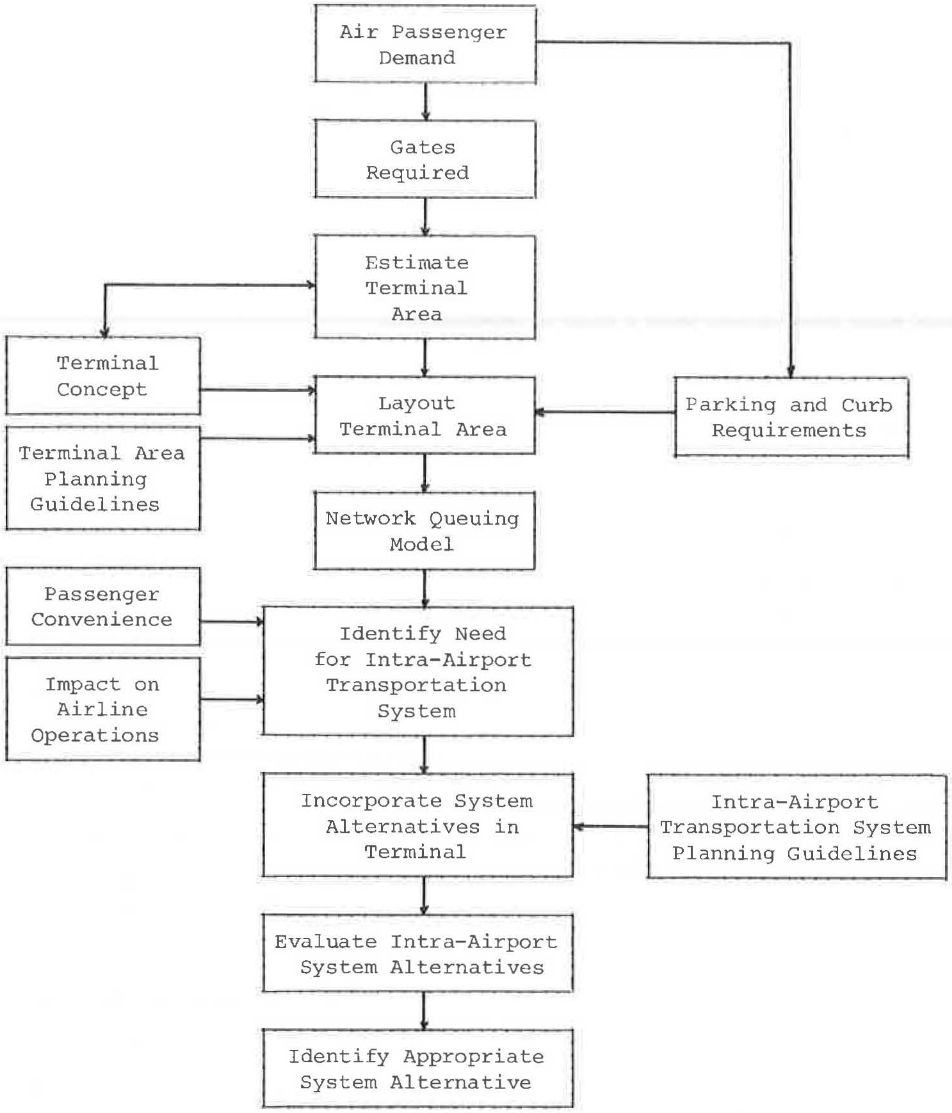


FIGURE 1 Methodology to determine appropriate intraairport transportation system.

for processing greater passenger activity. Modules were placed side by side in configuration A and on opposite sides of the parking facility in configuration B. When modules are placed side by side, the distance between pier and satellite modules is governed by the separation criteria for aircraft operations on the apron and taxi lanes, the distance between the taxi lane and gate positions, and the size of the gate positions. When the linear and transporter modules are placed adjacent to each other, however, it is only the aircraft dimensions and separation criteria at the gates that determine the size of the modules. When modules have been placed on opposite sides of the parking facilities, the parking was placed in the structure to maintain compactness of the terminal unit. Combinations of up to four modules were developed for this study. Figure 2 illustrates the difference between the two configurations and the results of combining the basic eight-gate modules into terminal units in the pier concept. Similarly, Figure 3 illustrates the same for the basic sixteen-gate module. Note that the basic eight-gate module was used to construct terminal units consisting of from eight to thirty-two gates, whereas the basic sixteen-gate module was used to construct terminal units consisting of from sixteen to sixty-four gates.

The selection of the appropriate arrangement or configuration of terminals at an airport is governed by many factors. These include the number and orientation of the runways, the layout of the ground access system, terminal area curb requirements, airline operation requirements, the number of transferring or connecting passengers, and site limitations and restrictions. An evaluation of the most appropriate combination of terminals for a specific case was beyond the scope of this study. The terminal units were developed in this manner only to assist in identifying guidelines for intraairport transportation systems. Such a mechanism, however, provides insights into terminal alternatives to accommodate a range in passenger demand levels as shown in Table 1.

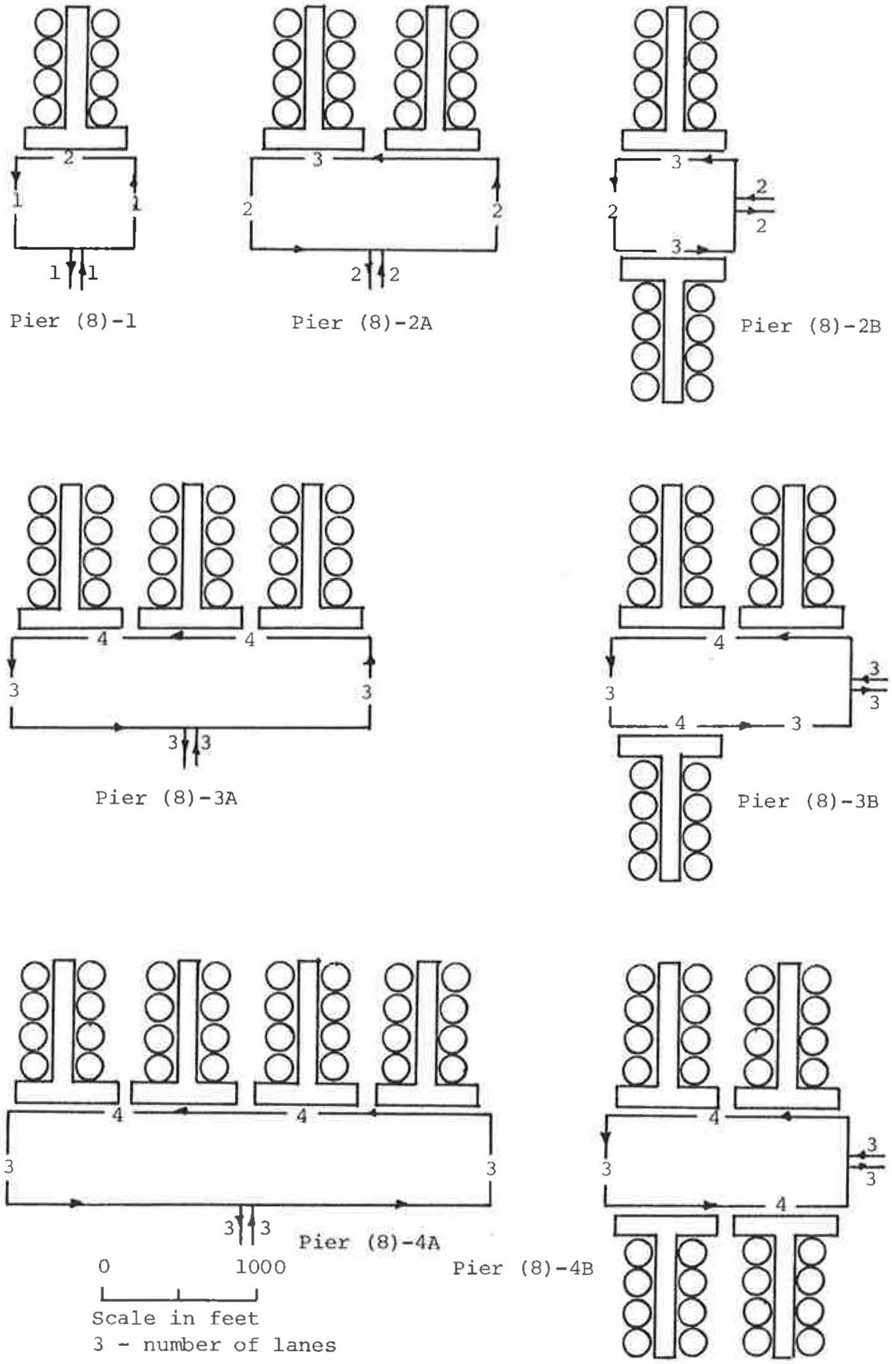


FIGURE 2 Combinations of eight-gate pier modules into terminal units.

