Passenger Boarding Station and Curbfront Configuration Concepts for On-Demand Services with Small Automated Vehicles

Preprint

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Presented at ICTD 2022: International Conference on Transportation and Development
Seattle, Washington
May 31 – June 3, 2022

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Conference Paper
NREL/CP-5400-81976
June 2022

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Contract No. DE-AC36-08GO28308

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Suggested Citation
Lott, J. Sam, Stanley E. Young, Andrew Duvall, and Alejandro Henao. 2022. *Passenger Boarding Station and Curbfront Configuration Concepts for On-Demand Services with Small Automated Vehicles: Preprint*. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5400-81976. https://www.nrel.gov/docs/fy22osti/81976.pdf.

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National Renewable Energy Laboratory
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Golden, CO 80401
303-275-3000 • www.nrel.gov

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Passenger Boarding Station and Curbfront Configuration Concepts for On-Demand Services with Small Automated Vehicles

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ABSTRACT

This paper explores the various configurations of off-line stations and vehicle berthing that have been found to be fundamentally important parameters in the analysis of system performance, operations, and capacity. The proposed Automated Transit Network system concept, which provides a direct ride between a passenger's origin and destination station, is applicable to both fixed guideway automated transit and to systems with self-driving vehicles. Addressed at a conceptual level are the vehicle/station interface in terms of Americans with Disability Act compliance and station capacity concerns. The concept of open-edge platforms monitored by advanced sensing technology combined with artificial intelligence-powered perception for the purpose of protecting passengers from entering the active vehicle lanes is also discussed. Finally, the paper draws initial conclusions on how these station configurations, operational complexities, and associated costs can be better understood through appropriate research and development.

INTRODUCTION

This paper explores concepts for automated vehicle transit station and curb front configurations and their related operational considerations on a conceptual level only, though drawing from a body of quantitative analysis over the last 20 years—particularly from automated transit network research and design. The development of concepts and the associated high-level assessments provide an initial framework for continuing research. Analytical studies of facility operations, comparisons to similar facilities in airports and urban centers—such as valet parking and transportation network company (TNC) loading at curbs—and the associated adaptation of existing infrastructure such as parking structures will be addressed in future research.

Precursors from PRT Systems. Over the last 20 years, passenger station configuration concepts have been studied for fully automated transit systems designed for small vehicles that provide a direct ride between a passenger's origin and destination station without other station stops in between. Historically referred to as personal rapid transit (PRT) technology when configured this way, this type of system has been extensively analyzed to understand the associated capacity implications, fleet size requirements, and operational complexity. However, during that same 20 years, only a few systems of this type have ever been built and operated. Two well-known examples are the ULTra PRT system operating at London Heathrow Airport's Terminal 5 (popularly called the "Pod System") and ZF/2getthere's PRT system at Abu Dhabi's Masdar City master planned

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development. Both systems have self-driving vehicles that steer themselves along their dedicated transitway and turn into diverting paths without the use of physical or mechanical devices such as guideway switches mounted either on the vehicle or on the guideway.

Figure 1 shows photographs of these two different four-passenger vehicles parked in their station berths, which are located off the mainline to allow other vehicles to pass without any operating delays. A key feature common between them is that the transitway on which the vehicles run is exclusively dedicated to the operation of these vehicles, with no other vehicles or pedestrians allowed in the protected right-of-way—thus their inclusion in the type of automated systems classified as "fixed-guideway" systems.

Masdar City PRT station configuration
Source: 2getthere, a subsidiary of ZF Group

Heathrow Airport PRT station configuration
Source: https://www.ultraglobalprt.com/photos-videos/photos/
Accessed 12 January, 2022

Figure 1. Operating PRT systems with small, self-steering vehicle technologies.

In more recent years, the new self-driving automated roadway vehicle technology is developing rapidly. It will soon allow completely automated transit-like service to operate along at-grade surface roadways with pedestrians present and, in some applications, there are already automated vehicle deployments also interacting in mixed traffic on city streets with conventional, human-operated vehicles.

