Rail Baltica
Coordinated by RB Rail

DESIGN GUIDELINE

DIGITAL INFORMATION REQUIREMENTS FOR CONSTRUCTION AND HANDOVER STAGES

RBDG-MAN-040-0101

Revision: 0101

Author: VDC

Date: 2023-12-29

Funded by
the European Union

The sole responsibility of this publication lies with the author.
The European Union is not responsible for any use that may be made of the information contained therein.

LIMITED ACCESS

DOCUMENT DEVELOPMENT AND APPROVAL

Ownership	
Head of Virtual Design and Construction	VDC

Approved by	Decision No.	Date
[Approving body name]	[Decision number]	[approval date]

DOCUMENT HISTORY

This document has been issued and amended as follows:

Revision	Issue Date	Author	Issue purpose	Description of changes	Notes
1.0	2020-11-06	VDC	First issue		Under different title: "BIM use cases for Construction and handover stage"
1.1	2021-10-12	VDC	Updates	Paragraph 6 "Project Implementation plan" was updated Paragraph 6.4 "Supplier Building Information Management (BIM) Assessment Form" was deleted	
1.1	2022-01-21	VDC	Updates	Standards list was updated	
2.0	TBC	VDC	Major restructure of the document	Whole document updated, most chapters changed, requirements updated Title changed to "Digital Information Requirements for Construction and Handover Stages"	

CONTENTS

TERMINOLOGY AND ABBREVIATIONS

A full list of acronyms and abbreviations can be found in RBR Glossary of Abbreviations. The following specific acronyms and abbreviations are used throughout this document:

Abbreviation	Definition
4D BIM	Construction sequencing – a dimension of information to a project information model in the form of scheduling data. This data is added to components which will build in detail as the project progresses. This information must be used to obtain accurate programme information and visualisations showing how your project will develop sequentially.
5D BIM	Cost sequencing – a dimension of information to a project information model in the form of costs.
6D BIM	Project lifecycle information – all the information about the as-built assets that is used for maintenance and operations of the infrastructure and buildings during the whole lifecycle of it.
AD4	Asset Data Definition Dictionary Documents
ADD	Asset Data Dictionary is populated by AD4's
AIM	Asset Information Management
AR	Asset Register
As-built information	A revised set of BIM models, data, information and drawings submitted by a Designer and/or General Contractor upon completion of a project or a particular job. They reflect all changes made in the specifications, BIM models, data, information and working drawings during the construction process, and show the exact, quantities, attributes, dimensions, geometry, and location of all elements as required by the legislation and Client. Any element of a model is a field verified representation in terms of size, shape, location, quantity, and orientation after its final installation. The Modelling (As-Built) is a mandatory Use Case for the Construction Stage. The Designer during the Design Stage will develop a model that shall be used / updated as a base for the As-Built models. The As-Built documentation will be also stored and used during the Operation stage. The detailed description of As-Built information can be found in the "BIM Manual".
BIM	Building Information Management or Building Information Modelling, depending on the context.
BIM Execution Plan (BEP)	A formal document that defines how the project will be executed, monitored and controlled with regard to BIM. A BEP is developed at project initiation to provide important information/data management plans and assignment of roles and responsibilities for model creation and data integration throughout the project.
COBie	Construction Operations Building Information Exchange (COBie) is a non-proprietary data format for the publication of a subset of building information models (BIM) focused on delivering asset data as distinct from geometric information.
CAD	Computer-Aided Design

Client	Defined by signed the Agreement – Implementing Body or/and RB Rail AS.
Common Data Environment (CDE)	It is a central repository where construction project information is housed. The contents of the CDE are not limited to assets created in a "BIM environment" and it will therefore include data, documentation, graphical model and non-graphical assets.
DG	Design Guidelines
Designer	Service provider awarded with an Agreement to conduct the design and design supervision works specified in the Technical Specification and Agreement and which has contractually binding responsibility against Rail Baltica Project Owner (Client) to implement design of any part/project of Rail Baltica Global Project.
Digital Construction	Record/capture models and information to physical use of equipment on the construction site and during the maintenance period that uses this information. Modern sustainable Asset Register and Management system usage is a part of the Digital Construction process. The aim of the Digital Construction is to create a digital twin of the built structures – from graphical representation to capturing the relevant attribute information about the built asset.
EIR	Employer's Information Requirements. A set of requirements, that specifies the Clients requirements for the BIM implementation.
FM	Facility Management
General Contractor	Service provider awarded with an agreement to conduct construction works and which has contractually binding responsibility against Rail Baltica Project Owner (Client) to implement Construction of any part/project of Rail Baltica Global Project.
GIS	Geographic Information System.
Handover	A stage where all necessary information about the product shall be included in the Handover document and attached to the commissioning and Hand-over documentation. The As-Built model shall represent the as-constructed project in content and dimensional accuracy and shall be the part of Asset Register.
IFC	File format. Data model neutral and open specification (e.g. one that is not controlled by a single software vendor or group of vendors) that is used by BIM programs and that contains a model of a building or facility, including spatial elements, materials, shapes and information and attribute data.
Level Of Definition (LOD)	Consists of Level of Geometric Detail (LoG) and Level of Information (LoI)
Level of Geometric Detail (LoG)	The description of graphical content of models at each of the stages

Level of Information (LoI)	The description of non-graphical content of models at each of the stages
PIM model	Project Information Model. File based federated BIM (models), set of BIM extraction (drawings, data exchanges) and project related documentation (reports and forms) developed during the design and construction stages.
RBDatum	The Geodetic Reference System dedicated to the Rail Baltica Project.
Supply chain or Supplier	Provider of services. In this context it can be any actor involved in the project that delivers information, works or services for the project implementation – Designer, General Contractor, Sub-General Contractor, etc. The General Contractor take full responsibility of the actions/works/materials of the Supply chain members.
SI, VE, MD, DTD	Design stages of the project. Respectively: Site Investigations, Value Engineering, Master Design and Detailed Technical Design.
QA/QC	Quality Assurance / Quality Control
RB Geodetic network	Prepared document by RB Rail AS, as Technical specifications for Geodetic network construction and supervision services for Rail Baltica highspeed railway
UAV	Unmanned Autonomous Vehicles
Tenderer	Service providers who participate in particular procurement process for the construction stage during the tender stage

STANDARDS

The mandatory technical standards are:

Abbreviation	Definition
ISO 19650-1:2018	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 1: Concepts and principles.
ISO 19650-2:2018	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 2: Delivery stage of the assets
ISO 19650-3:2020	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 3: Operational stage of the assets
BS 1192-4:2014	Collaborative production of information. Fulfilling employer's information exchange requirements using COBie.

ISO 19650-5:2020	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 5: Security-minded approach to information management
LVS 1052:2018	Building Information Modelling (BIM) terminology
EVS 928:2016	Building Information Modelling (BIM) terminology
LVS EN ISO 16739:2017	Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries (ISO 16739:2013)
LVS EN ISO 29481-1:2018	Building information models - Information delivery manual - Part 1: Methodology and format (ISO 29481-1:2016)
LVS EN ISO 29481-2:2017	Building information models - Information delivery manual - Part 2: Interaction framework (ISO 29481-2:2012)
LVS EN ISO 12006-3:2017	Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information (ISO 12006-3:2007)
ISO/TS 12911:2012	Framework for building information modelling (BIM) guidance
ISO 12006-2:2015	Building construction - Organization of information about construction works - Part 2: Framework for classification
ISO 15686-4:2014	Building Construction - Service Life Planning - Part 4: Service Life Planning using Building Information Modelling

1 Introduction

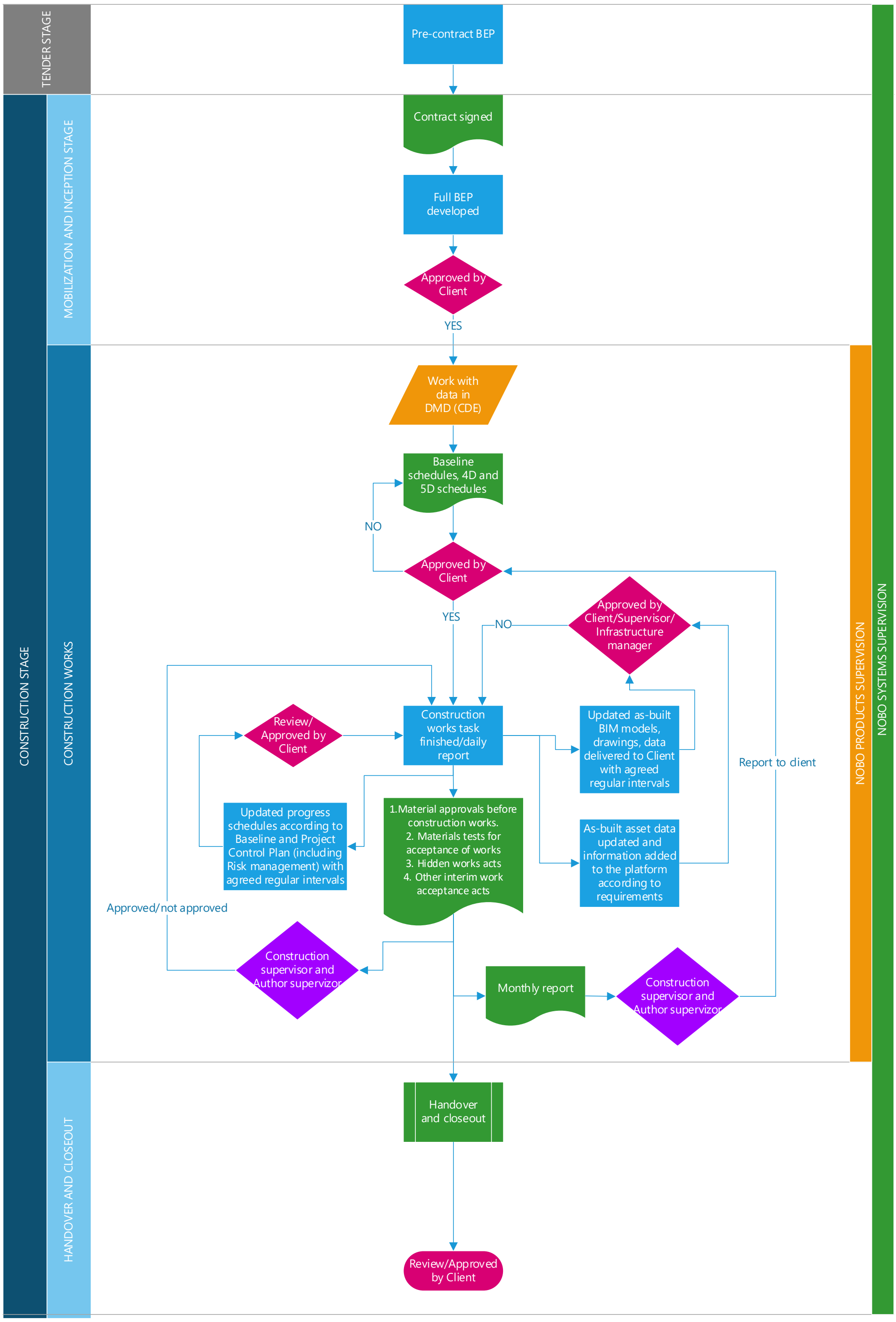
1.1 Purpose

1. This document is valid for signed Agreements started from 01.07.2022, but nevertheless document can be used for existing Contracts as additional source of information for explanation in more details of processes mentioned in document "BIM use cases for Construction and handover stage".
2. The purpose of this document is to clarify and set requirements for Construction and As-Built stages. This document is further clarification on the requirements mentioned in Design Guidelines. Therefore, this document is part of Design Guidelines and always should be considered and viewed together with related documentation, namely RBDG-MAN-033 (BIM Manual) and RBDG-MAN-030 (BIM_EIR) and all directly and indirectly connected documentation.
3. This document contains requirements and instructions for the General Contractor towards:
   3.1. BEP preparation
      (a) BIM, GIS, AR use cases including, but not limited to:
      (b) Model geometry update
      (c) Model information update
      (d) Drawing data update
      (e) Other data and report update
   3.2. Laser scanning use cases
   3.3. 4D and 5D simulations
   3.4. IT infrastructure
   3.5. Document Control, codification, and numbering
4. The following requirements and instructions by the General Contractor shall be followed during the:
   4.1. Tender stage for the construction works
   4.2. Inception or mobilization stage after the Contract award
   4.3. Active construction works stage
   4.4. As-built, construction works close-out and handover stages

2 General requirements

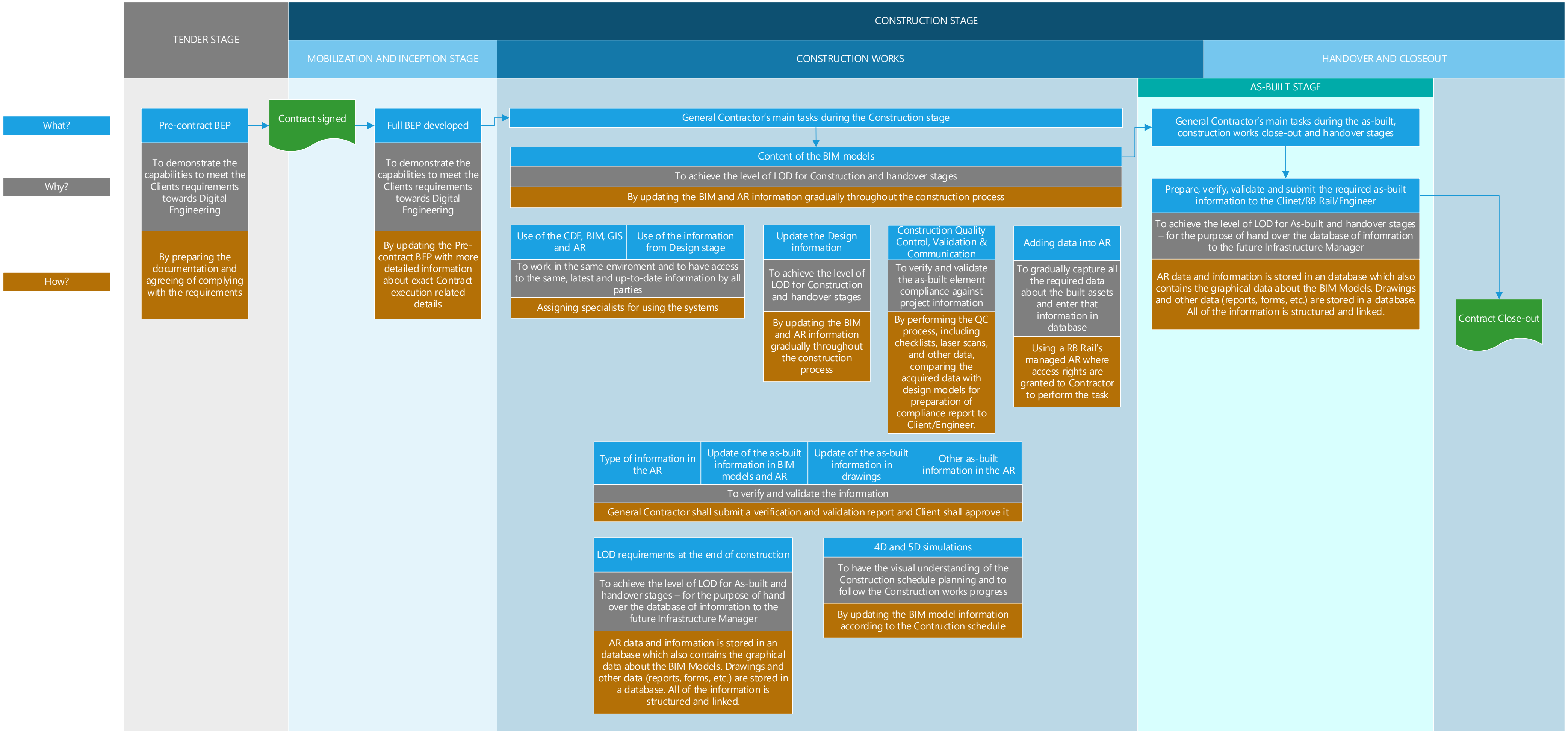
2.1 General workflow

5. The general workflow of the construction process towards the digital engineering is reflected in the flowchart below (Flowchart 1). Processes and workflow described in the Flowchart 1 might differ, depending on specifics of signed contract's Technical Specification. More detailed description of the requirements is described in the following chapters of this document. In case there is different workflow expected by Contract, corresponding flowchart should be agreed in BEP document.



