Automated Systems for Last Mile Connections at High Speed Rail Stations

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ABSTRACT

The paper examines the prospect of applying automated transit circulator systems for the “last mile” conveyance of passengers between a high speed rail station and their destination in the surrounding urban district. The characteristics of high speed rail stations are discussed with respect to their scale, urban context and ridership demand patterns, and the capacity requirements for automated systems to serve in the “last mile” function. Current project work on the Texas DOT Intercity Passenger Rail Ridership Study is referenced, and a discussion of the simulation and analysis methodologies being used in the study are compared to similar methodologies previously applied to study automated guideway transit connector systems in airports. The paper concludes with an assessment of the suitability of conceptual aerial guideway automated transit systems in conjunction with high speed rail stations for each of the main classifications of automated transit technologies.

INTRODUCTION

There is a growing initiative to plan and build high speed intercity rail systems within the United States which would provide convenient service connecting our densest, most populated urban areas. The justification of building such sophisticated rail systems is based on their ability to compete with air travel by improving the total travel times of intercity travelers, typically for travel distances of 150 to 350 miles (250 to 550 kilometers). When total travel time advantages are combined with the prospect of rail connections penetrating into the heart of the largest cities, ridership potential can begin to favor the rail option. The successes of high speed rail (HSR) service connecting the largest cities within Europe and Asia have fostered the new U.S. federal and state government initiatives to advance HSR projects in the U.S.

These initiatives are bringing into focus the important “next question” of how large numbers of passengers will be moved from the HSR station to the surrounding urban districts located in proximity to the station. And for the wholly new rail stations that will be created to serve high speed rail in particular, this question is critically important to answer.

Along the northeastern coast of the United States where population densities have been at levels comparable to Europe since the 1900s, the introduction of higher speed rail service has been underway for over a decade. In this particular part of the country, there already exists effective mass transit infrastructure to connect the high speed rail stations with the surrounding urban districts so the issues addressed in this paper are less relevant.

However, most of the new high speed rail projects currently being initiated in the U.S. would connect cities throughout the parts of the nation where the existence of mature, high capacity transit is far less common. As a result, there is an important need to also address new transit connector systems that are sufficient for the "last mile" access and circulation movements within the urban districts near the high speed rail station. And with respect to the largest metropolitan areas, it is particularly problematic in that the roadways and surface transportation systems are often extremely congested and incapable of supporting at-grade transit solutions that have adequate capacity for this last mile connectivity, especially when future growth and development that will likely be induced by the new station are considered. Furthermore, regional-scale transit connections such as conventional commuter rail service are often naturally incorporated into the HSR station location.

The challenge therefore involves planning for adequate local district connections and circulation/distribution functions, creating an even greater need for a suitable connector/circulator system. The use of automated systems for this very purpose has been proposed in prior technical presentations at major transportation conferences (Lott, 2009; Lott, 2012). Past studies by Bay Area Rapid Transit (BART) have evaluated automated guideway transit systems that would serve as circulator systems to connect major rail stations with the nearby urban district (Lu, Hathaway, Lott, 2003). These studies clearly indicated that the application of advanced technology is viable, but that the selection of the class of automated guideway transit system is important to carefully analyze in the early stage of planning. Other specific studies are described below that provide further insight into these issues.

Note that in the discussion that follows, reference will be made to high speed rail service with the designation of "Core Express", which FTA identifies as service having average commercial speeds of 150 mph or greater.