This new class of automated transit vehicle is typically identified under the broader category of automated vehicle (AV) technology, with demonstration pilots operating fleets of up to a few dozen vehicles in managed systems. The respective vehicle sizes now in development range from small 2-passenger specialty vehicles to automotive-scale vehicles that carry 4 to 6 passengers, and all the way up to larger vehicles the size of small 10- to 24-passenger buses.

Figure 2 shows a mini-bus size "AV shuttle" that is now deployed in the Netherlands at the Rivium Business Park near Rotterdam. This vehicle represents a "cross-over" technology that began its development for exclusive travel lanes (i.e., similar to a "guideway") but which is now being prepared to extend service beyond the dedicated transitway to enter mixed traffic operations on city streets.

AUTOMATED TRANSIT NETWORK OPERATIONS

Throughout this paper, terminology will be referenced that has been codified by the 2021 release of the American Society of Civil Engineers (ASCE) Automated People Mover (APM) Standards (ASCE 2021). An Automated Transit Network (ATN) is now defined in the APM Standards as a system of automated vehicles configured with "all stations off-line, switching that requires no track-based moving parts and train capacity less than 25 passengers." With these features, the ATN form of operations is distinct from the classical fixed-route, multi-car train APM operations. The off-line station features allow for a robust demand-response dispatching of individual vehicles to carry their passengers directly to their destination station without other station stops.

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The ZF/2getthere GRT shuttle will soon provide automated vehicle operations in mixed traffic.
Source: 2getthere, a subsidiary of ZF Group

Shuttle deployment in Rivium Business Park near Rotterdam has wheelchair compatible level-platform boarding at stations.

Figure 2. Automated transit system with AV technology operating along a roadway facility.

The authors propose that this definition of "ATN," and the station configurations that are off-line from the main transitway route, can also be applied apart from the traditional "fixed guideway" class of APM systems that are covered by the ASCE 21 APM Standards. Specifically, it is proposed that the ATN operating concept with its on-demand service from off-line stations is also applicable to vehicle systems that can operate in a fully automated, unmanned mode of passenger service. This definition includes the class of small "transit-scale" vehicles that have mini-bus size capacities of 10 to 24 passengers, which meets the definition of ATN systems given in the APM Standards, while being inherently designed to carry multiple travel parties along a route. The small-bus size of vehicle technology (**Figure 2**) is readily adaptable to provide not only fixed-route transport, but also demand-responsive ATN type operations. When the associated stations are configured to be off the mainline, this can facilitate the direct dispatch of vehicles by their automated supervisory control system to transport passengers between a specific origin station and specific destination station(s) without unnecessary intermediate station stops.

It is further proposed that the ATN terminology, particularly with respect to the operating system concept with off-line stations, is also applicable to vehicle systems that will eventually operate in a fully automated, unmanned mode—providing customized, on-demand passenger service. Another example concept that can fit the ATN operating system definition is that of on-demand "ride-hailing" AV services, such as the well-known developments underway by Waymo and Cruise. The authors are monitoring another shared-ride on-demand AV car service that is currently operated as a demonstration pilot project in Arlington, Texas. The automated driving system (ADS), comprising artificial intelligence-powered (AI-powered) sensing technology and robotic controls to steer the vehicle safely through traffic, is operating as a component of the city's Rideshare, Automation, and Payment Integration Demonstration (RAPID) service. Although this on-demand service is managed by the City of Arlington as part of their existing public rideshare service in the downtown area (provided by VIA), RAPID is essentially a demonstration of an automated service typically identified for TNCs such as Uber or Lyft. **Figure 3** shows the Lexus RX450 hybrid-electric vehicles that are being automatically driven by May Mobility's ADS technology, with a safety attendant onboard.

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Figure 3. Arlington's RAPID Lexus RX450 vehicles use May Mobility's ADS technology.
Source: City of Arlington, Texas

From this proposed expansion of the ATN definition beyond the domain of a fixed guideway APM system by applying the ATN operational concept to both small, single travel-party size vehicles as well as to larger multiparty size transit vehicles, a systems view is presented below for these types of transport services with automated control and operational attributes.

