Moving Walkway for Mass Transit

Mass transit in urban centers has been centered around busing or subway systems – both options require stopping and starting at stations and provide non-continuous service. A large fraction of the transit time is spent waiting for a conveyance and during the loading/offloading process at station stops.

Replacing subway systems with a continuously moving walkway in underground tunnels provides multiple benefits over current mass transit solutions:

1. It is always available and there is no waiting.
2. Crowding is less of a consideration since the riders are evenly spread throughout the system rather than on discrete vehicles.
3. Infrastructure is decreased as the continuity of moving walkways allows for increased ridership with smaller space requirements.
4. Surface streets can be freed up and used for increased pedestrian traffic, hired vehicles, deliveries, and personal transport.

Basis of Design

For there to be an advantage to a moving walkway, the speed must significantly exceed that of walking unassisted and provide trip times that on average are less than existing public transport systems. Assuming most urban centers are approximately 15 miles across, the system with a target speed of 30mph or greater would allow end to end transit in under half an hour. This is considered the design goal for the system.

Different designs for high-speed walkways have been developed, and a few successfully implemented on a small scale. The primary consideration with a high-speed walkway is safe entry and exit by pedestrians. Multiple means of addressing this consideration have been proposed and implemented, but none of them achieve the high speeds needed to meet the requirements for urban transport.

To achieve the transit speeds required to make the system effective, a new technology solution must be developed, leveraging concepts already developed in a unique way. Integration of parallel walkways and walkways with linear acceleration capability as a consolidated system creates a new concept that is appropriate as a public transit system replacement.

The first part of the concept is use of parallel walkways. In the past, parallel walkways with a speed differential were used as a means of providing a low entry speed with the ability to transfer to a higher speed for longer travel. On its own, this concept is not suitable as urban transit for two reasons:

1. Transferring between walkways at different speeds is difficult, especially without handrails.
2. The maximum gain in speed from a transfer can be no more than the differential speed which is limited to approximately half walking speed for practical purpsoes. The number of transfers required to achieve any effective velocity would be too cumbersome to be useful.

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The second piece of the concept is using walkways that accelerate as they move forward. Linear acceleration in a walkway has been implemented in several means, but the method using by ThyssonKrupp for their ACCEL system is the most modern and appropriate for this application. The system slowly inserts plates into the walkway as it moves forward, increasing the walkway effective length (and thus causes acceleration). A speed increase by a factor of three is possible (as currently implemented in the Toronto airport) by inserting a plate twice as long as the base plate in the walkway. This system has some challenges which limit its applicability to urban transit:

1. The speed increase is fixed by the length of the inserted plate and there is a practical limit on plate size.
2. The current system has a maximum speed much lower than would be required.

The proposed design integrates these two concepts to address some of their individual problems.

1. Difficulty transferring between walkways of differing speeds – If the parallel walkways had the ability to vary their speed, the speed between the walkways can be matched during the transfer so there is no speed differential.
2. Low maximum speed gain with parallel belts – A variable speed walkway can start at a low speed during the transfer and accelerate to increase the speed by a factor of 3, providing high speed gains without addition of more parallel walkways. This is a multiplicative gain, not an additive gain as with parallel belts.
3. The speed increase is fixed by the plate size – The ability to transfer to a parallel walkway in low speed configuration while the current walkway is in high speed configuration allows for continual compounding of the speed increase without adding more plates.

Therefore, by integrating two different concepts for high speed walkways, the requirements for a public transit replacement system can be met. To make such a system practical, new and innovative design solutions are required to solve some of the challenges with integrating these two concepts and expanding it into a public transit system. These are discussed below.

Unique Aspects of Design

A number of technological innovations are required to implement the proposed transit system. After a review of the conceptual design, a list of critical technology areas was developed for more detailed study. The list is shown below. The detailed design section addresses each of these critical technical areas and outlines a preliminary concept for each.

- The speeds of operation would be significantly higher than those currently envisioned for moving walkways. A unique means of driving the walkway is required.
- The ability to remove and service elements without disrupting the entire system is needed.
- At the transfer point, the gap between the walkways will have to be addressed.
- At the end of the transfer point, a safe means of separating the walkways is required.
- Station design addressing loading and unloading must be addressed.

