Land Transport Authority

GRANT CALL FOR DESIGNING BUS STOPS, TAXI STANDS AND PICK-UP DROP-OFFS FOR AN AUTONOMOUS VEHICLE FUTURE

1. OVERVIEW

1.1. Autonomous Vehicles (AVs) have the potential to provide commuters with a safe, inclusive and efficient mobility option. Most of the research on AVs are focused on improving the accuracy, reliability and affordability of in-vehicle technologies. To strengthen Singapore's AV readiness, research is needed to identify the potential gaps and challenges posed by existing infrastructure for AVs. Bus stops, taxi stands, and Pick-Up Drop-Offs (PUDOs) are dedicated spaces where commuters board and alight from vehicles. As Singapore prepares for a transition towards having AVs operating on public roads, there is a need to determine if AVs would be able to smoothly and safely manoeuvre through these facilities to pick up or drop off their passengers.

1.2. During this period, bus stops, taxi stands and PUDOs will be complex and busy environments where manned vehicles and AVs interface with commuters, especially during peak hours. It is hence important to understand the impacts of AV activity on the flows and interactions at these facilities. This includes the interaction of AVs with the existing infrastructure. With the exception of bus stops, there are no standardised design specifications for taxi stands and PUDOs at residential and commercial developments. The varied designs of existing taxi stand and PUDOs make them potentially challenging for AVs to operate in.

1.3. Having a standardised design that is recognisable by AVs and removing the physical hinderances to their navigation could help to accelerate the adoption of AVs and ensure a safe and efficient operating environment at bus stops, taxi stands and PUDOs. The use of Vehicle to Infrastructure (V2I) technology can also provide additional support and coordination, lowering the cost of AV deployment.

1.4. Commuters and drivers of manned vehicles contribute to the other forms of interactions found at bus stops, taxi stands and PUDOs. Understanding their behaviour and needs when using these facilities would help infrastructure providers design a safer and more user-friendly space with AVs in the picture.

1.5. LTA and URA are interested to better understand the potential challenges that existing bus stop, taxi stand and PUDO designs pose to AVs, and investigate how these facilities can be designed and equipped to facilitate AV deployment and greater user experience. Recommendations from the study will contribute to the formulation and review of guidelines or standards to ensure the safe operation of AVs with other manned vehicles. The early establishment of such guidelines would also help avoid the need for costly retrofitting of bus stops, taxi stands and PUDOs in the future.

2. SCOPE

2.1. This grant call seeks research proposals that articulate a comprehensive approach to identify good design recommendations and strategies that facilitate AV operation at bus stops, taxi stands and PUDOs, during the transition period. The study shall include public bus stops as well as taxi stands and PUDOs at commercial, residential, mixed-use buildings and public transport node developments. It shall also cover three types of AVs – AV buses, AV shuttles and AV sedans (7-seaters and below). The research team is to work closely with the relevant agencies on the selection of bus stop, taxi stand and PUDO typologies and eventual pilot site(s).

2.2. This project, which is co-led by LTA and URA, has identified three focus areas. The focus areas are (a) Analyse demand and throughput, (b) Propose design suited for AVs, and (c) Explore the impact of AVs at bus stops, taxi stands and PUDOs for commuters. These are elaborated in the sections below.

Focus Area A: Analyse demand and throughput of bus stops, taxi stands and PUDOs

Objective	To understand the effect of design, development characteristics, and AV-type scenarios on the demand and throughput of bus stops, taxi stands and PUDOs.
Current Situation	Today, the capacity of bus stops, taxi stands and PUDOs can be constrained by the rising inflow of vehicles due to changing mobility preferences. When AVs are introduced, it is uncertain what impact they will have on the vehicular flows at these facilities.
Scope	The research team is expected to:

	a) Conduct a baseline assessment of the existing conditions and challenges of selected bus stops, taxi stands and PUDOs, such as the vehicle flow rate, dwell time, queue length, number of traffic conflicts, etc. at different times of the day, particularly during peak hours. b) Establish traffic and pedestrian peak flows at selected bus stops, taxi stands and PUDOs. c) Identify development-level factors (such as development type, tenant-mix, etc.) and bus stop/taxi stand/PUDO design factors (such as the number of lanes, storage length, presence of dedicated lanes, etc.) that affect the demand and throughput of bus stops, taxi stands, and PUDOs. d) Model future demand and throughput based on the identified factors under different AV-type scenarios (e.g. AV buses, AV shuttles, and AV-sedans that include taxis or private hire).
Possible Deliverables (but not limited to)	The study shall develop a model (or equivalent) to predict the demand and throughput at bus stops, taxi stands and PUDOs based on development-level factors and design factors. The model (or equivalent) should demonstrate the demand and throughput values for different AV-type scenarios (e.g. AV buses, AV shuttles, and AV-sedans that include taxis or private hire). The research team should ensure that the final product, if hosted on a platform, is compatible with agencies' existing systems and will not require additional licenses that may impose recurring costs.

Focus Area B: Propose design suited for AVs

Objective	To propose design recommendations for bus stops, taxi stands and PUDOs that allow AVs and manned vehicles to operate safely and efficiently, considering the sensor capabilities of AVs and the range of physical elements found at these facilities.
Current Situation	It is unsure if the way that existing bus stops, taxi stands and PUDOs are designed will be suitable to support AV deployment. Moreover, PUDOs in Singapore are designed

	differently based on building type or site constraint, posing challenges for AVs to safely navigate them.
Scope	The research team is expected to: a) Identify the physical elements at bus stops, taxi stands and PUDOs which would pose challenges to the perception, navigation and localisation of AVs. The research team should take into consideration how AV technology would evolve and mature. b) Taking reference from international best practices and the findings of this study (including in Focus Areas A and C), propose design recommendations for bus stops, taxi stands and PUDOs of different development types to cater for the entry, boarding/alighting of passengers, and departure of AVs, while keeping in mind other functions and trade-offs (such as to minimise land take). The design specifications to be explored shall include, but not limited to i. The layout of the bus stop/taxi stand/PUDO facility ii. Setting up of dedicated bays iii. Demarcation of bays iv. Type of signages v. Types of barriers vi. Safety features (e.g. Barrier Free Access ramp, wheelchair waiting area) vii. Provision of commuter facilities viii. Integration plan with cycling infrastructure, pedestrian links and building entrances The design recommendations should also consider prevailing guidelines in Singapore associated with bus stops, taxi stands and PUDOs, where relevant. c) The study may propose low-cost supporting elements (e.g. reflective strips, additional signages) or supporting sensors (including LIDAR, RADAR and cameras) that could assist AVs in navigating a bus stop, taxi stand or PUDO. These additions should ideally be modular to allow for easy installation and removal. d) The recommendations from this Focus Area shall be validated by simulation studies (e.g. swept path studies) and piloted on site for evaluation. Recommendations shall be evaluated for their

	effectiveness under various scenarios (e.g. glare from the sun, poor lighting conditions, obstruction from pedestrian or other objects).
Possible Deliverables (but not limited to)	To develop a set of design recommendations for bus stops, taxi stands and PUDOs of different development types that will facilitate the efficient entry, boarding/alighting, and departure of AVs. The recommendations should also highlight the elements which are found to be difficult for AVs to recognise and respond to effectively. To design a prototype for a new bus stop, taxi stand and PUDO based on the study findings/recommendations and propose strategies for retrofitting of existing bus stops, taxi stands and PUDOs for the transition period. The study shall include a validation plan for the proposed design recommendations through an identified pilot site.