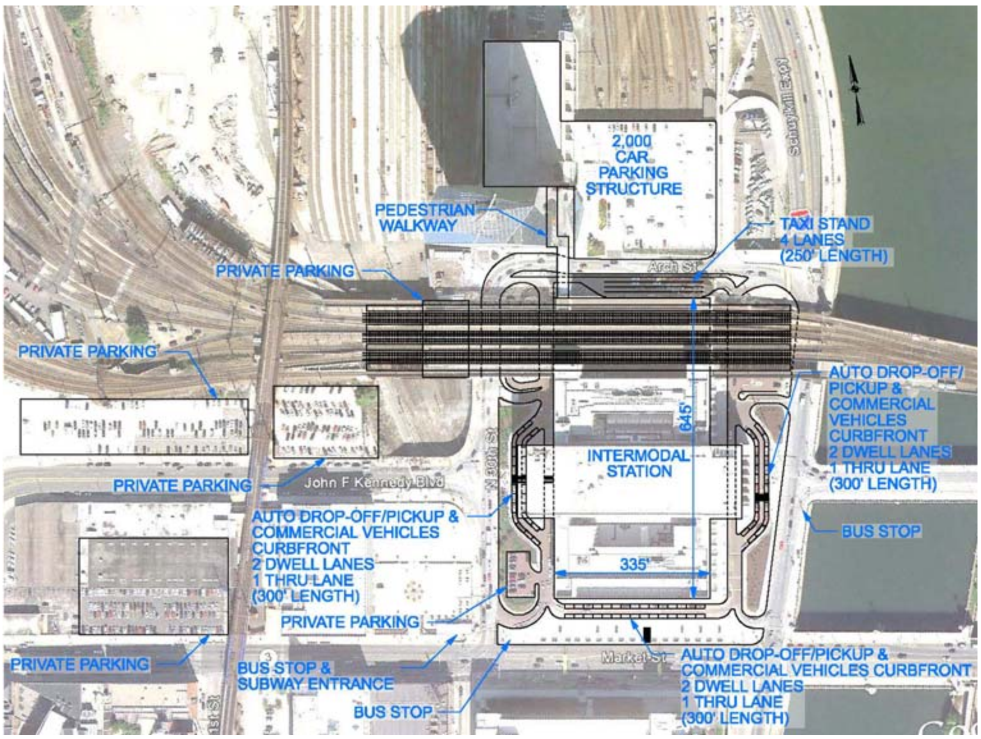
Unique Requirements of High Speed Rail Stations

Multimodal transit solutions are currently being investigated as part of the Texas high speed rail (HSR) studies. These studies are providing analytical information and practical insight into the intermodal functions required at the stations, which can then be considered in assessing the benefits of using automated transit technology to provide the last-mile connections into the dense urban districts.

Six sites in Texas are currently undergoing specific study for HSR stations – three in the Dallas/Fort Worth region, and one each in Houston, Austin and San Antonio. The studies show that the scale of operations at these locations begins to replicate the intermodal environment of an airport, since the Core Express class of HSR service is expected to have trains arriving and departing at least every 30 minutes between specific city pairs during peak periods of the day. Due to the rail traveler having characteristics and expectations very similar to air passengers, the transportation facilities are being planned in a manner similar to the landside/terminal intermodal infrastructure of a medium sized airport. In addition, the HSR stations also typically serve other transit modes such as light rail, commuter rail, bus and pedestrian access.

In most of the cities around the world where HSR stations are located in urban settings, these is existing, mature transit infrastructure with adequate capacity to move large quantities of arriving and departing HSR passengers between the station and the nearby urban districts. In Texas, however, mature high capacity transit systems and infrastructure are typically not in existence at the most desirable station locations.

As a model for the functional aspects of an effective station design, the high speed intercity passenger rail ridership study currently being performed under the auspices of the Texas Department of Transportation (TxDOT) is using the Philadelphia 30th Street Station to establish a general benchmark – a generic definition of a complete HSR intermodal station. **Figure 1** illustrates the set of reference metrics that have been established for each functional element of 30th Street Station, including automotive curbfronts, commercial vehicle staging and loading areas, taxi queuing provisions, as well as structures to house rental car and parking. Transit provisions include additional station berths and platforms to serve light rail, commuter rail, regional bus and intercity bus, as well provisions for local bus service. Intermodal facilities for new HSR station sites must be considered for all of these modes.



SOURCE: Kimley-Horn and Associates, Inc.

Figure 1 Philadelphia 30th Street Station Provides a Benchmark for High Speed Rail Station Functional Elements

With respect to creating a transit circulator/connector system to serve the station site, almost all conventional transit technologies – such as buses or light rail systems – which access and egress the station site would have limited capacity. The basis for this limited capacity assessment is that the transit operations would typically occur at grade-level in the midst of traffic moving along congested roadways.