Flowchart 1 - General workflow

2.2 Main tasks, explanation, and methods



Flowchart 2 - Main tasks, explanation, and methods

2.3 Specialists

6. It is required that the General Contractor shall employ or subcontract enough resources to cover these main responsibilities and tasks, but not limited to:

   6.1. BIM Manager / Supplier Information Manager

      (a) Coordinate overall BIM model and information management process between different involved parties of the Construction process;

      (b) Make sure that overall information used during the construction process is the latest, up-to-date and accurate;

      (c) Verify and validate the overall geometry and information accuracy in the BIM and AR against the requirements;

      (d) Oversee and manage all the latest updates of the model, drawing and other data;

      (e) Coordinate, manage, verify and validate the overall as-built information accuracy handed over to the Client, RB Rail, (and Engineer, depending on contract);

      (f) Be the direct contact point between the General Contractor, Client, RB Rail and Engineer;

   6.2. BIM Discipline Coordinator

      (a) Coordinate the discipline BIM model and information management process between different involved parties of the Construction process;

      (b) Make sure that discipline information used during the construction process is the latest, up-to-date and accurate;

      (c) Verify and validate the discipline geometry and information accuracy in the BIM and AR against the requirements;

      (d) Oversee and manage discipline geometry and information latest updates of the model, drawing and other data;

      (e) Be the direct contact point for the discipline between the General Contractor, Client, RB Rail and Engineer;

   6.3. CDE information manager

      (a) Coordinate and manage the overall information accuracy in General Contractor's and in Clients CDEs;

      (b) Make sure that overall information used during the construction process is the latest, up-to-date and accurate;

      (c) Be the direct contact point for the CDE and information management topics between the General Contractor, Client, RB Rail (and Engineer, depending on contract);

   6.4. GIS Specialist

      (a) Manage the relevant geospatial information;

      (b) Prepare and submit to Client, RB Rail (and Engineer, depending on contract) the requested geospatial information;

      (c) Work with Mobile and WEB applications provided by the Client, RB Rail for processing and submitting the AR and geospatial data;

(d) Be the direct contact point for the AR and geospatial topics between the General Contractor, Client, RB Rail (and Engineer, depending on contract);

7. Other important roles and responsibilities which are not directly required from Digital Construction process point of view, but will contribute and help to organize the Construction process:

7.1. Document Controller

(a) Coordinate and manage the overall information accuracy in General Contractor's and in Clients CDEs;

(b) Coordinate and manage the document codification and numbering, versioning, revisioning;

(c) Coordinate and manage the document submissions to the Client, RB Rail and Engineer using the required tools and systems;

(d) Be the direct contact point for the Document Control topics between the General Contractor, Client, RB Rail and Engineer;

7.2. Interface Manager

(a) Organizing and managing the interface resolution work with the Supporting Entities;

(b) Issuing an interface resolution action plan;

(c) Resolving the interface according to the resolution action plan;

(d) Drafting and updating the Interface Control Document, with the support of the Supporting Entity and the RBR technical experts if required;

(e) Keeping track of the resolution process in a Quality Controlled manner;

(f) Informing Interface Management Team Leader and Area Supervisor in case of delay/problem in the resolution;

(g) Calling for the relevant Interface Meeting;

(h) Issuing the Interface Meeting Minutes;

(i) Following up the actions from the Interface Meeting Minutes;

(j) Issue the ICD after receiving the signature of the Supporting Entity.

7.3. Construction Scheduling and/or Planning Manager

(a) Together with BIM Manager and BIM Discipline Coordinator coordinate the overall and discipline 4D and 5D BIM compliance with overall construction schedule;

2.4 Risks and recommendations

8. In the current market situation, there is a lack of Digital Construction specialists available. This shall be considered as a potential risk and the General Contractors shall propose a clear structure of the roles and responsibilities for the specialists that will work and update the technical information in the digital environment.

2.5 IT infrastructure/equipment/IT hardware requirements

9. The General Contractor must ensure an IT infrastructure, that allows it to perform all the tasks required for fulling the requirements towards the data information management and exchange.

10. All the lead experts and engineers which must work with technical documentation of the project, must be equipped with powerful mobile workstations, and required licensed software, in order to fulfil their tasks promptly and in time and quality. It is recommended, that the site engineers shall be equipped with rugged mobile workstations designed for the work in field.
11. As minimum, but not limited to, the requirements stated in the "RBDG-MAN-030 (BIM_EIR) on BIM coordination meetings shall be followed.
12. Specific software requirements please see in the "Annex 1 – Specific software and hardware requirements".

3 Tasks and Objectives

3.1 Start of the construction works stage

3.1.1 The main tasks and objectives for the Contractor

13. During the tender stage it is recommended that the Tenderer shall follow these steps:

13.1. Develop a Pre-Contract BEP and state the readiness to comply with the Client's requirements for the Digital Construction and to develop a Post-contract BEP in case of contract award.

13.2. If the Tenderer identifies any issues or mistakes in any of the design information, it shall immediately inform the responsible parties and the Client about the identified issues already during the Tender stage. During the Construction stage it is the General Contractor's responsibility in agreement with the RB Rail and the Client to improve the drawings and models before carrying out the respective construction works.

3.1.2 Pre-contract BEP

14. In order to standardize the required information from the Tenderers during the Procurement stage towards the Digital Engineering a "Pre-contract BEP" (Annex 4) template shall be filled in and submitted as a part of Technical Proposal for the Procurement exercise.

15. The Pre-contract BEP shall serve as basis for the Post-contract BEP (also referred as BEP) which the General Contractor shall prepare and submit to the Client and RB Rail for the Inception Report deliverable.

3.2 Inception or mobilization stage after the Contract award

16. After the contract award, during the Inception/Mobilization stage the General Contractor shall develop a full post-contract BEP and receive acceptance from the Client, RB Rail (and Engineer, depending on contract) for the prepared document.

3.2.1 Post-contract BEP

17. Post-contract BEP or just BEP has to be developed based on the "pre-contract BEP" which the General Contractor prepared during the Procurement exercise and which shall be a part of the Technical Proposal. For the development of the BEP the General Contractor shall use the RBDG-TPL-013 (BEP template) and as minimum, but not limited to, has to prepare and submit the required information.

18. For more information about the BEP please refer to RBDG-MAN-030 (BIM EIR).

19. The BEP shall be treated as a "live document" and shall be updated during the Contract execution stage to reflect and capture the proposed changes and updates in the Digital Engineering process agreed between the parties.

20. The General Contractor shall prepare the BEP and divide that in:

20.1. General part – this part shall contain BEP parts which are common for all Building Permits/Construction objects/Structures included in Contractors scope;

20.2. Specific part – this part shall be specific for each Building Permit/Construction object/Structure which shall contain and address specific items for each of the objects from Digital Construction point of view. The split and division of the BEP shall be agreed with the Client during the Inception/Mobilization stage.

3.3 Active construction works stage

3.3.1 Content of the BIM models

21. The BIM models are developed throughout the design process. The information about the assets and other attribute information is within each and every design model. The level of information in the models according to each design and construction stage are as described in "RBDG-MAN-030 (BIM EIR) paragraph "11.Level of Definition".

RAIL BALTICA BIM DEVELOPMENT PLAN	RAIL BALTICA PROJECT STAGES				
	Value engineering (VE)	Master Design (MD)	Detailed Technical Design (DTD)	Construction	Operation
BIM Stage definition (reference: PAS 1192-2) **BIM object LoG** (reference: "BIM Manual" + BIM Forum) **BIM object LoI** (reference: "BIM Manual")	Stage 2 - Concept / Stage 3 - Definition	Stage 3 - Definition / Stage 4 - Design	Stage 4 - Design / Stage 5 - Build and commission	Stage 5 - Build and commission / Stage 6 - Handover and Closeout	Stage 6 - Handover and Closeout / Stage 7 - Operation
BIM MODELS (Geometry + Data)	Project models within RB Rail scope				
Level of Geometric Detail (LoG)	LoG 200*	LoG 300*	LoG 400*	LoG 400 / 500*	LoG 500*
Level of Information (LoI)	LoI 200*	LoI 300*	LoI 400*	LoI 400 / 500*	LoI 500*
3D MODELS (Geometry)	Environment models / Existing Utilities models / Buildable & Non-buildable out-of-scope elements models				
Level of Geometric Detail (LoG)	LoG 200*	LoG 300*	LoG 400*	LoG 400 / 500*	LoG 300*
Level of Information (LoI)	LoI 0	LoI 0	LoI 0	All calculations shall be submitted and stored in the clients CDE	All calculations shall be submitted and stored in the clients CDE

Table 1 - General LoG and LoI table

22. * - this is a minimum target number and LoG and LoI for each discipline and system shall be agreed with the Client separately in the BEP, but shall not be lower unless derogations are applied using change management procedure. The General Contractor shall prepare the BEP document according to required LOD of each stage of the project and agree that with the Client, RB Rail and Engineer during the Inception/Mobilization stage of the project.

23. Minimum LoG and LoI requirements and descriptions for each discipline and system for each project stage see in Annex 1, Annex 2 and Annex 3 of "RBDG-MAN-030 (BIM EIR .

24. During the Construction and Handover stages the asset attribute information shall be included in the AIM model and ADD – see “4.1 - Post-contract BEP”.

3.4 General Contractor’s main tasks during - Construction to As-build

3.4.1 Use of the CDE, BIM, GIS and AR

25. The General Contractor shall:

    25.1. Use of the CDE to access and manage the Design and Construction documentation;

    25.2. Use of the Design Stage BIM models to update those to achieve LoG and LoI required for the Construction and As-built stages;

    25.3. Use of GIS platform to submit the information about the as-built asset information to AR The approved models will be handled and uploaded by RB Rail. However, item-specific attributes shall be updated by Contractor

    25.4. Manage and submit the Construction stage documentation to Client, RB Rail or Engineer;

26. See “Annex 1 – Specific software and hardware requirements” for more detailed technical requirements and information.

3.4.2 Use of the information from Design stage

27. The General Contractor shall:

    27.1. Use the Design information including the drawings, models and other data to perform construction works;

3.4.3 Update the Design information

28. During the Construction and Handover stages the models shall be updated in order to achieve the LOD requirements for the respective project stage. The minimum information level that shall be included in the construction model is stated in this document and in the Annex 3 of “RBDG-MAN-030”, deviations, derogations, updates shall be agreed during the Inception/Mobilization stage of the project for each discipline, but the Level of Information shall not be defined less than it is defined in the DG for the respective stage of the project.

29. If any AD4 tables are missing or the information required from the Client is insufficient in order to meet the maintenance criteria required to perform the Infrastructure maintenance procedures, the General Contractor shall advise the Client on the missing information and shall propose the list of information which is relevant for the maintenance procedures. It is General Contractors responsibility to develop the full list of information and add that information properly in the AR system.

30. If any updates/changes are implemented in the design solutions during the construction works of the building permit which includes those design solutions, the General Contractor is responsible for adapting the PIM model accordingly and including all the LOD information. Detailed workflows and sequence, file formats, attribute information etc. has to be agreed with Client, RB Rail (and engineer, depending on contract) and fixed in respective BEP beforehand..

31. The PIM model shall be updated on monthly basis if not agreed otherwise in the BEP or other Contract condition and shall follow the same schedule as for the progress reports.

32. The updated model shall be submitted for the review to the Client, RB Rail (and Engineer, depending on contract) for information verification and validation purposes.

33. As minimum General Contractor shall perform required tasks regarding data updates and ensure the monitoring of construction process. Some examples of expected tasks, but not limited:

    33.1. Geospatial data attribute updates in Web GIS environment or in mobile application which is provided by Client.

    33.2. Geo-located photo capturing and uploading into GIS.

    33.3. Geo-located point capturing and attribute information entry.

    33.4. Etc.

34. General Contractor must have appropriate hardware (mobile devices and personal computers) that can carry out these tasks and meet the technical requirements.

35. See “Annex 1 – Specific software and hardware requirements” for more detailed technical requirements and information.

36. All drawings (electronical or paper format) shall be clearly marked with the latest revision number and identified by General Contractor as the latest in-force version to be used for construction works. All updated revisions of the in-force drawings shall be registered according to the local National norms, laws and legislation.

37. The generation and use case of additional Structural Detailing (Construction shop drawings) is described in the BIM Manual RBDG-MAN-033 (BIM Manual) paragraph “Structural Detailing (Construction shop drawings).

38. Structural Detailing (Construction shop drawings) shall be extracted and developed from the PIM model, therefore the PIM model shall achieve the LoG to fulfil this requirement.

3.4.4 Construction Quality Control, Validation & Communication

39. As described in “RBDG-MAN-033” paragraph 8.3.6.4, Laser scanning and/or photogrammetry shall be carried out on regular basis as a support mechanism for Construction Quality Control, Validation & Communication to control and follow the progress and quality of the construction works. The laser scanning and/or photogrammetry work schedule, data collection methods and equipment to be used and tolerances for each type of scanning, location of scans shall be described by the General Contractor in each BEP according to the requirements and it shall be agreed and approved as per the Contract. It is the direct responsibility of the General Contractor to carry out these works and submit the information/data and validation reports to the supervisors and the Client.

40. The following tasks shall be performed for each scan location:

    40.1. Geolocated scanning of the structural element/section/object;

    40.2. Postprocessing of the pointcloud (clean-up/categorization);

    40.3. Compare the pointcould with the built construction element/section/object BIM model and create a compliance report;

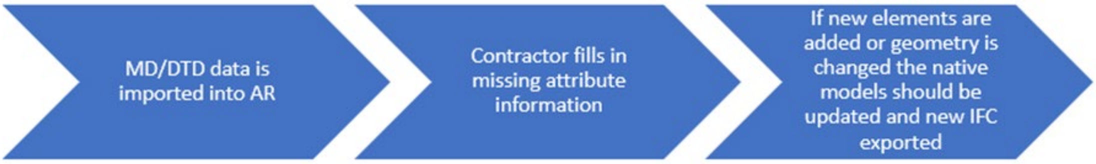
    40.4. Submits the compliance report to the Engineer for verification and validation together with the postprocessed pointcloud file in one of the agreed formats.

41. See “Annex 2 – Laser scanning requirements” for more technical information.

3.4.5 Adding data into AR

42. The General Contractor shall enter into RB Rail’s AR (FM) system or provide as COBie spreadsheets the information about the built fixed assets (e.g. attributes, maintenance schedules, maintenance manuals).

