DUNLOP S-TYPE SPEEDAWAY: A HIGH-SPEED PASSENGER CONVEYOR

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This paper shows that there is an obvious need for a continuous system to transport large numbers of passengers at speeds as high as 10 mph for distances as great as 1 mile. The disadvantages of various systems that have been proposed are discussed, and the operation of the S-Type Speedaway and the ways in which this design overcomes the disadvantages of earlier proposals are described. The development of the system began in 1968, and a full-scale prototype has been operating since 1971. Aspects of the design and the particular attention paid to passenger acceptability and safety are discussed. The point-to-point S-Type Speedaway has a short constant-speed entry section after which the passenger is accelerated smoothly in a curved path until the main high-speed section is reached. The speed of this section is as much as 5 times the entry speed. At the end of the high-speed section, the passenger is decelerated to step off the system at low speed. Capacity of a single unit is 10,000 people per hour. Applications and installations for high-speed moving walkways are described, and the paper concludes with a look at possible future developments of the system.

THE BASIC problems of moving people over relatively long distances by road, by rail, and by air have to some extent been solved, although undoubtedly future developments will reduce journey times and improve passenger comfort and safety. One of the major problems with most cities is the congestion caused by vehicles, and many suggestions for improved transportation systems are being considered throughout the world. The problem of moving large numbers of people over relatively short distances has, however, not been given so much attention, possibly because until recently no satisfactory system has been available.

Figure 1 shows that there are 2 important gaps left to be filled by new forms of transportation. The top line shows the total demand for transportation plotted against distance to be traveled. The heavy curves show the demand for the 3 main forms of existing transportation, and the distances for which each is most suitable. The curves are also a measure of the degree of satisfaction with the chosen form of transport; at the peak of each curve, virtually 100 percent of the passengers will be satisfied with that particular form of transport for the distances indicated at the peak. For distances much smaller or much greater than this, only a small percentage of passengers will be satisfied with that particular method of travel.

The total number of potential passengers for a new transport system in the first gap is, of course, much greater than that for a new transport system in the second gap. In addition the development of high-speed trains is now extending the middle curve to the right, and the development of helicopters and STOL aircraft could extend the right curve to the left so that the second gap is rapidly being bridged. The first gap, therefore, indicates that there is a large potential market for a high-speed moving walkway like the Dunlop S-Type Speedaway.

Although new forms of transportation may extend the middle curve slightly to the left, human nature is not likely to change much to extend the pedestrian curve to the right. Thus, not only do high-speed moving walkways have a great potential demand but, positioned as they are to the left of center of the first gap, they are unlikely to be challenged by other forms of transportation.

Figure 1. Transport gaps.

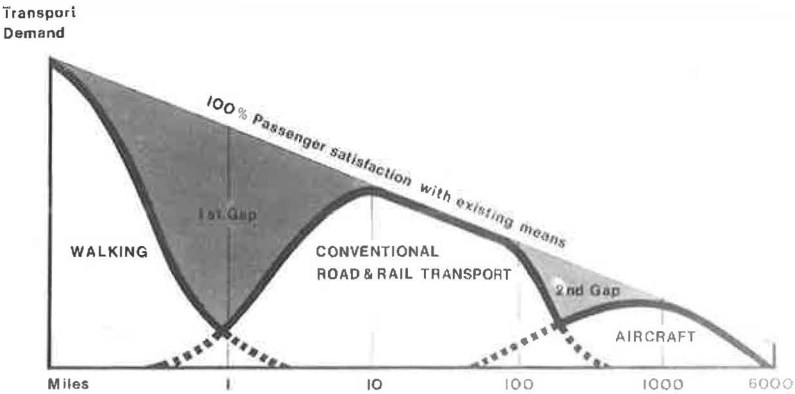


Figure 2. Moving sidewalks at Paris Exhibition.

