INTEGRATED DIGITAL DELIVERY - UNMANNED AERIAL VEHICLES (IDD - UAVS)

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INTRODUCTION

Singapore aims to be the world's first Smart Nation, one that will improve the quality of life for individuals and provide business opportunities for enterprises (OpenGov Asia, 2017). In aiding the built environment to be a digitalised industry as a response to the city state's Smart Nation's vision, Building and Construction Authority (BCA) under the Ministry of National Development (MND) introduced the Construction Industry Transformation Map (ITM) in October 2017. The Construction ITM is one of the twenty-three ITMs identified under a $4.5 billion Industry Transformation Programme proposed by the government's Future Economy Council (FEC). The transformation aims to review the construction processes by adopting new technologies to make the built environment sector more advanced and integrated and ultimately create new and better jobs in the sector. The three key approaches of the Construction ITM are (1) Green Buildings (2) Design for Manufacturing & Assembly (DfMA) and (3) Integrated Digital Delivery (IDD).

IDD is not a total new digital concept but an initiative further enhances from the existing Building Information Model (BIM) roadmap and Virtual Design Construction (VDC) roadmap launched in 2010 and 2015. It expands the involvement of digital technologies to integrate work processes and connect project stakeholders throughout the construction and building life-cycle (i.e. design, manufacturing, construction and operation). IDD covers four areas namely:

1. Digital design;
2. Digital manufacturing and fabrication;
3. Digital construction; and
4. Digital asset delivery and management.

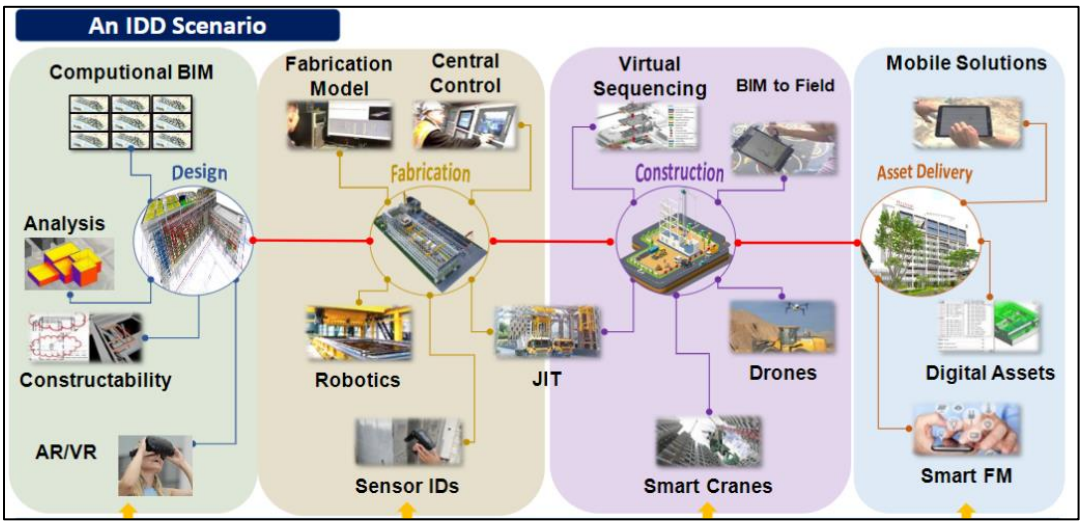

Figure 1: IDD Scenario (Design, Fabrication, Construction and Asset Delivery)
Source: BCA Academy, 2018

UNMANNED AERIAL VEHICLES (UAVs)

Unmanned Aerial Vehicles (UAVs) is one of the new emerging technologies in the built environment sector due to the latest digital concept. UAVs, commonly known as drones, is a flying robot that can fly autonomously through software-controlled flight plans in their embedded systems without human pilot onboard, and working in conjunction with onboard smart sensors and Global Positioning System (GPS) (IoTAgenda, 2018).