ASSESSMENT OF STATION CONFIGURATIONS

Through modeling and simulation, past studies have found that the vehicle berthing strategy employed at boarding locations is fundamentally important for small-to-medium size vehicle ATN systems. The configuration of individual vehicle berths in a serial versus a parallel sequence has both practical and strategic impacts on station performance and capacity. **Figure 4** shows examples of these two basic types of vehicle berths within an off-line station.

The serial berth concept shown in the figure does not allow a following vehicle to pass the leading vehicle within the station, and any delays in loading or unloading of passengers of the lead vehicle will correspondingly delay all following vehicles. This can have serious capacity implications when a passenger intentionally delays the boarding process to wait for other persons in their travel party, becomes confused or medically ill, or needs additional time to board because of a disability. Such situations could indefinitely delay a lead vehicle and effectively halt the station operations for all following vehicles.

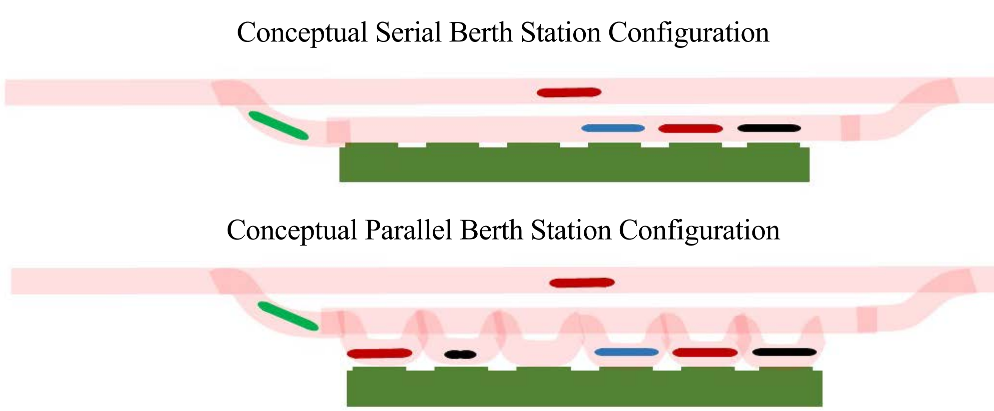

Figure 4. Comparison of station serial berth and parallel berth configurations.

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Parallel Berth Advantages. In comparison to the serial berth configuration, **Figure 4** also depicts a parallel berth configuration by which each vehicle can enter a station lane, maneuver to an open berth, and dock at the berth without first requiring other vehicles to move or dispatch into operation.

The "parallel berth" configuration provides for a passing lane inside the confines of the off-line station such that each vehicle entering or exiting its assigned station berth can maneuver around vehicles that are in position at other station berths. This is also the typical configuration for a curbfront operation when it is not directly adjacent to the roadway's main operating lanes.

As depicted in the figure, a parallel berth configuration provides more flexibility for accommodating automated vehicles of different sizes at common station berths when station equipment and infrastructure is deployed to better ensure safe and efficient operations—a topic addressed in a subsequent section.

Another key advantage of the parallel berth station configuration is that dispatching of other vehicles from a "leading" berth(s) is not required when another vehicle needs to be dispatched into service from a "following" berth position. **Figure 5** depicts an example in which a vehicle in the last berth on the far left can begin its dispatch from the station without necessarily having to wait for all vehicles in leading berths ahead of it to first dispatch themselves, as would be required with a serial berth configuration. This operational flexibility of the parallel berth station configuration will also have significant implications for station management when a shared-ride service is being provided, as discussed further in a subsequent section.

Figure 5 additionally shows the effectiveness of parallel berths when platooning of vehicles is beneficial on the mainline or within the street lanes adjacent to the station or curbfront.