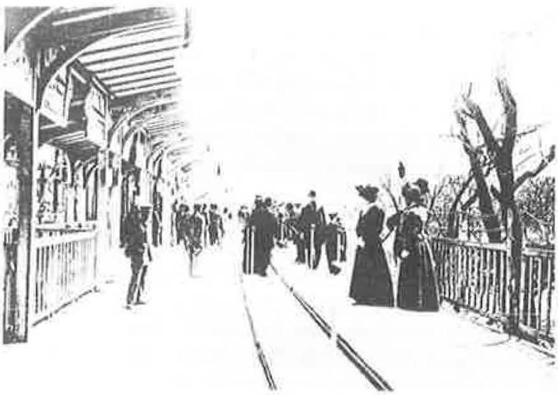
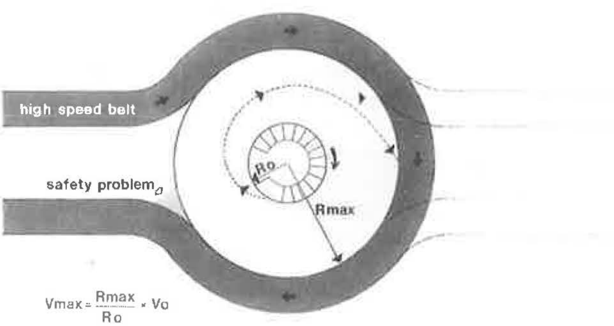


Figure 3. Circular loading disk.



The Dunlop-Angus Belting Group has been involved for a number of years in the manufacture of conventional passenger conveyors and has more than 100 installations throughout the world. However, the speed of the conventional moving pavement is the same all along its length, and this speed is governed by the speed at the entry. This is normally kept to about half normal walking speed so that the elderly and the non-habitual users do not have any difficulty in stepping onto the moving belt. The low speed, however, can be frustrating to many people, particularly where installations of more than 100 m are involved. Therefore, Dunlop developed the S-Type Speed-away, which allows passengers to step onto the system with the same speed at entry as that of the conventional moving pavement, but then for the main part of their journey accelerates them safely and smoothly to speeds 5 times greater than the entry speed. They are decelerated automatically before stepping off in the normal manner.

HISTORY OF ALTERNATIVE SYSTEMS

Parallel Belts

Before the turn of this century, inventors saw the need for and have made attempts to design high-speed passenger conveyors. Among the earliest of these was a system exhibited at the Paris Exposition in 1900. This consisted of 2 rows of parallel platforms (Fig. 2) onto which the passengers side-stepped. The speed of the fastest pavement was limited, and the system had to be arranged in a closed loop to be endless and avoid the problem of a barrier at the ends. Posts were provided on the platform to aid the side-stepping maneuver.

The problem with a parallel-belt system is that the speed differential between the different rows of belts must be limited to about 1½ mph and certainly no more than 2 mph for it to be acceptable to most people. Therefore, to achieve a maximum speed of, say, 10 mph requires a minimum of 5 parallel belts. The cost of the system itself and of land acquisition for such a wide installation rules it out in present-day cities.

Loading Disk

A second system that has been proposed for loading passengers onto a high-speed belt is the circular loading disk. In this system (Fig. 3), the passengers enter at the center of the washer-shaped disk, where they board by side-stepping onto the inner diameter, which is moving at about 2 mph. They then walk out across the disk, which is rotating at constant velocity, to the outer diameter, where the peripheral speed has increased in proportion to the radius. At the periphery they transfer to the moving belt.

Passengers experience the unpleasant effects of the Coriolis force as they walk out across the revolving disk and, although the system has been used as a means of loading never-stop railways, the peripheral speed at the outside of the disk has been limited to about 4 mph. This is thought to be about the limit. An increase in speed from 2 to 10 mph is almost certainly quite unacceptable for the comfort and safety of the passengers. In addition, such a system requires unacceptably large stations and has a severe safety problem at the point where the high-speed belt leaves the disk. At this point there must be a gap, and this must be covered by a stationery post or surface of some kind. If a passenger has not completed a transfer before reaching this point, a serious accident could occur.