UAVs was first invented due to military needs which were the driving force behind developing UAV technology until the 21st century (Mark and Junshan, 2017). In 2006, the establishment of DJI, the current leading commercial drone company, opened the era of personal and commercial drone (Tarek and Alice, 2018). The technology advancements have made UAVs more accessible to the public, user-friendly and inexpensive. As such, the usage of UAVs is increasing rapidly across the sectors such as film and television sector and education, training and research sector. The built environment sector is also taking advantage of UAV technology.

Pre-Construction Stage: Land Surveying and Site Inspection

UAVs able to capture accurate and realistic aerial, exterior and real time views of a project site or buildings through photography and/or videography. Equipped with smart sensors, camera technologies and GPS, UAVs can obtain topographical data by following the GPS controlled flight path planned in advance independently. The smart sensors and GPS technology connects UAVs to a cloud based platform in which the captured drone imagery will be uploaded instantaneously to the cloud. The high resolution images, overlapping photos and video taken by the UAVs will then be processed to be a high resolution 3D surface model that can be used for topographic mapping, volumetric calculations, or three dimensional representations of a construction site.

Construction Stage: Progress Monitoring, Site Measurement and Safety/Security Monitoring

UAVs's photography and videography can be taken daily from the same aerial perspective through the preprogrammed routes with the help of GPS technology. It helps to track actual construction progress against planned progress, site resources (manpower and material) planning and identify the potential construction issues. The high quality, precise 3D model rendered from the UAVs's photography and videography can be used to showcase during the weekly site meeting and technical meeting for progress monitoring and design/construction coordination. The consultants such as quantity surveyor can also make use of the 3D model in carrying out payment valuation and measurement for construction variations. The 3D model can also become a marketing tool for real estate agents to potential buyers and/or investors.

Real time images and video captured by UAVs provide the opportunity for the project team to enhance safety and security at construction site. It documents the actual site conditions and covers a larger area with shorter amount of time spent as compared to the current site safety supervision. The UAVs can be integrated with security alarm system and conduct programmed periodic security sweeps to further enhance the site safety and security. The video and photo captured could be streamed to smartphone or other real time device so that the site safety manager or relevant site personnel can react promptly.