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Design Details

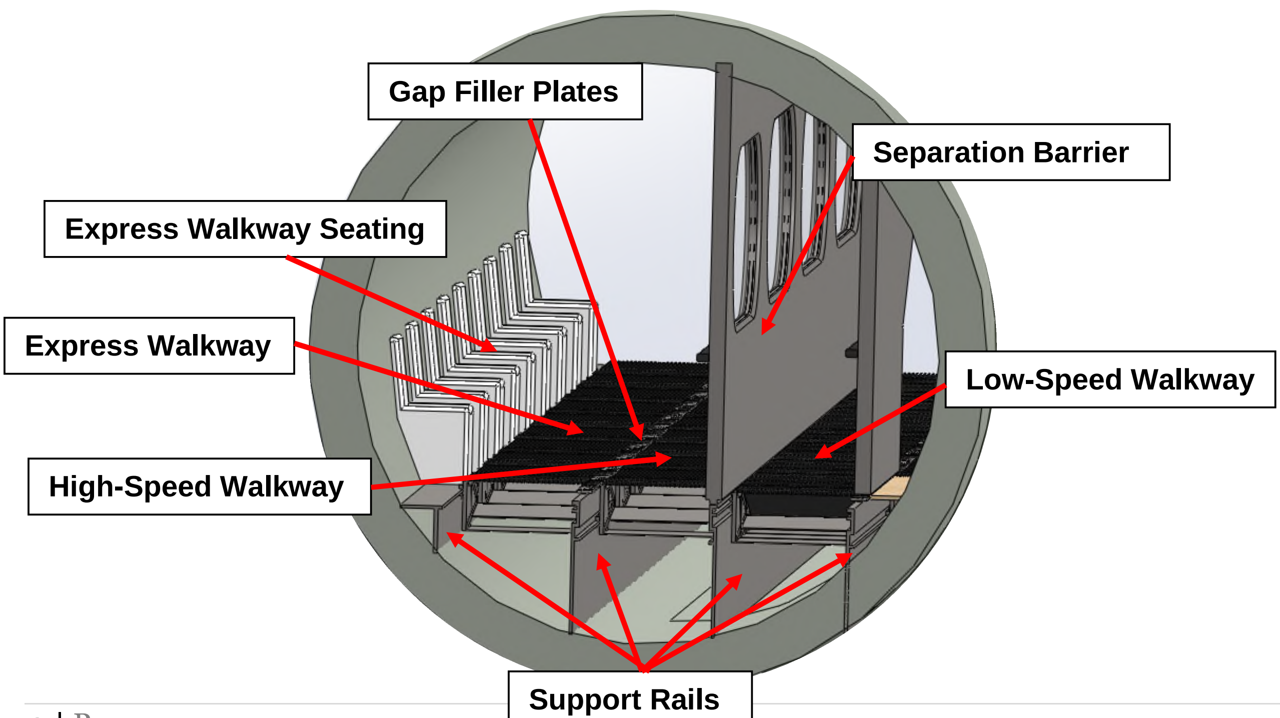
Conceptual Design Description

The conceptual design consists of continuous moving walkways inside a 12 foot diameter underground tunnel. This small diameter tunnel is sized to match the equipment being developed by the Boring Company for compatibility with currently available technology. Three parallel walkways approximately 34 inches wide fit inside this tunnel along with seating in the express section. The first two walkways are variable speed, with the ability to increase speed by a factor of three. These are termed the low-speed and high-speed walkways. The third walkway, termed the express walkway, maintains a speed equal to the top speed of the high-speed walkway. Transfer between adjacent walkways is allowed when their speeds are matched, with a physical barrier separating the walkways where there is speed differential. Entry into the walkway system is through a station that contains an onboarding walkway to accelerate passengers to the low speed walkway slowest speed.

The figure below shows a cross-section of the system as it enters a station. In this location the high-speed walkway and express walkway are at the same speed. The low-speed walkway has deaccelerated to match speed with the onboarding walkway of the station in preparation for station entry.

The conceptual speed range for each walkway is:

- Onboarding Walkway Speeds – 1.5mph accelerated to 4.5mph
- Low Speed Tunnel Walkway Speeds – 4.5mph accelerated to 13.5mph
- High Speed Tunnel Walkway Speeds – 13.5mph accelerated to 40.5mph
- Express Walkway Speed – constant 40.5mph



High Speed Operation

To meet the high-speed requirements for an urban transit walkway system, miniaturized magnetic levitation and linear motor "cars" are used, each containing one base walkway plate and one expansion plate. Coils and power electronics are embedded in the rails on either side, with magnets and control systems housed within each "car". This solution is energy efficient as the energy required for levitation would be minimal when plates are unloaded (which would be the majority of the time) and the low friction due to no mechanical contact. This also results in fewer wear components than a typical friction wheel-based system.