43. A simplified workflow looks like this:

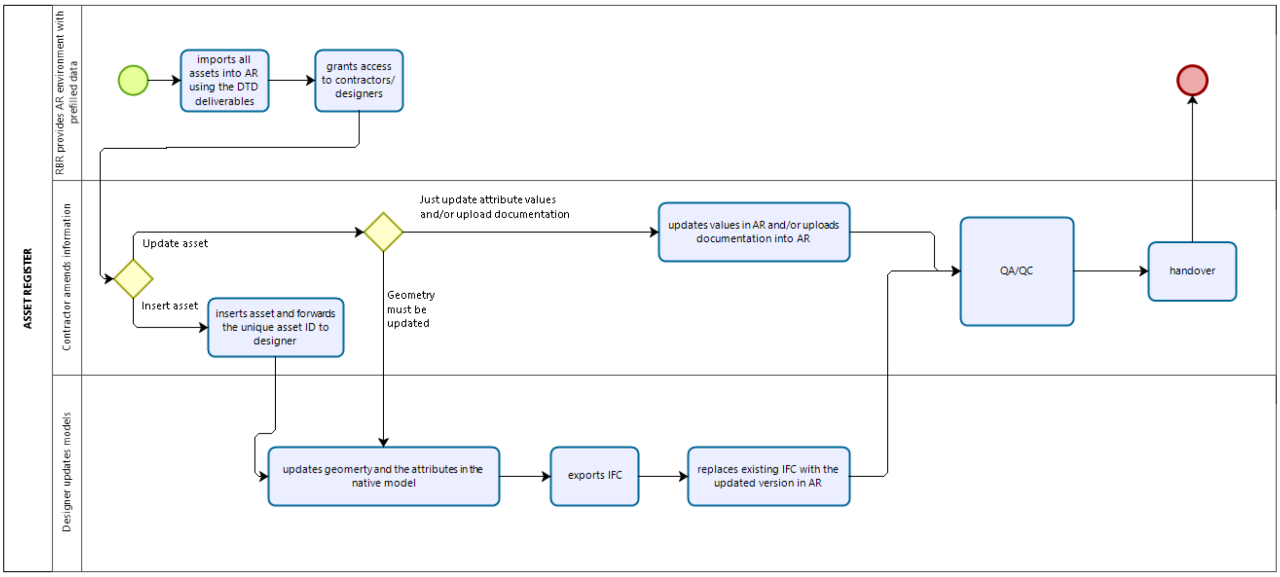


Flowchart 3 - Simplified workflow for information the update during Construction stage

44. Import objects/elements geometry based on Construction / as-built stage IFC into AR – by RB Rail

45. Information about model, manufacturer and serial number for equipment or any other element shall be entered into AR as soon as it becomes available – by General Contractor.

46. The term "Designer" in the context of the graphic below means the legal entity which is tasked to modify the models/drawings in native format and extract the exchange formats as part of the documentation. The General Contractor can outsource these works or it can do it using its own personnel to perform such tasks if the capabilities and knowledge allows to do it. It is the General Contractor's direct liability and responsibility to ensure the quality of the performed tasks.



Flowchart 4 - Workflow for information the update during Construction stage

47. Maintenance documentation must be assembled by General Contractor and presented to the Client, RB Rail and Engineer. It is a direct responsibility of the General Contractor that all the required maintenance information about the assets is entered in the AR and handed over to the Client, RB Rail and Engineer right after the installation, verification, and acceptance of the asset. All construction documents are assembled and presented immediately after an event or the moment when documentation obligation emerges.

48. The General Contractor shall have their QA/QC processes in place making sure that the information entered into AR is verified and validated. As the data is entered in real time (not later than 10 days after the asset installation), Construction supervisor/Engineer will compare the entered information with the 4D BIM (construction schedule).

49. For example, if the schedule says that on day X the staircase of a bridge shall be ready then by day X+10 we shall see in AR the colour code and product code of the paint on the hand rail and how often it shall be repainted to avoid exposing of the metal to the weather conditions.

50. NOTE: None of the above-mentioned procedures does not exempt the General Contractor not to perform all the legal procedures stipulated in the Country's legislation, laws and regulations.

3.4.6 Type of information in the AR

51. The General Contractor shall:

51.1. Enter all as-built information in the Asset Register solution.

51.2. Add as-built information/update the information about and within:

51.2.1. Asset Data Dictionary (ADD) and Asset Information Models General Contractor shall make sure that the values of attributes required in EIR are entered into AR (not into IFC file). The most relevant attributes are:

(a) RBR-Product_Name (= TypeName in COBie)

(b) RBR-Product_Description (= Description in COBie)

(c) RBR-Manufacturer_Name (= Manufacturer in COBie)

(d) RBR-Material_reference (= ModelNumber in COBie)

(e) RBR-Installation_date (= InstallationDate in COBie)

(f) Before construction stage up to 10 attributes may be added.

52. All the progress reported with act of performed works, material approvals before construction works, materials tests for acceptance of works, other interim work acceptance acts and other documents shall comply with the information added to as-built drawings, as-built model and information data and as-built asset information.

53. During the Handover stage of the project, the General Contractor must ensure, that all the required information about each built asset is submitted and stored within BIM models and ADD.

54. If a missing information about the as-built models is identified it is General Contractor's responsibility to add the information and structure it according to Client's requirements. The missing information shall be added and submitted to the Client during 1 week's period if not otherwise agreed with the Client.

55. In case the Client requires any attribute information that has not been previously agreed, the General Contractor must include it in the BIM models and ADD upon Client's request without any additional financial requests and variations towards the Client.

56. All the digital information (as-built drawings, as-built models and ADD), shall be uploaded to Client's CDE following the data formats stipulated and agreed with the Client in the Post-contract BEP. See paragraph "4.1 - Post-contract BEP" for more information.

57. None of the above-mentioned procedures does not exempt the General Contractor not to perform all the legal procedures stipulated in the Country's legislation, laws and regulations.

3.4.7 Update of the As-built information in BIM models and AR

58. The General Contractor shall:

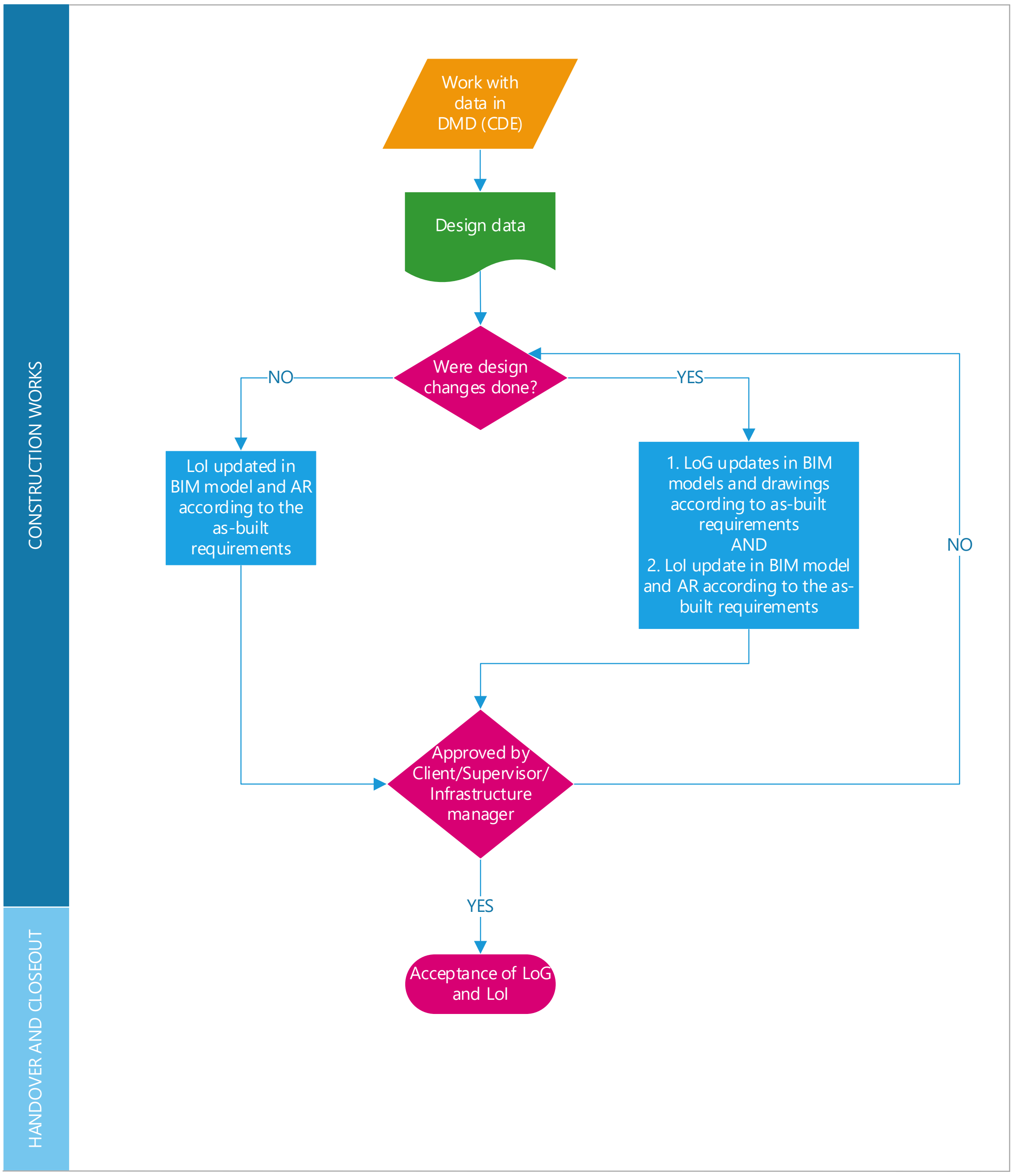
58.1. All as-built BIM models shall be updated according to the requirements of LoG and LoI. Native and exchange formats of the information shall be delivered. Drawings (extracted from BIM models) must be delivered in dwg/dgn and pdf formats.

58.2. During the construction stage the as-built information shall be entered gradually as the construction works progresses. After each act of performed works, material approvals before construction works, materials tests for acceptance of works, other interim work acceptance acts and other documents are created and record done, the information in the AIM models, ADD shall be updated accordingly.

58.3. For the geometrical compliance check there are 2 uses cases/scenarios how the General Contractor shall update the information:

(a) If the as-built models and drawings are fully compliant with the geometry and global geolocation of the built asset/structure within the allowed tolerances, the General Contractor shall use the same Design model and update it and the AR with the required attribute information keeping the same geometry of models and drawings.

(b) If the as-built models and drawings do not match the design geometry and/or the design solution for some reason is changed and is approved by all relevant parties during the construction stage or deviate from the allowed tolerances, a new or updated as-build geometry of the BIM models and drawings with the required attribute information shall be prepared and submitted for approval to relevant parties.



Flowchart 5 – Generalized extract from flowchart 1. Update of the As-built information in BIM models and AR

59. To maintain the references to the documentation it is essential to follow the naming logic of the assets (for example railings, pillars, doors) – each asset on the entire Rail Baltica project is uniquely defined through the combination of the asset ID (RBR-Object_ID in models) and site ID (RBR-VolSysZone in models).

60. If some non-geometrical information during the construction stage is changed and the attribute information within the design BIM models and drawings needs to be changed, then it is General Contractor's direct responsibility to submit the design models with updated information by adding the additional required attribute information as required in AR. An example for this use case would be if a construction material is changed/replaced during the construction stage. In this case a design BIM model and drawing shall be used for

geometrical purposes and submitted with updated attribute information – geometry remains the same, but the information about the elements and assets must be updated.

61. In case for the ground works, such as, but not limited to – cutting, embankment layer construction, back-filling, etc. the as-built information shall be created also using the surface data acquired using laser scanning/photogrammetry methods explained in the chapter "Annex 2 – Laser scanning requirements" and to be compared to the design models and data.

62. In case the geometrical data from the surface created from the data acquired using laser scanning/photogrammetry matches the design model within the allowed tolerances, the design model shall be used as as-built geometry models.

63. In case the geometrical data from the surface created from the data acquired using laser scanning/photogrammetry deviates from the design state outside the allowed tolerances a new BIM model shall be prepared with all the attribute information and submitted together with the surface created from the data acquired using laser scanning/photogrammetry methods.

64. Control points and control measurements shall be performed additionally to laser scanning/photogrammetry methods according to requirements of the legislation, laws and supervisor.

65. The General Contractor as minimum shall add as-built information/update the information about and within:

    65.1. BIM and other data models, according to the use cases and scenarios. As-built BIM models having the geometrical compliance with the real as-built assets/structures/systems and containing the relevant and required asset attribute information.

    65.2. As-built drawings, which represent the actual as-built geometry and information and are required by legislation and law in each respective Country.

66. The models with the required attribute information must be updated after the act of performed works is submitted.

67. The attribute information, that must be updated are listed in the "RBDG-TPL-019-0102_BIM_Objects_Attributes_Matrix" corresponding to LOD400 and LOD500. In some cases, the LOD300 also shall be applied, and that indicated in the BIM EIR "RBDG-MAN-030-0103" in Annex 1, but that shall be agreed with Client separately.

68. The following documents must be followed as a set of documents to get understand what kind of information must be updated during the construction and handover stages of the models, data and drawings:

    68.1. BIM EIR "RBDG-MAN-030-0103" (and updated versions); special attention, but not limited to, shall be made to:

        (a) Paragraph 4 – BIM use cases

        (b) Paragraph 11 - Level of Definition (LOD)

        (c) Annex 1 – Level of Definition

        (d) Annex 2 – Level of Geometric Detail

        (e) Annex 3 – Level of Information (attributes)

    68.2. "RBDG-TPL-019-0102_BIM_Objects_Attributes_Matrix"

    68.3. "RBDG-TPL-024-0101_BIM_Objects_LoG_Matrix"

69. In case the design solution is not changed, the required information about the as-built assets must be added as stated in the above-mentioned documents and "5.2 – Workflows and process of digital construction - ADD"

chapter in this document. The BIM models with the updated information must be submitted to the Client's CDE according to the agreed procedure between the parties. If the procedure is not agreed it is General Contractors responsibility to initiate this procedure and agree it with the Client.

70. If the as-built structure or components of the structure are changed from the design solutions and agreed with the Designer and the Client per the Contract, then the updated models according to the as-built geometry (LoG) and as-built information (LoI) data must be submitted to Client's CDE according to the agreed procedure between the parties. If the procedure is not agreed it is General Contractors responsibility to initiate this procedure and agree it with the Client.

71. The geometry of the as-built models shall comply with the geometry of the structures/construction gathered from the laser scanned point clouds/photogrammetry results. The acceptable tolerances shall be agreed in the BEP but shall not exceed the allowed construction tolerances defined in the Countries laws and legislation.

72. General workflow of updating the model information during the construction is described in "RBDG-MAN-033-0101_BIMManual" paragraph 8.3.6.2 "Delivery times of the updated models during Construction".

73. The procedure of the information preparation and flow shall be agreed during the Inception/mobilization stage and be a part of BEP.

3.4.8 Update of the as-built information in drawings

74. The as-built drawings shall be created from the as-built models (extracted). If that is not possible, the General Contractor shall inform and explain it to the Client and the procedure shall be agreed.

75. The as-built drawings with the required graphical and non-graphical information must be updated after the act of performed works is submitted, after the solution is agreed with Construction Supervisor and Design Supervisor, and respective Construction works are finalized.