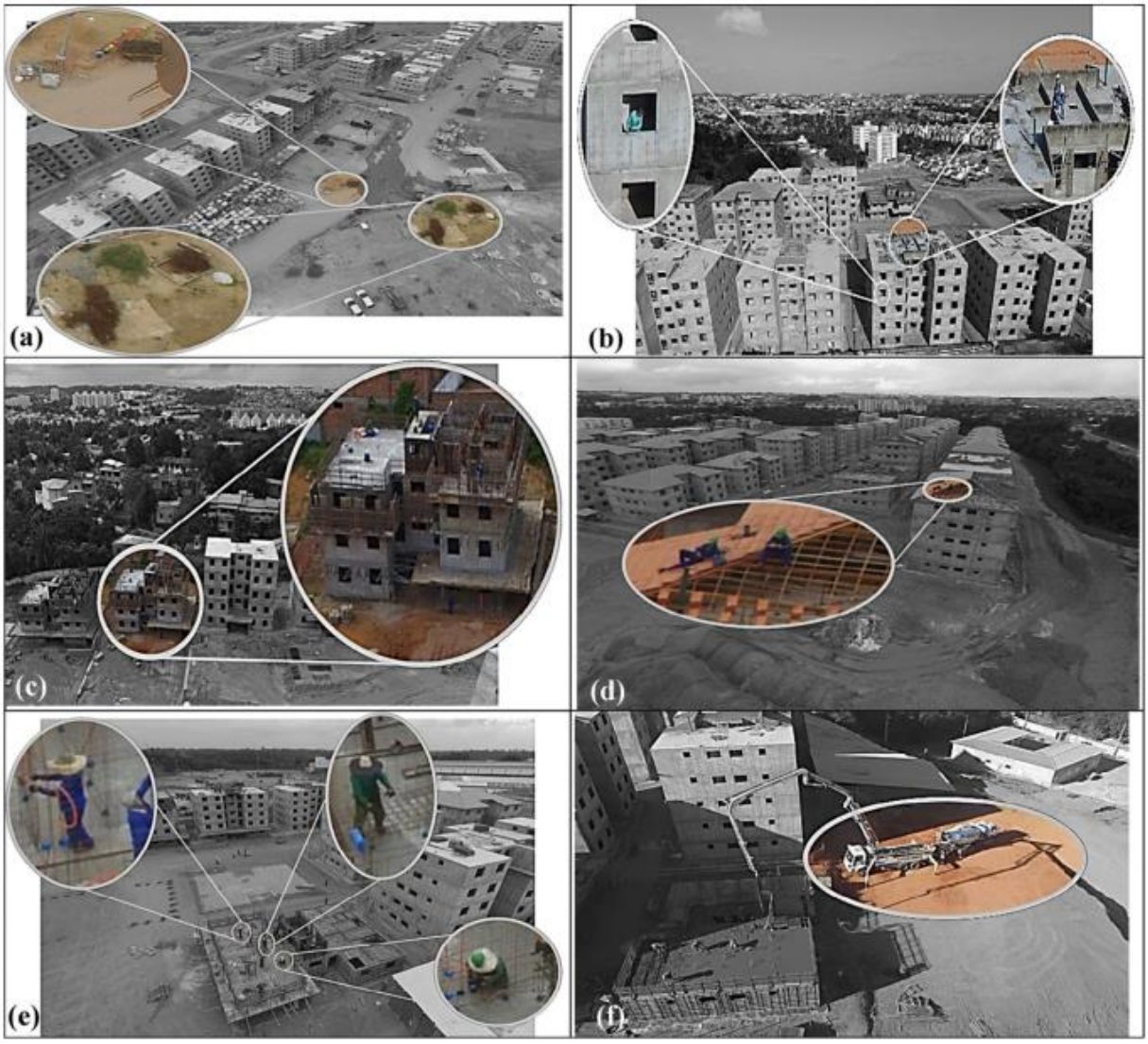

Figure 2: Examples of non-compliances observed on a construction project:
(a) Waste unprotected from rain;
(b) Workers without hard-hats and personal fall arrest systems;
(c) Safety platforms not installed on the entire perimeter of the building;
(d) Workers on the roof unprotected from falling;
(e) Inappropriate use of hard-hats;
(f) There is not isolation of areas for loading and unloading of material

Source: Roseneia, Dayana, Juliana and Javier, 2017

Operation Stage: Routine Asset Inspection (eg. Facade, Roof and Road Inspection)

UAVs has the ability to collect data from as lower altitude as starting from ground level, sweeping through the project or building at various heights and viewpoints, and bird-eye views above the site. Equipped with thermal sensor and photography, UAVs is a very useful tool in conducting routine asset inspection such as facade, roof and road inspection. UAVs inspection particularly offers its advantages to places that inaccessible or would normally require additional equipment to reach, for instance, installation of suspended scaffolding to a suspected leaking source of an upper floor of a high rise building. It can capture high resolution images and videos from different angles in a matter of minutes at greatly lower cost and with little safety risk.