In-Line System

The third general category, and perhaps the one that has received most attention from inventors through the years, is the straight-line acceleration type of system. In theory, if not in practice, this can be achieved in 2 different ways. The first of these is shown in Figure 4 and is based on the well-known "lazy tongs" mechanism. The links are compressed in the slow-speed zone and stretched out in the high-speed zone. When the links are stretched out, large gaps make the mechanism unacceptable and it has therefore to be covered with some elastic material that will both support the weight of the passengers and extend sufficiently. To achieve a speed ratio of 1:5 (i.e.,

Figure 4. Lazy-tongs accelerator.

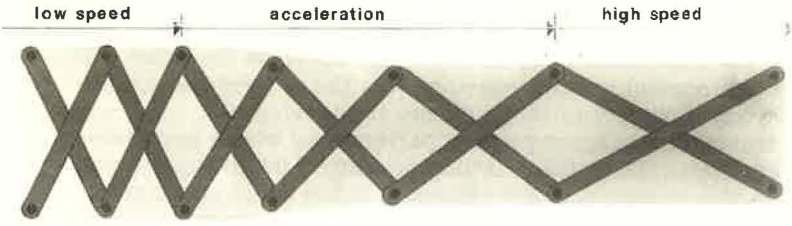


Figure 5. In-line accelerator.

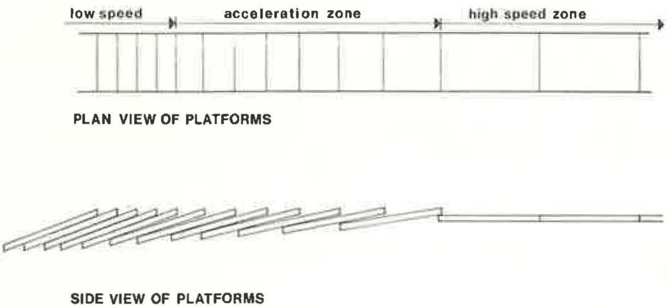
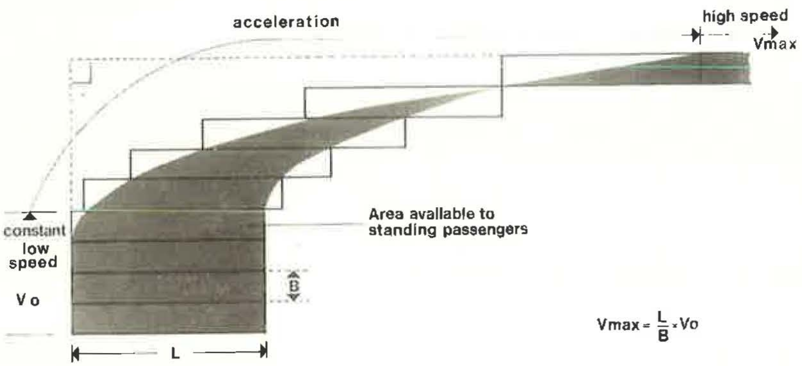


Figure 6. Original Battelle accelerator.



from 2 to 10 mph) requires a material with an extension ratio of 1:5, and this ratio is well beyond present-day materials. The second basic method of achieving in-line acceleration is to have a system of plates that slide over one another as shown in Figure 5. This presents a severe safety problem as the plates or "scales" slide over one another and, in addition, imparts a feeling of discomfort as the plates lift or tilt. Despite every possible safety precaution that is taken in the design of transportation systems, no system has proved to be 100 percent safe.

A high percentage of the few accidents that do occur on conventional moving pavements or escalators occur at the exit comb plate, which each passenger has to step over once in every journey. In an in-line accelerator with plates that are sliding into or over one another, the passenger is, in effect, continuously standing on a comb plate that moves with him for the duration of the deceleration, and the chances of an accident must be increased many times.