As a proposed alternative, the utilization of a grade-separated automated guideway transit system has significant capacity advantages when applied as the primary means to convey transit patrons to and from the HSR intermodal station district and beyond to the surrounding subregional area.

Effectiveness of Automated Aerial-Guideway Circulator Systems

The initial studies of HSR system for Texas are being performed on the premise that the station activity will be high, having traffic and pedestrian movements similar to that of the landside and terminal complex of a medium sized airport. The passengers passing through the station will be using not only the HSR system, but also the other mass transit systems that are expected to interconnect at most of the station locations.

A common misconception among urban planners is that to provide a district-wide transit circulator system, all that should be required is a local bus route or streetcar/light rail line operating along the city streets between the HSR intermodal station and the surrounding urban district. However as noted above, the increase of traffic and densification of the major Texas cities within the urban environment around the station sites will often render at-grade transit solutions ineffective and incapable of providing a suitable carrying capacity. **Figure 2** shows the type of intense multimodal environment that is expected around a major HSR station – operating conditions which substantially constrain the capacity of at-grade transit systems.

SOURCE: Kimley-Horn and Associates, Inc.

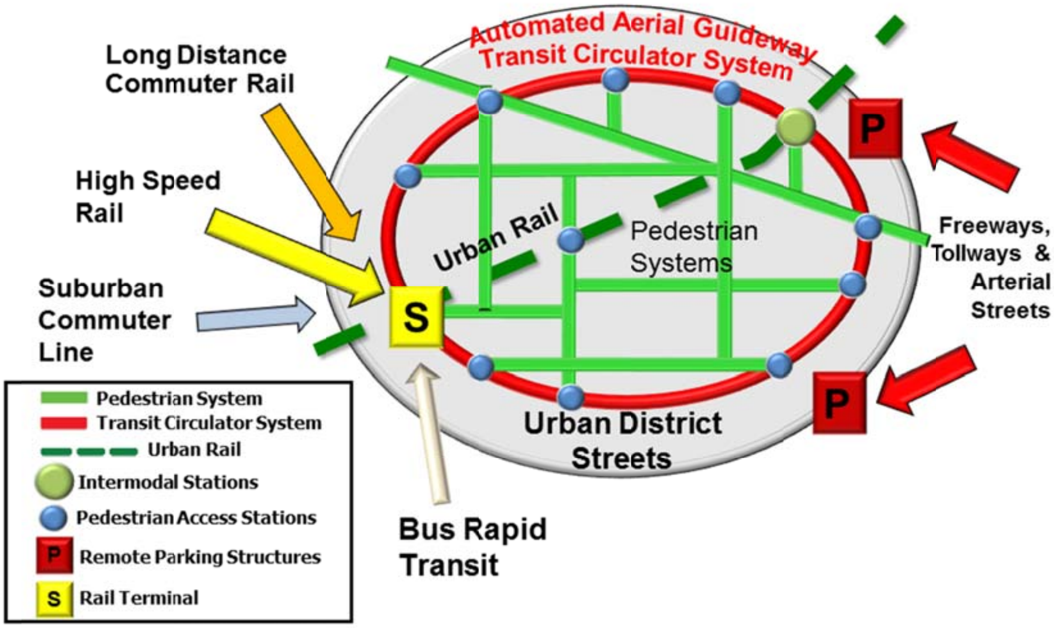
Figure 2 Intense Intermodal Operations Constrain the Capacity of At-Grade Transit

In contrast, grade-separated transit systems can provide substantially greater capacity to meet the high demand conditions that are expected on the district circulator system serving the HSR intermodal station, since the guideways are isolated from the at-grade traffic and pedestrian activity within the urban district. A grade-separated circulator system alignment will provide the necessary reliability of service and passenger carrying capacity irrespective of how traffic congestion builds; and with full grade-separation comes the opportunity to install automated guideway transit technology. These advanced transit technologies include those of automated people mover systems (ASCE, 2013), automated urban guided transport systems (IEC, 2009) or automated transit network systems (increasingly referred to as “pod” systems).

Nearly a half-century of experience has now been gained by the worldwide automated transit industry since the first prototypes were tested, and automated systems are well proven as flexible and effective transit technologies for deployment as a high capacity circulator system within the environment of a dense urban district or major activity center.