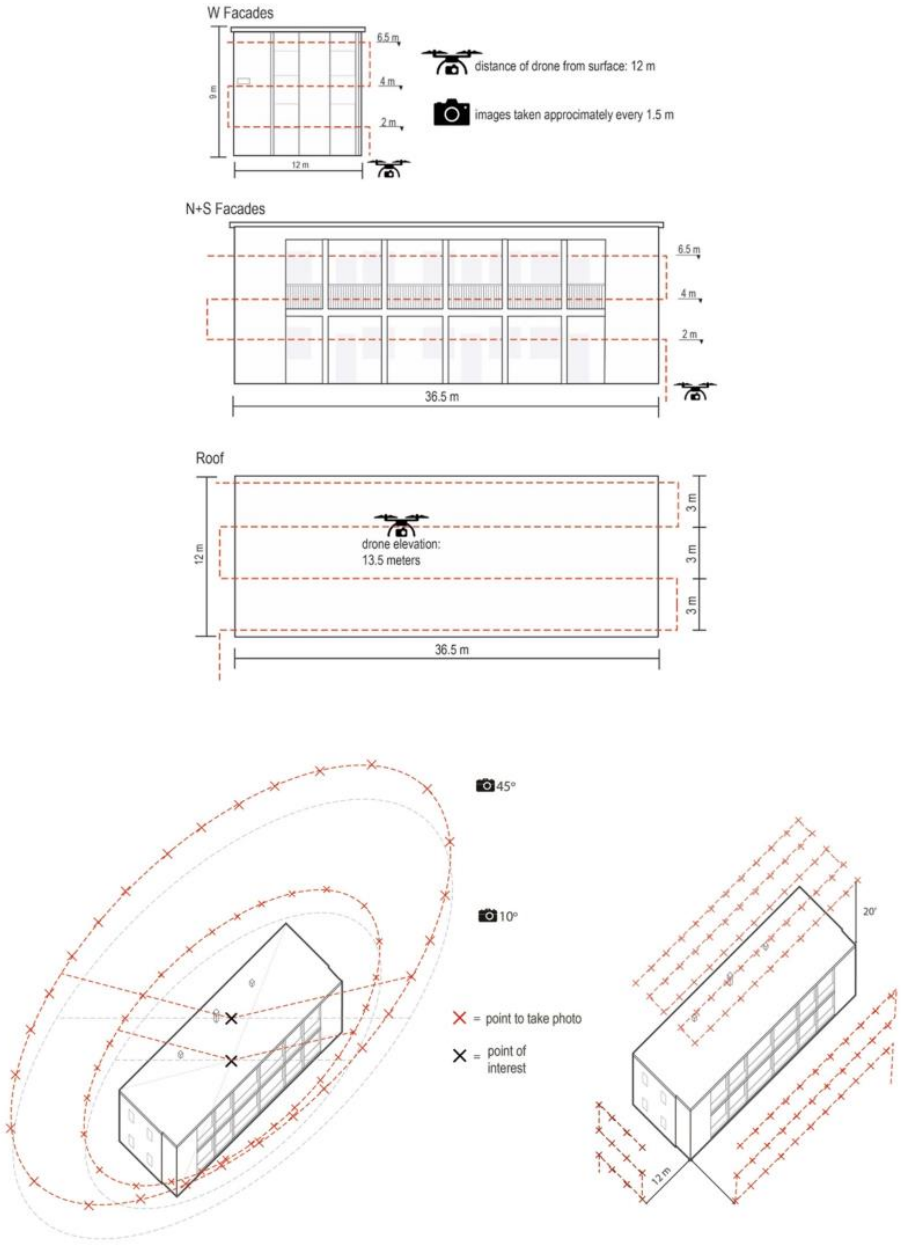

Figure 3: Flight Path for Building Inspection
Source: Tarek and Alice, 2018

Design and Manufacturing Stage: BIM Data

The information collected in pre-construction, construction and operation stages of the past projects can contribute as useful data for future project planning at design and manufacturing stage. UAVs can also obtain the video and photo of the construction site's landscape which can be integrated into the BIM modelling software. The landscape reality will then be efficiently taken into consultant's consideration for building space usage and design through UAV image.

UNMANNED AERIAL VEHICLES (UAVs) IN SINGAPORE

UAVs is being identified as part of the Singapore's Smart Nation strategy. The Singapore Government believes that UAVs can and are playing a transformative role in many areas to improve the productivity and efficiency. Some activities that already involving UAVs are petrochemical plants inspections, sand-pile volume calculation and aerial mapping, photography and videography.