Another much less obvious but perhaps even more important safety problem with these in-line acceleration systems is that the surface area available to the passengers decreases in the deceleration zone in comparison to that available in the high-speed zone. As standing passengers are accelerated, the distance between them increases as more of each plate becomes uncovered; and in the high-speed zone there is nothing to prevent passengers from walking along the platforms and bunching together. In the deceleration zone the plates again slide over one another, drastically reducing the area available to the bunched-together passengers. On a crowded conveyor this could result in a serious accident.

Ideal System

From experience gained through the years, we should be able to set out the basic requirements for an ideal high-speed passenger conveyor to meet present-day needs.

1. The entry and exit speeds should be the same as those of conventional low-speed passenger conveyors and escalators, i.e., not greater than about 2 mph.
2. The high-speed section should travel at speeds of about 10 mph; i.e., the unit should have a speed ratio of 1:5, although anything with a speed ratio of 1:3.5 or higher would be useful.
3. The unit must be as safe as current low-speed passenger conveyors and must be acceptable to those who may use it.
4. Acceleration and deceleration levels must be acceptable.
5. The surface areas available to passengers should remain constant and, in particular, should not decrease in the deceleration zone.
6. The system should take up the minimum amount of room both at the ends and along its high-speed length.
7. A moving handrail should be provided.

DUNLOP S-TYPE SPEEDAWAY

The velocity of water flowing through a channel of constant depth is directly proportional to the width of the channel. If the beginning of the channel is wide, the velocity of the water is low; if the width is gradually reduced, the velocity has to increase to get the same quantity of water through. The surface of the water, therefore, represents the ideal acceleration zone for a high-speed passenger conveyor. The basis of most high-speed passenger conveyors is an attempt to produce a solid mechanical equivalent of the surface of the water.

To understand the operation of the Dunlop S-Type Speedaway, one should consider a series of rectangular platforms (Fig. 6) that start moving in a direction parallel to their short sides and then slide across one another so that their centers move around a curve, resulting in the platforms moving end to end at right angles to their original direction. The speed ratio of such a system is the ratio of the breadth to the length of the platforms. Figure 6 shows that the platforms reach an intermediate position where they are corner to corner before they can slide end to end and that unacceptable gaps appear in the surface of the system around this point. The patented Dunlop S-Type

Speedaway used a modification of this system. The platforms always remain parallel, but the change in angle between the initial direction and the final direction is restricted to less than 90 deg. This results in a system that presents to the passenger a continuous surface, without gaps, the speed ratio being determined by the angle of the platforms to the sides of the high-speed transportation zone (Fig. 7). The maximum speed ratio between entry and high-speed zone currently proposed is approximately 1:5, although the theoretical ratio that can be achieved with this arrangement is well beyond this.

Parallel sides are provided, and the width in the high-speed zone is reduced by the removal of a triangular portion from each end of the platforms. The complete S-Type Speedaway is shown in Figure 8. A single unit has a capacity of 10,000 people per hour.

Development of System

The original concept for the speedaway system was proposed by the Battelle Research Centre in Geneva. The Dunlop-Angus Belting Group sponsored a design feasibility study in November 1968 and jointly sponsored a detailed design study with the National Research Development Corporation, an agency of the U.K. Government. This was followed by the decision to build a full-scale prototype unit in Geneva and at the same time to build a number of rigs to test a number of the vital components before the prototype unit was completely assembled.

The prototype unit (Fig. 9) was commissioned in March 1971. It consists of a short constant-speed entry section, curved acceleration section, a relatively short high-speed section, and a corresponding curved deceleration zone and exit zone. The total length is approximately 33 m. The speed ratio between the entrance speed and the high-speed zone is 1:3.5 or, in other words, passengers travel $3\frac{1}{2}$ times faster than they do on a conventional passenger conveyor.

The unit proved the engineering feasibility of the design and has been run for many hundreds of hours. The engineering is entirely conventional, and no exotic materials are used. Tolerances are within normal engineering limits for escalators and moving pavements. Besides proving the basic engineering, the unit has been used to test passenger acceptability and safety. Although from the inception we considered that a moving handrail would eventually be necessary, all the initial testing of passenger reaction was conducted without one.