Incorporation of Intraairport Transportation

Two route alignment alternatives were developed for all terminal systems. The shuttle alignment is the most direct route between terminals, whereas the loop alignment basically follows the terminal access road alignment. Figure 4 highlights the difference between the route alignment for the shuttle and loop systems for various combinations of terminal units for the satellite concept.

Three basic types of intraairport transportation systems were studied for these terminal units. These were moving walkways, bus transit systems, and automated guideway transit. For each of these types of systems, differing assumptions were made.

It was assumed that moving walkways would be installed on a shuttle alignment and be protected from the weather. Therefore, where modules are placed side by side, as in configuration A, additional terminal facilities are required for both the pier and satellite concepts. For configuration B concepts, the moving walkway is assumed to be incorporated in the parking structure so that additional adjustments to terminal area facilities are not required for the

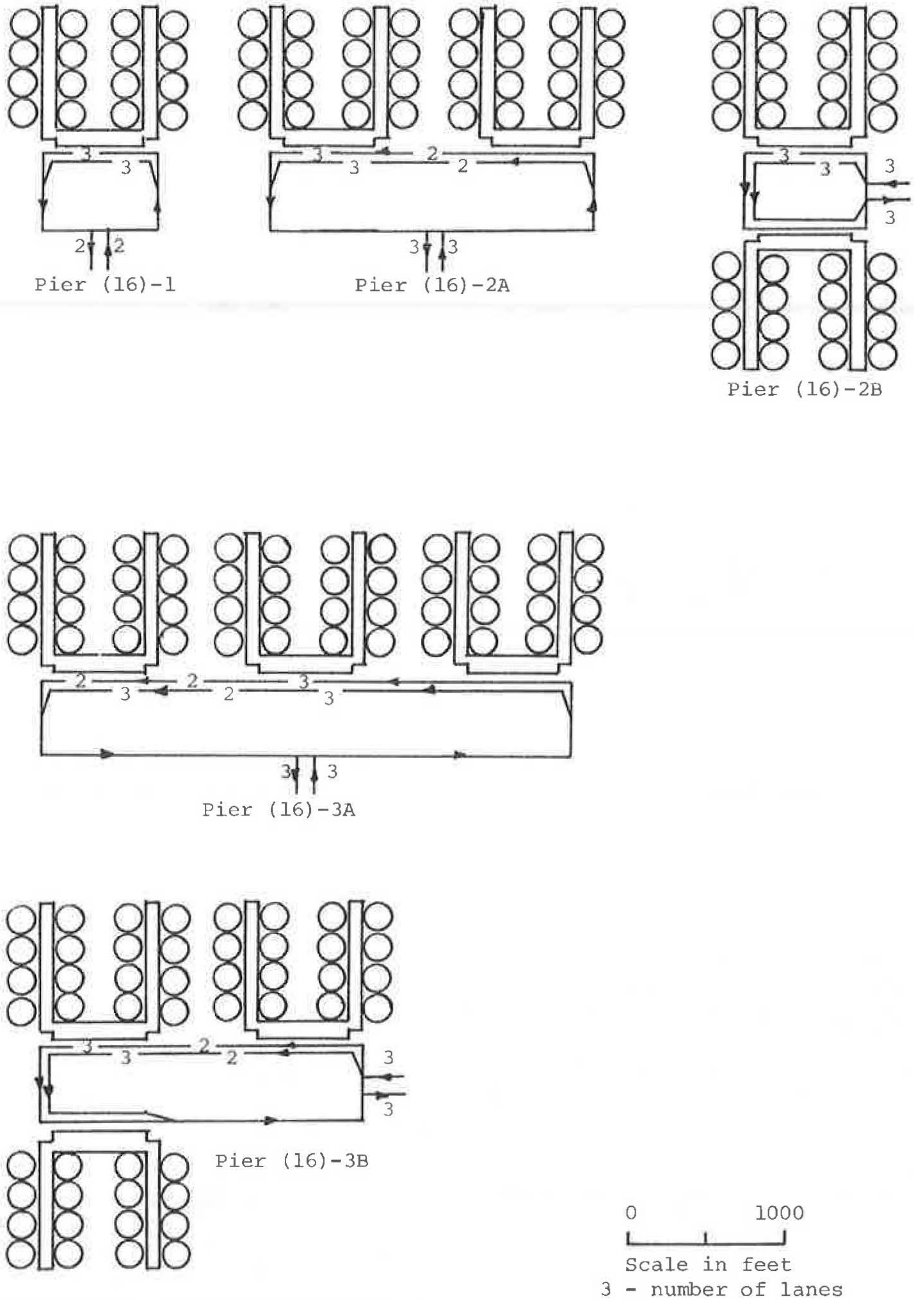
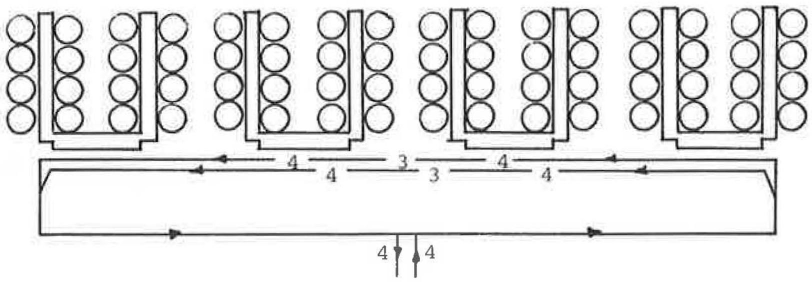


FIGURE 3 Combinations of sixteen-gate pier modules into terminal units.

shuttle movement across the parking area. The maximum length of a moving walkway is assumed to be 600 feet.

For bus transit systems, it was assumed that the buses would circulate on a loop alignment on the terminal access road and that there would be one stop at each module.

Automated guideway transit (AGT) systems were allowed to operate on either shuttle or loop alignment. When they operated on a shuttle alignment, it was assumed that the vehicles operated in both directions and therefore no turnaround facilities were required. If only one vehicle was required for service, one guideway between stations was sufficient, whereas two parallel guideways would be necessary if two vehicles were required. There would be onc online station for each module, and the guideway was considered an elevated structure. When these systems operated on a loop alignment, it was assumed that the vehicles operate in one direction. A system serving the terminal units in configuration B was assumed to be on an elevated structure, whereas those systems serving the terminal units in configuration A were assumed to be operating on an elevated guideway adjacent to terminals and at-grade on the remainder of the route.



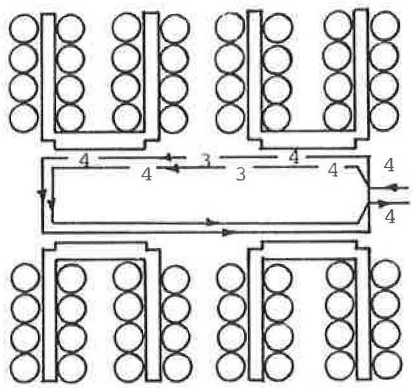


FIGURE 3 *continued*

TABLE 1 AIR PASSENGER DEMAND ACCOMMODATED BY VARIOUS TERMINAL UNITS

Number of Gates per Module	Number of Modules	Annual Enplaned Passengers	Peak Hour Passengers PMAD*
8	1	1 million	730
8	2	2 million	1460
8	3	3 million	2190
8	4	4 million	2920
16	1	2 million	1400
16	2	4 million	2800
16	3	6 million	4200
16	4	8 million	5600

* PMAD = Peak Month, Average Day

Cost Estimate Development

Terminal Costs

One aspect of cost that this study examined was the incremental change in the cost of the terminal area facilities caused by incorporating an intraairport transportation system. Unit costs were developed from various sources to estimate both the capital costs and the operating and maintenance costs for the terminal buildings, terminal access roads, parking, and apron area. Since these unit costs were extracted from several sources in different years, all were adjusted to 1984 dollars using the Consumer Price Index and the Engineering News-Record Cost Index. It is expected that these unit costs, which are presented in the original research (*1*), represent national average figures subject to adjustment in specific applications. For annual cost calculations, the capital costs of the terminal area were amortized over a twenty-year period using a 10 percent discount rate.