Operator Permit and Activity Permit

Similar to other countries, in order to ensure aviation and public safety particularly given Singapore's busy airspace and densely populated urban environment, the relevant legislation is enacted under the purview of Civil Aviation Authority of Singapore (CAAS). In accordance to the Air Navigation Act, all UAVs for non recreation and research purpose is required to obtain operator permit regardless of the UAV's weight and flying height. The operator permit is valid for up to one (1) year and costs S$600. If the UAV activity is to be carried out beyond the CAAS's permitted area (see Figure 4), an additional activity permit is required before the flying of the UAV at the planned location. The activity permit is granted for a single activity or a block of repeated activities at a specific area of operation. There are two (2) types of activity permits: Class 1 Activity Permit and Class 2 Activity Permit and the UAV activities for non recreation and research are belonged to Class 1 activities. In addition, Class 1 activities require valid operator permit before application and it costs S$75 per activity.

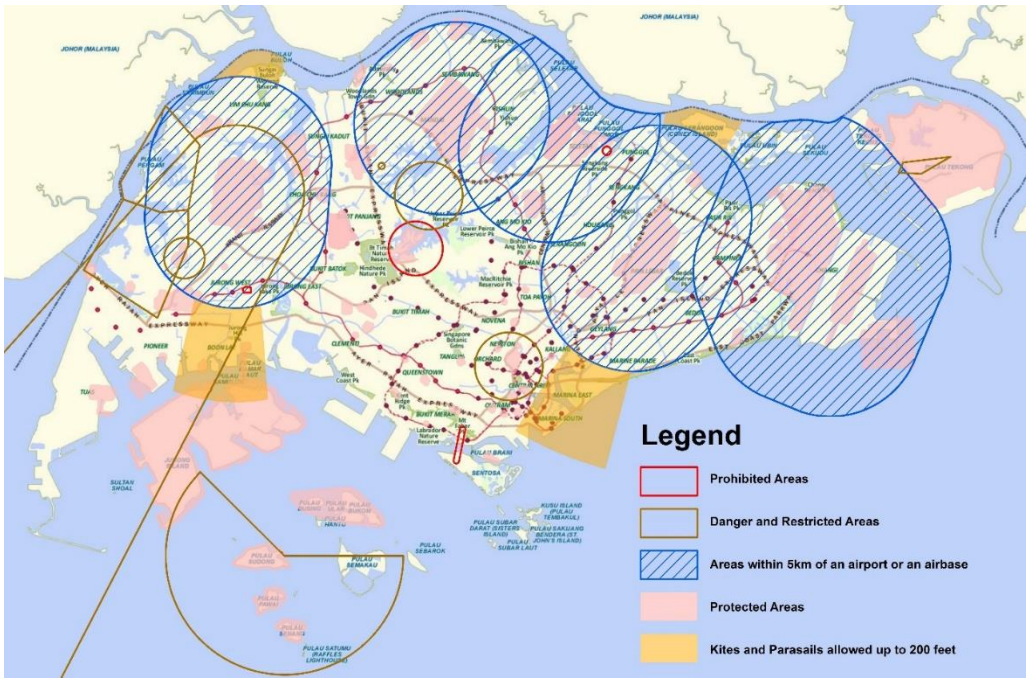

Figure 4: Permitted Area for Flying UAVs
Source: CASS, 2017

Other permits may require from various agencies such as Singapore Police Force (SPF) and Info-communications Media Development Authority of Singapore (IMDA) for certain aspects of the UAV activities. Hence, it is advisable for the UAV operator to do a proper check on the relevant rule and regulation before flying the UAV in Singapore.