76. The generation and use case of additional Structural Detailing (Construction shop drawings) is described in the BIM Manual "RBDG-MAN-033" paragraph "3.3.7. Structural Detailing (Construction shop drawings)".

77. The as-built drawings must comply with Countries laws, legislation and requirements.

78. Structural Detailing (Construction shop drawings) shall be extracted and developed from the PIM model, therefore the PIM model shall achieve the LoG to fulfil this requirement.

79. The procedure of the information preparation and flow shall be agreed during the Inception/mobilization stage and be a part of BEP.

3.4.9 Other as-built information in the AR

80. The General Contractor shall deliver all the related as-built and field progress tracking information to GIS solution according to the requirements of the Client:

    80.1. Geotagged photographs from field showing work progress and existing/foreseeable issues.

    80.2. Geolocated surveys forms/reports

    80.3. Additional Field investigations data

    80.4. Field progress tracking using survey forms and reports

81. Note: If the General Contractor identifies any issues or mistakes in any of the design information, it shall immediately inform the responsible parties and the Client about the identified issues. It is General Contractors responsibility in agreement with the Author and the Client to improve the drawings and BIM models with all data, before carrying out the respective construction works.

82. The exact procedures and workflows shall be agreed in BEP initially or by update of BEP document when Asset Register solution (ESRI ArcGIS) on Client's side is implemented.

3.4.10 LOD requirements at the end of construction

83. This paragraph defines the requirements that the PIM, AIM and GIS models (databases) must achieve at the handover of any Construction object or system. This paragraph focuses on the handover stage of the construction and describes what level of information needs to achieve, so that the infrastructure manager and facility manager would be able to use it during the lifecycle of the infrastructure.

84. LOD requirements for Handover stage in general are covered in the table in the paragraph "5.3 - Content of the BIM models" - RAIL BALTICA PROJECT STAGES – Construction and Operations.

85. The following documents must be followed as a set of documents to get understand what kind of information must be updated during the construction and handover stages of the models, data and drawings:

85.1. BIM EIR "RBDG-MAN-030"; special attention, but not limited to, shall be made to:

(a) Paragraph 4 – BIM use cases

(b) Paragraph 11 - Level of Definition (LOD); the same table is referenced in this document's paragraph "5.3 - Content of the BIM models".

(c) Annex 1 – Level of Definition

(d) Annex 2 – Level of Geometric Detail

Example:

Architecture	Structure	Mechanical	Electrical	Civil	System	Elements	VE		MD		DTD		CO	
							LOG 200		LOG 300		LOG 400		LOG 500	
Discipline							2D	BIM	2D	BIM	2D	BIM	2D	BIM
				X		Schematic Layout	X		X		X	o		X
				X		Vertical alignment	X	o	X	o		X		X
				X		Horizontal alignment	X	o	X	o		X		X
				X		Cross-section	X		X	o		X		X
				X		Speed diagram	X		X		X			X
				X		Rails	X			X		X		X
						Cross Passages	X			X		X		X
				X		Sleepers	X			X		X		X
				X		Fastening system	X			X		X		X
				X		Turnouts	X			X		X		X
				X		Substructure		X		X		X		X
				X		Railroad corridor	X			X		X		X
	X			X		Retaining Walls		X		X		X		X
				X		Noise barriers		X		X		X		X
			X	X		Utilities	X			X		X		X
				X		Fencing				X		X		X

(e) Annex 3 – Level of Information (attributes)

85.2. “RBDG-TPL-019”

Example:

Element Type	Code		Image	Description
Element Type	XXX		Image	Description

X:Mandatory O:Optional

Type	Group	Attribute	Recommended Data Type	Units	Description	Commentary	200	300	400	500	Responsible
			attribute Description				LOI				
	All attribute must be included in models										
All	Global attributes										
	Member Mark										
		RBR-Project_ID	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-Section_ID	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-SubSection_ID	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-Originator	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-Discipline_Code	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-VolSysZone	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-Location	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
		RBR-Functional_classification	Text		See Member Mark section	Classification code according with the functional hierachy	X	X	X	X	PIM
		RBR-Object_ID	Text		See Member Mark section	See codification tables	X	X	X	X	PIM
	Common Asset Data										
		RBR-Asset_ID	Text		Unique Asset ID		-	-	-	X	AIM
		RBR-AR_ID	Text		Asset register identificator		-	-	-	X	AIM
		RBR-Asset_Name_1	Text		Descriptive name (e.g. "Pump 01")	Operator defined, (Supplier defined if not by operator). Attributes used to relate components/sub-components hierarchically within assets.	-	-	-	X	PIM / AIM
		RBR-Asset_Name_2	Text		Descriptive name (e.g. "Pump 01")		-	-	-	X	PIM / AIM
		RBR-Easting	Number		point object	According to the WGS in use, refer to BIM models' Geo-reference in the BIM Manual f	X	X	X	X	PIM
		RBR-Northing	Number		point object	According to the WGS in use, refer to BIM models' Geo-reference in the BIM Manual f	X	X	X	X	PIM
		RBR-Elevation	Number		point object	According to the WGS in use, refer to BIM models' Geo-reference in the BIM Manual f	O	O	O	O	PIM
		RBR-Easting_Start	Number		line objects		X	X	X	X	PIM
		RBR-Northing_Start	Number		line objects		X	X	X	X	PIM
		RBR-Elevation_Start	Number		line objects		O	O	O	O	PIM
		RBR-Easting_End	Number		line objects		X	X	X	X	PIM
		RBR-Northing_End	Number		line objects		X	X	X	X	PIM
		RBR-Elevation_End	Number		line objects		O	O	O	O	PIM
		RBR-Design_life	Integer		Design whole life	Design whole life, in years	-	X	X	X	PIM

85.3. “RBDG-TPL-024-0101_BIM_Objects_LoG_Matrix”

Example:

COMPONENT			LEVEL OF GEOMETRIC DETAIL (LoG) DEFINITION			
Category	System	Description	200	300	400	500
Rail	Superstructure	Rail including	3D Models of:	Detailed 3D models of (integrated to GIS):	LoG 300 objects including:	LoG 400 geometry updated as built + further specific geometry detail needed to act as an Infrastructuure manager for the LoI 500 (for Operation & Maintenance)
		all components	• 3D Track Allignment Geometry integrated to GIS	• Track Allignment Geometry, including turnouts, expansion joints, cant	• Specific Geometry and reinforcement according to Brand / model of sleepers, rails, fastening systen, track slabs (if prefab) or any other supplied product (pre-cast).	
		to formation	• 3D Railway superstructure and substructure realistic model (for visualisation purposes only)	• Ballast layer (with volumes for calculations)	• Layouts of turnouts with sleepers	
				• Kinematic structural clearance, including overhead carenary	• Any additional geometry required for the construction, installation and assmembling works	
			2D CAD Models of:	• Sidewalks and crossings (sation areas)		
			• Schematic track layout for the railway	• Slab Track		

3.4.11 4D and 5D simulations

86. The 4D (Construction scheduling / planning - time) and 5D (Quantity Extraction - cost) simulations is a mandatory requirement for the General Contractor to be prepared and submitted to the client. See the paragraph “3.3.1 - Content of the BIM models”.

87. The generation and use case of 4D simulations – Phasing and Construction Sequencing Simulations is described in the BIM Manual “RBDG-MAN-033-0101_BIMManual” paragraph “3.3.10. Phasing and Construction Sequencing Simulations (4D)” and paragraph 15.4 “4D: Planning and scheduling. Construction sequencing”.

88. The 4D simulations shall be submitted to the Client in native format – in the format in which the simulation is created. The recommended software to use for this purpose is Autodesk Navisworks 2020, but other software can be used if that is separately agreed with the Client, RB Rail and Engineer during the Inception/Mobilization stage of the project.

89. To secure the compliance with other SW solutions a table in XLSX format should be provided. The table of 4D simulation shall contain at least 4 fields:

   89.1. asset ID (RBR-Object_ID in models),

   89.2. site ID (RBR-VolSysZone in models)

   89.3. Date_Start

   89.4. Date_End

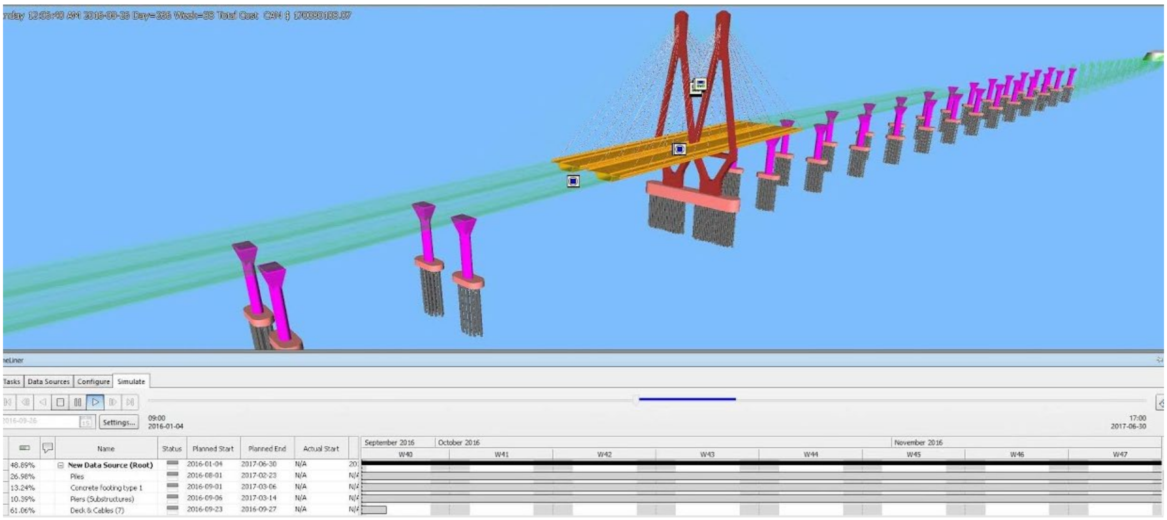
90. In case the integer field Duration for the duration in days is used instead of date fields, two fields for predecessors asset ID and site ID are required.

91. The 4D simulation shall be submitted to the client also in video (*.mp4 or similar) formats. In the video it shall be displayed:

   91.1. The work sequencing of construction object – representation/simulation of the progress of the works;

   91.2. The schedule and timeline of works with clear indication of the progress of the works;

This is an example, how the video composition shall look like:



92. The schedule used for the 4D simulation shall be the same schedule which is used for the project planning and scheduling.

93. The generation and use case of 5D simulations – Quantity Take-Off (5D) is described in the BIM Manual "RBDG-MAN-033-0101_BIMManual" paragraph "3.3.12. Quantity Take-Off (5D)" and paragraph 15.5 "5D: quantity extraction and tracking".

94. The generation of these simulations shall follow the same principles as for the 4D simulations.

95. 4D and 5D simulations shall be prepared for each Construction object during the Inception/Mobilization stage. The simulations shall be updated according to the schedule changes and updates during the construction progress reports at least on a monthly basis.

3.5 As-built, construction works close-out and handover – as a result

3.5.1 General Contractor's main tasks during the as-built, construction works close-out and handover stages

96. All as-built data is the result of the updated information during and throughout the Construction stage and must be submitted to the CDE, Asset Register and GIS platform according to the requirements set out in the previous paragraphs of this document. Submitting the as-built data to any and/or to all of these platforms owned by the Client or RB Rail, does not exempt the General Contractor to follow the Countries local laws, requirements and legislation towards the procedures handling the construction documentation.

3.5.1.1 Submission of As-built information

97. All as-built information to be submitted to the Client using the RB Rail's/Client's CDE platform and AR.

3.5.1.2 Content of the As-built information

98. General Contractor shall validate that all information submitted during the construction stage representing the as-built situation of any structure/element/system is already recorded and included in the BIM models, AR, drawings and other required information. The following information that has been submitted at the as-built stage, shall contain, but is not limited to:

    98.1. As-built stage information validation reports, including the as-built pointclouds;

    98.2. As-built BIM models;

    98.3. As-built drawings;

    98.4. As-build information in AR;

    98.5. Maintenance manuals and other related information;

    98.6. Additional information that is required for Client to issue the handover certificate.

99. If the submitted information/quality of the information is not sufficient for the Client to issue a handover certificate, the General Contractor shall prepare, verify, validate and submit the missing information at this stage.

ANNEX 1 - SPECIFIC SOFTWARE AND HARDWARE REQUIREMENTS

Annex 1 to the Digital Construction Information Handover Requirements, RBGL-VDC-INS-R-00001, 2.0

1 Common software requirements

1. General Contractor has the obligation to ensure, that it has in its possession all the required software licenses in order to work with all the file formats of the Detailed Technical Design deliverables. All of the required file formats are listed in "RBDG-MAN-030" paragraph "7.Model types, content and file formats" and "RBDG-MAN-033" paragraph "16. File Formats".
2. Most of the delivered BIM models are in OpenBIM IFC2x3 file format which can be viewed with license free viewer software's. Some of most commonly used are listed in "RBDG-MAN-033" paragraph "16.4. Open BIM Viewers".
3. In order to update the BIM model data, attribute information within the models, manipulate the content of the models, update the models with As-built information, in most cases the native design software is required. The General Contractor has the obligation to ensure the purchase of the software license in order to perform these tasks.
4. All of the technical drawings are available in PDF formats. Drawings in editable format are available in DWG and/or in DGN formats.
5. Explanatory notes and other textual technical documents are available in PDF formats. If agreed with the Client separately, those documents are available in MS Office compatible file formats.
6. Quantity take off sheets must be available in MS Excel formats and "printouts" as PDF formats.
7. GIS data shall be delivered in compatible formats for Esri ArcGIS solutions and the deliverable content and scope shall be agreed in BEP.
8. All the used file formats and software versions shall be agreed with Client during the Inception/Mobilization stage of the contract and shall be a part of post-Contract BEP. Please see the paragraph "4.1 - Post-contract BEP".

2 Common Data Environment (CDE)

9. All the data about the design projects delivered to the Client must be stored in a Common Data Environment (CDE). CDE shall be mutually agreed on based on the Electronic Document Management System (EDMS) used by the Client.
10. All the data is stored within a data source and access to this data shall be granted as required and requested by the Client. A separate process must be established how the access rights are granted to the General Contractor.
11. It is required that all of the technical documentation about the project during the Construction stage and Handover stage must be stored in the repository and all of the up-to-date information is stored in this data repository. The information uploaded to Clients/RB Rail CDE shall be done using the system/prepared

tools/forms. All the data required by the national legislation must be included, organized and must be digitally signed by the responsible expert.

12. Additionally, must be included:

    12.1. As-built 3D and BIM models according the LOI and LOG requirements for the respective stage;

    12.2. As-built laser scanning and/or photogrammetry data according to the contract and geodetic requirements set by the Client;

    12.3. Attribute data about the as-built assets. See more information in "5.2 - Workflows and process of digital construction - ADD"

13. In order for the General Contractor to access the information, they must allocate financial and human resources. The financial resources in order to access the platform, must include named user license for each user accessing the system. How many named users the General Contractor allocates for usage of the platform is up the General Contractor, but it must ensure that the information flow is realized in a timely manner and the information is updated on regular basis as stipulated in the Contract and Technical Specification. The exact list of all named users using and accessing the platform must be agreed with the RB Rail/Client directly.

14. Indicative[1] license costs as of year 2022 for accessing RB Rail's/Clients CDE are as follows:

    14.1. VISA license cost for ProjectWise CONNECT Edition ~1000 EUR/user/year

    14.2. PASSPORT license cost for ProjectWise CONNECT Edition ~300 EUR/user/year

15. This is an indicative table, which describes the general functionalities for each of the services as of year 2022. The General Contractor is responsible for evaluating the amount of each licenses required for the performance of the required tasks.