When an automated guideway circulator system as illustrated in **Figure 3** is considered as a last-mile solution for a HSR intermodal station, then additional benefits can also be realized for the surrounding urban district served by the circulator/connector system. In particular, intermodal connections can be accomplished even when some of the important transportation infrastructure is located away from the HSR station site.

- <u>Pedestrian Access</u> – An aerial transit circulator system can connect numerous pedestrian access points to the station with pedestrian nodes in other parts of the district, even when these pedestrian nodes are located some distance from the intermodal station or when they are isolated by a major freeway or highway system.
- <u>Transit Connections</u> – Correspondingly, an automated circulator system can provide convenient connections to passengers transferring to of from existing transit lines also serving the district, but which have stations/stops along an alignment some distance away from the HSR station site.
- <u>Perimeter Parking</u> – Finally, aerial guideway transit circulator systems can conveniently connect the district and the HSR station with multiple parking facilities that are often remote from the station, such as parking located around the perimeter of the district where convenient access and egress can be provided to the surrounding local street, arterial and freeway network.



SOURCE: Kimley-Horn and Associates, Inc.

Figure 3 HSR Intermodal Station With Multimodal Connections and Last Mile Circulator/Distributor Automated Guideway Transit System

This application of automated, advanced transit technology on aerial guideways can be described as a "Mini-Metro" system, since transit systems of this type are relatively small and flexible compared to other fixed guideway options, yet provide suitably-high capacity to serve as a full metro system when the application is properly designed. It is the attributes of high passenger carrying capacity, alignment flexibility and reasonable capital and operating costs that make automated aerial-guideway systems ideal for the last-mile circulator/distributor function.

Passenger Carrying Capability – As a general objective, the highest activity levels at some major intermodal stations serving HSR are anticipated to occur in brief periods of time (e.g., 15 minute periods). This peaked pattern of ridership ultimately require a local circulator/distributor transit system with a carrying-capacity suitable for passenger flow rates of 5,000 to 10,000 or more passengers per hour per direction (pphpd) during the surge flow periods. This functional requirement of carrying passengers away from the station site with a high level of service should not be underestimated. An intercity rail passenger who has traveled long distances with extended travel times should not be met with delays of 10 or 15 minutes while they are waiting to board the district circulator system, no matter whether the delay is due to extended operating headways or to inadequate capacity of the circulator system itself.

A fully automated, driverless transit system designed for application as an urban district circulator can provide a moderately-high capacity of up to 10,000 to 15,000 passengers per hour per direction (pphpd). Such carrying capacity can be provided by 4-car trains operating 90 to 120 second headways – assuming that the vehicles are 40 to 50 feet (12.2 to 15.2 meters) long and that most passengers are standing as they make the brief local trip within a district or subregional area. This directional capacity equates to a throughput roughly equivalent to a freeway with 5 lanes in each direction, or a bus system operating with 200 buses an hour in each direction.

Alignment Flexibility – A second key characteristic of automated guideway transit is that the guideway alignment flexibility facilitates the circulator system's insertion into a dense urban environment, in part due to its capability to run short trains on very close headways. The resulting benefits are smaller station platforms and footprints. When combined with the other common attributes of smaller curve radii and steeper grades along the alignment, the aerial guideway systems can be realistically retrofitted into even a fully built environment.

Figure 4 shows the very compact stations in Downtown Miami along the Metromover urban circulator system, demonstrating how automated aerial guideway systems can be integrated into the urban context.

Reasonable Capital Cost – Although in some locations below-grade alignments could be the preferred choice for grade separation of a district circulator/connecter system, the most cost-effective grade-separated alignment for a high capacity transit system is typically achieved with aerial guideways – a configuration which is around half the capital cost of below-grade alignments. A further cost benefit of a fully automated system is that the size and number of trains has no significant impact on the operating cost of the transit line, since there are no drivers or operations personnel required to be continuously present on any train. And finally the capability to operate short trains on very close headways allows the stations to be much smaller in size than more traditional transit systems, which in turn substantially reduces the capital costs. In fact, the total capital costs may be close to the same order of magnitude of capital costs as some projects that have installed conventional at-grade light rail transit within dense urban district environments.

