## Building & Construction Authority and Housing & Development Board

### Problem Statement

| Current situation                                                                                       | Building facades need to be regularly inspected and maintained to ensure that the façade elements (e.g. wall plasters, tiles and claddings) or any installations (e.g. awnings, sunshades and air-conditioner units) that attach to the facade will remain intact so that they do not fall and pose a danger to the people and properties below them. However, inspection of the building façade itself can be a challenging task, and this is further aggravated by the increasing building height and complexity of the façade elements. The current practice of inspecting building façade usually involves using scaffold, gondola, boom lifts or even rope access, which requires the inspector to work at height and is a tedious and costly method. There is an urgent need for a new inspection model, using innovative technological solution to improve the inspection efficiency, reduce safety risk to personnel, save time and at the same time being cost effective. |
| Key challenges                                                                                          | 1. **Personnel safety**  
Inspectors may be required to perform visual inspection of the building façade using a gondola, scaffolding, boom lift or rope access to detect visible tell-tales signs such as cracks, spalling concrete, efflorescence, loosen joints, corrosion and detachments, which pose a safety risk of working at height.  
2. **Productivity/Manpower**  
Currently, the façade inspection is a slow, resource and manpower intensive process.  
3. **Coverage**  
With increasing complexity of building façade, compounded by increasingly taller buildings, inspection is limited to area where gondola, boom lift and scaffold are able to reach. The enhanced inspection system is expected to overcome these obstacles to capture images of the entire building.  
4. **Reliability of Results**  
The reliability of traditional inspection method relies heavily on experience and judgement of the inspector. Such inspection may also be delegated to lower-skilled workers who may not be equipped with the competency required for the inspection. |
| Aim                                                                                                      | To develop a drone inspection system using advanced image-capturing drone with an integrated software platform and tapping on artificial intelligence to enhance the effectiveness of performing building façade inspection and to drive automation. |
| Desired outcomes                                                                                         | BCA / HDB seeks technological solutions to develop the drone inspection system for building façade. The development of the solutions are to be carried out in 2 main phases: Phase 1 comprises of Phase 1A and 1B which are to be conducted concurrently. Phase 2 is separated into 2 stages - Phase 2A and 2B. The activities and key requirements under each of these phases are as follows: |
Phase 1A: Drone Image Mapping & Processing Software

The program is expected to include, but not limited, to the following features or capabilities:

a) Provide mapping and image indexing for traceability (position, geolocation, date, time of survey, etc.). Images should be organized to allow easy browsing and navigation, identify and mark the defects or anomalies, make annotation and present the results for reporting purpose. Integrate daylight visual and thermal images to be examined in tandem and providing side-by-side comparison.

b) Visual 3D reconstruction of building for general building visualization and localization of defects with the ability to pan, rotate and zoom. The 3D rendered model should be linked to an individual or group of high resolution images to allow closer examination by inspectors, vice versa. The model should allow overlaying of defects or anomalies on its surfaces.

c) The program basic functions i.e. viewing and browsing of images, marking of defects and anomalies, and making annotations should be made accessible via mobile devices using apps.

Notwithstanding the envisaged features or capabilities mentioned above, BCA / HDB is open to other approaches in achieving the intended outcomes of the project.

Defect Detection using Artificial Intelligence (AI)

The program shall apply artificial intelligence (AI) to perform autonomous defect detection, based on image recognition and machine learning. The proposed artificial intelligence module, together with the image databank of the defects, are to be developed as an extension (add-ons/plugins) to the program.

The aim is to design a program which could identify and analyze the façade elements and defects, determine and classify the anomalies according to the type, confidence level and measuring the severity or magnitude. For Phase 1A, the defects required for auto-recognition should minimally include a) cracks, b) spalling (include early indication and tell-tale sign leading to spalling) on concrete, plaster and tile surfaces. The measurement or classification of the magnitude or severity need not be carried out in this phase.

It is envisaged that the image databank would contain images and of various façade elements and defects commonly found in building façade. Applicant must ensure, with all reasonable efforts, that the image databank is built up to such a scale, capacity and accuracy that would enable the system to perform autonomous defect detection effectively. To ensure the accuracy of the defects detection, Inspector shall conduct close-up inspection to validate defect images collected during the field trials (under Phase 1B). The image recognition system shall be updated and retrained to improve the detection accuracy.
**Phase 1B: Drone Flight Operation**

This phase involves field trials to assist the development of the program under Phase 1A and therefore to be conducted concurrently with Phase 1A. Drones are to be deployed to perform survey on the condition on the entire façade areas of the building using both visible light and infrared thermal cameras (other alternative scanning technology can be proposed). The specifications for the drone and its camera can be found in Annex A.

The field trials are to be conducted on 2 existing buildings on 2 separate occasion assigned by BCA / HDB. The building sites will be announced in due course.

**Phase 2A: Defect Recognition using Artificial Intelligence (AI)**

Phase 2A will focus on extending the defect recognition scope and capability of the program developed in Phase 1. The extended scopes include, but not limited to, a) void/ hollow/ delamination, b) efflorescence/disco colouration on concrete, plaster and tile surface, and c) metallic corrosion. Additionally, assessment of defects, by way of measuring the magnitude and/or analysing the patterns and classify them according to the severity of the defects should be conducted in this phase. In addition to visual imaging, Phase 2A should include the image recognition and analysis using thermal infrared imaging (or the adopted alternative scanning technique) in providing a more accurate detection of the defects.

Applicant is to conduct one field trial on an existing building to assist in developing the program and defect recognition capability. The defects should be verified by Inspector with a close-up site inspection and results further retrained. Building site will be announced in due course.

**Phase 2B: Pilot Testbed**

The final phase involved pilot implementation of the proposed solution developed after successful completion of the earlier phases. One existing building will be assigned by BCA / HDB to demonstrate the effectiveness of the solution.

| Other possible outcomes | Nil |