[1] The license cost has indicative nature and exact prices shall be quoted from the vendor

ProjectWise Services	Service	Accessed Through	Capabilities	CONNECTIONS Passport	Design Integration Visa
365 Services	Share	CONNECT Center	Share and access files	✓	✓
			View models	✓	✓
			View and markup PDFs	✓	✓
			Access and save from engineering applications	✓	✓
	Deliverables Management	CONNECT Center	Receive, send, and manage transmittals, submittals, RFIs	✓	✓
	Issues Resolution	CONNECT Center	Report, manage, and resolve issues	✓	✓
	Forms	CONNECT Center	Collect, manage, view, and approve field data	✓	✓
	Project Insights	CONNECT Center	Gain insights on past, current, and future performance	✓	✓
Collaboration Services	Collaboration	ProjectWise Web	Review and approve workflows	✓	✓
			Read-only access to Design Integration content	✓	✓
			Check in/out with Design Integration content	✓	✓
			Collect data in the field	✓	✓
Design Integration Services	Design Integration	ProjectWise Explorer	Implement project delivery workflows		✓
			Integrate engineering applications		✓
			Automate title block generation		✓
			Manage dependencies and references		✓
			Manage drafting, modeling, project, and industry standards		✓
			Manage workspaces		✓
			Create and manage specifications		✓
			Leverage delta file transfer and caching		✓

16. It shall be noted that Experts and Engineers (or any other employees of the General Contractor) that will directly work with Technical Design Data and perform actions with CAD/BIM models, shall use VISA licenses for better workflows.

17. All users who must access the platform must undergo a security background check and receive a security clearance. The security clearance must be granted by the Security Risk Manager of RB Rail or to equivalent instance/person from Client's side. All information must be treated as minimum as Limited Access Information and must be treated that way.

18. Any violation and security threat and breach must be immediately reported to Security Risk Manager in RB Rail or to equivalent instance/person from Client's side.

19. The General Contractor's human resources and experts must be trained to use the platform for the specific tasks. The training materials in written or video format should be prepared and delivered to the General Contractor by the Client or RB Rail AS. Any additional training required performed for the General Contractor employees is the responsibility of the General Contractor.

20. The exact workflows of information flow and responsible persons must be defined during the Mobilization stage of the Construction project. The definition of the workflows is a collaborative work between the Client and the General Contractor. As minimum, but not limited to, those shall include:

    20.1. Any information management according to respective Country's laws, legislation and rules

    20.2. Any deliverables information exchange using RB Rail's/Client's EDMS CDE platform and Deliverables Management services

    20.3. Requests for information (RFI) exchange using RB Rail's/Client's EDMS CDE platform and Deliverables Management services

20.4. General and Contractual Communication exchange using RB Rail's/Client's EDMS CDE platform and Deliverables Management services

20.5. As-built information deliverables using RB Rail's/Client's EDMS CDE platform and Deliverables Management services

20.6. Asset information delivery to RB Rail's/Client's asset register solution according to the requirements

21. General Contractor is responsible for ensuring that its sub-General Contractors are able to use the CDE platform and are trained to do it. The General Contractor is responsible for any information uploaded/downloaded or any actions performed by its sub-General Contractor within the CDE platform.

3 GIS platform

22. As minimum General Contractor must be able to perform required tasks regarding data updates and ensure the monitoring of construction process. Some examples of expected tasks, but not limited:

22.1. Geospatial data attribute updates in Web GIS environment or in mobile application which is provided by RB Rail AS.

22.2. Geo-located photo capturing and uploading into GIS.

22.3. Geo-located point capturing and attribute information entry.

22.4. Etc.

23. Specification for mobile devices:

23.1. For Survey123 field app:

(a) (https://doc.arcgis.com/en/survey123/faq/systemrequirements.htm)

(b) Browser: Chrome, Firefox, Safari, Edge (For best performance, use the latest version.)

Operating system	OS version
Windows	• Windows 10 Pro and Windows 10 Enterprise (32 bit and 64 bit [EM64T]) minimum version 1809 • Windows 8.1, Windows 8.1 Pro, and Windows 8.1 Enterprise (32 bit and 64 bit [EM64T]) • Windows Server 2016 (64 bit) • Windows Server 2019 (64 bit)
Ubuntu	16.04 LTS (64 bit) or later
macOS	10.13 High Sierra or later
Android	5.0 Lollipop or later (ARMv7 32 bit), 6.0 Marshmallow or later (ARMv8 64 bit)
iOS	12 or later (64 bit)

23.2. For ArcGIS Field Maps:

(a) (https://doc.arcgis.com/en/field-maps/faq/requirements.htm)

(b) Mobile workers use the Field Maps mobile app to view maps, collect data, and track their location.

(c) Android - Android 8.0 (Oreo) or later; Processor: ARMv7 or later; OpenGL ES 2.0 support. To use the location tracking capability on Android, Google Play services 11.6.0 or later must be installed on the device.

(d) iOS - iOS 13.5 or later; iPhone, iPad, iPod touch

(e) watchOS - watchOS 6.0 or later; Apple Watch; A paired iPhone or iPad

23.3. For QuickCapture:

(a) (https://doc.arcgis.com/en/quickcapture/faq/requirements.htm)

(b) Browser: Chrome, Firefox, Safari, Edge (For best performance, use the latest version.)

Operating system	OS version
Windows	Windows 10 Pro and Windows 10 Enterprise minimum version 1809 (64 bit) Windows 8.1, Windows 8.1 Pro, and Windows 8.1 Enterprise (64 bit) Windows Server 2016 (64 bit) Windows Server 2019 (64 bit)
Android	6.0 Marshmallow or later (ARMv7 32 bit and ARMv8 64 bit)
iOS	12 or later (64 bit)

24. For information and data updates into Clients GIS database appropriate GIS user account will be provided by Client as well as specific environment (like Web maps and applications etc.). Client ensures user trainings and consultations for the customized GIS maps and applications.

25. Specification for desktop software:

25.1. In some cases, especially for spatial data analysis, desktop software (ArcGIS Pro) may be required.

25.2. Operating system and hardware requirements (recommended) for ArcGIS Pro:

Operating system	OS version
Windows	Windows 11 Home, Pro, and Enterprise (64 bit) Windows 10 Home, Pro, and Enterprise (64 bit) Windows 8.1 Pro and Enterprise (64 bit)
CPU	4 cores
Platform	X64
Storage	32 GB or more free space on a solid-state drive (SSD)
Memory/RAM	16 GB
Dedicated graphics memory	4 GB or more

26. More detailed information: https://pro.arcgis.com/en/pro-app/2.8/get-started/arcgis-pro-system-requirements.htm

26.1. Indicative[2] Named Users costs for accessing RB Rail's/Clients ESRI ArcGIS Enterprise are as follows:

(a) ArcGIS Enterprise (Portal for ArcGIS) EDITOR User type Term license subscription ~280 EUR/user/year

(b) ArcGIS Enterprise (Portal for ArcGIS) FIELD WORKER User type Term license subscription ~490 EUR/user/year

(c) ArcGIS Enterprise (Portal for ArcGIS) CREATOR User type Term license subscription ~700 EUR/user/year

(d) ArcGIS Enterprise (Portal for ArcGIS) GIS PROFESSIONAL Basic User type Term license subscription ~980 EUR/user/year

(e) ArcGIS Enterprise (Portal for ArcGIS) GIS PROFESSIONAL Standard User type Term license subscription ~3850 EUR/user/year

4 BIM, CAD and other digital engineering software

27. There are no restrictions, what software shall be used for its internal processes in order to fulfil the required tasks.

28. For more information refer to paragraph "2.5- IT infrastructure/equipment/IT hardware requirements".

29. The general recommendations towards the most commonly used software solutions from the Client are the following:

29.1. CDE (Data, model and drawing management) – The EDMS used and provided by the Client shall be mutually agreed on

29.2. Project Control, Planning, Scheduling and Risk management – Primavera P6 from Oracle

29.3. Geographic Information System (GIS) – ArcGIS Pro, ArcGIS Enterprise from Esri

29.4. Asset Register (AR) – ArcGIS Pro, ArcGIS Enterprise from Esri

29.5. CAD design (*.dwg) – TrueView (viewer), AutoCAD and CIVIL 3D (latest versions) from Autodesk

29.6. CAD design (*.dgn) – Bentley View CONNECT Edition (viewer), MicroStation CONNECT Edition from Bentley Systems

29.7. BIM Model viewers

(a) IFC – Solibri Anywhere, Trimble Connect, Navisworks Manage (also for *.nwd and *.nwc), Bentley View CONNECT Edition (also for *.imodel), BIM Collab ZOOM

(b) Native – depending on the software solution used to create the models

(c) *.rvt – Revit (different versions) from Autodesk

(d) *.dgn – various Bentley Systems products (different versions)

(e) *.db1 – Tekla Structures (different versions) from Trimble

[2] The license cost has indicative nature and exact prices shall be quoted from the vendor

(f) *.ndw – Allplan (different versions) from Nemechek

29.8. Text, spreadsheet, presentation, simple schedule, email creators/editors – Microsoft 365 Suite.

ANNEX2 - LASER SCANNING AND PHOTOGRAMMETRY REQUIREMENTS

Annex 2 to the Digital Construction Information Handover Requirements, RBGL-VDC-INS-R-00001, 2.0

1 General information of application of measurement methods

Item	Measurement method	
	Laser scanning (LiDAR)	Photogrammetry
Scanning tolerances and precision	Where the required scanning tolerance is **<50 mm**	Where the required scanning tolerance is **≥50 mm**
Application type	1. All point-type objects: a. Stations, stops, halts, platforms, etc. b. Infrastructure Maintenance Facilities, Depots, etc. c. Bridges, viaducts, overpasses, underpasses, etc. d. Ecoducts e. Large and medium sized culverts (all concrete culverts) f. Retaining walls and noise walls g. Underground utilities (before covering) h. Railway systems, electrification and signalling equipment (catenary posts, energy sub-stations, etc.) i. Railway superstructure NOTE: Any other point-type infrastructure object which is not listed shall be agreed with the Client and RB Rail	1. All earthworks a. All layers of embankment (sub-structure) b. Cuts and all layers before superstructure 2. Deforestation areas NOTE: It is allowed to substitute laser scanning measurement method with photogrammetry method if Contractor can achieve the required scanning tolerances.

Type of deliverable	a. RGB Pointcloud b. 3D surface mesh - DTM c. Orthophoto raster images	a. 3D surface mesh - DTM b. Pointcloud c. Orthophoto raster images
Classification	Delivered point clouds shall be colour-enabled (RGB) and classified in the following categories, but not limited to: a. Ground b. Low vegetation c. Medium vegetation d. High vegetation e. Buildings f. Structures (Bridges, viaducts, overpasses, underpasses, etc.) g. Water h. Rails i. Road surfaces j. Transmission towers and other railway systems, electrification and signalling equipment k. Unclassified NOTE: Exact classification shall be agreed in the BEP	N/A
File formats	Point cloud (colour RGB): LAS/LAZ/XYZ/PTS/PTX/E57 and RCP/RCS 3D surface mesh: OBJ/RCS/TIF/ECW Orthophoto raster images TIF/ECW	3D surface mesh: OBJ/RCS/TIF/ECW Point cloud: LAS/LAZ/XYZ/PTS/PTX/E57 and RCP/RCS Orthophoto raster images TIF/ECW
Data collection method	Station and UAV	UAV
Data collection frequency	At least monthly or according to 5.4	

Table 2 - General information of application of measurement methods

2 File formats

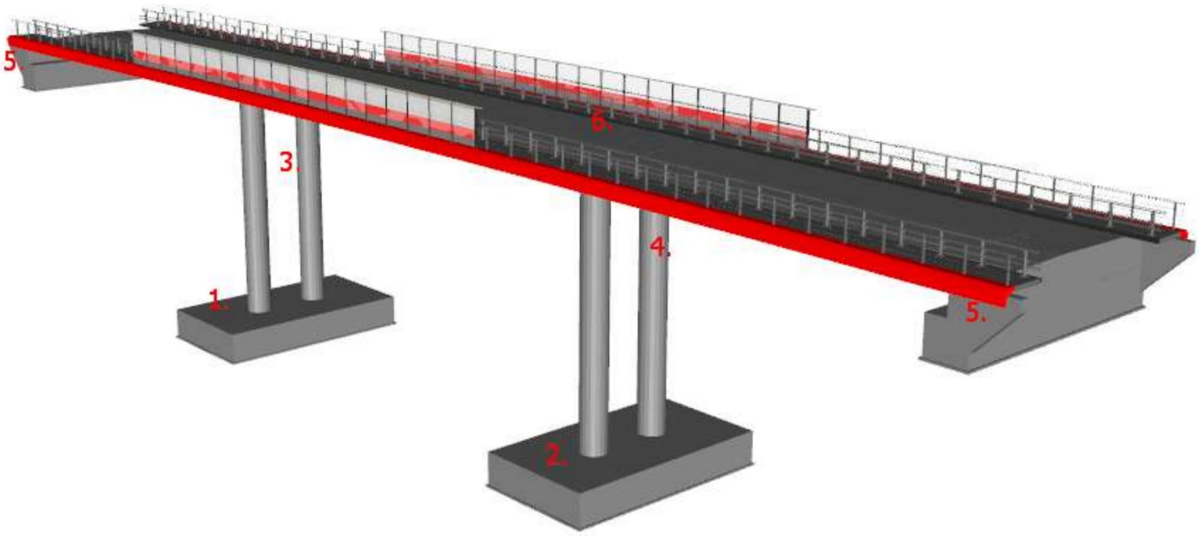
1. The results of the laser scan point clouds shall be submitted in two formats – Navisworks-ready ReCap-processed point cloud (RCP and RCS) and one of the following master formats:
   1.1. Laser scanning (colour RGB) - LAS/LAZ/XYZ/PTS/PTX/E57
   1.2. Photogrammetry – OBJ/RCS/TIF/ECW (other formats may apply but shall be agreed separately in BEP)
2. The exact file formats shall be agreed in the full BEP.

3 Scanning tolerances and precision

3. The tolerances for measurements (x,y,z) with laser scanning/photogrammetry for construction progress/as-built information shall be the following:
   3.1. Civil structures (bridges, overpasses, viaducts, tunnels, culverts, etc.), concrete and steel structures and it's elements: +/- 10 mm
   3.2. Maintenance and access roads, its elements and equipment: +/- 20 mm
   3.3. Earthworks, cut surfaces, layers of compacted embankment structure: +/- 25 mm
   3.4. Station buildings, its elements and systems, platforms, stops and its elements: +/- 10 mm
   3.5. Railway systems, electrification and signalling equipment: +/- 10 mm
   3.6. Other elements: agreed separately with Client
      (a) NOTE: Measurement result together with allowable tolerance mentioned above must fulfil the applicable construction tolerance stipulated in Country's legislation, laws, standards and regulations.
      (b) None of the above-mentioned procedures and tolerances does not exempt the General Contractor not to perform all the legal procedures stipulated in the Country's legislation, laws, standards and regulations. If the requirements in this document contradicts with the requirements stipulated in the Country's legislation, laws, standards and regulations it shall be agreed separately in BEP.