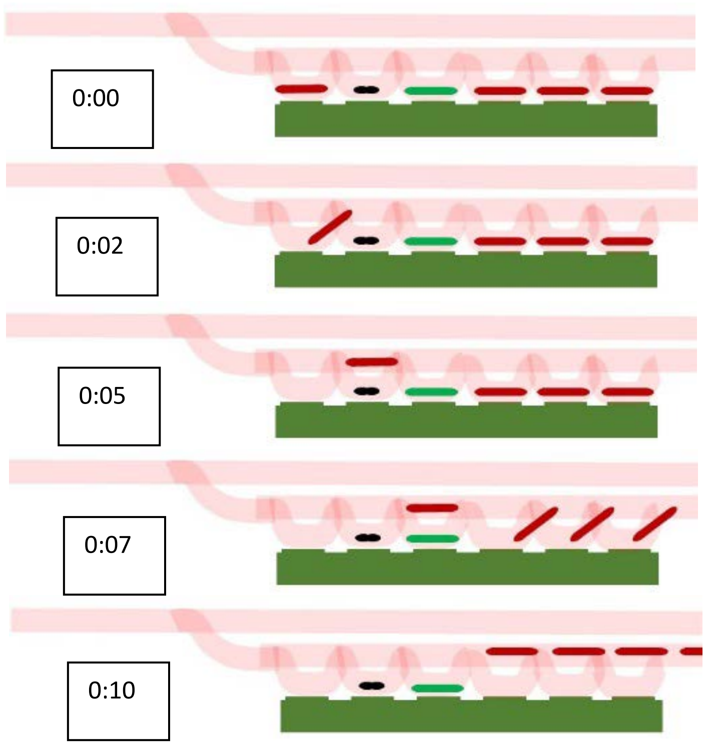

Figure 5. Parallel berth station concept allowing dynamic reconfiguration of AV platoons.
Source: Technical paper presented at the 2016 ASCE Intl. Conference on APMs and Automated Transit Systems (Lott 2016).

Through the application of "virtual coupling," any available berth(s) at the off-line station can be utilized by vehicles arriving in a platoon, and new configurations of the platoon can be

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accommodated by the supervisory control system's concurrent dispatching of vehicles that are bound for a common destination (Lott 2016).

Impacts of Station Footprints. This highly flexible operational benefit of parallel berths in off-line stations comes at the expense of the station's enlarged footprint when the extra lanes providing bypass capabilities for the individual vehicle berths are considered. The price for large station footprints when the station vertical alignment is either above or below grade can be quite large compared to stations located at ground level. However, there are situations where the real estate necessary to create surface-level stations (or extensive curbfront facilities) is simply not available, and aerial facilities are the only option. As a general rule of thumb, station structures on aerial alignments are twice the cost of at-grade stations, though only half the cost of subsurface stations.

An additional consideration of the station footprint when specific vehicle technologies are being analyzed is their minimum turning radius capability, and the provisions required for "nosing and chording" clearances as the vehicles turn into and out of the parallel berth positions. These factors and characteristics make the planning and conceptual layouts, operational analyses, and early design studies critically important when automated systems are to provide on-demand service for every passenger.

Figure 6 shows a simple concept that can be considered for this type of off-line station with parallel berth configurations, when the enlarged station footprint providing this ultimate operational flexibility is possible to accommodate. Although geometrically simplistic as shown, the circular configuration allows any berth on either side of the passenger boarding platform to serve any vehicle arriving or departing in either direction. As a result, this station concept is very efficient at the system operations level.

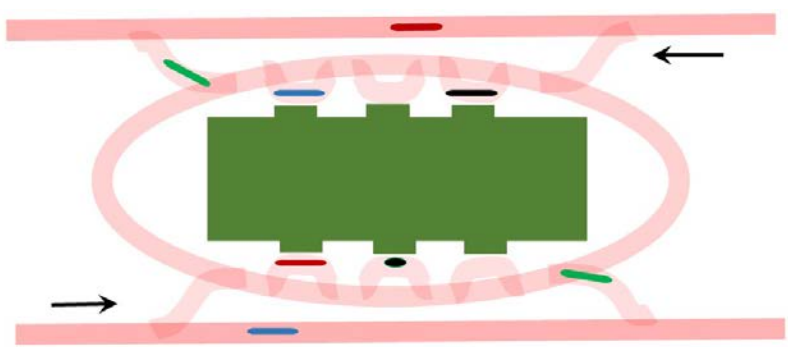

Figure 6. Bidirectional station with maximum operational flexibility.

