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22 CONSTRUCTION PRODUCTIVITY, TECHNOLOGY AND DIGITISATION

22.1 General

22.1.1 In view of the Authority's ongoing effort to improve the safety supervision and productivity to the work sites, the Authority embraces the digital transformation by introducing the use of innovative technologies and work methods for the Works.

22.1.2 The Contractor shall note his obligations and allow in his Contract Price for the innovative technologies and work methods required by the Authority.

22.1.3 In addition to the Authority's requirements, the Contractor shall innovate further and propose other suitable methods to enhance productivity and innovation as well as sustainability. The Contract Price shall be deemed to include these additional enhancements and the Authority reserves the right to omit from the Contract Sum for the proposed initiatives in the event that any were not implemented. The amount of omission shall be based on **Clause 57.2** of the Conditions of Contract.

22.2 Construction Productivity

22.2.1 In view of Singapore Government's on-going effort to improve the productivity in the construction industry, the Contractor shall explore the use of mechanization and game-changing technologies to improve productivity in his Works.

22.2.2 Wherever practical, the Contractor shall consider the use of automation and mechanization, or innovative and efficient plant and machinery in his construction works, such as road marking machine, automatic cone laying machine, automatic signal for traffic control at work zones, 3-dimensional grade control system for excavators and compactors and automated washing of truck wheels. The Contractor may consider the use of prefabricated rebars (such as rebar carpet, rebar cage and rebar panels), electrical gantry cranes, precast building elements and system formwork, spray painting works and automatic plastering machines to improve productivity in his construction works. Where the site and ground conditions are suitable, the Contractor may explore the use of efficient methods, such as tubular struts, trench mixing wall, in his design and construction of the ERSS to improve the productivity of his underground construction works. The Contractor shall seek the Engineer's acceptance of his proposal prior to the implementation of the productivity measures.

22.2.3 The Contractor shall submit worker training proposals which include the use of videos translated into the workers' native languages to educate workers on safety, use of machinery, specialized construction techniques, etc.

22.2.4 The Contractor shall propose and implement mobile technology for real-time monitoring of the prefabrication/precasting process when such manufacturing and production of the prefabricated/precast components are carried out outside Singapore. The monitoring system shall be suitable to assist in the quality assurance and supervision of the processes by the QPS.

22.2.5 A Productivity Gateway (PG) framework has been developed by the Ministry of National Development (MND) / Building and Construction Authority (BCA) for implementation of productive technologies and practices. The PG framework is a structured process to incorporate productivity considerations upstream during development planning, as well as implement productive technologies and practices downstream in their actual projects. The PG framework comprises two stages, namely the Master Productivity Plan (MPP) and Project Productivity Plan (P3).

22.2.6 The Contractor shall adopt and develop the P3 initiatives and liaise with the Authority and BCA to obtain their agreement on the proposed schemes to be implemented during the Design and Build stage. All necessary submissions shall be in accordance with BCA's prescribed templates.

22.2.7 The Contractor may propose productive design and construction approaches, technologies and measures including but not limited to the following examples to be implemented under Contract CR206 main works:

a) Use of tubular struts to reduce king posts, bracing and welding;

b) Precast concrete elements, prefabrication of structural and architectural elements and reinforcement cages;

c) Use of system/modular formwork, and prefabricated formwork elements;

d) Use of specialised tunnelling machinery for subways;

e) Use of robotic equipment e.g. hydraulic breaker;

f) Use of water cutter / hydro-demolition and other non-percussive demolition methods;

g) Enhance access to the worksite and structures e.g. use of passenger hoist into underground station during construction, truck mounted working platform;

h) Dust control in station using approved industrial vacuum, misting, air filter machines, etc;

i) Use of enhanced PPE such as noise cancelling headphones for noisy works, respiratory dust masks, exoskeleton robotic suit for workers;

j) Productivity analysis and internal bonus schemes for achieving realistic goals using data from real-time labour tracking (over and above the current provisions of biometric tracking);