Focus Area C: Exploring the impact of AVs at bus stops, taxi stands, and PUDOs for commuters

Objective	To explore the impact of AVs at bus stops, taxi stands, and PUDOs for different users.
Current Situation	Bus stops, taxi stands and PUDOs are busy locations with multiple activities. In the near future, we expect more PUDOs to be co-located with other facilities, increasing the types of human and vehicular interactions.
Scope	The research team is expected to: a) Evaluate the impact of AVs on the safe movement of manned vehicles and commuters at bus stops, taxi stands, and PUDOs under i. different conditions of lighting, weather, peak volume, etc. and ii. different design specifications e.g. presence of dedicated lanes, presence of pedestrian crossings, etc. b) Identify and analyse the behaviour and needs of different passenger groups (such as the elderly,

	families, and persons with disabilities) when using AV-ready bus stops, taxi stands and PUDOs. c) Recommend a set of strategies, that could include the use of V2I technology, to enhance service quality and propose how these could be integrated into the overall design of the bus stop, taxi stand or PUDO. d) The recommendations from this Focus Area shall be evaluated for their effectiveness on site, where applicable.
Possible Deliverables (but not limited to)	A set of recommended strategies to enhance the service quality at bus stops, taxi stands and PUDOs based on an understanding of the interactions between AVs and other entities as well as the needs of different user groups. There should be clear demonstration of how these strategies could be integrated into the overall design of the bus stop, taxi stand and PUDO prototype as proposed in Focus Area B. it should also include a validation plan for the proposed recommendations.

3. ELIGIBILITY CRITERIA

3.1. This call is open to all R&D organisations in Singapore including publicly funded institutes of higher learning (IHLs), not-for-profit research institutions, public sector agencies, companies and company-affiliated research entities.

3.2. The Lead Principal Investigator will be required to have a minimum commitment duration of 9 months per year in Singapore. International parties can participate in the project as Collaborators. All work should be done in Singapore, unless expressly approved by LTA.

4. APPLICATION PROCESS AND EVALUATION CRITERIA

4.1. Proposals will be selected and evaluated based on i) potential for impact, ii) strength of project execution, and iii) technical competency of the team.

4.2. The grant call will be launched on 19 October 2020 (Monday), 1200hrs. Interested applicants should submit proposals to the following email address LTA_Innovate@lta.gov.sg by 16 November 2020 (Monday), 1200hrs. Only documents in **Word**, **Excel** and **PDF** formats should be submitted.

4.3. Proposals should cover the objectives, proposed approach and project execution plan. The guidelines for drafting the proposal is in Attachment 1. Proposals must respond to all 3 Focus Areas in the scope above with no prescribed order for their completion.

4.4. Proposals should be submitted together with Application template (Attachment 2).

4.5. This grant call will support up to 100% of the approved qualifying direct costs of a project for IHLs, not-for-profit research institutions and public sector agencies. Companies and company-affiliated research entities will qualify for up to 70% of the approved qualifying direct costs of a project. Up to 20% of indirect costs (costs that are incurred for common or joint objectives and therefore cannot be identified readily and specifically with a particular project) will only be allowed for IHLs and not-for-profit entities. A list of non-fundable direct cost items is in Attachment 3.

4.6. Projects with duration of two years or less are preferred to allow for timely deployment of solutions. Deliverables are expected to be commensurate with the level of funding requested. Funding support will be based on the achievement of milestones in a payment schedule.

4.7. Proposals that provide cash or in-kind contributions will be viewed favourably. Multi-disciplinary/organisation teams or teams with industry partners are encouraged and the proposal should describe clearly the roles and contributions of the collaborator(s) and industry partner(s). Proposals which involve a trial or pilot with clear plans to deploy / scale-up the solutions developed are highly preferred. The team is strongly encouraged to include an industry partner that is able to supply a working AV for pilots. Where applicable, technology readiness level (TRL) of the proposed technology should be at least TRL 6 (prototype demonstration in a relevant environment) and above at the end of the project. Appendix 1 shows the definitions of the TRLs.