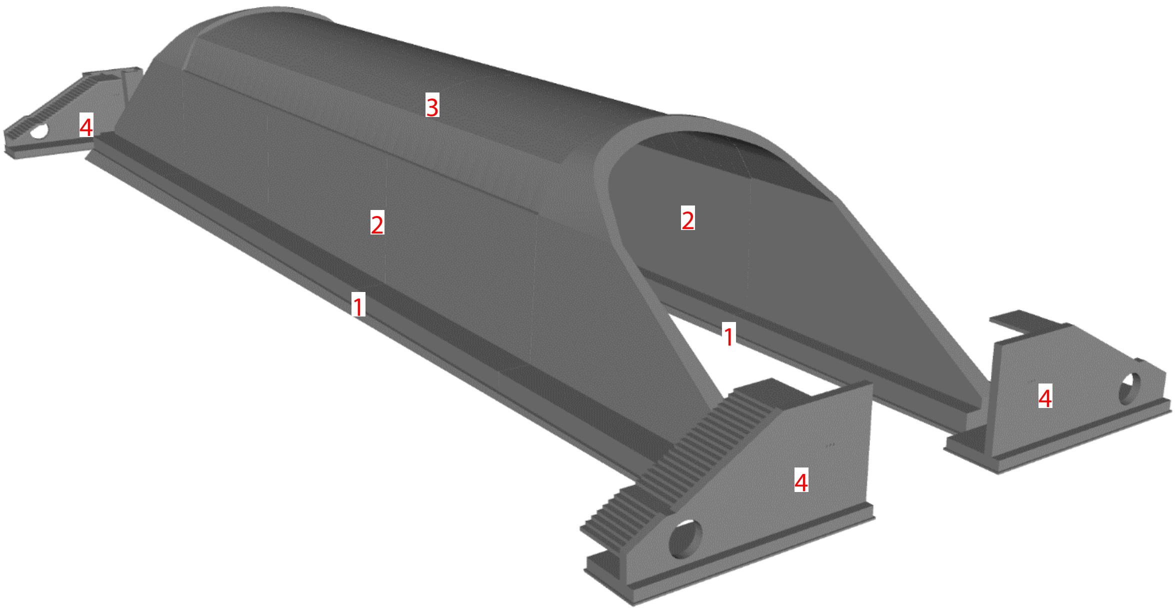
4 Guidance of laser scan/photogrammetry stages

4.1 Bridges, viaducts, overpasses, underpasses and other point-type infrastructure objects



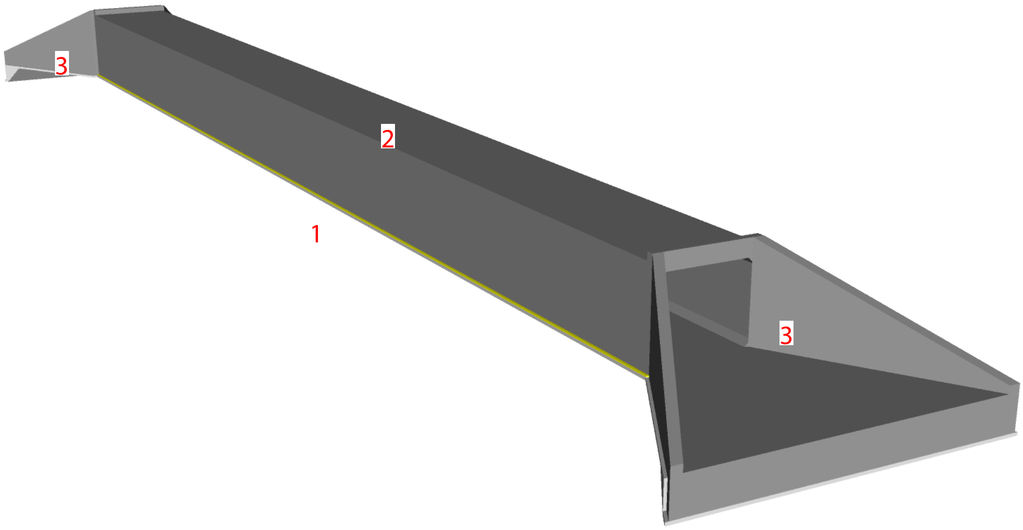
1. Scanning of pile cap 1 after formwork removal
2. Scanning of pile cap 2 after formwork removal
3. Scanning of overpass pier / pier set 1
4. Scanning of overpass pier / pier set 2
5. Scanning of both abutments
6. Scanning of finished deck, top and bottom
7. Overall complete scan of the structure including all the secondary elements, e.g. crash barriers, catenary posts, railing, etc. (as-built situation)

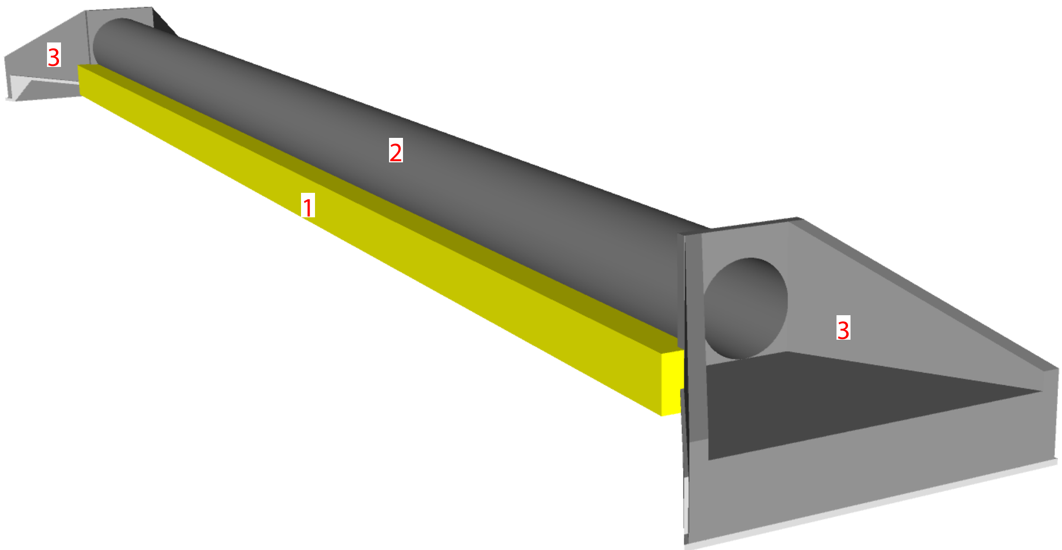
4.2 Ecoducts



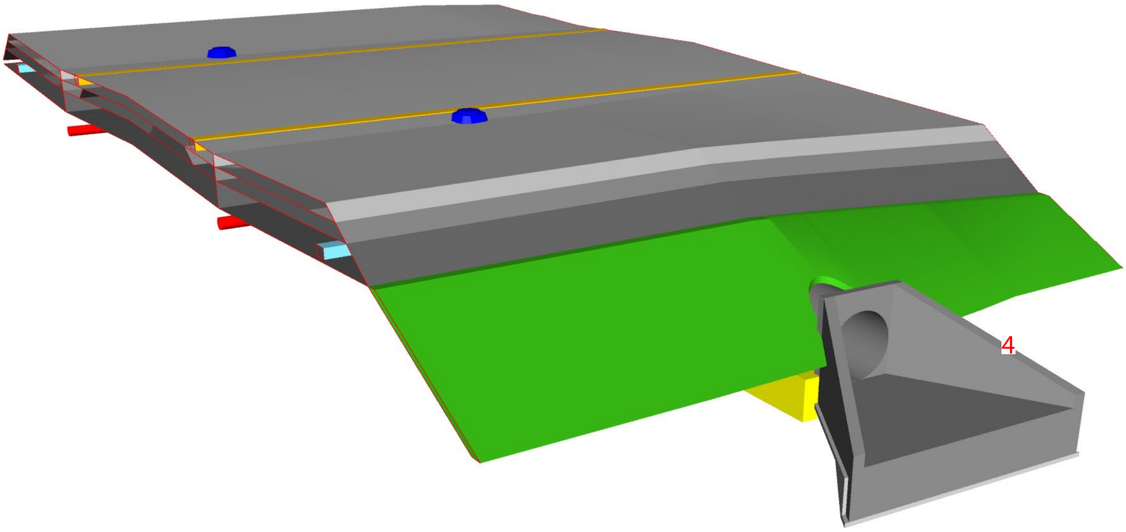
1. Scanning of concrete foundation after formwork removal
2. Scanning concrete walls after formwork removal
3. Scanning precast vault
4. Scanning of wingwalls, stairs and other auxiliary elements after formwork removal
5. Overall complete scan of the structure including all the secondary elements before the backfilling and natural soil cover

4.3 Large and medium sized culverts (all concrete culverts)



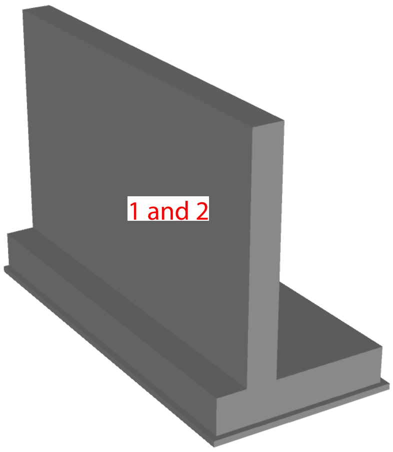


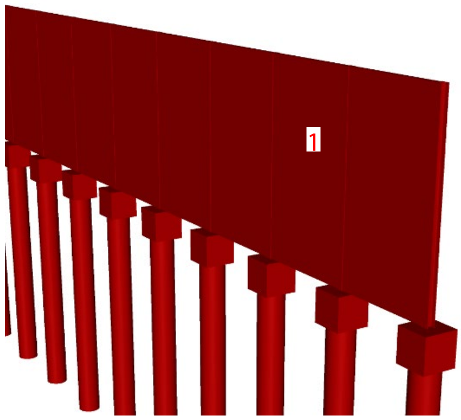
1. Scanning of the leveling concrete foundation
2. Scanning to the main culvert after concreting/installing it
3. Scanning of the wingwalls after the formwork removal



4. Overall complete scan of the structure after the backfilling and compacting the embankment structure

4.4 Retaining walls and noise walls

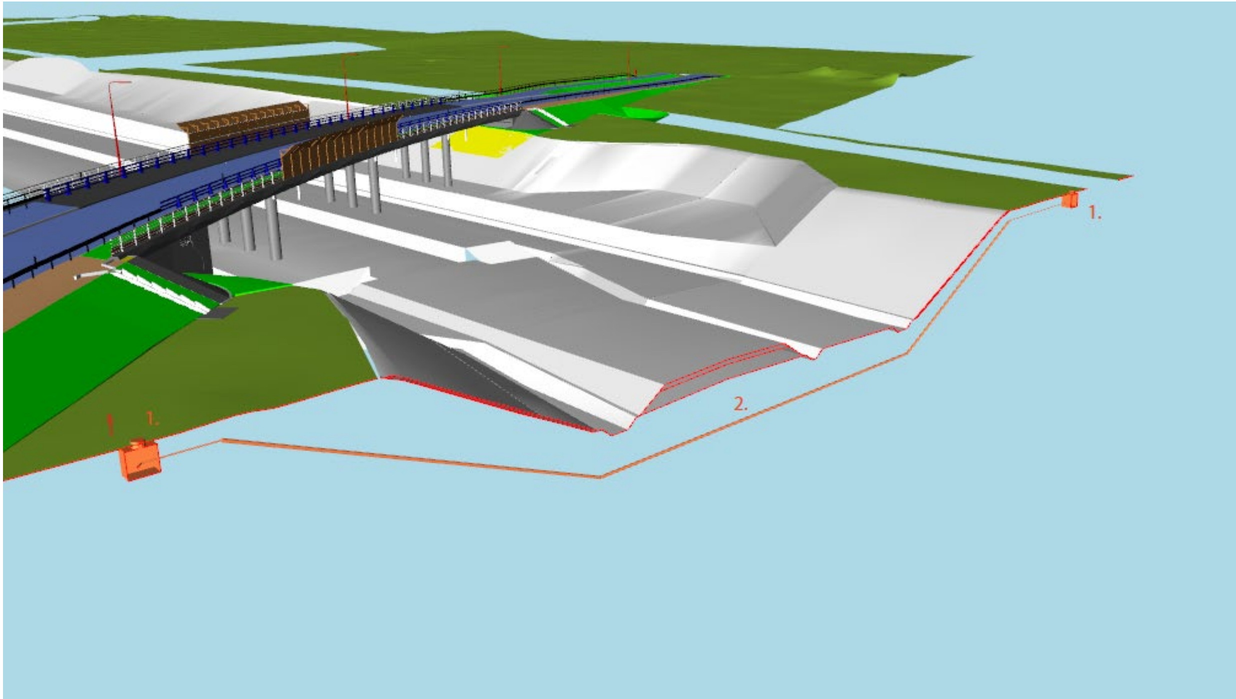




1. Overall complete scan of the structure before backfilling it
2. Overall complete scan of the structure after backfilling it

4.5 Underground utilities

4. The laser scanning of top of underground utilities shall be performed before covering.

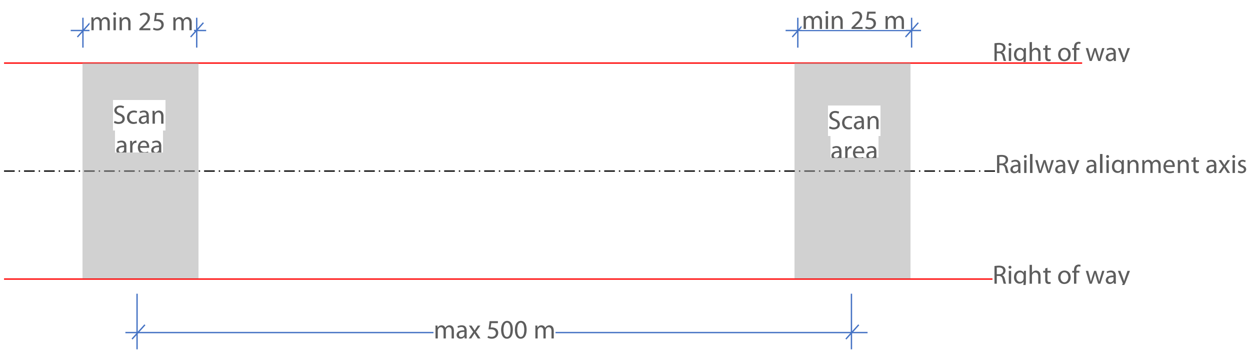


1. Scanning of major utility connections and ends

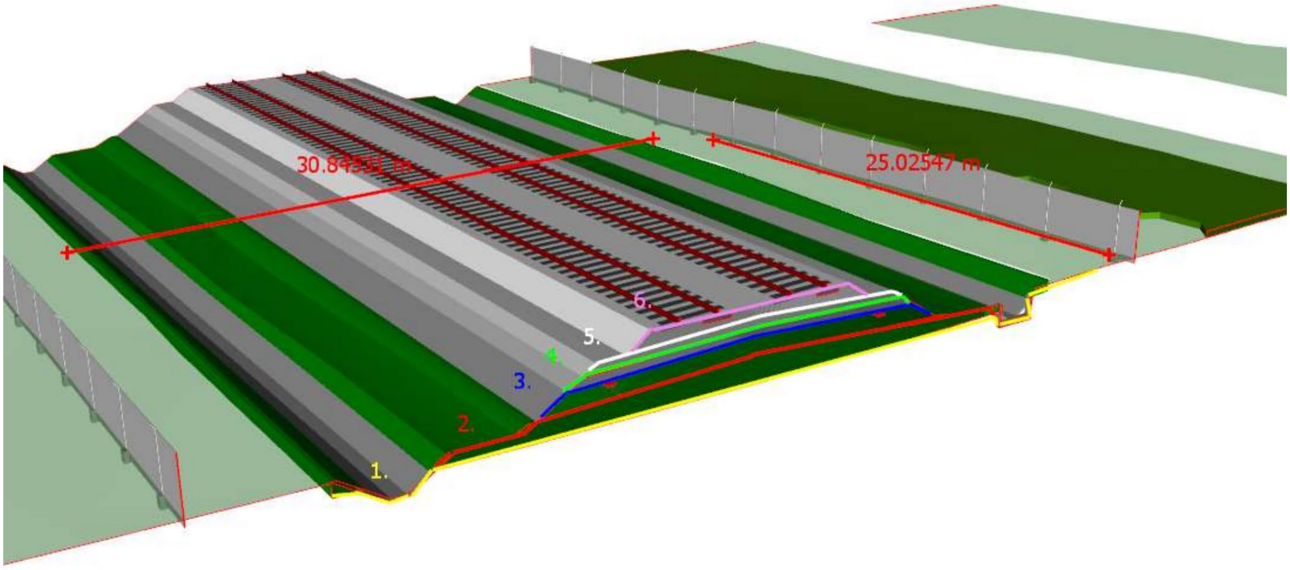
2. Scanning of top of utility min every 50 m

4.6 Linear objects (embankments, cuts, etc.)

5. The laser scanning/photogrammetry of linear objects shall be performed every 500 m for a 25 m long section for the entire width of the right of way for the railway line.