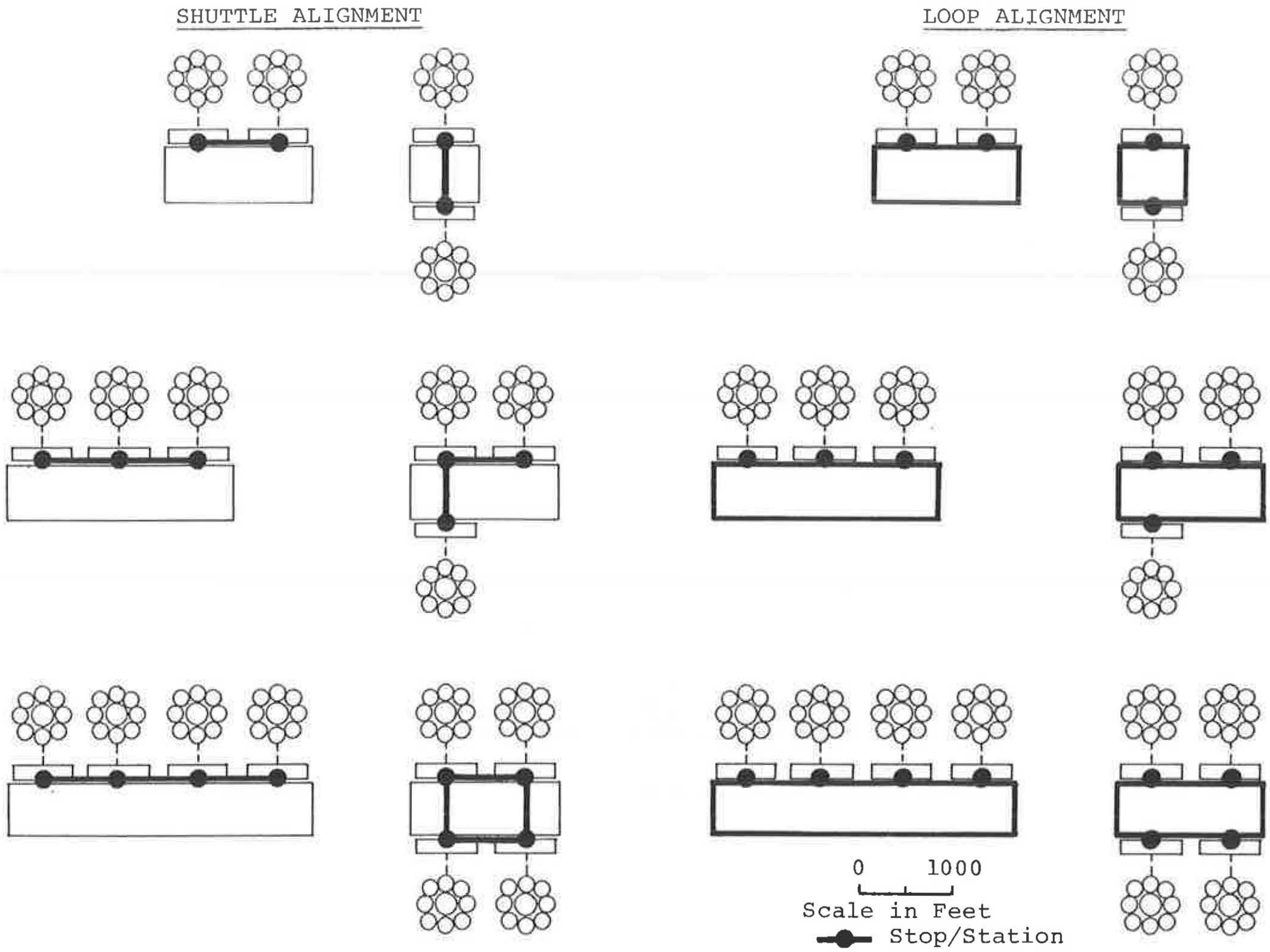


FIGURE 4 Intraairport transportation route system alternatives, satellite terminal units.

Intraairport Transportation System Costs

Unit costs were identified for both capital costs and operating and maintenance costs for moving walkways, bus transit systems, and automated guideway transit systems in airport applications. The cost of capital and operating costs of a moving walkway unit vary widely depending on the type of application and the area in which it is installed (*5*). Several sources (*6–8*) were reviewed, and costs based upon a linear foot measure were deemed appropriate for terminal concept planning. All costs were adjusted to 1984 dollars, as already noted. The approximate cost of installing a moving walkway unit, with a width of 40 inches and an operating speed of 120 feet per minute, is about $2,000 per linear foot. The annual operating and maintenance cost for such a unit is about $80 per linear foot.

It was assumed that the capital cost of a bus transit system for intraairport transportation consisted only of the cost of the vehicles required for service, since these vehicles would use existing terminal access roads. Normally, vehicle maintenance is performed off-site, and the system is operated on a contract basis. Costs were identified for two bus sizes, a conventional or standard urban diesel bus with a seating capacity of about 50 passengers and a minibus with a seating capacity of up to 25 passengers. The estimated capital costs in 1984 dollars for the conventional bus were taken as $125,000 and for the minibus, $80,000. Operating costs were developed on the basis of vehicle-miles of travel; these included such items as driver wages, maintenance, fuel, insurance, administration, and other variable costs associated with the provision of such service. Several sources (*6–11*) were reviewed to determine the approximate operating costs for bus operations on an airport site. The operating costs used in this study were $2.75 per vehicle-mile for the conventional bus and $2.50 per vehicle-mile for the minibus.

Since an automated guideway transit system requires the construction of an exclusive guideway and stations, the cost of these fixed facilities must be included as part of the capital cost estimate for such a system. A procedure developed in an Urban Mass Transportation Administration (UMTA) study (*12*) was used as the basis for preparation of cost estimates for the automated guideway transit system. Although the original procedure was prepared for downtown people-mover systems, it incorporated all of the required cost data for an airport application, and identified adjustments that should be considered when using the procedure for such an application. Data from all operating automated guideway transit systems were summarized in the UMTA study to develop unit costs. These costs were updated to 1984 dollars using the relevant cost indices and adjusted to include the most recent cost summary of such systems (*13*). Operating and maintenance costs for such systems were assumed to be $1.75 per vehicle-mile based on the UMTA study and other cost summaries.

The annual operating and maintenance costs of an automated guideway system are a function of the number of vehicles used in service, the service frequency or headway, the route distance, and the hours of system operation. These parameters have been estimated for each of the terminal modules used in this study. The annual capital costs have been calculated assuming a 10 percent discount rate and amortization periods of twenty years for moving walkways and automated guideway transit systems, ten years for conventional bus systems, and five years for minibus systems. Total annual costs were obtained by summing the annual capital, operating, and maintenance costs of each system.

Factors Affecting Needs for Intraairport Transportation Systems

Passenger Walking Distance and Travel Time Reduction

As an initial step in identifying the potential applications of intraairport transportation systems, approximate walking distances for passengers were calculated for each terminal unit. The distances shown have been derived using networks prepared for the development and testing of the terminal modules using the FAA queuing model (*4*). A typical distribution of passenger movement through a terminal unit was used. As might be expected, the lowest average walking distances between terminal curb and aircraft gate are observed for the linear and transporter modules, and the longest distances occur with the pier and satellite modules. A comparison of these calculated walking distances with the recommended guideline of a maximum passenger walking distance of 1,000 feet, the one recommended by the International Civil Aviation Organization (*14*) and the International Air Transport Association (*15*), suggests that intraterminal transportation systems be considered for inclusion in the basic eight-gate pier module and in both the basic eight-gate and the basic sixteen-gate satellite modules to reduce walking distance.