4.8. The following may be rejected without review:

- Late or incomplete proposals (including proposals that do not follow the guidelines)
- Proposals that do not fall within the scope of the grant call
- Duplicates of proposals submitted to any other funding agencies for simultaneous consideration
- Ineligibility of the Investigators or R&D organisation

4.9. Submission of proposals for this grant call shall be construed as consent by the applicants to participate in the evaluation process. Selection of reviewers is at the sole and exclusive discretion of LTA.

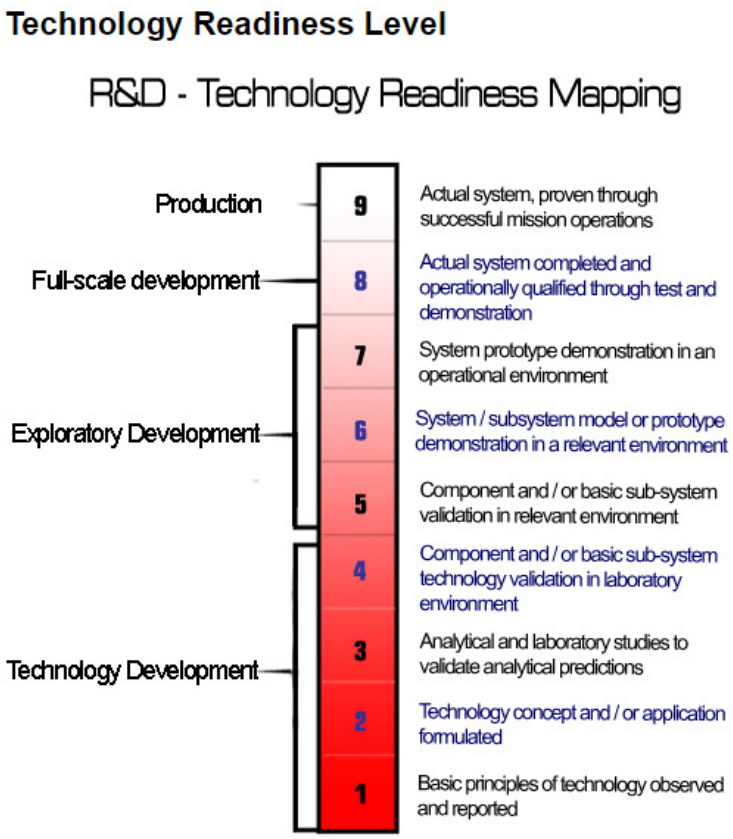
4.10. LTA may require proposals to be revised or combined as it sees fit to enhance outcomes, facilitate integration of approaches, and optimise funding resources. LTA's funding decision will be final.

5. CONTACT INFORMATION

5.1. For further enquiries on this Open Call, please email LTA at LTA_Innovate@lta.gov.sg.

Appendix 1: Technology Readiness Level Chart

A progressive approach, depending on the Technology Readiness Level (TRL) at the point of decision, is used to evaluate test-bedding of new mobility concepts.



<u>Prototype demonstration in a relevant environment (for TRL 5 & 6)</u>

A technology of interest has demonstrated potential to meet certain transport objectives. It will then be pursued for further development at the component level and subsequently tested for operational viability within confined test areas that mimic part of an envisaged operational environment.

<u>Proof-of-Concept (POC) demonstration in an operational environment (for TRL 7)</u>

If a technology of interest has been proven its potential at the component level, its development will be further pursued. In this case, the test-bedding environment will be escalated into the actual operational environment with actual interaction with other road users and commuters. At this stage, we will focus on evaluating the proposed mobility concept, which deploys the technology of interest, for its envisaged benefits and values in meeting the transport objectives.

Full Scale Deployment (FSD) (for TRL 8 & 9)

This level will be considered after a successful Proof-of-Concept (POC) demonstration. However, it may not be a straight-forward process as other considerations like commercial viability, operational sustainability, and other policy considerations (especially when the new mobility concept could be disruptive to existing modes of travel).