Such a berthing configuration was utilized in the recent construction and operation of the Las Vegas Convention Center (LVCC) Loop System by the Boring Company. The system comprises a three-station underground transit system that connects the three halls of the convention center. The system currently utilizes manually driven Tesla vehicles to shuttle convention attendees between stations. As shown in **Figure 7**, the central station is underground and exhibits off-line parallel berths for curbside boarding/alighting, thereby allowing other vehicles to bypass those already at the station and circulate to find open berths.

Accommodation of Stations in Dense Urban Settings. Integrating these stations into the built environment as multimodal junctions for pedestrian access to AV transit and AV on-demand ride-hailing transport will be a key challenge for establishing automated mobility services in dense urban settings. One possible solution can be seen in **Figure 8** from the example of the design decisions made in the early 2000s for the London Heathrow Airport Pod System.

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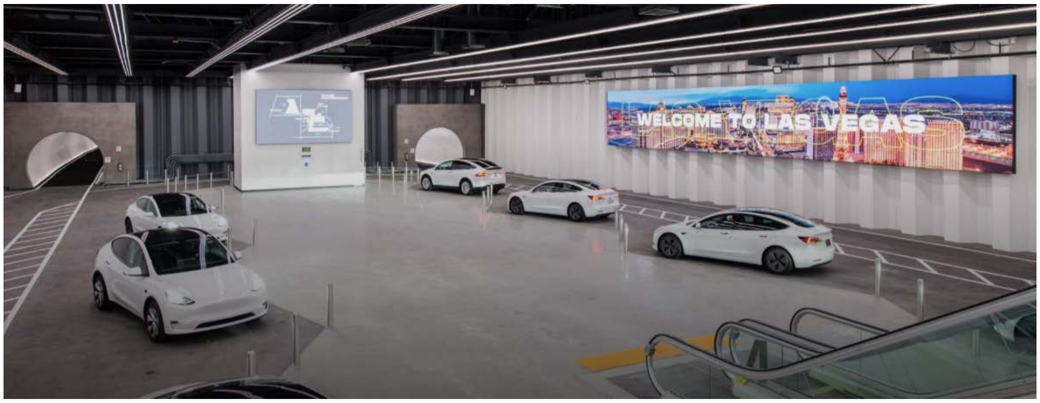

Source: The Boring Company website – https://www.boringcompany.com/lvcc Accessed 23 January 2022

Figure 7. Bidirectional station with parallel berths at LVCC Loop System Central Station.

London Heathrow Terminal 5 Pod System with lightweight transitway structures

Source: Photo library of J. Sam Lott

Source: Photo library of J. Sam Lott

Source: Google Earth

ULTra PRT technology installed as a retrofit system in the Terminal 5 ground transportation structures and parking garage facilities – **Refer also to Figure 2 above.**

Figure 8. Example parking garage structure use for retrofit of ATN small-vehicle system.

Terminal 5 was already in operation when the decision was made to install the ULTra PRT system to connect the terminal to a remote parking facility. The lightweight vehicles allowed a low-cost transitway structure to be built spanning across and weaving through the terminal roadways. However, space in front of the terminal was already allocated to other modes, and the installation of aerial structures to place a station there was not possible. Therefore, the decision was made to repurpose one of the levels of an existing terminal parking structure to provide a place for the

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Terminal 5 Pod System station to be inserted. **Figure 8** shows photographs of the lightweight transitway structures, and the parking structure accommodations made to retrofit the automated transit system into the built environment.

This approach of repurposing selected levels of a parking structure is an important concept that is also relevant to successfully deploying small- to medium-AV transport technology into dense urban settings in the coming decades. The repurposing/retrofitting of new intermodal junctions, where pedestrians can conveniently access and board the ATN transport system(s), whether AV transit or AV on-demand ride-hailing services, provides a practical and cost-effective option that should be studied further. This reuse of parking structures is highly relevant as the need for private parking of privately owned vehicles is forecasted to decline, and as AV transport systems mature. Mode shift to automated transport is expected to occur in the coming decades as more people choose these new modal options for many of their personal trips.