In determining the average walking distances for connecting passengers, several assumptions were made:

- that all connecting passengers transferred from one module to another module,
- that there was an equal distribution of connecting passengers among the modules,
- that all connecting passengers left the deplaning gate area of one module and proceeded through the central terminal area to the enplaning gate area of another module,
- that all connecting passengers used security in the module used for departure, and
- that connecting passengers did not use baggage check-in or claim facilities.

In virtually all cases, the average walking distance for connecting passengers transferring between modules is greater than 1,000 feet. Therefore, intraairport transportation systems were incorporated in all these terminal units to reduce the walking distances and related travel times for connecting passengers.

Trade-Off Considerations Used in Evaluation

Many factors could be included in an evaluation of the feasibility of incorporating intraairport transportation systems at airports, and these factors will vary from airport to airport to meet specific local concerns. Two factors, cost and convenience, were used in this study to provide a quantitative comparison that could then be used to identify trade-offs between system alternatives. The comparative measures that were used to evaluate cost were capital cost, operating and maintenance cost, total annual cost per passenger, and the incremental cost of including an intraairport transportation system in a terminal design plan. Those used to evaluate convenience included a reduction in passenger walking distance and its effect on passenger travel time.

RESEARCH RESULTS

Capital Costs

Using the unit costs and procedures presented earlier, estimates were made for the capital cost for each of the intraairport transportation systems for connecting passenger levels ranging from 10 to 50 percent of enplaned passengers. To illustrate typical results, the capital costs for 20 percent connecting passengers are given in Figures 5 and 6 for configurations A and B for each of the modules in both shuttle and loop alignments.

As would be expected, the cost of all transportation system alternatives increases as the number of modules increases. The costs of transportation system alternatives for configuration B modules are generally less than for configuration A modules because of the compactness inherent in the former. This results in shorter walking distances for connecting passengers and shorter guideway requirements for automated guideway transit systems. Because of the fixed guideway and station requirements, automated guideway transit system alternatives are the most expensive and the bus alternatives are the least expensive.

Similar conclusions result for other levels of connecting passengers, and the costs are approximately the same as the fixed facilities are required as a minimum cost for all passenger levels. The vehicle requirements vary with pas-

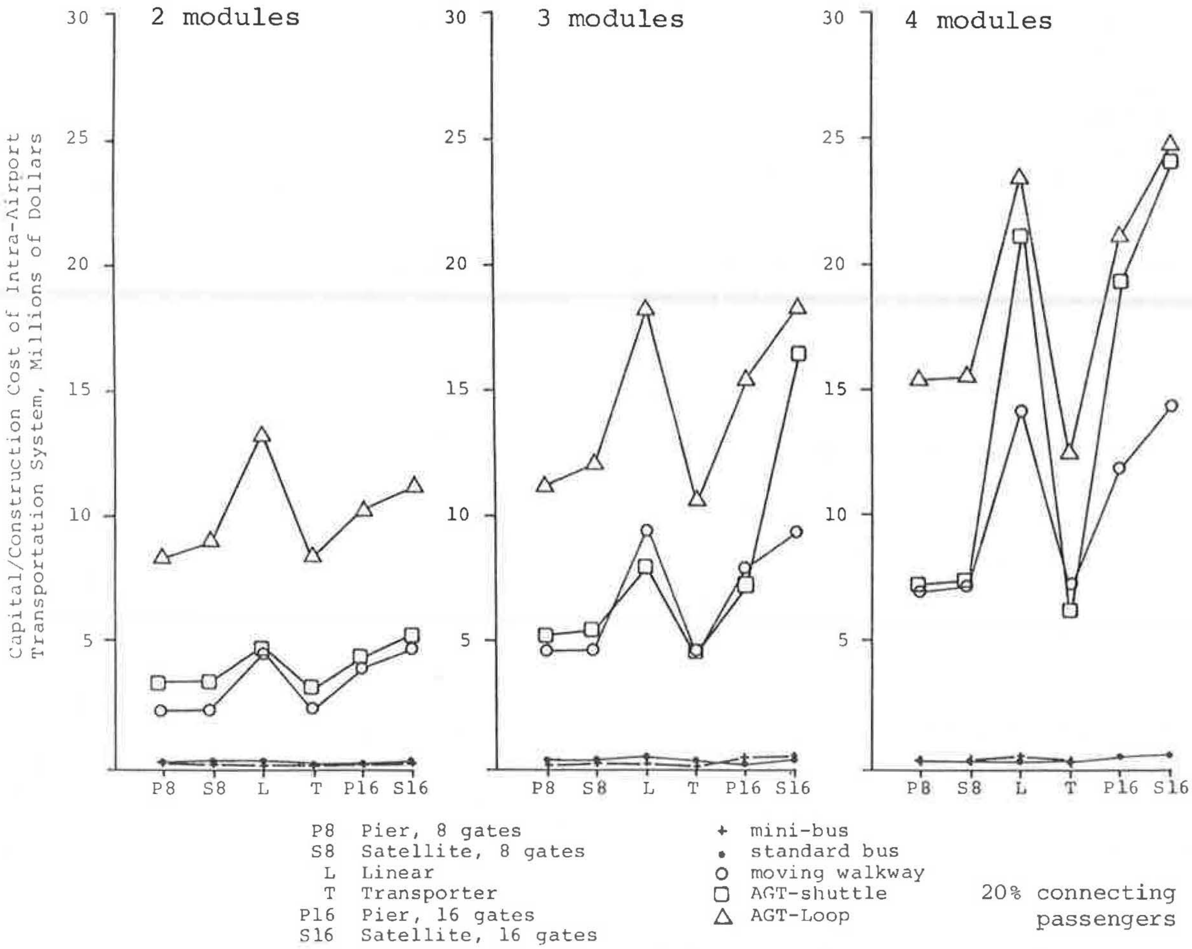


FIGURE 5 Capital costs of intraairport transportation systems, terminal configuration A.

senger levels. As a result, the capital costs of alternatives for higher connecting passenger levels are slightly higher, and the capital costs of alternatives for lower connecting passenger levels are somewhat lower. In many cases, however, the vehicle requirements are the same since headway requirements for the service govern this cost.

At low connecting volumes, the minibus is the least expensive alternative; as demand increases, however, additional buses are required and, at higher demand levels, the standard bus becomes the preferred alternative. When the demand exceeds 750 passengers per hour per direction at the maximum load point, the minibus cannot be used because its service capacity is exceeded. The capacity of conventional bus service is 1,500 passengers per hour per direction. Because of the greater length of fixed guideways, and that of routes on the terminal access roads, the capital costs of providing intraairport transportation service for the linear terminal concept are the highest.

Operating and Maintenance Cost

Another factor considered in assessing the cost of intraairport transportation system alternatives was the operating and maintenance costs. Estimates of annual operating and maintenance costs were made for each of the systems at connecting passenger levels varying between 10 and 50 percent of enplaned passengers using the unit costs and procedures discussed earlier. Figures 7 and 8 present illustrative cost estimates in a format similar to that used for capital costs.

The lowest annual operating and maintenance costs occur with automated guideway transit system alternatives, while moving walkways and bus alternatives involve the highest costs. Similar findings were observed for other connecting passenger levels.