Many hundreds of people have now traveled on the Speedaway in this form and with few exceptions passenger reaction has been enthusiastic, and most passengers have found the Speedaway as easy to use as an escalator. Test passengers included families with young children, people with wheelchairs, and the disabled.

The prototype unit has, as one would expect, highlighted a number of simplifications and modifications in engineering and a number of improvements for the comfort and safety of passengers. All of these features have been incorporated in the design of the commercial unit.

During 1973 the patented moving handrail (Fig. 9) was developed, and one side of the prototype unit has now been fitted with a conventional balustrade, which is curved at entry and exit to follow the line of the edge of the platforms. A moving rubber handrail of conventional appearance is fitted on top of the balustrade. This handrail is divided into a series of constant-speed zones that approximately match the mean speed of the platforms in that zone. Passengers entering the system hold the handrail, which moves at exactly the same speed as the platform on which they stand. As they begin to accelerate they can continue to hold the handrail in the same position, but their hand begins to move back for they are then moving slightly faster than the handrail. Before a passenger's arm position has become uncomfortable, he or she has reached the next section of the handrail and can readily transfer to it. In the high-speed transport zone, the handrail moves at exactly the same speed as the platforms. Care has been taken with the design of the balustrading in the area where the handrails overlap to ensure that there is no safety problem irrespective of the direction of travel of the system.

Figure 7. Speedaway principle.

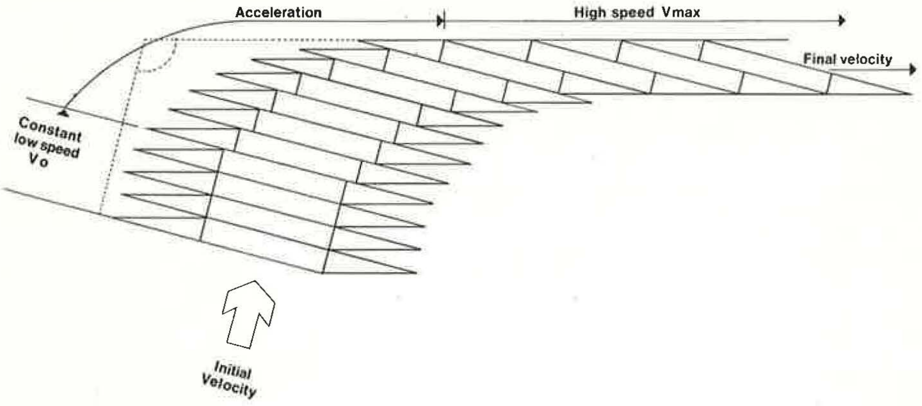


Figure 8. S-Type Speedaway.

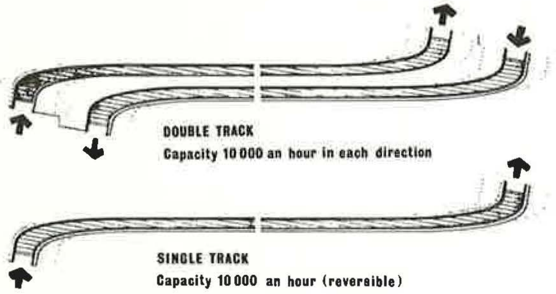


Figure 9. Full-scale prototype unit.

Engineering Details

The platforms themselves are made from aluminium extrusions, which require little machining, and are covered with grooved aluminium tread plates so that they pass through a conventional comb plate at each end of the system. Each platform is connected to its neighbor by 2 sliding members to keep it parallel to, but to allow it to slide relative to, the next platform as it passes through the curved acceleration and deceleration zones. In the relatively long high-speed zone, there is no relative sliding between platforms. The sliding members also allow the platforms to pivot relative to one another in the vertical plane so that they can recycle beneath the passenger surface after they have passed through the comb plate. Each platform is supported and guided by 2 bogies that are free to pivot and that run on circular section rails. The platforms are driven by a friction drive powered by variable-speed electric motors that are positioned along the length of the system and run on the undersides of the platforms. Disk brakes are provided on the driving wheels to provide for emergency stops. Linear electric motors can be used in the variable-speed zones. A simple control system synchronizes the various drives.