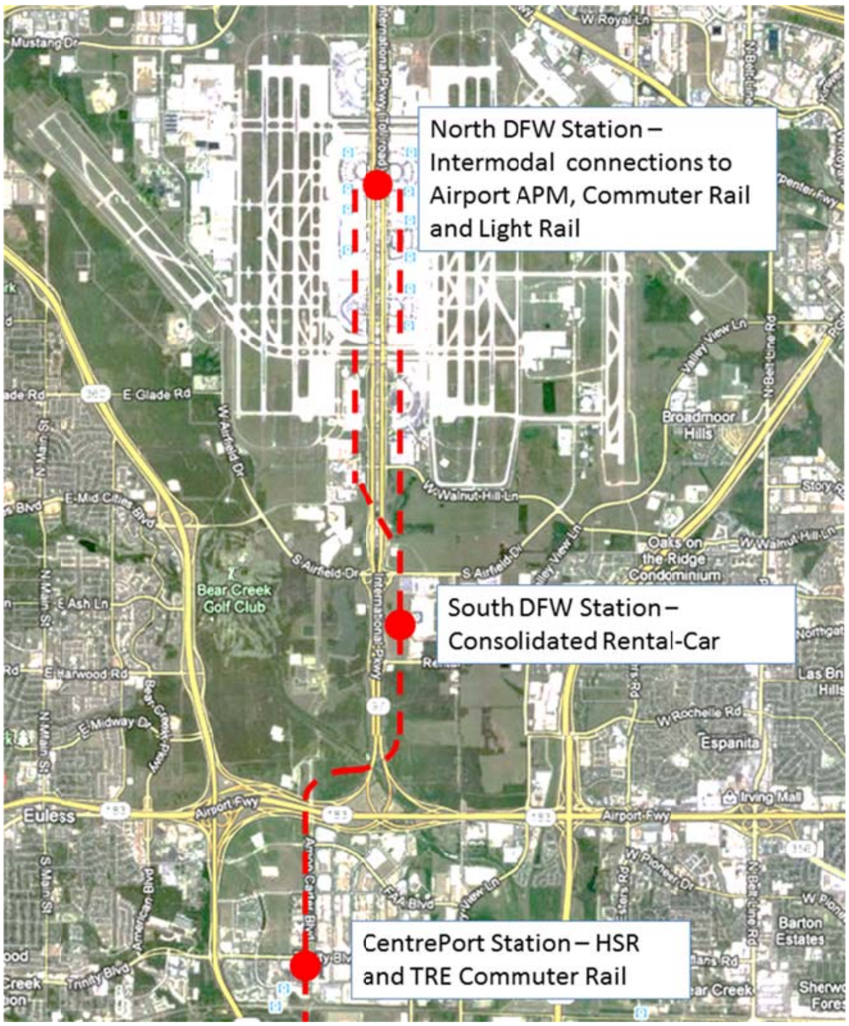
SOURCE: Kimley-Horn and Associates, Inc.

Figure 4 Photos of Miami Metromover Showing a Typical Downtown Station Integrated Into Urban Environment and Flexibility of Guideway Alignment

High Speed Rail Station Area Studies

The application of a fully automated transit system to connect a major intermodal station with a nearby district /major activity center has several precedent-setting projects here in the United States. For over a decade a fully automated, aerial-guideway transit system has been operated by the Port Authority of New York and New Jersey to connect the Northeast Corridor Station (NEC) with the airport terminals, remote parking, ground transportation center and rental car facilities at the Newark Liberty International Airport. The NEC is a major rail station where air passengers connect to high speed trains operated by Amtrak and to conventional intercity and regional commuter trains operated by New Jersey Transit. Recent studies have evaluated the technology and alignment alternatives for a replacement or upgrade to the existing small monorail transit connector system in order to provide increased capacity to serve a planned new Terminal A (Lott, Cronin, 2011).