Model of UAVs

There are various types of UAVs in the current market catered for different user's preferences and needs. Some of the common models used in Singapore's built environment are DJI Matrice series, DJI Mavic series and DJI Phantom series. Other important components associated with UAVs are camera (for normal photo taking and video recording or thermal sensitive; eg. Zenmuse series), controller and software (eg. 3DR Site Scan).

Figure 5: DJI Phantom 4 Pro (left) and Zenmuse X5S (right)
Source: DJI, 2019

CASE STUDIES IN SINGAPORE

Land Transport Authority (LTA) - Rail Tunnel Inspection

Land Transport Authority (LTA) of Singapore used UAV to record and inspect the construction progress of the rail line - Thomson-East Coast Line (TEL). DJI Phantom 4 Pro+ with a battery life of around 30 minutes was used for the progress inspection. With a speed of 2 meter per second, the UAV took around 7 minutes in conducting the inspection for the 800m stretch of tunnel connecting the Orchard and Orchard Boulevard stations, including videos and photos recording. The manpower involved in the inspections are only one pilot, a co-pilot, and a safety observer.

Before UAVs, to conduct a similar visual inspection on the same distance of the MRT tunnel, a four-man team will need around two or three days to first assemble scaffolding. Then a three-engineers inspection team can take up to three months for the construction progress inspection. The use of UAVs have reduced the time, manpower and cost spent on the rail tunnel inspection drastically; improved the quality of the checking with more accurate data collected and enhanced the site personnel safety. As the engineers' time has been effectively freed up from inspection, they can focus more on analysing the captured data for any necessary remedial measures.

Currently, 30 LTA engineers are the CASS-certified UAVs pilots and LTA has deployed the UAVs inspection services at 10 work sites along the TEL which includes Orchard Road, Marina Bay, Gardens by the Bay, Upper Thomson, Great World City and Havelock.

Figure 6: Inspection in the TEL Tunnel between Orchard and Orchard Boulevard stations
Source: TODAY, 2017

Jurong Town Corporation (JTC) - Volumetric Survey and Analysis

Jurong Town Corporation (JTC) engaged consultancy firm - Arcadis Singapore Pte Ltd (Arcadis) to carry out a pilot study on volumetric survey and analysis on sand pile carried by a moving sea vessel for a land reclamation project. Traditionally, the sand-pile volume calculation involves the use of laser scanners or cranes and require intensive labour which can cost up to S$10,000 for a small project. With the pre-planned flight paths, the UAV operator from Arcadis flew the DJI Matrice M210 RTK (Real Time Kinetic) with a battery life of around 40 minutes to the sea vessel from ashore. The data gathered through the Zenmuse X5S camera were uploaded to the cloud based platform that connects to the UAV. The high resolution images, overlapping photos and video taken by the UAVs will then be generated as a point cloud models in post-processing for volumetric computation.

This improved health and safety as surveyors need not travel offshore and be exposed to risks in dangerous and spatially-challenging surveillance activities such as climbing pilot ladders and boarding vessels. It also reduced fuel costs as well as associated intensive labour cost and man hour spent. UAVs is also a more reliable operation in light rain and fast deployment as compared to the traditional exercise.