APPLICATIONS AND INSTALLATIONS

The Dunlop S-Type Speedaway can be used in any installation where a low-speed moving pavement is used at present. In practice, however, it will normally be used for the longer installations of more than 125 m. In those installations, the low speed of the conventional unit can become extremely frustrating, particularly to those passengers in a hurry. The advantages of the high-speed passenger conveyor are that the passenger never needs to wait for it to arrive because it is a continuous rather than an intermittent transport system and it can handle large numbers of passengers (as many as 10,000 per hour) when this is required.

S-Type Speedaways can be installed singly, in pairs, or 3 or more abreast. The units are reversible, and in multiple installations directions of travel can be altered or units shut down depending on passenger demand. The Speedaway can be installed in an overhead tube, at ground level, or underground. Ground level units are, however, not always acceptable because they prevent access from one side of the system to the other. The obvious application for the Speedaway system is in mass activity centers such as airports, railway and bus stations, shopping centers, pedestrianized streets, and other traffic-free areas.

In airports, Speedaway can be used as a link between terminal buildings, from main terminal buildings to satellite terminals on the apron, and from car parks and other transport facilities to the main terminal building. Passengers can deposit their luggage on the platforms while they ride beside it or they can park luggage trolleys on the Speedaway. Figure 10 shows how the Speedaway might be used as a link between an underground railway station and a nearby surface train or bus station. The applications to pedestrian areas are for transport along pedestrianized streets and as a means of linking those traffic-free areas with transport facilities and car parks. In many instances the cost of the Speedaway system can be largely offset by moving car parks to more remote areas where land is cheaper.

Specific Studies

The Dunlop-Angus Belting Group has carried out, in conjunction with its consultant architects and civil engineers, a number of detailed studies on the application of Speedaway in various parts of the world. These include studies relating to London Bridge and cross-town Manhattan.

During the rush hour each morning some 20,000 people per hour leave London Bridge Station and cross London Bridge for their offices in the city. A similar reverse flow occurs during the evening rush hour. The new London Bridge already has the foundations for a central overhead walkway, and studies have shown that this would be an ideal application for 2 S-Type Speedaways in parallel. In the morning, both units would travel in the same direction to give the required capacity and would be reversed in the

Figure 10. Speedaway underground.