Total Annual Costs

Total annual costs were estimated by amortizing the capital costs and adding the annual operating and maintenance costs. Two approaches have been used to compare annual costs. The first approach bases unit costs on annual cost per connecting passenger or user of the intraairport transportation system; the second bases them on the annual cost per enplaned passenger. Annual costs were developed for connecting passenger levels varying from 10 to 50 percent at various levels of annual demand. On the

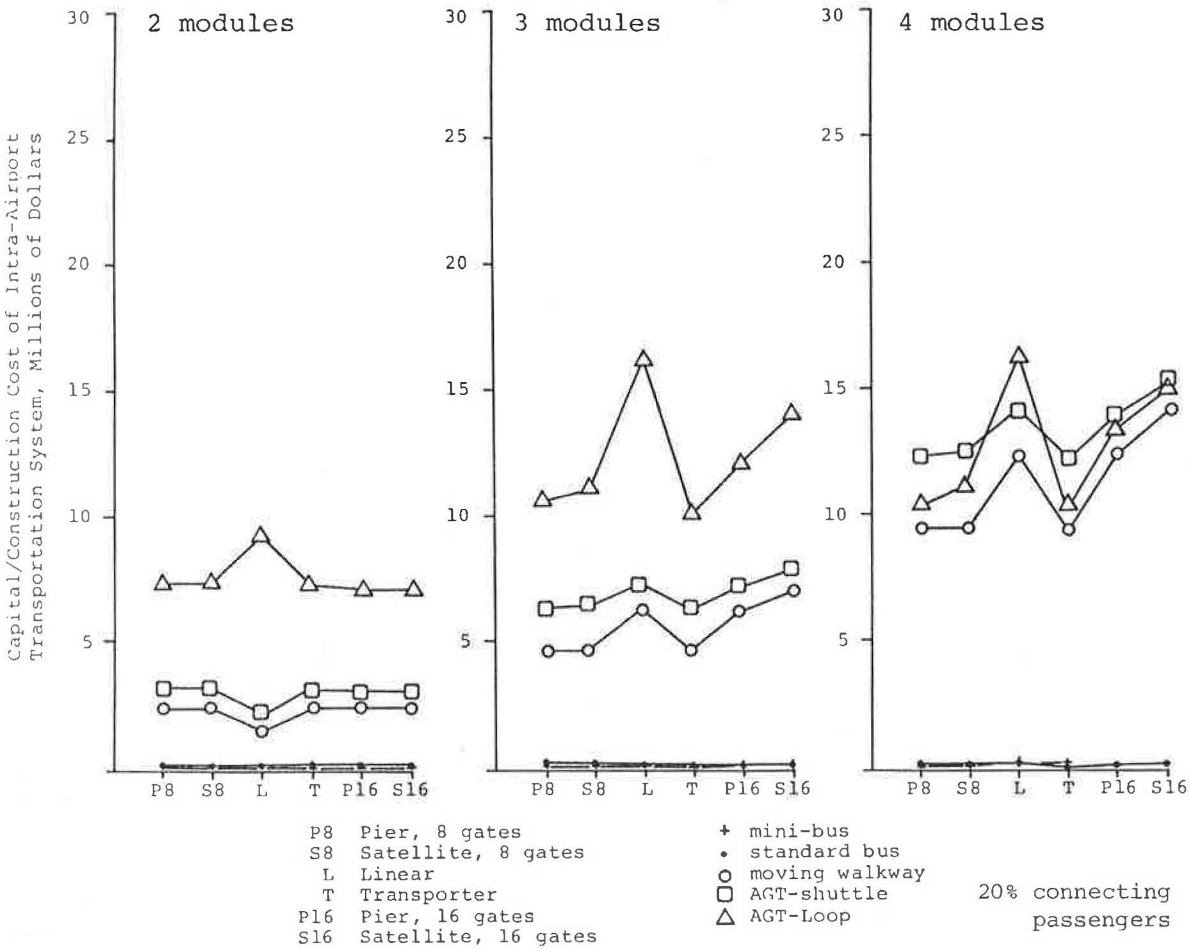


FIGURE 6 Capital costs of intraairport transportation systems, terminal configuration B.

basis of these cost studies, the expected ranges in total annual unit costs of five system alternatives based upon connecting passengers are presented in Table 2. This table indicates that the lowest unit costs are obtained for the pier configuration using the basic sixteen-gate module; the highest unit costs are obtained in the linear concept using the basic eight-gate module. By considering the connecting passenger demand on each of the terminal unit configurations, it was found that there were wide variations in annual unit costs for the loop and shuttle alignment of the automated ground transport systems, moving walkways, conventional bus, and minibus. Estimated average annual unit cost curves are presented for each of these systems in the original research (*1*).

Incremental Costs

The cost of incorporating intraairport transportation system alternatives into an airport was combined with terminal area costs to ascertain the impact of such systems on overall terminal development costs. The average percentage increase or decrease in annual cost per enplaned passenger caused by the addition of an intraairport transportation system for connecting passengers is summarized in Table 3 for each terminal concept and configuration. For this study, it was assumed that only one means of transfer would be provided for passengers between modules. As a result, negative values appear in this tabulation for cases where an intraairport transportation system that transfers passengers between terminal modules would have a lower cost than extending the terminals and providing a walking link. In actual terminal planning, modules that are located close to each other would be linked, and passengers may have several choices for movement within the terminal.

It is apparent from the data presented in Table 3 that the additional annual cost per enplaned passenger for the incorporation of intraairport transportation systems into terminal units at airports is relatively small, ranging up to a maximum of about 23 percent in the most costly case.

Travel Time

The automated guideway transit alternatives are naturally the most expensive options examined in the study. When evaluating intraairport transportation systems, however,

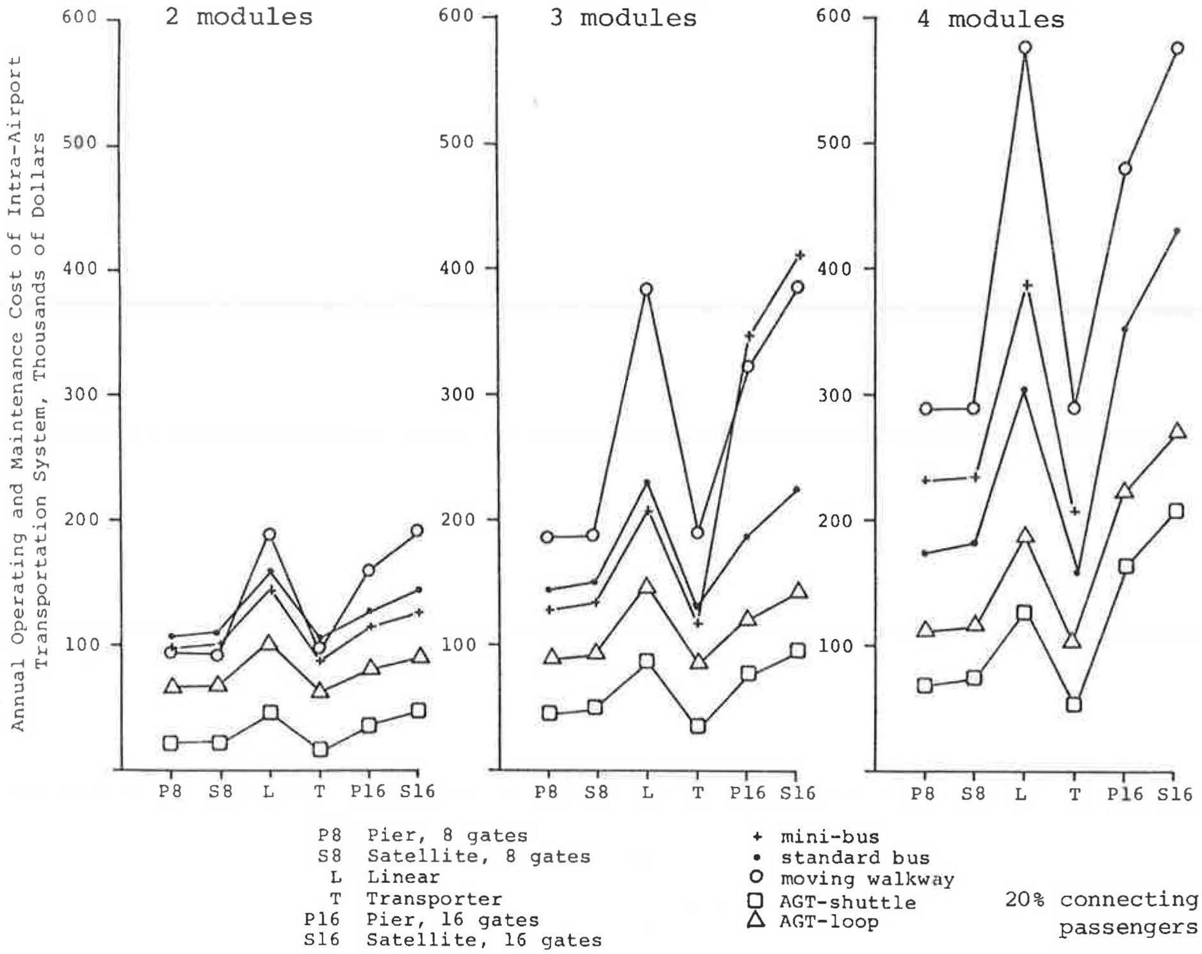


FIGURE 7 Operating and maintenance costs of intraairport transportation systems, terminal configuration A.

trade-offs are expected to be made. Because of higher operating speeds, it is anticipated that automated guideway transit would rank high in convenience measures. One measure of convenience that has been considered in this study is travel time. This time also has an impact on airlines in that increased connecting passenger travel time affects, at least to some extent, the minimum connecting time for passengers.