k) Grade control system for earthworks, automatic levelling for road paving machines, automatic tack coat sprayer for road pavements, rollers with real time compaction data displays;

l) Automatic cone laying/picking machine, automatic road marking, traffic signs placed using robotic machine;

m) Subsurface object scanner for utility detection;

n) Excavator with electromagnet attachment for moving steel plates;

o) Computer software / mobile applications to monitor and manage the movement of machinery, equipment, materials, logistics, etc. within the site and interface with suppliers for deliveries;

p) Tile laying by the use of robotic technology;

q) Automatic mechanised plastering of walls;

r) 3D printing for cladding panels, ceiling tiles and other elements;

s) Use of certified green building products and materials for the Works (above and beyond the Greenmark requirements);

t) Installation of photovoltaic system at worksites e.g. solar panels during construction;

u) Implementation of special noise control initiatives to reduce noise emission from equipment and construction activities;

v) Use of zero-emission vehicles and machineries;

w) Eco-friendly waste management proposals including sustainable consumption (reduce, reuse and recycle) and waste segregation (above and beyond the Greenmark requirements); and

x) Use of electrified equipment and plants to reduce air pollution and carbon emissions.

y) Avoidance of transfer beams, seal spaces and high voids;

z) Standardisation of floor to floor heights and door structural sizes;

aa) Use of power float concrete floor for back of house areas; and

bb) Standardisation of signage.

22.3 Construction Digitisation

22.3.1 The Authority intends to digitise workflows to improve collaboration and communications between the Authority and the Contractor. The adoption of the following technology solutions will facilitate sharing of information and improve work efficiency.

22.3.2 Engineering Project Integration and Collaboration (EPIC) System

22.3.2.1 The Contractor shall comply with all requirements related to design submissions as described in **Appendix I** of the General Specification.

22.3.2.2 Where requested by the Engineer, the Contractor shall submit all the correspondences inclusive of documents, drawings, transmittals etc in digital format through the Authority's System, "EPIC" or any other online platform including but not limited to "InSIGHT". Hardcopy submissions for the above-mentioned correspondence are not required.

22.3.2.3 The Contractor shall allow for all cost and time for the adoption of any new procedures for document submissions including but not limited to provision of new or modification of existing hardware, software and internet connectivity.

22.3.2.4 The Contractor shall comply with the Engineer's procedures for submissions to be digitally signed by the Contractor's authorised persons.

22.3.2.5 In the event that the Authority's EPIC System or online portal malfunctions during its operation for any reason, all document submissions shall be made in compliance with the Engineer's procedures. The Contractor shall allow for all time and cost associated with this compliance.

22.3.3 The Authority's Inspection Mobile Application

22.3.3.1 The Authority's inspection mobile application will be used by the Authority, the QP(S) Consultant, the Contractor and any other persons as directed by the Engineer to input observations, photos and comments for direct online exchange of inspection reports.

22.3.3.2 Upon the launch of the Authority's inspection mobile application by the Authority, the Contractor shall procure mobile devices capable of supporting the latest version of Apple iOS mobile operating system including all subsequent updates until the Completion of the whole of the Works (CWW) or any other date as requested by the Engineer, whichever is later. The Contractor shall ensure that his staff are adequately furnished with mobile devices for use in all inspection works.

22.3.3.3 The Contractor shall propose to the Engineer for acceptance of the number of mobile devices to be sent to the Authority or the Authority's appointed vendor for security configuration and installation of Authority's inspection mobile application. The payment for these mobile devices is at the Contractor's cost. The payment(s) for the cost of the initial security software license, installation and support are to be first made by the Contractor and subsequently reimbursed by the Authority based on actual invoices from the Authority's appointed vendor without mark-up and subject to proof of payment made.

22.3.3.4 The cost for replacement mobile devices and additional security software licence, configuration, installation and support required for these replacement mobile devices that are lost and/or damaged by the Contractor and his staff shall be borne by the Contractor.