Continuous Operation and Maintenance

In the current design for moving walkways, system maintenance requires shutting down the whole system to inspect, service, and replace components. This is unacceptable for a mass transit system where the walkway may serve tens of miles. To address this consideration, each of the plates in the walkway is designed as an individual "car" with independent controls, electronics, diagnostics, and mechanical systems. Preventative and corrective maintenance could be performed on an individual car without disabling the entire system. The challenge is removing "cars" for maintenance without disrupting the rest of the walkway. An approach similar to that used to remove the expansion plates is envisioned. The preliminary concept is for the "cars" to be supported on rails external to the footprint of the plates. A rail switch to a lower maintenance rail system would allow the car to drop out of the walkway without bringing the walkway to a halt. Adjacent cars would react as needed to simultaneously fill the gap left behind. Similarly, a car could be inserted into the walkway to take its place, maintaining walkway continuity and average speed.

Interface at the Transfer Point

At the transfer points, two walkways will be running in parallel. Due to the design of the rail system (external to the plates), there will be a gap between the two walkways. This gap poses a significant hazard for high-speed walkways. To address this gap, a temporary gap spanning plate is inserted between the two walkways as they exit from underneath the separation barrier to the transfer area. Then the plates are removed by a mechanism in the separation barrier after the transfer area. The plates lock together the parallel walkways, providing a continuous surface and ensuring they are synchronized during the transfer section.

Separating the Walkways

The most dangerous location in the walkway transit system is where the two walkways are separated after a transfer point. The walkways must be completely separated from each other by a physical boundary when they are operating at different speeds to prevent injury. A means of moving all passengers to one of the two walkways safely, even in crowded conditions is necessary prior to speed changes. A gradually "growing" wall from the ceiling area would force those that are unaware to choose a side, and a set of rollers at the pinch point would minimize the potential of getting caught and push anyone encountering the point to one side. Additional signage, signaling, lights, etc. would also be needed. This is anticipated to be the most problematic aspect of the design – not from a technology aspect, but from a human factors

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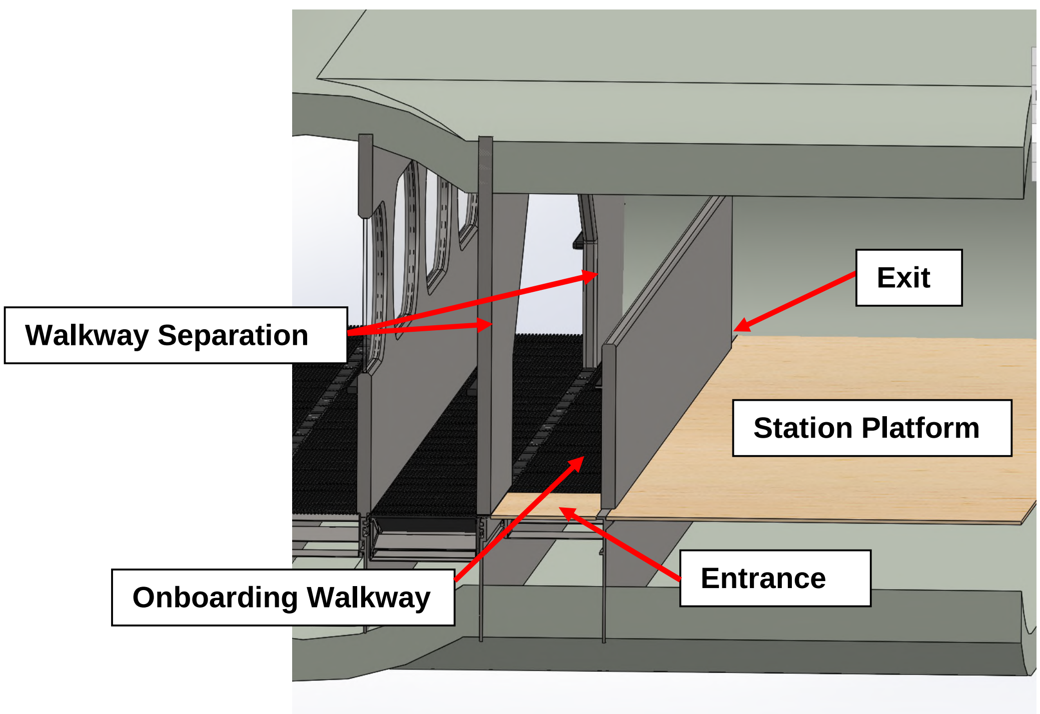
consideration. In many ways, this is no different than a freeway offramp, but the potential for injury, especially in crowded conditions is high.