Reuse of parking facilities for passenger transfer is increasingly found at airports for the management of ride-hailing transactions, as well as many facilities throughout the United States in which curbside access traffic activity has saturated available capacity. A common example is found with the dedication of one floor of an existing garage for passenger pickup, with various off-line berthing configurations to maximize customer exchange throughput capacity and safety.

COMPLEXITIES OF HIGH-CAPACITY AUTOMATED TRANSIT NETWORK STATION OPERATIONS

Analytical studies of fully automated transport systems with small ATN vehicles supplying on-demand passenger service have found that a practical system capacity is generally not determined by the throughput capacity of the system's mainline transitways. **Rather, capacity is typically determined by the throughput capacity of the stations where the highest demand exists for passenger boarding and alighting.** Thus, the station configuration challenges, the factors impacting station operational complexity, and the associated integration into the built environment are all critical to ensure adequate system capacity. Note, this is not unlike freeway capacity where breakdowns of flow typically occur at exits and entries, and not as a result of fundamental lane capacity restraints on the mainline.

Adding to the challenge of station/intermodal junction configuration and capacity provisions when deploying AV technologies operating on city streets are other factors that have not been addressed at typical TNC/ride-hailing curbfront facilities. Specifically missing are the provisions that concern the Americans with Disability Act (ADA) requirements, which are already defined for transit systems in the United States. These have been codified for fully automated guideway transport systems in the APM Standards.

Provisions for Disabled Passenger Boarding. ADA provisions for fully automated guideway systems have been addressed in the ASCE 21 APM Standards, with the full concurrence of the U.S. Department of Transportation. The basic ADA requirements allow a mobility-, sight-, or hearing-impaired passenger to safely navigate the boarding process without other human involvement, such as from vehicle or station attendants. These requirements are highly relevant to the station and intermodal junction curbfront configurations, specifically when using dedicated berthing positions for each vehicle being boarded. In many ways, the single most complicated situation is the boarding and alighting of automated vehicles by passengers in wheelchairs.

In recent years, pilot projects deploying AV technology have generally not demonstrated a fully compliant ADA solution for vehicle boarding by wheelchair-bound passengers, usually because the slope of the wheelchair access ramp is too steep. And even when the slope is sufficient,

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the wheelchair ramps or bridge plates that are built into the vehicle or provided at the boarding platforms require dedicated vehicle or station attendants to perform the ramp deployment. This approach of ramp (or wheelchair lift) deployment falls short of the design objectives for providing unmanned, automated vehicle operation that meets existing ADA regulations.

The solution required by the ASCE 21 APM Standards is for a design providing a common boarding elevation between the platform and the vehicle doorway threshold. This wheelchair "roll-on" design requires a precise docking of the vehicle at the station berth—both in in terms of the vehicle floor elevation accuracy under all load conditions and the horizontal gap between the station platform edge and the vehicle doorway threshold.[1]

Figure 2 shows this type of provision met by the AV shuttle system technology now operating in the Netherlands. The vehicle performs a precision docking maneuver to align the vehicle doorway and its threshold with the raised platform edge. This example supports the ultimate design objective proposed for all future ATN systems by reference to the ADA requirements stated in the ASCE 21 APM Standards.

The associated requirement for "precision docking" by self-steering AVs has been identified in recent years as a key design feature for AV technology applications to meet existing U.S. Department of Transportation government policy[2] (Gettman 2017). A common design feature of fully automated guideway transit systems is a design with special system and vehicle equipment, which ensures localization accuracy as the vehicle approaches the station berth. This same design feature is an essential element of vehicle berth design for stations/curbfronts, particularly for AV technology designed to operate on city streets and to board passengers at designated berthing positions along multimodal curbfront facilities.