The average percentage increase or decrease in travel time with an intraairport transportation system compared to walking only is summarized in Table 4. The largest reductions in travel time are obtained by incorporating automated guideway transit on the shuttle alignment. This alignment would be similar to a direct route that a connecting passenger walking from arrival gate to departure gate would follow when automated guideway transit has been used to replace walking over a portion of the trip. Larger reductions may be achieved for the pier and satellite concepts by selecting an alignment that reduces the walking portion even further. Moving walkways are frequently used to replace walking on a direct trip. Since the operating speed of moving walkways is less than walking speed, however, the travel time from gate to gate with moving walkways may actually increase. Since both the bus system and the automated guideway transit system on a loop alignment follow the terminal access road, the routing is not as direct and the reduction in travel time is not as pronounced as those of the more direct routing of the latter system on a shuttle alignment.

Walking Distance

Often intraairport transportation systems have been incorporated in terminals to reduce the walking distances for connecting passengers. Average walking distances for connecting passengers have been determined both with and without an intraairport transportation system. Figures 9 and 10 show these results for configuration A and configuration B modules, respectively. It is apparent that the provision of such a system results in significant reductions in connecting passenger walking distance.

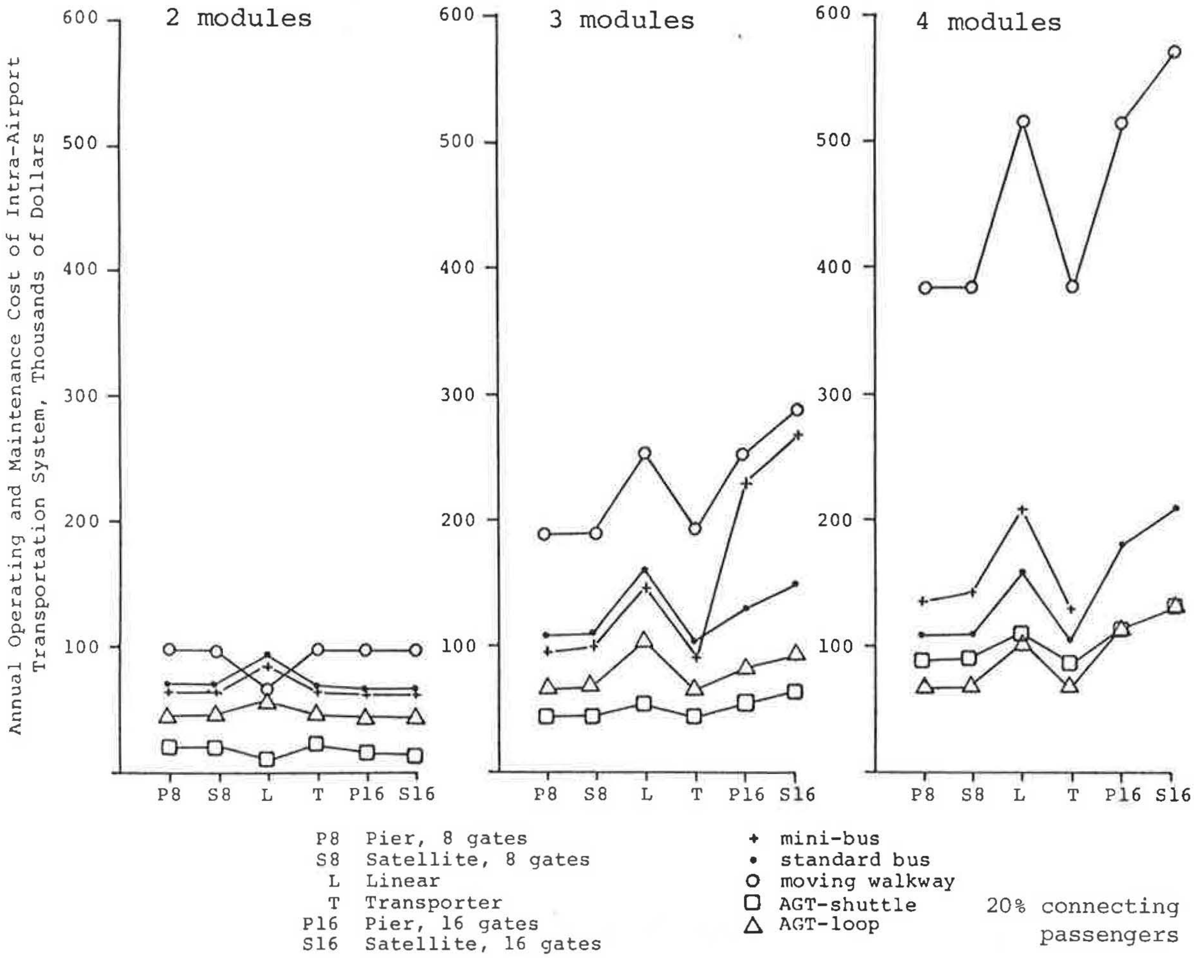


FIGURE 8 Operating and maintenance costs of intraairport transportation systems, terminal configuration B.

TABLE 2 RANGE IN ANNUAL COSTS PER CONNECTING PASSENGER OF INTRAAIRPORT TRANSPORTATION SYSTEMS (DOLLARS)

		Intra-Airport Transportation System *				
Terminal Concept	Terminal Configuration	Minibus	Standard Bus	Moving Walkway	AGT-Shuttle	AGT-Loop
Pier (8)	A	.16-.69	.14- .74	.38-2.83	.44-2.36	1.00-5.55
	B	.10-.46	.09- .49	.38-3.78	.41-3.90	.75-4.64
Satellite (8)	A	.17-.71	.15- .75	.38-2.83	.45-2.40	1.02-5.70
	B	.10-.47	.09- .50	.38-3.78	.41-3.99	.79-4.64
Linear (8)	A	.23-.94	.20-1.01	.76-5.76	.63-6.70	1.58-8.52
	B	.15-.63	.11- .67	.25-5.04	.28-4.49	1.08-6.74
Transporter (8)	A	.16-.56	.12- .60	.38-2.83	.40-2.04	.84-5.30
	B	.10-.43	.09- .45	.38-3.78	.44-3.86	.66-4.64
Pier (16)	A	.17-.56	.10- .42	.31-2.36	.29-3.00	.72-3.31
	B	.09-.26	.05- .28	.19-2.52	.20-2.23	.45-2.59
Satellite (16)	A	.20-.62	.11- .48	.38-2.83	.34-3.73	.73-3.83
	B	.10-.32	.05- .32	.19-2.83	.20-2.46	.45-2.95

* Low end of range is for 4 modules, 50% connecting passengers; upper end of range is for 2 modules, 10% connecting passengers.