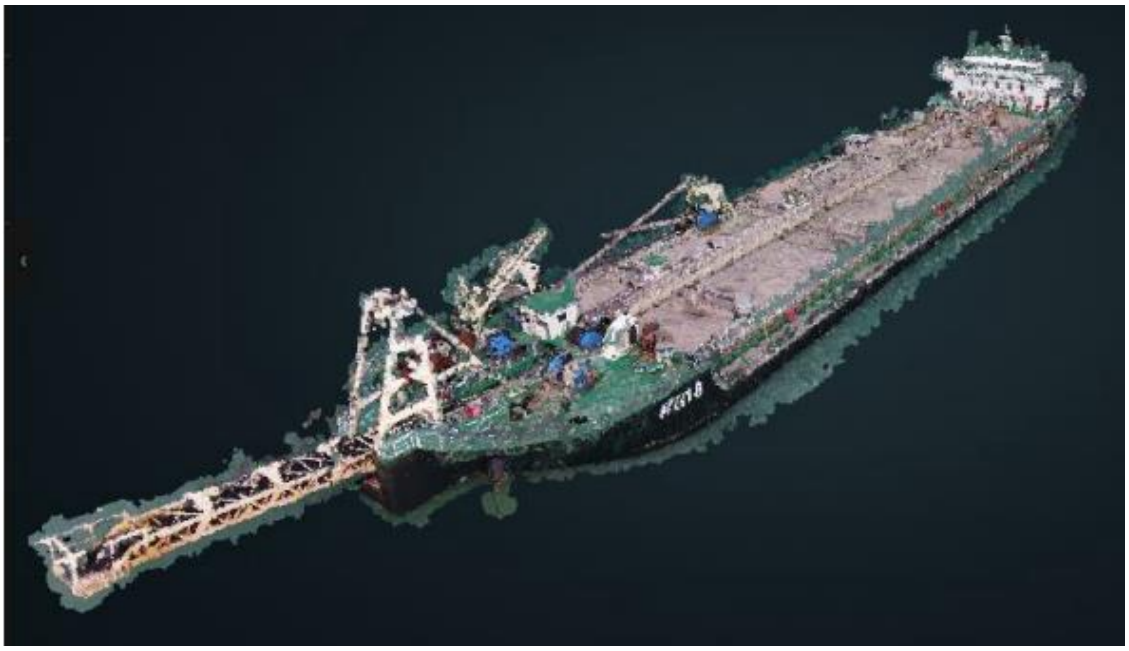

Figure 7: Volumetric Survey and Analysis of Sea Vessels
Source: Arcadis, 2018

Housing and Development Board (HDB) - Building Facade Inspection

Housing and Development Board (HDB) embarked on a small-scale, one-week trial of using UAVs for the building facade inspection to four public housing blocks in Jurong East. The key objective of the UAV trial was to determine if UAVs able to enhance building facade inspection particularly to places that hardly accessed by public or inaccessible. Typically, the building facade inspection is carried out by workers using gondolas.

HUS Unmanned Systems was the UAVs operator engaged by HDB for this study. A team of six men was set up at an open basketball court. They were further divided into two sub-team: while the operator was flying the UAV, the two others will watched on. It took 10 to 15 minutes for UAV to inspect one side of the HDB block.

The UAVs took thousands of pictures and uploaded to the cloud based platform that connects to the UAV. After generating the captured data into high resolution 3D model, the software system will do a quick analysis and identifying the defects which will be automatically processed as a report in a much shorter time than the conventional way.