Figure 5 shows an example that is defined as a conceptual connector system to a station near the Dallas/Fort Worth International Airport. This connector system is being assumed to exist as part of the TxDOT study of high speed intercity passenger rail ridership in order to represent local area connectivity of the HSR intermodal station with DFW Airport. For reference purposes in the TxDOT study, a baseline automated aerial guideway technology used to define this conceptual connector transit system has been established as that of the AirTrain system currently connecting New York's JFK Airport with Jamaica Station in Queens.



Aerial Photo Source: Google Maps
Graphical Concept Source: Kimley-Horn and Associates, Inc.

Figure 5 Conceptual Transit Connector System Between a High Speed Rail Intermodal Station and Dallas/Fort Worth International Airport

This baseline example of an aerial guideway circulator system is a project also conceived and implemented by the Port Authority of New York and New Jersey. The fully automated system provides a direct connection between the Long Island Railroad at Jamaica Station, the New York City Transit at Jamaica Station and Howard Beach Station, and the airport district comprising all airport terminals and the airport landside facilities that provide parking and rental car services. The technology is a rail car with linear induction motor (LIM) propulsion. The system operates along an aerial guideway that was built within a freeway median over a portion of its length. **Figure 6** shows photographs of the JFK AirTrain system and its aerial alignment.

The figure shows that many passengers choose to stand throughout their ride on the AirTrain system, since the duration of the trip is short and the ride is quite comfortable. Seating is available for the any who desire it and the station/platform interface is fully ADA compliant, allowing wheelchairs to easily roll onboard.

SOURCE: Kimley-Horn and Associates, Inc.

Figure 6 JFK AirTrain connects the JFK Airport District with Jamaica Station

Planning Techniques Applying Simulation-Based Analyses

The similarities of airport intermodal functions and HSR station intermodal functions have been noted above, and in light of those similarities there is considerable benefit in utilizing planning techniques and analysis tools that are commonly used to study airport landside, ground transportation and terminal facilities. The TxDOT study of intercity rail ridership and associated HSR intermodal stations is applying the Advanced Land-Transportation Performance Simulation^{TM} (ALPS^{TM}) software in the studies of the station operations and the passenger's access to the various station sites. This software has been applied to studies of ground transportation and terminal facilities at a number of major airports and rail stations, providing a deeper understanding of the multimodal operational dynamics that result from large quantities of passengers arriving and departing on a fixed schedule of transport (Lott, 2007).

Important aspects of the ALPS methodology which are of great benefit in the study of automated guideway transit systems serving as circulator/connector systems for both airports and HSR intermodal stations include:

- Detailed transit circulator/connector system performance, fleet operations and train-by-train ridership analyses.
- Holistic analysis of all modes and all transit systems/lines operating together in one integrated simulation.
- Functional, performance and operational analysis of the multimodal transportation system throughout the entire 24-hour day.

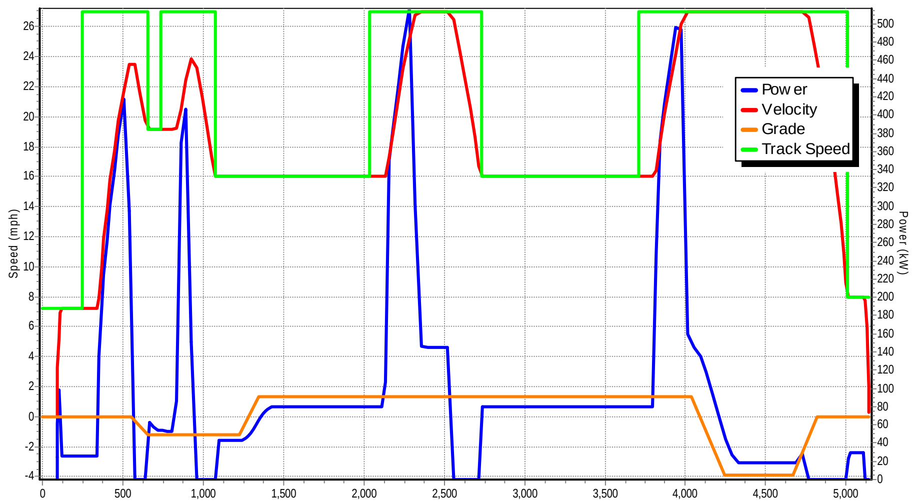
The ALPS models have been used extensively to study automated guideway transit and APM systems of all types in a variety of applications. In fact, when Jamaica Station was expanded to incorporate the JFK AirTrain, during the design phase of the project ALPS simulation studies were conducted to analyze the comprehensive pedestrian environment throughout the station.