TABLE 3 AVERAGE PERCENTAGE INCREASE OR DECREASE IN ANNUAL COST PER ENPLANED PASSENGER OF TERMINAL AREA WITH ADDITION OF INTRAAIRPORT TRANSPORTATION SYSTEM FOR CONNECTING PASSENGERS

		Intra-Airport Transportation System				
Terminal Concept	Terminal Configuration	Minibus	Standard Bus	Moving Walkway	AGT-Shuttle	AGT-Loop
Pier (8)	A	0.2	-0.2	6.6	4.6	12.1
	B	0.6	0.4	6.7	6.4	9.5
Satellite (8)	A	0.1	-0.2	6.2	5.0	12.3
	B	0.5	0.3	6.7	6.4	9.7
Linear (8)	A	3.5	3.0	13.6	13.2	22.7
	B	1.9	1.5	8.0	7.5	14.7
Transporter (8)	A	1.9	1.6	6.5	5.4	12.5
	B	1.2	1.0	6.5	6.9	9.7
Average for 8 Gate Modules		1.3	0.9	7.7	6.9	12.9
Pier (16)	A	-1.6	-1.7	5.1	3.2	6.0
	B	-0.6	-0.4	4.1	3.2	4.7
Satellite (16)	A	-3.6	-3.7	5.8	2.3	4.5
	B	-1.4	-1.2	4.4	2.6	4.0
Average for 16 Gate Modules		-1.8	-1.8	4.9	2.8	4.8

TABLE 4 AVERAGE PERCENTAGE INCREASE OR DECREASE IN TRAVEL TIME WITH INTRAAIRPORT TRANSPORTATION SYSTEM FOR CONNECTING PASSENGERS

			Travel Time with Intra-Airport Transportation System *				
Terminal Concept	Terminal Configuration	Average Travel Time ** Walking Only (minutes)	Minibus	Standard Bus	Moving Walkway	AGT-Shuttle	AGT-Loop
Pier (8)	A	11.9	-1	+1	+18	-22	-9
	B	11.1	-5	-2	+18	-17	-9
Satellite (8)	A	14.9	-4	-2	+16	-20	-9
	B	13.7	-3	-1	+15	-13	-10
Linear (8)	A	11.8	+1	+4	+62	-31	-12
	B	8.3	+16	+20	+39	-11	+6
Transporter (8)	A	6.5	+16	+21	+40	-18	+2
	B	7.1	-9	-4	+33	-25	-14
Pier (16)	A	19.4	-18	-18	+19	-35	-26
	B	15.4	-9	-8	+16	-19	-14
Satellite (16)	A	23.4	-20	-19	+19	-38	-29
	B	17.8	-11	-10	+14	-22	-16

* Compared to walking only.

** Travel time for connecting passenger, arrival gate to departure gate.

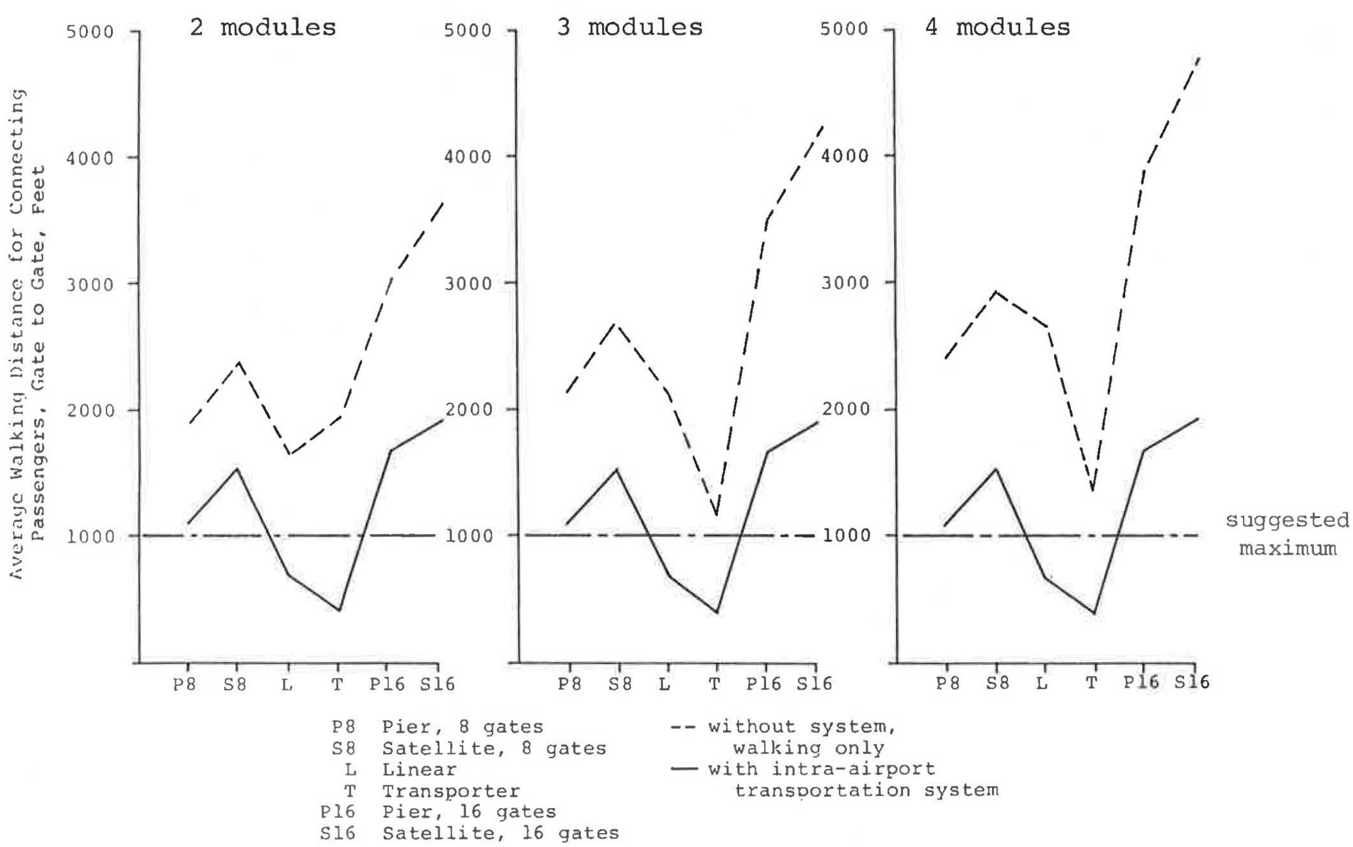


FIGURE 9 Average walking distance for connecting passengers, terminal configuration A.