22.3.3.5 The configured mobile devices shall have access only to the Authority's authorised applications and services needed for the Works. In the event the Authority's inspection mobile application malfunctions for any reason, the Contractor shall contact the Helpdesk Contact number provided by the Authority. The Contractor shall carry out all inspection works in compliance with the Engineer's procedures until the system's resolution. The Contractor shall allow for all time and cost associated with this compliance.

22.3.3.6 Upon the Completion of the whole of the Works or at any time where the mobile devices are no longer in use, the Contractor shall send these configured mobile devices to the Authority or the Authority's appointed vendor for uninstallation of the security software and the Authority's inspection mobile application.

22.3.4 Mobile Interactive Digital LED Touchscreen

22.3.4.1 The Contractor shall supply, install and maintain a mobile interactive digital LED touchscreen within the Authority's office to review Building Information Modelling (BIM) models, DAR submissions and drawings. The Contractor shall refer to **Clause 5** of the Particular Specification on the requirements.

22.4 Adoption of Technology for Construction Supervision

22.4.1 The Contractor shall leverage on technologies to enhance worksite safety supervision. Closed Circuit Television (CCTV) cameras shall be installed to monitor high risk activities on Site with real-time video feeds piped back to the Remote Control Centre at the Authority's Office. The Remote Control Centre to be manned by the Engineer shall be continuously manned to monitor for safety compliance and prompt intervention on non-compliant behaviors. The recorded video footages shall be proactively used for safety training purpose.

22.4.2 The Contractor shall refer to **Clause 5** of the Particular Specification for the provision of Remote Monitoring System Control Centre at the Authority's Office. The Contractor shall also refer to **Clause 17** of the Particular Specification for requirements of CCTV system provision for construction supervision.

22.4.3 The Authority also intends to leverage on Video Analytics (VA) to enhance safety supervision processes by automatically detecting safety non-compliance from the recorded video feeds and trigger alerts for prompt intervention. It shall augment and allow better safety supervision, using predefined algorithms and safety rules to ensure safety compliance. The focus of VA shall target at high risk work activities and serve as additional control measures to mitigate related risks on Site. Customized solutions shall be established using machine learning methodology.

22.4.4 The Contractor shall engage a VA specialist with relevant experience and the necessary equipment to design, deploy, calibrate, fine-tune and troubleshoot the VA system. The Contractor shall refer to **Appendix AW** of the Particular Specification for requirements of VA system.

22.4.5 The VA System shall be able to perform the following anomalies detection function and trigger alerts:

a) Facial Recognition to track the whereabouts of personnel;

b) Pedestrian Intrusion into Construction Vehicular Access;

c) Detection on body harness for personnel working at height, with continuous anchorage;

d) Detection on safe means of access for working at height, for instance platform ladders for access instead of A-frame ladder;

e) Detection on continuous presence of effective barricades to demarcate 'no-access' zones;

f) Detection on the continuous presence of effective guardrails to prevent fall; and

g) Detection on skillsets and credentials of personnel of the competent workforce and unauthorized workforce into hazardous area.

22.4.6 The Contractor shall provide a customized graphical user interface for alerts generated, on the workstation at the Remote Monitoring System Control Centre.

22.4.7 The Contractor shall produce annotated/labelled datasets to build up the VA algorithms in order to meet the performance requirements. The Authority will provide the Contractor a set of training datasets to aid the machine learning process for VA. It shall not relieve the Contractor from collecting their own datasets to achieve the performance requirements set out in **Appendix AW** of the Particular Specification. The Contractor shall share all annotated/labelled datasets created through the images/videos collected from the worksite with the Authority.

22.5 Adoption of Technology for Monitoring of Spoil Disposal Activities

22.5.1 The Contractor shall note the requirements for provision of CCTV System and Truck Recognition System in **Clause 12** of the Particular Specification. The Contractor shall be responsible for issuance of spoil disposal tickets in accordance with the Authority's requirements and the technology requirements are to enable auditing and monitoring of the Contractor's spoil disposal activities by the Engineer.