Schematic representation of laser scan locations along railway alignment



1. Scanning of surface after excavation
2. Scanning after laying and compaction of fill layer
3. Scanning after laying and compaction of frost-resistant layer
4. Scanning after laying and compaction of subgrade fill layer
5. Scanning after laying and compaction of sub-ballast layer
6. Scanning after laying and compaction of ballast track bed

4.7 Other requirements

6. Exact laser scanning program, locations in Building permit/construction object and sequencing for linear objects shall be agreed in BEP document including, but not limited to:
   - 6.1. PK measurement
   - 6.2. Types/sequences of laser scans to be performed
   - 6.3. Equipment used for the scans
   - 6.4. Achievable tolerances of the scans
   - 6.5. File formats to be delivered
7. All point type objects with a scanning program, locations and sequencing shall be agreed in BEP document including, but not limited to:
   - 7.1. SiteID/VolSystem ID of the structure
   - 7.2. Types/sequences of laser scans to be performed

7.3. Equipment used for the scans

7.4. Achievable tolerances of the scans

7.5. File formats to be delivered

8. Laser scanning and/or photogrammetry scanning schedule shall follow the progress of the construction works.

9. Detailed schedule and exact scan location, phasing and frequency listing all the construction works after which the scanning and/or photogrammetry will be carried out shall be agreed in BEP.

ANNEX 3 - OTHER REQUIREMENTS

Annex 3 to the Digital Construction Information Handover Requirements, RBGL-VDC-INS-R-00001, 2.0

1 UAV use cases during the construction stage

1. Usage of Unmanned Autonomous Vehicles (UAV – commonly known as drones), shall be used on construction sites for gathering data by laser scanning and/or photogrammetry methods. Other use cases and data collection methods using UAVs may apply.
2. All UAV flights must comply with the respective Countries laws, regulations and legislation.
3. All safety measures and procedures must be established to ensure safe usage of UAVs.
4. It is the direct responsibility of the General Contractor to ensure that all UAV flights are performed by a licensed pilot (if Country's legislation requires it) and that all the required authorizations and permits are received in order to perform the flights within the respective construction object.
5. The UAV flights shall be planned in good weather conditions in order to achieve the quality of the scanned data and to ensure safety. Flights cannot be performed in dark or during night-time or during bad weather conditions – during snowfall, rainfall or fog. During the wintertime, the flights can be performed with a condition, that snow cover does not affect the accuracy of the measurements – the snow must be cleaned before scanning the area. After heavy rain or in areas with high groundwater levels, the scanning of trenches and/or cuts must be performed, when there is no water (puddles) in the area of scanning within the construction site.
6. In some construction objects, the nearby infrastructure might prohibit or have limitations for such flights – e.g. nearby airports, nearby critical infrastructure objects, nearby military objects, etc. Other restrictions may apply.

2 Specifications for Ground Control for Photogrammetric Mapping

2.1 General

7. This document covers ground control requirements for photogrammetric mapping projects. The fundamental requirements for control network configuration, point location, and characteristics are discussed in this document. However, the overview presented is not intended to be used for field survey design. The photogrammetric engineer should refer to appropriate survey standards and specifications for guidance in designing the project control surveys. Current standards should be employed, and outdated standards and practices should be revised from time to time.

2.1.1 Projection, Datum, Coordinate System

	Horizontal	Vertical
Estonia	L-EST 97	EH2000
Latvia	LKS-92	LAS-2000,5
Lithuania	LKS94	LAS07

Table 3 - Countries' Coordinate and Altimetry systems

8. The Geodetic Reference System dedicated to the Rail Baltica Project, is RBDatum. Until the RB ELL22 unified Project dedicated Coordinate System, applicable along the whole alignment of Rail Baltica Project is established, RBDatum will be directly connected to each country local coordinate system (presented in Table 1)

2.2 Ground Control Requirements

9. Field surveying for photogrammetric control is generally a two-step process. The first step consists of establishing a network of basic control in the project area. This basic control consists of horizontal control monuments and benchmarks of vertical control that will serve as a reference framework for subsequent surveys. The second step involves establishing photo control by means of surveys originating from the basic control network. Photo control points are the actual points appearing in the photos (photo identifiable points that are used to control photogrammetric operations. The accuracy of basic control surveys is generally of higher order than subsequent photo control surveys.

10. GPS technology is now an integral part of almost any field survey project. It is also the most cost-effective method for photogrammetric control surveys.

2.2.1 Basic Control

11. A basic control survey provides a fundamental framework of control for all project-related surveys, such as property surveys, photo control surveys, location and design surveys, and construction layout. The accuracy, location, and density of the basic control must be designed to satisfy all the project tasks that will be referenced to the control.

12. In planning the basic control survey, maximum advantage should be taken of existing control networks established in the area. Care should be exercised before using any existing control points to verify that they are adequately interconnected or are adequately connected to the national Geodetic network in RBDatum

2.2.2 Photo Control

13. Photo control points are photo identifiable or panel points that can be measured on the photograph and stereomodel. Photo control points are connected to the basic control framework by short spur traverses, intersections, and short level loops. Lengthy side shots and open traverses should be avoided.

14. Photo control surveys are local surveys of limited extent. Photo control points are surveyed to the accuracy required to control the photogrammetric solution. The accuracy requirement for photo control points should generally be an order better (at least 5 times) than the accuracies of the control points computed by aerial triangulation.

2.2.2.1 Characteristics

15. Photo control points should be designed by considering the following characteristics: location of the control point on the photograph; positive identification of the image point; and measurement characteristics of the image point. GPS derived photo control points require special consideration. The locations of GPS points must be in a location that will allow for the required GPS horizon parameters to be met.

    (a) Location. Of the characteristics listed above, location is always the overriding factor. Photo control points must be in the proper geometric location to accurately reference the photogrammetric solution to the ground coordinate system. Horizontal photo control points should define a long line across the photographic coverage. The horizontal control accurately fixes the scale and azimuth of the solution. Vertical photo control should define a geometrically strong horizontal triangle spanning the photographic coverage. The vertical control accurately fixes the elevation datum of the solution. The location should be established in accordance with current photogrammetric practice considering the project area and the map accuracy requirements.

    (b) Identification. The identification of the photo control points on the aerial photography is critical. Extreme care should be exercised to make this identification accurate. The surveyor should examine the photo control point in the field with the aerial photographs. Once a photo control point is identified, its position on the photograph should be recorded and a brief description and sketch and/or cutout of aerial photo, of each point should be made. Each photo control point should be given a unique name or number.

    (c) Measurement. Subject to the constraints imposed by location considerations, photo control points should be designed to provide accurate pointing characteristics during photogrammetric measurements. Furthermore, control points should not be located at the edge of the image format. Photo control points falling in the outside 10 to 15 percent of the image format should be rejected.

2.2.2.2 Horizontal Photo Control

16. Images for horizontal control have slightly different requirements from images for vertical control. Because their horizontal positions on the photographs must be precisely measured, images of horizontal control points must be very sharp and well-defined horizontally.

2.2.2.3 Vertical Photo Control

17. Images for vertical control need not be so sharp and well-defined horizontally. Points selected should, however, be well-defined vertically. Good vertical control points should have characteristics that make it easy for the operator to accurately put the floating mark at the correct elevation. Vertical control points are best located in

small, flat, or slightly crowned areas with some natural features nearby that assist with stereoscopic depth perception.

2.2.2.4 GPS for Horizontal and Vertical Control

18. GPS survey is now popular method for surveying both horizontal and vertical control since it provides precise spatial (X, Y and Z) coordinates.

2.2.3 Control Point Distribution

19. If the project is small, requiring just a few models, the control can be established on the ground by conventional field or GPS surveys. The absolute geometric minimum amount of photo control needed in each stereomodel is four points.

20. For larger projects requiring aerial triangulation, the distribution of ground control is discussed in the chapter for Aerial Triangulation.

21. If airborne GPS procedures are integrated into the photographic flight the amount of primary ground control points required may be further reduced. Its distribution is also discussed in the document for Aerial Triangulation.

2.3 Marking Photo Control

22. Photo identifiable control points can be established by marking points with targets before the flight or by selecting identifiable image points after the flight.

2.3.1 Premarking

23. Premarking photo control points is recommended. Marking control points with targets before the flight is the most reliable and accurate way to establish photo control points. Survey points in the basic control network can also be targeted to make them photo identifiable. When the terrain is relatively featureless, targeting will always produce a well-defined image in the proper location. However, premarking is also a significant expense in the project because target materials must be purchased, and targets must be placed in the field and maintained until flying is completed. The target itself should be designed to produce the best possible photo control image point. The main elements in target design are good color contrast, a symmetrical target that can be centered over the control point, and a target size that yields a satisfactory image on the resulting photographs.

    (a) Location. Target location should be designed according to the ground control distribution for aerial triangulation. However, it is difficult to ensure that the target will fall in the planned location in the photograph when the photography is flown. Care should be taken that targets are not located too near the edge of the strip coverage so that the target does not fall outside of the model.

    (b) Shape. Targets should be symmetrical in design to aid the operator in pointing on the control point. Typical shapes that may be used are “+”, “T” or “Y” shape.

    (c) Size. Target sizes should be designed on the basis of intended photo scale so that the target images are the optimum size for pointing on the photos. Target size is related to the size of the measuring mark in the stereoplotter instruments used. An image size of about 0.050 mm square (or 2 pixels) for the central panel is a typical design value. Each leg can have width same as the central panel, i.e. 0.050 mm or 2 pixels, and length 5 times the width.

2.3.2 Postmarking

24. The postmarking method consists of examining the photography after it is flown and choosing natural image features that most closely meet the characteristics for horizontal or vertical photo control points. The selected

features are then located in the field and surveyed from the basic control monuments. One advantage of postmarking photo control points is that the control point can be chosen in the optimum location (the corners of neat models and in the triple overlap area). The principal disadvantage of postmarking is that the natural feature is not as well defined as a targeted survey monument either in the field or on the image.

25. Typical feature that may be used for postmarking photo control points include:

    25.1. Traffic lines

    25.2. Sidewalk intersection (must be perpendicular)

    25.3. Tennis Court, Basketball Court, Football field lines intersection

2.3.3 Airborne Global Positioning System (ABGPS) and Inertial Measurement Unit (IMU) Control

26. ABGPS and IMU technologies are now recommended for photo control. This procedure involves establishing the horizontal and vertical location, and attitude of the principal point of every photo at the instant of exposure. If all conditions are ideal for ABGPS and IMU (i.e., satellite configuration and signal, geoid model consistency), then no additional ground control would be required. In practice, this is not an acceptable risk considering the cost of deploying equipment and personnel to revisit the project site if problems surface after the flight. Therefore, minimal ground control should be planned. Flights plan may also incorporate a few cross flights to increase strength and accuracy to the block.

2.4 Deliverables

27. Unless otherwise modified by the contract specifications, the following materials will be delivered upon completion of the control surveys:

    (a) General report describing the project and survey procedures used including description of the project area, location, and existing control found; description of the basic and photo control survey network geometry; description of the survey instruments and field methods used; description of the survey adjustment method and results such as closures and precision of adjusted positions; justification for any survey points omitted from the final adjusted network and any problems incurred and how they were resolved.

    (b) Details of each control points, showing X, Y and Z coordinates and sketch or cutout photograph with control point clearly marked. Date and time, surveyor name, organization, as well as comments if any.

    (c) A list of the adjusted coordinates of all horizontal and vertical basic and photo control points.

3 Specifications for Aerial Triangulation

3.1 General

28. These specifications pertain to the aerial triangulation of standard, wide-angle aerial digital or analog photography exposed with average of 60 percent forward overlap and 30 percent side overlap. The specifications apply to both strips and blocks of photography. The specifications apply to fully analytical methods based on softcopy digital photogrammetric workstation (DPW). Airborne GPS control (AGPS) and inertial measuring unit (IMU) are relatively new technologies though are now operationally available. These specifications will cover both aerial triangulation with and without ABGPS and IMU.

3.2 Aerial Triangulation

3.2.1 Definition

29. Aerial triangulation is the process of densifying and extending ground control through computational means. The process "bridges" or carries ground control to contiguous stereo models, which falls between models, which contain ground control.

30. Aerial triangulation is the simultaneous space resection and space intersection of image rays recorded by an aerial mapping camera. Conjugate image rays projected from two or more overlapping photographs intersect at common points on the ground to define the three-dimensional coordinates of each point. The entire assemblage of image rays is fit to known ground control points in a least-squares adjustment process. When complete, ground coordinates of previously unknown points are determined by the intersection of adjusted rays. Besides the ground coordinates, the location of the camera center (principal center) as well as the orientation of the camera will also be determined.

31. The ground coordinates of fixed photogrammetric points on each stereo model are utilized to scale and level the model during the process of absolute orientation. In DPW, the computed camera location and orientation can also be utilized in absolute orientation.

32. Aerial triangulation is essentially an interpolation tool, capable of extending control points to areas between ground survey control points using several contiguous uncontrolled stereomodels. An aerial triangulation solution should never be extended or cantilevered beyond the ground control. Ground control should be located at the ends of single strips and along the perimeter of block configurations. Within a strip or block, ground control is added at intervals of several stereomodels to limit error propagation in the adjusted pass point coordinates.