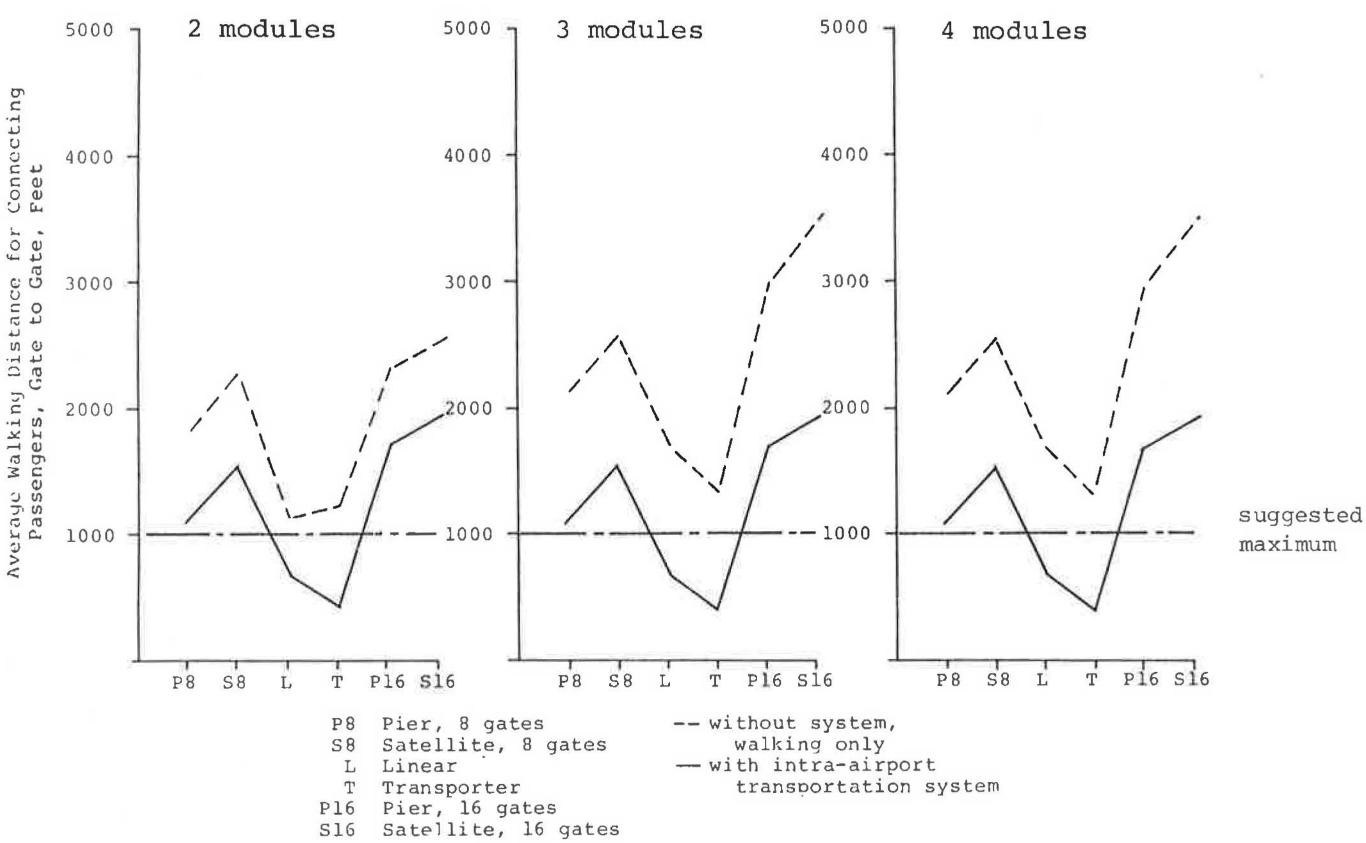


FIGURE 10 Average walking distance for connecting passengers, terminal configuration B.

SUMMARY AND CONCLUSIONS

This paper has presented research results that are of considerable value to airport operators, airlines, and planners considering the incorporation of intraairport systems into airport terminals for the purpose of improving connecting passenger circulation. Guidelines have been presented that will allow for a determination of appropriate applications for such systems, an estimation of the benefits in terms of reduced passenger walking distance and travel time, and an estimation of the total and incremental costs of such systems.

Overall, this research indicates that intraairport transportation systems operating in linear concepts are the most costly and that those operating in pier, satellite, and transporter concepts are the least costly on the basis of total annual costs per enplaned passenger. Bus systems have the lowest costs but are subject to capacity restraints at relatively low passenger volumes. Minibus systems are appropriate for annual demands ranging up to about 1 million annual connecting passengers. Automated guideway transit systems are the most expensive to incorporate, but they become appropriate for airport applications when the annual connecting passenger volume begins to exceed 2.5 to 3 million.

A direct or shuttle type alignment for intraairport transportation affords the greatest reductions in walking distance and travel time for connecting passengers and results in the lowest costs. The impact on the annual cost per enplaned passenger of incorporating an intraairport transportation system for connecting passengers varies with the system, terminal concept, terminal configuration, and level of connecting passengers. The largest impact occurs with the automated guideway system operating on a loop alignment in a linear concept. Finally, the walking distance guideline becomes an important consideration in identifying intraairport transportation system alternatives.

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DISCUSSION

S. Bandara
Department of Civil Engineering, University of Calgary, Calgary, Alberta T2N 1N4, Canada.

The issue addressed in this paper, development of planning guidelines and unit cost estimates for the incorporation of intraairport transportation systems into terminal facilities, is an important and challenging one. A proven set of guidelines is yet to be developed. The authors have made great efforts to include as many parameters as possible for evaluation purposes. What should be stressed most is the incorporation of the disutility associated with passenger walking, which has been neglected in most of the literature on this subject. Possibly because of the number and diversity of the parameters considered, the authors have failed to achieve their main goal of providing a clear set of guidelines for planners.

The analysis has been restricted to two basic unit terminals with eight and sixteen gates and their combinations. Since the authors admit that the terminal facilities would not be increased proportionately to passenger demand (number of gates), it would have been more appropriate if the proposed method was made capable of handling any size unit terminal. As an example for the pier concept, a terminal with three piers may have a lesser average passenger walking distance compared to an equal size terminal with two piers. On the other hand a single terminal with thirty-two gates may be more economical than two terminals with sixteen gates each.

The two measures that have been considered to represent the disutility associated with walking, the average walking distance and the change in travel time due to intraairport transportation system, have been calculated and compared mainly for connecting passengers. Average walking distance based on connecting passengers may not represent the actual walking distribution, because the walking distance for originating and terminating passengers is neglected. The preceding is more significant when the percentage of connecting passengers is relatively small. As an example, for the pier concept, four modules of eight-gate unit terminals may have a higher average walking distance than two modules of sixteen-gate unit terminals if only connecting passengers are considered. When all the passengers are taken into account, however, the preceding may not be true, especially when the percentage of connecting passengers is low.

In determining the average walking distance for connecting passengers, the authors have assumed that all connecting passengers transfer from one module to another. The distribution of connecting passengers among the modules is equal. By making these assumptions, they have missed the possible transfers within a terminal. This will be more significant when the module size increases while the number of modules decreases.

When defining the cost components for comparison purposes, the authors have clearly shown that the cost of the intraairport transportation system correlates with the percentage of connecting passengers by presenting the cost values on a per connecting passenger basis. Later, they neglect this fact, and the total cost of the system is compared on a per enplaned passenger basis. The preceding comparison may not be realistic as the number of connecting passengers has been defined as a percentage of the total enplanements (annual demand). Consider two different situations with an equal annual demand, D, and $P1$ and $P2$ percent connecting passengers. Let $P1 < P2$, and it is decided to provide an intraairport transportation system that costs $X1$ and $X2$ dollars, respectively, where $X1 < X2$. If the terminal cost, C, is assumed to be the same, the situation with $P1$ percent connecting passengers will have a lesser total cost per enplaned passenger. It is necessary, however, to consider the possibility that the cost of the intraairport transportation system per connecting passenger for the second case $(100*X2/(P2*D))$ is less than that for the first case $(100*X1/(P1*D))$. As the terminal facility is used by all the passengers and the intraairport transportation system is used by only the connecting passengers, it would have been more appropriate if the total of terminal cost per enplaned passenger and intraairport transportation system cost per connecting passenger were considered instead of the total cost per enplaned passenger. This will allow the planners to choose for a higher-cost alternative when the percentage of connecting passengers is high.

AUTHORS' CLOSURE

Bandara has made a good point about the consideration of the disutility associated with passenger walking. However, the two measures of disutility considered, walking distance and travel time, are the most predominant measures of disutility normally considered in passenger terminal planning. It is difficult to consider other disutility measures, such as the value of time, without a distinct consideration of the type of market being served, for example, business versus tourist. In the case of the research reported in this paper the results were not determined for a single type of airport but were generalized to provide some guidance to airport planners in a variety of situations. It is true that such a generalization may not result in findings that are applicable to a specific airport design, but it does provide a framework from which consideration of intraairport transportation systems might be initiated for a specific airport application. The study was limited in its scope to the consideration of only eight- and sixteen-gate modules because of resource constraints. It is expected that by presenting the relevant information associated with these data points, a determination of the approximate ranges in cost and utility might be possible. Since the cost data used in the study were average costs obtained from a variety of automated ground transportation and airport studies, it is possible that a given airport study may obtain different results owing to the specific costs associated with the project. It is reasonable, however, to expect that the overall ranges in costs and utility should not be significantly different from those obtained in this study. It should be emphasized that the paper presents a summary of the findings of the original research and does not contain all of the information found in that study. For example, Bandara indicates the potential variability of the results for differing percentages of connecting passengers and the fact that the paper presents annual costs in light of a cost per connecting passenger. The original research addresses both of these items in that varying percentages of connecting passengers were utilized in the analysis and the annual costs were also obtained on the basis of a cost per enplaned passenger. This research was not intended to stand alone as the definitive study of the incorporation of intraairport transportation systems but was meant to contribute to existing knowledge of such systems.