22.6 Use of Unmanned Aircraft (UA) for Aerial Photography, Video Taking, and Other Purposes

22.6.1 The Contractor shall employ the use of UA or drones to conduct aerial photography and/or videography of works from a suitable height on a monthly basis or as and when requested by the Engineer. The photographs shall be taken from a top down and/or oblique angles and capable of forming a complete stitched panoramic photograph if required.

22.6.2 The aerial photographs shall be in full colour with a minimum of 8 megapixels, and a total of at least twenty-four (24) different photographs in hard print and digital format (.jpg) shall be provided by the Contractor for each flight. The Contractor shall submit the softcopies of the photographs in digital format. The Contractor shall submit one (1) hardcopy in a collated photograph album after each flight is conducted upon the request by the Engineer.

22.6.3 The aerial photographs shall form part of the Progress Photographs as specified in **Clause 21** of the General Specification.

22.6.4 The Contractor shall make reference and comply with the requirements of Civil Aviation Authority of Singapore (CAAS) in the safe use of the UA as outlined at https://www.caas.gov.sg/public-passengers/unmanned-aircraft-systems.

22.6.5 The Contractor shall also be responsible to make all the necessary arrangements, including obtaining the necessary permits and approvals from CAAS and other authorities for the aerial photographs and videos to be taken. Before commencement of each flight, the Contractor shall be in possession of valid permits from CAAS. A copy of the permit shall be extended to the Engineer for his information. The Contractor shall note the flying restrictions of Security-Sensitive Locations (SSL), areas within 5km from aerodromes, any other prohibited or restricted areas, as well as CAAS rules and regulations.

22.6.6 The Contractor shall only operate the drone(s) within the scope and conditions stated on CAAS issued permits. The Contractor shall take all necessary measures and precautions to ensure that the flights of the drone(s) will not pose a hazard and/or cause injury or death to persons and/or damage to properties. The Contractor shall indemnify the Authority and provide the requisite insurance for the drone flights. All cost of the permit applications, required insurance, personnel to be provided and other associated cost to use drones for aerial photographs, video taking and other purposes are deemed included in the Contract Price.

22.6.7 The negatives/softcopies/hardcopies of the photographs and videos shall be the property of the Authority and while in custody of the photographer or his processor, no copies must be supplied to any person or otherwise made use of. All negatives/softcopies shall be handed over to the Engineer together with the submission of the hardcopy prints. Any copies that are required to be handed over to any agencies or authorities due to security or other sensitive reasons as specified in the permit shall be made known to the Engineer.

22.6.8 The Contractor shall also note that there are stakeholders within the vicinity of the aerial photographs and video taking locations and permission for these UA activities shall be obtained from these stakeholders.

22.6.9 In the event that the photographs and videos are of a quality that is unacceptable to the Engineer, they shall be retaken at the Contractor’s own cost.

22.6.10 Photogrammetry

22.6.10.1 Photogrammetry is a workflow to convert photographs or videos of a physical space into a virtual 3D model that can be measured and manipulated.

22.6.10.2 The Contractor shall create digital 3D models of the site using photogrammetry (Photogrammetry Models) with aerial photos and/or videos taken using drone(s) to update on site status and other purposes, with the aim to enhance construction productivity, if the site conditions allow.

22.6.10.3 The requirements for the Photogrammetry Model are as listed below:

a) The Photogrammetry Models shall be georeferenced using Ground Control Points (GCPs) with known SVY21 coordinates together with Singapore Height Datum (SHD), or other reliable methods, subject to the acceptance of the Engineer;

b) The georeferenced Photogrammetry Models shall achieve an accuracy of at least ±10 cm in the x-y-z directions or better;

c) The Photogrammetry Models shall be created or be able to be converted into a sharable file format for viewing and collaboration purposes; and

d) Provision for integration of the Photogrammetry Models with BIM software shall be made.

22.6.10.4 The Contractor shall employ their own staff and/or external service provider(s) to perform the photogrammetry works.