The same ALPS simulation models have also been used to study the alternative technologies and alignments for the transit circulator system that connects Newark Airport and the Northeast Corridor Station. The study described previously analyzed multiple alternatives for upgrade or replacement of the existing technology (Lott, Cronin, 2011).

Figure 7 shows a train performance graph of one case study from the ALPS models of Newark Airport transit connector system. The comparative assessment of train performance and fleet operations for the alternative train control systems and vehicle/guideway technologies was one aspect of the study. ALPS was also used to modeled the flow of passengers as they traveled from NEC corridor trains through the station to board the circulator/ connector transit system and then complete their trip a specific terminal destination. The person-trips for all of the pedestrian movements and transit ridership were generated from an airport flight schedule representing the future forecasted air travel and terminal operations.

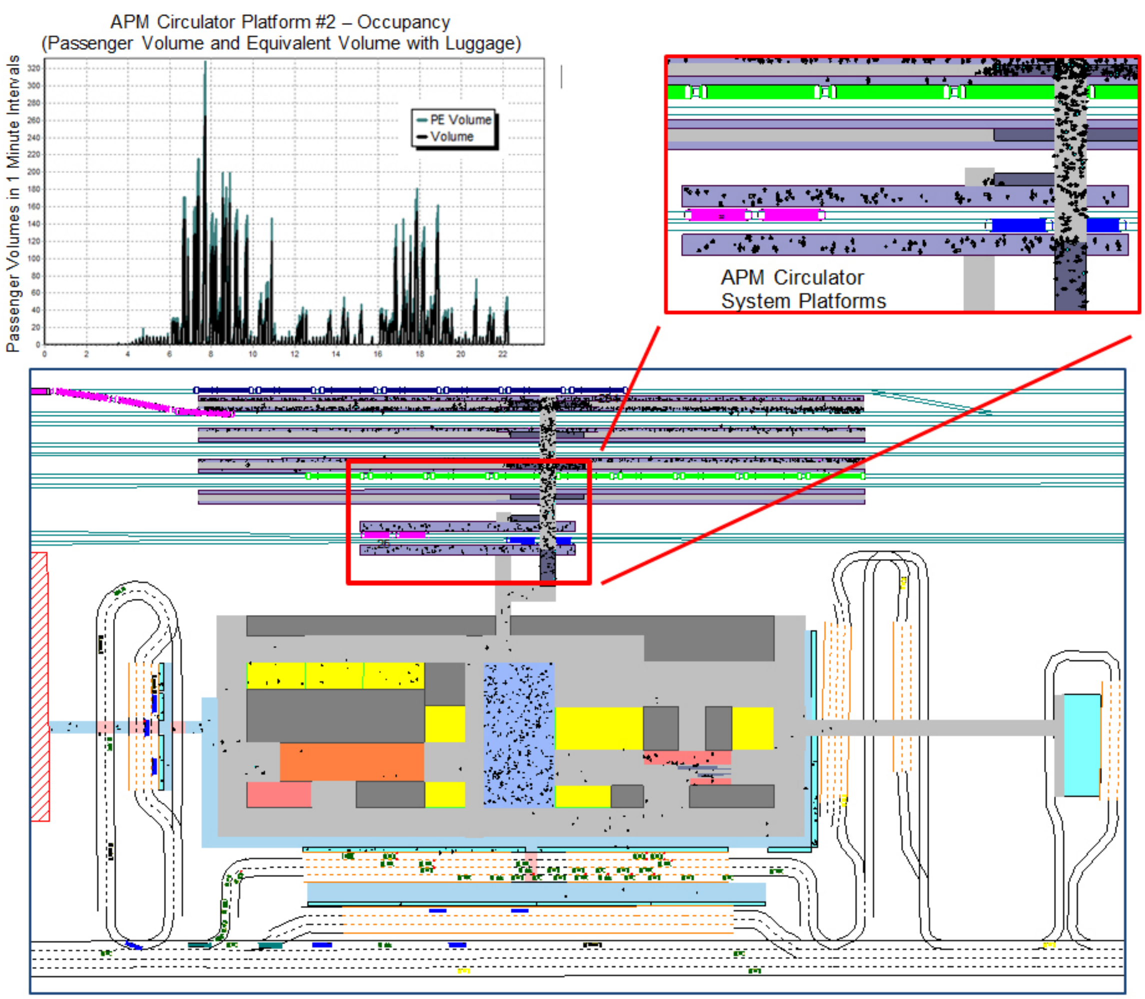
In the same way, the use of simulation models allows the study of a complete operational environment of a HSR intermodal station, with pedestrian, automobile, commercial vehicles, buses, light rail and commuter rail, and intercity trains all dynamically interacting within the station site (Lott, Dixon, 2006). The ALPS analysis tools are being used in this way to analyze the complex intermodal station operation in the initial phase of study of early concepts for the HSR system in Texas. The analysis has practical benefits, even when the stations are only defined conceptually. The vehicular and pedestrian activity is being driven by a hypothetical schedule of trains and ridership, allowing the intensity of activity that is plausible at each station site to be visually portrayed and statistically analyzed.