Provisions for Ride Sharing. Further complications are imposed on the station configuration and passenger facility designs necessary to maximize the station throughput capacity when ridesharing is added to the station operational management requirements. Although current TNC ride-hailing protocols typically use smartphones to provide connections between passengers and their drivers by identifying the vehicle make/model and color as passengers wait at a designated curbfront, this is not considered to be a viable option when the human driver is removed from the vehicle and when all the ATN vehicles are essentially identical in appearance.

This challenge is further complicated when the automated system must communicate to different passenger travel parties the information on where to board for their destination when accessing a small-vehicle ATN system at a large multi-berth station or intermodal curbfront. The use of kiosks and display monitors like those used in airport concourses to direct passengers to their proper gate for their departing flight is a plausible AV station/curbfront solution for industry consideration and development. This approach inherently requires that passenger flow through the station/curbfront facility be configured in a logical way that allows them to quickly locate their departure vehicle's berth, while not imposing significant delays to their time in the station. The use of dynamic signage at vehicle berths may be an important aspect of addressing this operational

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[1] The ASCE 21, Section 7.3 Clearance in Stations has a requirement that calls for the vehicle floor and doorway threshold height to be within 0.625 inches of the station platform level and for the doorway threshold edge to have no greater than a 2.0-inch gap with the platform edge.

[2] Refer to the discussion of precision docking in APPENDIX B Examples of Station Precision-Docking Subsystems, found on page 30 in Working Paper #4 Operating Agency Policy – Potential Issues and Changes Required, prepared for the 2017 TRB Study (Gettman 2017). Working Paper #4 was accessed on 14 January 2021, from the identified link found on the associated project webpage at: https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3935.

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complexity, potentially supplementing instructions on passengers' smartphones. Some airport high-capacity TNC stations already use a series of labeled lanes (A, B, C …) and berths in each lane (1,2,3 …) to help passengers and drivers easily locate each other.

Figure 9 shows another example of a large screen monitor that designates the station berths available to boarding vehicles bound for the other station destinations on the Las Vegas Convention Center Loop System.

Source: Stanley Young

Figure 9. Station dynamic signage designating berth locations for the LVCC Loop System.

Such station and system operational aspects and the associated passenger information factors that must be vetted in the station/curbfront facility planning and design process add complexity; however, they are proposed as essential design elements for creating large multimodal stations that provide high passenger throughput.

INTELLIGENT INFRASTRUCTURE TO SIMPLIFY STATIONS

Traditional APM designs incorporate physical barriers at the edge of the station platform to elevate safety during the boarding and alighting process. In fact, most modern automated people movers in high-ridership environments use full height partitions with station doors that open simultaneously with the vehicle doors in a similar fashion to elevators. Such configurations are found throughout the United States at airport APMs and have also been applied to the ATN implementations at Heathrow and Masdar. Such physical infrastructure is effective for conventional APM systems, but it adds substantial station design complexity and expense when applied to high-capacity (multi-berth) stations envisioned for ATN systems at large-scale deployments. Further, platform edge for large ATN systems may impede efficiency of operation as well as reliability and resiliency of the system.

At the conceptual level, there are trade-offs between fixed facility station infrastructure such as platform edge partitions and automated station doors compared to more "lightweight," simplified station facilities with open-edge platforms monitored by appropriate sensing technology. The latter, until now, has been the domain of curbside facilities for traditional automobile operations—such as are common for taxis, TNCs, and even bus and bus-rapid-transit operations. However, lightweight, ADA-compliant berthing and vehicle interaction are needed for scaling of fully automated ATN operations with minimal costs. The ASCE 21 APM Standards allow for open platforms without edge partitions or automated station doors when suitable sensing technology is used to detect a passenger within the dangerous space near the platform edge, although available technology capabilities in the past have generally not provided good solutions for this open platform edge option.