33. The principal inputs to the aerial triangulation process are:

    (a) Aerial Photography

    (b) Camera Calibration Data

    (c) Ground Control Point Coordinates

3.2.2 Quality

34. Each of the above inputs will have a profound effect on the quality of the aerial triangulation adjustment. For example, the accuracy (for a given photo scale) is influenced by the following factors:

   (a) Quality of the original photograph/image (exposure, aircraft movement, image blur, handling)

   (b) Quality of scanning to convert negative/diapositive into digital file

   (c) Quality of the camera (the interior orientation of the camera)

   (d) Quality and density of ground control

   (e) Configuration of the ground control

   (f) Shape of the block

   (g) Quality of the point marking, transfer and mensuration

   (h) Block adjustment procedures and algorithms

   (i) Adjustments for earth curvature, atmospheric refraction and map projection

   (j) Analysis of adjustment results and the application of weights to photogrammetric control points

3.3 Specifications

3.3.1 Projection, Datum, Coordinate

35. System Refer to Section 6.2.1.1

3.3.2 Scanning of Negative/Diapositive

36. With present technology, analog and analytical stereoplotters are already obsolete. Softcopy digital photogrammetric workstation (DPW) methods should be employed.

3.3.3 Control Point Configuration

37. Control point configuration, monumentation, targeting and measurement are all prescribed in Specifications for Ground Control Surveys. The salient points describing configuration are summarized hereunder. The ground cover in Baltic Countries is such that horizontal control points should be targeted. Target configurations should be a "+", "T" or "Y". The minimum target sizes should be such that its resultant image on the photograph is no smaller than 15 pixel (or 15 x GSD in meters on ground).

38. Ground control points (GCPs) can either be horizontal control points (HCP) which carry measured X and Y values, vertical control points (VCP) which carry measured Z values only and full ground controls points (GCP) carry measured X, Y and Z values.

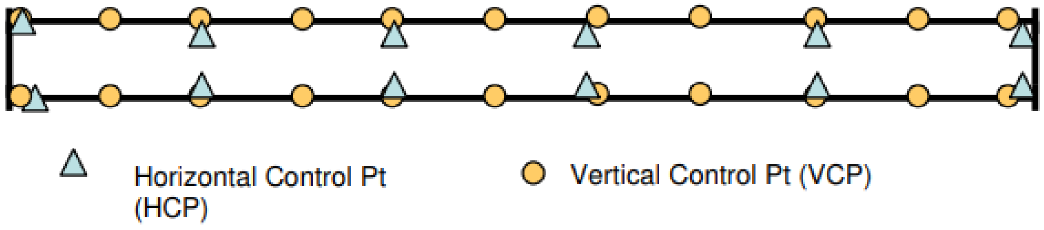
39. With the popularity of GPS surveying for ground control point acquisition, there is virtually no cost difference in measuring full GCPs with X, Y and Z values against HCP or VCP. It is better to use full GCP in place of HCP or VCP for aerial triangulation.

3.3.3.1 Without ABGPS and IMU

40. For aerial photography acquired without ABGPS and IMU, the control point requirements are as follows:

41. For single strip of photography horizontal control points (HCP) should be placed in pairs (opposite each other on either side of the flight line) within the first and last models in the strip and at intervals of not more than four model base lengths along the strip. Vertical control points (VCP) shall also be placed in pairs (opposite each

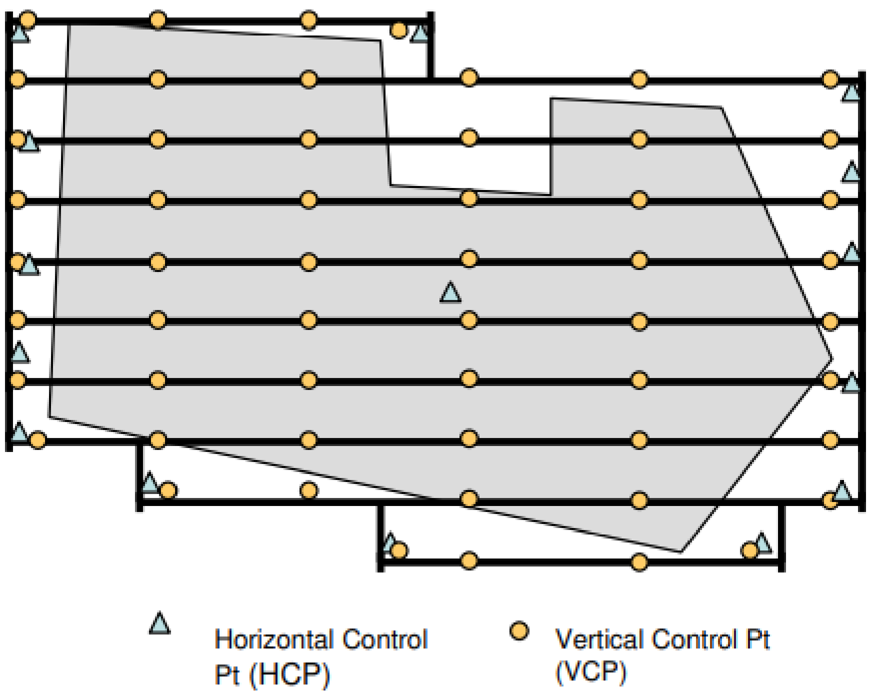
other on either side of the flight line) within the first and last models in the strip and at intervals of not more than two model base lengths along the strip.



42. For blocks of photography, horizontal and vertical control (full GCP) should be relatively evenly spaced and located around the periphery of the block. The spacing of horizontal control points (HCP) around the periphery should be 3 to 5 model base lengths along lines and every second line across lines. Vertical control points (VCP) should be placed at intervals of 3 to 5 models along lines and on every line. The vertical control points (VCPs) should be established in the sidelap portions of the photographs. The vertical control points (VCPs) should also be placed on every line around the perimeter of the block.

43. Photographic blocks should be designed to minimize irregularities: holes, projecting lines, indentations etc. Where these irregularities are unavoidable,

44. Horizontal control points (HCP) must be placed at all extremities and most inflection points in the block. Additional horizontal control points (HCP) and vertical control points (VCP) should be located at the center of the block, and in the case of large blocks, relatively evenly distributed throughout the block on a grid of approximately eight to ten base lengths.

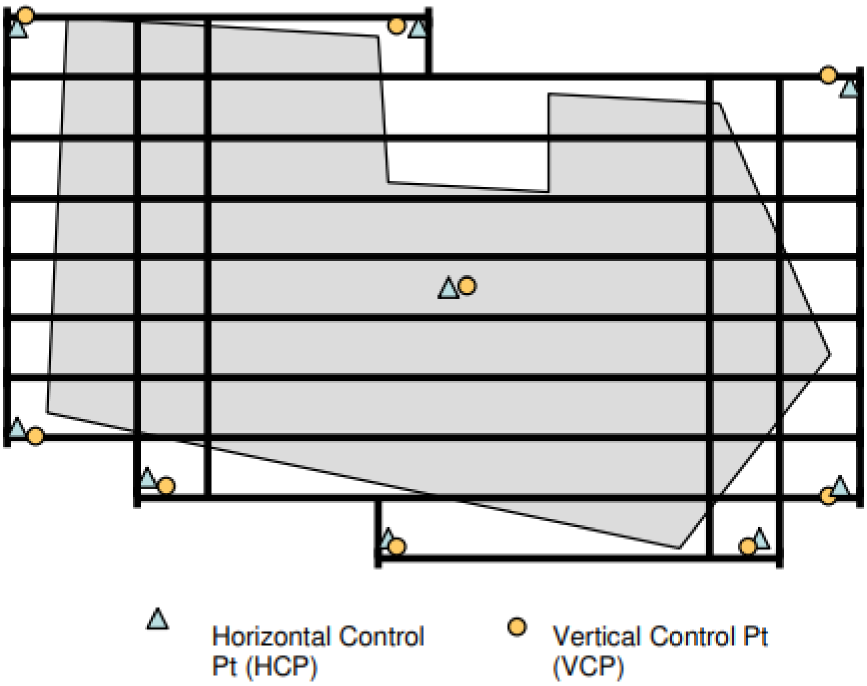


3.3.3.2 With ABGPS and IMU

45. Advancement in ABGPS and IMU technology incorporated in aerial camera system has allowed the camera coordinates and orientation during exposure to be precisely measured. With a base station within 30km, accuracy of 3 to 10 cms is possible. With GPS and IMU, it becomes possible to aerial triangulate the whole block without horizontal and vertical control points to acceptable accuracy.

46. Additional cross flights can be introduced to provide additional strength and accuracy to the block.

47. It is still advisable to provide some horizontal and vertical at the corners and the center of the block to ensure residual bias errors are eliminated and also provide quality checks on the aerial triangulated results.



3.3.3.3 Check Points

48. The Service may elect to establish checkpoints within the aerial triangulation scheme. In such case the Service will establish the points on the ground. The consultant shall provide adjusted coordinates for these points for approval prior to finalizing the block adjustment.

3.3.4 Preparation

3.3.4.1 Pass Points

49. Forward pass points are artificially marked points used to locate the same point in successive models along the flight line.

3.3.4.2 Tie Points

50. Tie points are artificially marked points used to locate the same point in adjacent models within different flight lines.

3.3.4.3 Softcopy Point Marking and Transfer

51. Aerial triangulation with softcopy simplifies the procedure of pass points processing. The process involved displaying two successive photo images on the monitor screen. The operator then selects arbitrary pass points in the images/photos, and the workstation will automatically assign appropriate image/photo coordinates of that point on each photo/image. If image matching option is enabled, the operator need only select the pass point in one photo and the computer will automatically select the matching point in the other image.

52. Images of adjacent flight line photos can also be displayed for simultaneous tie point marking.

53. The image/photo coordinates of these pass/tie points in the overlap/sidelap area are stored in the computer's database. The marking is only a graphic overlay and does not disturb the original image/photo pixels. This operation thus eliminates the necessity of manual pugging, plate reading, and transferring required with analog and analytical plotters.

3.3.4.4 Coding

54. A systematic coding scheme shall be employed which facilitates the identification of points according to:

    (a) Location in the Model

    (b) Flight Line

    (c) Exposure

    (d) Point Type

3.3.5 Adjustment

55. The adjustment shall be fully analytical and performed in two stages:

    (a) Preliminary Strip Formation

    (b) Bundle Adjustment

56. Prior to adjustment, inner orientation of the photographs is performed to provide each photograph with photograph coordinates that match the geometry of the image focal plane and perspective center. Affine transformation that matches the fiducial marks with camera focal plane template should be applied to remove scanner errors and lens distortion errors should also be corrected (from camera calibration information). Photographs acquired by digital camera are already inner oriented and will not need this step.

3.3.5.1 Preliminary Strip Formation

57. This step refers to the sequential assembly of independent stereomodels to form a strip unit. The sequential strip formation is a preliminary adjustment that develops initial approximations for the final simultaneous bundle adjustment. The strip formation also serves as a quality control check of the photo and in some cases also ground coordinate data.

    57.1. Relative orientation of each stereo pair is performed by a least squares adjustment using the collinearity equations and template matching at the selection part of the stereomodel. DPW usually can do this relative orientation step automatically. The stereomodel is created in an arbitrary coordinate system. The photo coordinate residuals should be representative of the point transfer and measuring precision. The photo coordinate residuals should be examined to detect misidentified or poorly measured points.

    57.2. When stereomodels are joined to form a strip, the pass points shared between models will have two coordinate values, one value in the strip coordinate system and one value in the transformed model coordinate system which is close to the ground coordinates. The coordinate differences or discrepancies between the two values can be examined to evaluate how well the models fit to one another. Outliers can be detected at this stage and corrected.

3.3.5.2 Simultaneous Bundle Adjustment

58. The strips are then joined (in virtual sense) into a block and simultaneous block bundle aerial triangulation must be adjusted by a weighted least squares adjustment method. Adjustment software will form the collinearity condition equations for all the photo coordinate observations in the block and solve for all photo orientation and ground point coordinates in each iteration until the solution converges. The adjustment shall also compensate for earth curvature and atmospheric refraction effects.

59. Least squares adjustment results should be examined to check the consistency of the photo coordinate measurements and the ground control fit. Residuals on the photo coordinates should be examined to see that they are representative of the random error expected from the instrument used to measure them. Residuals should be randomly plus or minus and have a uniform magnitude. Residuals should be checked carefully for outliers and systematic trends. Standard deviation of unit weight computed from the weighted adjusted residuals should be between 0.5 to 2 times the reference standard deviation used to compute the weights for the adjustment (0.5< 2).

60. Accuracy of aerial analytical triangulation should be measured by the RMSE of the error in each coordinate (X, Y, and Z) direction for the checkpoints if available. The RMSE should be less than flying height/10,000. The maximum residuals of photo coordinates and ground coordinates shall be less than 3 times the respective RMSEs.

Important Statistical Measure	
Standard Deviation of Unit Weight (σ_0)	Between 0.5 to 2.0
RMSE of X,Y,Z coordinates	< flying_height/10,000
Maximum Residuals of Coordinates	< 3 x respective RMSEs

Table 4- Important Statistical Measure criteria

61. The evaluation of the aerial triangulation and adjustment results will not be based solely on the statistical results of the adjustment. The following elements must also be evident in the adjustment:
    - (a) Proper aerial triangulation technique with respect to control point location and tie point location.
    - (b) There must be no evidence of a systematic nature to the residuals on either control points or photogrammetric points.
    - (c) The block must remain structurally sound while meeting a one percent rejection criterion.

3.4 Deliverables

62. A final report shall be delivered detailing:

Photography And Control Used	The photograph files, duly annotated shall be delivered
Hardware And Software Employed	This must include all details that pertain to meeting these specifications.
Methodology	
Preliminary Results	

Final Results	The final results, including an accuracy summary
Problems Encountered And Remedial Actions Taken	
Technical Concerns	e.g. weak areas in the block
List Of Control Problems	points rejected and adjustments to standard weights

Table 5 - Deliverables

63. A final, reproducible computer-generated index map in DXF format will be prepared which identifies all points included in the aerial triangulation and the limits of the photos. The index will also show line and photo numbers. A listing of all adjusted coordinates for all ground control, pass points and tie points.
64. A listing of calculated camera location at time of exposure and orientation parameters.
65. A listing of differences at ground scale between surveyed and adjusted coordinate values for all control points.
66. A listing of differences at ground scale between measured and adjusted tie photogrammetric points.
67. All deliverables shall be submitted in digital form and hard copy equivalent, in appropriate media and agreed format.

4 Additional Supervision

68. The General Contractor shall be aware that additional supervision may be carried out by the Client independently from construction supervision stipulated in respective Country's laws and legislation. The additional supervision works may consist of additional control measurements using different methods, including, but not limited to laser scanning/photogrammetry as well as all conventional methods.

69. UAV must be used also to record a fly over video to capture the construction work progress of the whole Construction object. The angle and view of the video shall clearly show the conducted construction works and progress of them. If one angle and view of the video cannot show the entire work progress, then additional video recordings are shall be performed to capture the entire Construction object and all areas. The UAV shall circulate around (360 degrees) a point type objects (e.g. bridges, overpasses, viaducts, etc.) to capture the obscured or hidden areas.

70. The video files shall be submitted to Client's CDE.

71. Technical specification of the video as minimum shall be:

    71.1. Resolution: 1920x1080px

    71.2. File format: *.MP4 or *.MOV (encoded using H.264 codec for the best quality/file size ratio)

    71.3. At least 25 fps

72. If there are places where UAVs cannot be used (e.g. inside tunnels, under smaller bridges, restricted fly zones, etc.) the video recording shall be done using alternative methods. In case the weather conditions are prohibiting to do the UAV flights for video recording/laser scanning/photogrammetry, other methods shall be used in order to comply with the schedules of capturing the above-mentioned information.

73. During the inception/mobilization stage, the General Contractor must inform the Client about the planned activities using UAVs and detailed flight plans shall be submitted. If in some areas, the flights are limited or not possible, the General Contractor shall inform the Client and propose an alternative method on how to collect the data.