Figure 8 shows images from the ALPS model of a generic high speed rail intermodal station such as those being used in the early stages of the TxDOT study. The model is providing preliminary insight into the operations of each prospective station in each strategic, high density urban area location that is being considered. The



SOURCE: Kimley-Horn and Associates, Inc.

Figure 7 ALPS Performance and Operations Model of Automated Guideway Transit Circulator System Connecting the NEC Station with Newark Airport



SOURCE: Kimley-Horn and Associates, Inc.

Figure 8 ALPS Model of a Generic High Speed Rail Intermodal Station

analyses of the hypothetical stations foster an effective dialogue with local working groups in each of the major regions that will be affected by the planned high speed intercity rail system. And with respect to the interests of this paper, the figure also illustrates the benefits of analyzing the ridership demands placed on an automated transit connector system under the different scenarios for station operations.

The boarding and alighting of the automated transit connector system ridership can be analyzed train-by-train, as well as for the intermodal station as a whole. Using the ALPS simulation as a conceptual planning tool, the platform densities, vertical circulation flows and access corridor level-of-service can also be quantified to assess the impacts of surge flows resulting from the overall schedule of arriving and departing trains.

CONCLUSIONS – The Role of APMs as HSR Station Connectors

High speed rail systems in the United States are expected to require major intermodal stations in some urban locations where high capacity transit infrastructure does not currently exist. This insertion of major HSR station facilities may require new transit infrastructure to be built that connects these intermodal stations with the surrounding district, especially when at-grade transit is seriously hindered by traffic congestion. Under such circumstances, it is concluded that the installation of grade-separated aerial guideway systems operating with fully automated trains can be an important element of the station area infrastructure when a high capacity connector system is required to serve the HSR intermodal stations.

All classes of automated system are candidate technologies to serve as connector systems, depending on the specific needs and demand requirements of each unique station site. Conventional automated guideway transit technologies with self-propelled vehicles are the anticipated norm for transit circulators that connect HSR intermodal station to the surrounding urban districts. However, some shuttle APM technologies (e.g., cable drawn systems) could also play an important role under some circumstances. For other applications where the demands are within a range suitable for automated transit network/PRT systems (i.e., pod systems), the demand-responsive nature of these new technology systems will also be an important part of the last-mile solutions to serve HSR stations in the years to come.

Due to the complexities of the intense intermodal activity and the dense urban settings within major downtown districts, the use of simulation models like those utilized to study airport landside and terminal environments is proving very beneficial in the Texas Department of Transportation study of HSR stations. The ALPS models are particularly useful to analyze the surge flow conditions as passengers move to and from the various transportation modes. In addition, the operations of the automated connector system can be beneficially studied using the ALPS simulation analysis tools, and in particular these analysis techniques can test the size and service frequency required for the connector system trains. Further, the suitability of alternative APM shuttle systems or automated network transit/PRT can be tested using simulation tools to determine the best technology application at each specific station/urban district location.

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