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New Development in Infrastructure Perception and Control. The rapid advancement of new types of spatial sensing technologies are poised to change the viability of safe automated system operations with open-edge platforms. These technologies—such as radar, LiDAR, and stereo video camera systems that can locate and track all objects in the field of view—are quickly maturing through AV technology research and development. Sensor stacks that were pioneered for providing AVs with sufficient perception to safely navigate roadways are currently being repurposed to provide roadway intersection traffic controllers a full operating picture of all approaching and departing vehicles, as well as pedestrians, bicycles, and other active modes of transportation. Through the machine perception powered by artificial intelligence, the ability now exists for AI-powered sensor stacks to monitor dangerous situations, such as near misses resulting from failure to yield and detection of vehicles within defined dilemma zones. Precedence for use of sensing and information systems for safety management is also seen in highway operations, where first-generation radar, LiDAR, and video image processing are being applied to address wrong way driving hazards on freeways.

The next logical application to the transit station and curbfront berthing locations is that of sensing and detection technology, combined with AI-powered perception to provide a forward path for cost-effective high-capacity stations. Design and operation of such applications need appropriate research and development to help protect passengers from entering the active vehicle lanes or dynamic vehicle operating envelope when the edge of the platform/curbfront is not completely protected by a physical partition. As with many ATN curbside berthing operations, the dedicated TNC ride-hailing curbfront interface at many high-capacity passenger interchanges offers an opportunity to observe and study hazards. Further, this research may offer not only significant applicability for ATN deployments, but also present opportunities for innovation in current TNC and similar operations using traditional human-operated vehicles. As with our current roadway system, multiuse space (such as lanes that convey passenger cars and trucks, bicycles, and freight) provide a robust, cost-effective, and shared transport system, so fully automated ATN stations, berths, and curbside areas also need to be engineered for maximum space efficiency while retaining safety for all operations.

CONCLUSIONS ON SYSTEM-LEVEL RESEARCH AND DEVELOPMENT FOR INTELLIGENT STATIONS

The concept advanced in this paper of using small, lightweight vehicles to deliver on-demand, personalized, automated, and direct origin-to-destination service for either a private party or multiple parties in a shared-ride context has been envisioned since the 1970s for automated systems operating on guideways. This paper uses the new ATN terminology from the APM Standards broadly applied to mobility-on-demand services by automated transit and ride-hailing fleets of automated, self-driving vehicles operating along either protected or semi-protected transitways, or even roadways in mixed traffic.

A first conclusion is that research is needed to understand the operational and capacity implications of this type of mobility, particularly with respect to station configuration, ADA compliance, and ridesharing provisions. Station configurations for ATN systems are critical because these will substantially impact the overall system capacity, operational safety and, for the most part, the viability of the system in terms of its cost. The operational complexities and the associated costs of alternative station configurations (such as serial or parallel berths) can be better understood for AV-based public mobility systems through appropriate research and development, both at the system level through planning and analysis, and at the operational level through initial demonstration and

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deployment. Some data can be gleaned from current high-capacity TNC boarding areas as they are typically operating at airports, serving as valuable benchmarks for initial design considerations.

This leads to a second natural conclusion that the associated station boarding platforms and curbfronts are an important new realm for the application of AI-facilitated sensing and detection technology, creating what can be called an "intelligent station" or "intelligent curbfront." Demonstration of sensing and perception using advanced detection systems and machine intelligence through research and development testing and performance evaluations will greatly advance understanding at the individual station level. These intelligent station deployments can then be expanded to an appropriate system-level implementation through larger-scale operational testing and demonstration pilot projects. Indeed, the application of advanced perception technology at existing TNC stations and curbfronts would yield previously uncaptured operational data.

The expectations of transportation planners, city transportation officials, and transportation agencies are that the justification for implementing fully automated on-demand transport systems comes from achieving mobility at a level where station waiting times never exceed a few minutes before a passenger can board. Ultimately, focused research and development initiatives such as those described in this paper will be necessary if this goal of deploying automated transport systems that accomplish the industry's "mobility-on-demand" objectives is to be fully achieved.

Accomplishing these goals and objectives over the next decade will require that individual station-level design and operation, as well as system-level performance demonstrations should be advanced through focused research endeavors involving simulations, operational testing, and demonstration pilot projects. This kind of facility, infrastructure, and systems research is now becoming as important as the continuing research and development underway for automated vehicle technology.

ACKNOWLEDGMENTS

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support was provided by the DOE Vehicle Technologies Office Technology Integration Program. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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