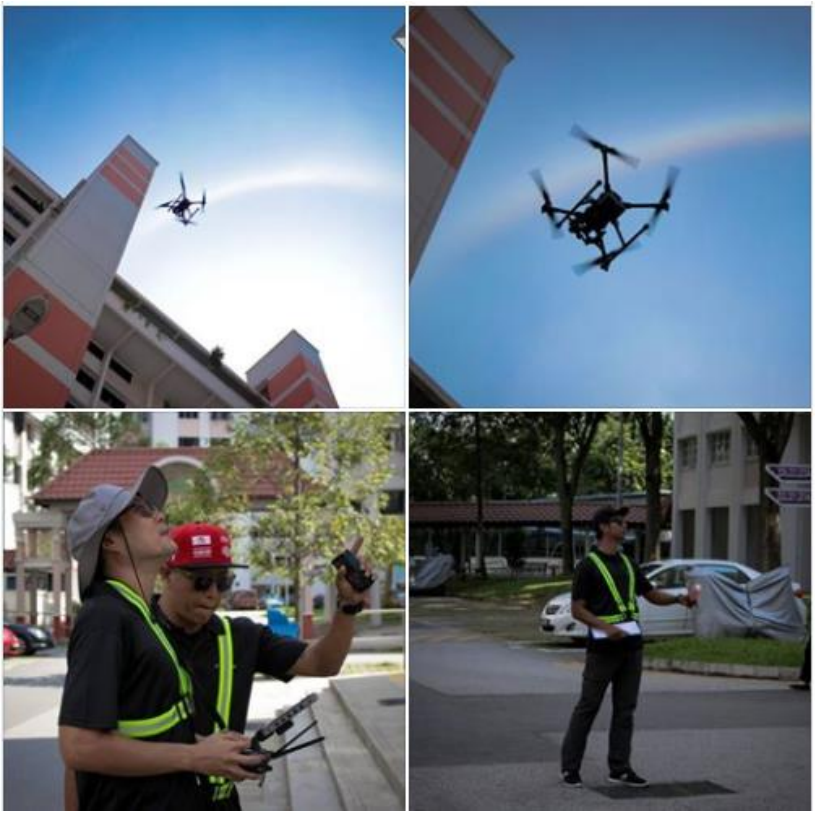

Figure 8: Building Facade Inspection to Public Housing Blocks in Jurong East
Source: Channel NewsAsia, 2018

CHALLENGES AND OPPORTUNITIES

Challenges

Increasing usage of UAVs posts privacy, security and safety concerns. On 18 and 19 June 2019 , 37 scheduled departure and arrival flights were delayed as a result of unauthorised UAVs spotted flying around Changi Airport. Under the Act, flying of UAVs within 5km of airports or military airbases without Class 1 or Class 2 activity permit is an offence. Hence, the operations of the runway were suspended between 11pm on June 18 and 9am on 19 June to ensure the safety of aircraft operations and passengers. On 5 July 2019, in a first, 2 men were charged after allegedly operating UAVs for recreational purposes within 5km of Paya Lebar Air Base without Class 2 activity permit. On 8th of the same month, construction firm - LT Sambo was fined $9,000 for operating a DJI Phantom 4 weighing 1.38kg along Marine Parade Road without a valid Class 1 activity permit.

While one may see increasing safety and security concern incurred due to UAVs, most UAVs operators are fully aware of the rules and regulations of UAVs in Singapore, especially the UAVs operators of non recreation and research. The industry players are optimistic with the implementation of the existing rules and regulations, it will help to ensure the safety for the operators, the general public and the air traffic.

Opportunities

As gathered from the above mentioned case studies in Singapore, the usage of UAVs in some construction activities has indeed brought significant benefits in terms of time-saving, cost-saving, quality-assuring as well as improvement of health and safety. Besides, Singapore Government is in progress to enforce the building owners to conduct building facade inspection in every seven years to all the buildings above 20 years and taller than 13m.

The new inspection regime consists of two stages: (1) full visual inspection for deterioration such as corrosion and cracks and (2) hands-on inspection of at least 10 percent of the building face. The new enforcement will help to prevent serious incidents such as facade cladding falling off through regular facade inspection. This will inevitably create a huge opportunity to the UAVs technology.

CONCLUSION

As part of the Smart Nation strategy, the Unmanned Aerial Vehicles has emerged in the Singapore's built environment sector due to the launching of Integrated Digital Delivery of the Construction Industry Transformation Map. UAVs able to capture accurate and realistic images and video through camera, smart sensor and GPS technology. The collected images and data will then be uploaded to the cloud spontaneously and being generated to a high resolution 3D surface model which can be used as land surveying, site inspection, site measurement for payment valuation, safety and security monitoring, facade inspection, BIM data and so on. Although the usage of UAVs post public security and safety challenges, it also creates opportunity due to significant time-saving, cost-saving, quality-assuring and improvement of health and safety. The learning curve of adopting IDD in the built environment is steep. The support of both industry partners and academia is certain to reap the full benefits of IDD and it will also help to attract and retain young talents in the built industry.

Keywords: ITM, IDD, UAVs, Drone, Digital