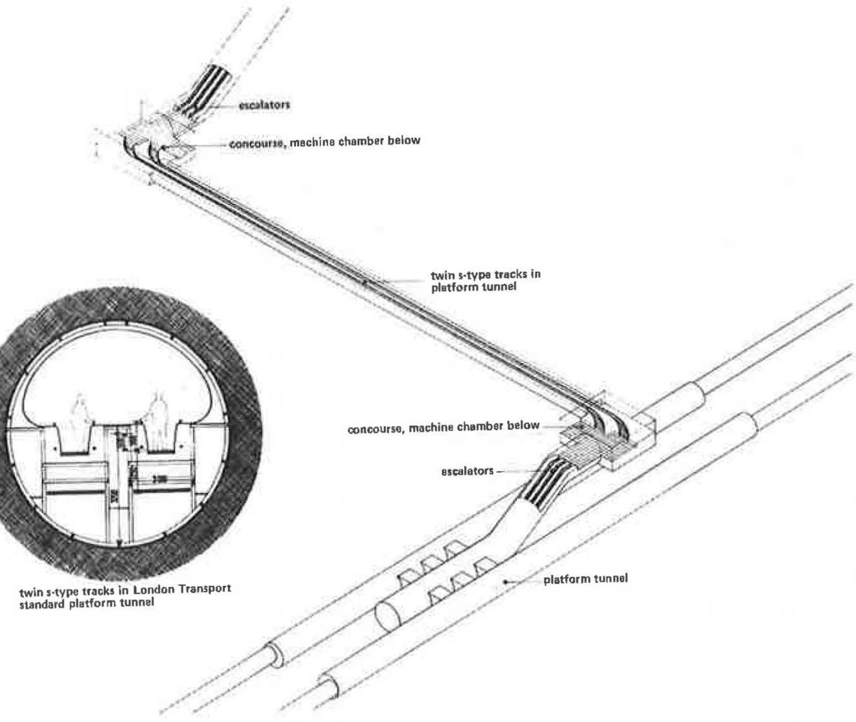


Figure 11. Speedaway overhead.

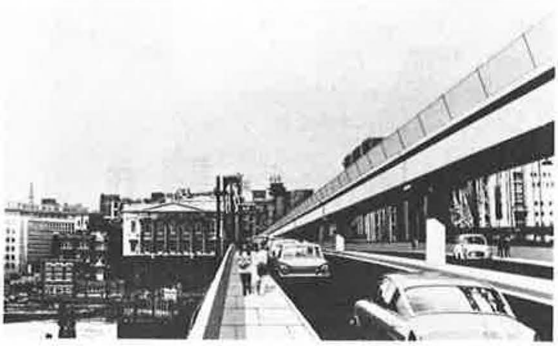


Figure 12. Speedaway at ground level.

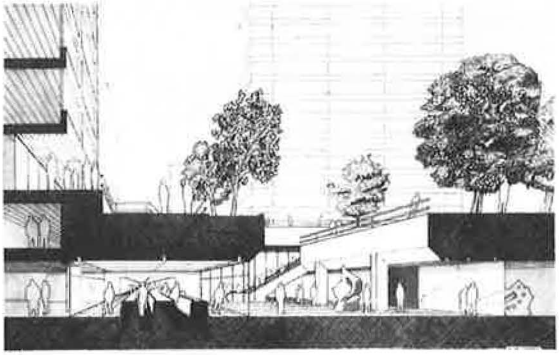


Figure 13. Speedaway below street level.