Station Layout

A station for the system consists of a small platform and an entry into the onboarding walkway. The figure below shows the layout. The major difference between this configuration and a subway station is the size. The entire station would be similar to only half of the platform section in the NYC subway system. There would be no seating or passengers waiting around.

Metered entrance (not shown) allows for flow control of the system, without imparting a large footprint. The onboarding walkway starts at 1.5mph and then accelerates to 4.5mph. A long transfer section of over 200ft is provided where the speed of the onboarding walkway matches the speed of the low-speed walkway. This provides 30 seconds for passengers to enter and exit the system between the two walkways.

After the transfer point, the two walkways are separated, and the onboarding walkway deaccelerates back to 1.5mph for offloading.



Using the System

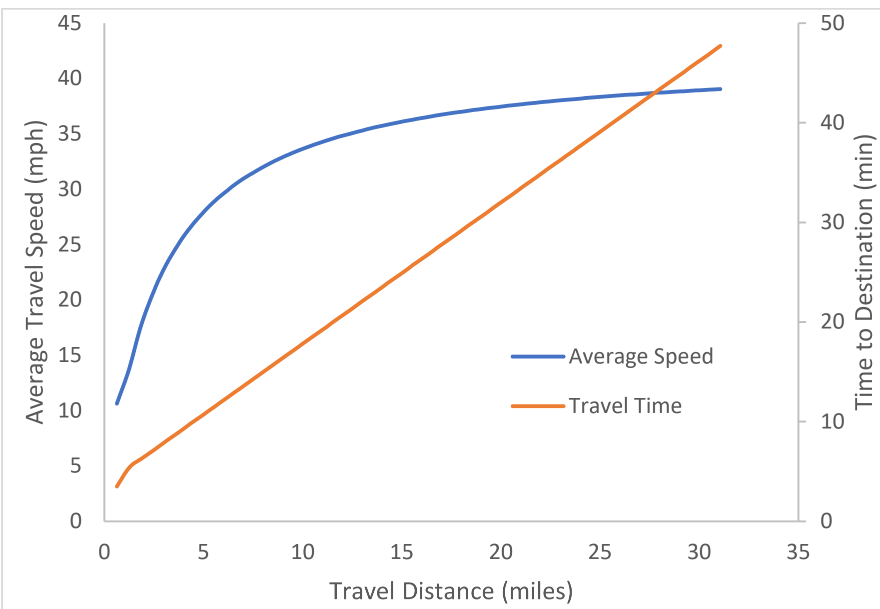
Use of the system is best understood by following a trip from point A to point B. A passenger enters an underground station, similar to a subway at point A. Entry is through a lane for the onboarding walkway, which allows metered entrance to spread out traffic during congested periods. The onboarding walkway starts at a speed of 1.5mph.

The onboarding walkway accelerates to match the speed of the low speed walkway at which point the barrier between the two disappears and the two walkways are joined by the gap filler plates. Transferring onto the low speed walkway completes entrance into the tunnel system. At the end of the transfer section, a wall separates the low-speed walkway from the station and the low-speed walkway accelerates to match the high-speed walkway. Transfers to the high-speed walkway and express walkway are performed similarly. Note that for short trips or during high congestion, transfer to the high-speed or express walkways may be omitted as appropriate.

To exit the system at point B, signage provided is used to indicate when to transfer from one walkway to the next. Upon entering the station, the low-speed walkway matches the speed of the onboarding walkway to allow for transfer and exit to the station at point B.

A calculation was performed to determine the minimum time between stations of a given distance with the system as described. A transfer window of 30 seconds was allowed for each transfer. The calculation assumes no forward walking and that every transfer to a higher speed walkway is utilized when available. The results are shown in the figure below.

Any trip duration where the distance is greater than 2 miles is only dependent on the total distance, since the additional mileage is all performed at the highest walkway velocity. Only one acceleration and deacceleration occurs per trip, regardless of distance. Also evident is how the average speed for the trip increases dramatically with increasing distance. On average, it is expected that most riders of this system will spend ten to fifteen minutes in transit with no waiting on a platform.



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