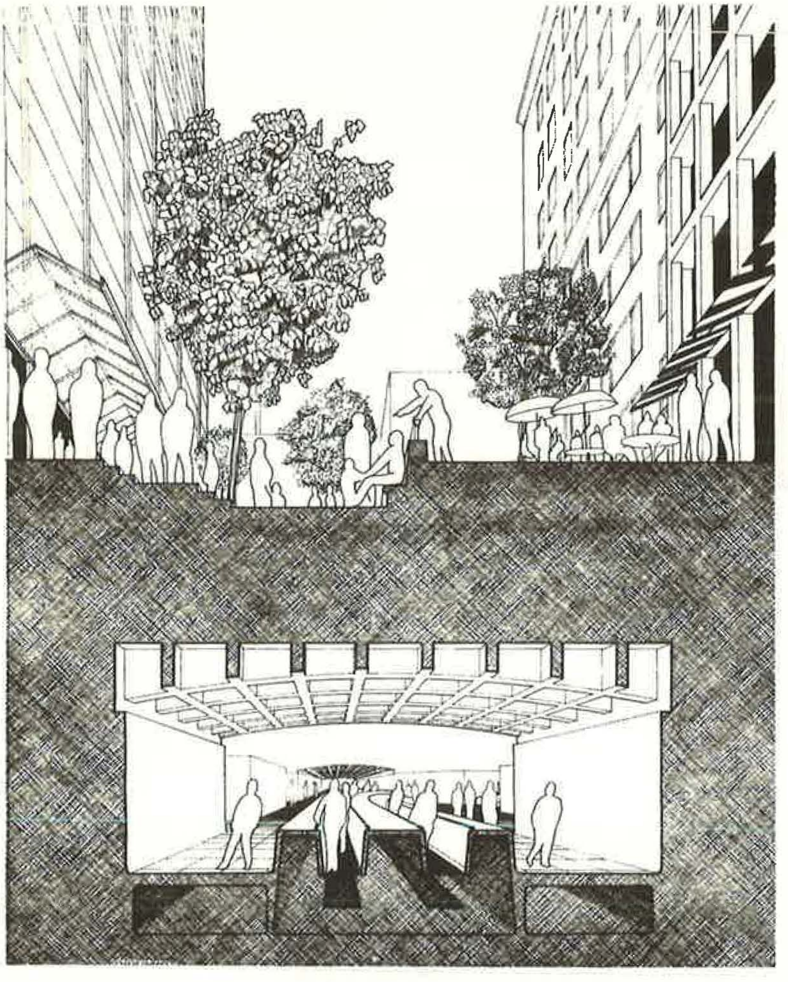
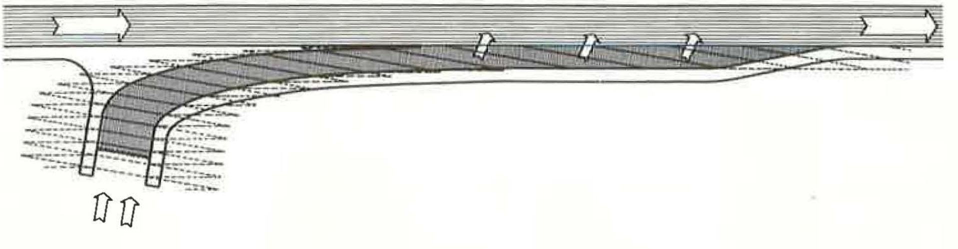


Figure 14. Possible future developments of Speedaway.



evening. During the rest of the day, the units would run in opposite directions. Figure 11 shows what the overhead air-conditioned tube could look like if it were installed on London Bridge.

In New York, Manhattan has good transport facilities from north to south, but east-west connecting links between the blocks are required. A study carried out in this area showed that the Speedaway system below street level could provide the missing links. Figure 12 shows a station below grade in a shopping plaza, and Figure 13 shows the system installed below a vehicular street.

First Public Installation

The first public installation of the Speedaway system might well be in a business area redevelopment in Paris. Dunlop, through its French licensees, has put forward a fully detailed scheme. The authority responsible for the redevelopment of the area has carried out detailed studies on the transportation requirements for the area, and our proposal is based on traffic flow estimates from those studies. When this development is completed it will have office accommodation for 100,000 people, homes for a further 20,000, and shops, restaurants, theatres, hotels, and cinemas. It is served by rail, express metro, and buses; these and the roads and car parks are underground. The main feature of the area is a central pedestrian deck about 1 km in length, and the proposed installation of the Speedaway is in an overhead tube along the center portion of this pedestrian deck.

An S-Type Speedaway has also been designed for a business redevelopment area in Paris. This installation has a length of just over 460 m and a speed ratio between entry and the main transportation zone of 1:4. If the contract specifies Speedaway, the system could be operational in 1976.

FUTURE DEVELOPMENT

The S-Type Speedaway is really a high-speed version of the existing low-speed moving pavements. It can be used for greater distances and with few additional problems for the designer or the passenger. In the future one can foresee further exciting developments in this field. The curved accelerating portion of the S-Type could be used as a means of loading passengers onto a high-speed belt. Figure 14 shows how an intermediate station on a belt system might be arranged. Such a system could be several miles long with intermediate stations at suitable intervals. Technically such a system could be designed almost immediately, but a number of safety problems will need to be overcome before it becomes operational. An ability to move around corners and to surmount inclines can also be developed.

CONCLUSION

For the first time, a high-speed passenger conveyor has been developed. The Dunlop S-Type Speedaway can be used to transport large numbers of passengers safely, efficiently, and without pollution over point-to-point distances of 450 m or greater in a single stage.