Issued by Email on 15.12.22

भारत सरकार GOVERNMENT OF INDIA
रेल मंत्रालय MINISTRY OF RAILWAYS
(रेलवे बोर्ड RAILWAY BOARD)
*****

No. 2021/25//CE-III/BR/BMS/Drone New Delhi, dated 15.12.2022

Principal Chief Engineer,
All Zonal Railways.

Sub:- Integration of 4D BrIM in BMS.

Ref:- GM/Civil Engg. Project-IV/CRIS's letter No. 2016/CRIS/NDLS-ITPI/OAEW/PROJECT/0081/PT-1 dated 26.09.2022.

(ii) NR's letter No. 198-W/e-Gov/TMS/BMS/Estimate dated 16.11.2022-(Copy enclosed).

*****

RDSO has issued the Report No. BS-129 (R1) in May-2021 related to "Guidelines for 4D (BrIM) based on inspection of Indian Railway Bridges using 3D Bridge Information Model and Unmanned Aerial System (Drone)". These guidelines only take care of the photography of the bridge by drone at a regular interval and by comparison/visualization of Photos/Images of the bridge, just an inference can be drawn about the condition of the bridge. This type of inspection is an incomplete inspection and only covers small part of the detailed technical inspection of the bridge as specified in IRBM.

Accordingly, the guidelines issued by RDSO vide Report No. BS-129 (R1) has been revised so that complete detailed technical inspection of the bridge may be carried out by using modern digital technology i.e. Photogrammetric and LiDAR. This will minimize the requirement of specialized technical man-power and detailed technical inspection may also be carried out in difficult terrain and other location like fast flowing rivers, where inspection by manual means is almost impossible.

Keeping in view of the above deliberations, Zonal Railways are requested to carry out/take up the detailed technical inspection of some of the bridges as per the revised Guidelines. The data generated may be used in validation of Integration of 4D BrIM in BMS.

This issues with the approval of PED/Bridge/Railway Board.

Kindly expedite the matter.

(S. N. Joshi)
Executive Director Civil Engg./B&S,
Ph. No.011-478-47571

Copy to:- CBEs/All Zonal Railways for information & necessary action please.

Northern Railway

Headquarters office,
Baroda House,
New Delhi.

No. 198-W/e-Gov/TMS/BMS/Estimate Dated: 16.11.2022

Pr. Executive Director (B&S),
Railway Board,
Ministry of Railways,
Rail Bhawan,
New Delhi.

Sub: Integration of 4D BrIM in BMS.

Ref: Railway Board vide letter no. 2021/25/CE-III/BR/BMS/Drone dated 09.05.2022/24.01.2022.

RDSO issued the report no. BS-129(R1) in May-2021 related to "Guidelines for 4D (BrIM) based Inspection of Indian Railway Bridges using 3D Bridge Information Model and Unmanned Aerial System (Drone)". These guidelines only take care of the photography of the bridge by drone at a regular interval and by comparison/visualization of Photos/Images of the bridges, just an inference can be drawn about the condition of the bridge. This type of inspection is an incomplete inspection and only covers small part of the detailed technical inspection of the bridge as specified in IRBM.

To overcome the deficiencies in the detailed technical inspection as mentioned above, Northern Railway carried out a proof of concept, using the Photogrammetry and LiDAR for detailed technical inspection of the bridge. The report of the same is enclosed.

Accordingly, the guidelines issued by the RDSO (BS-129(R1)) have been revised so that complete detailed technical inspection of the bridge may be carried out by using modern digital technology i.e. Photogrammetry and LiDAR. This will minimize the requirement of specialized technical man power and detailed technical inspection may also be carried out in difficult terrain and other location like fast flowing rivers, where inspection by manual means is almost impossible. The copy of revised guidelines is enclosed.

It is requested that the above subject matter may be examined, in light of above deliberation and suitable instruction as appropriate may be issued to all the Zonal Railways for detailed technical inspection of some of the bridges as per revised Guidelines. The data generated may be used in validation of Integration of 4D BrIM in BMS.

DA: As above

ACHAL JAIN
Digitally signed by ACHAL JAIN
Date: 2022.11.16 12:23:00 +05'30'

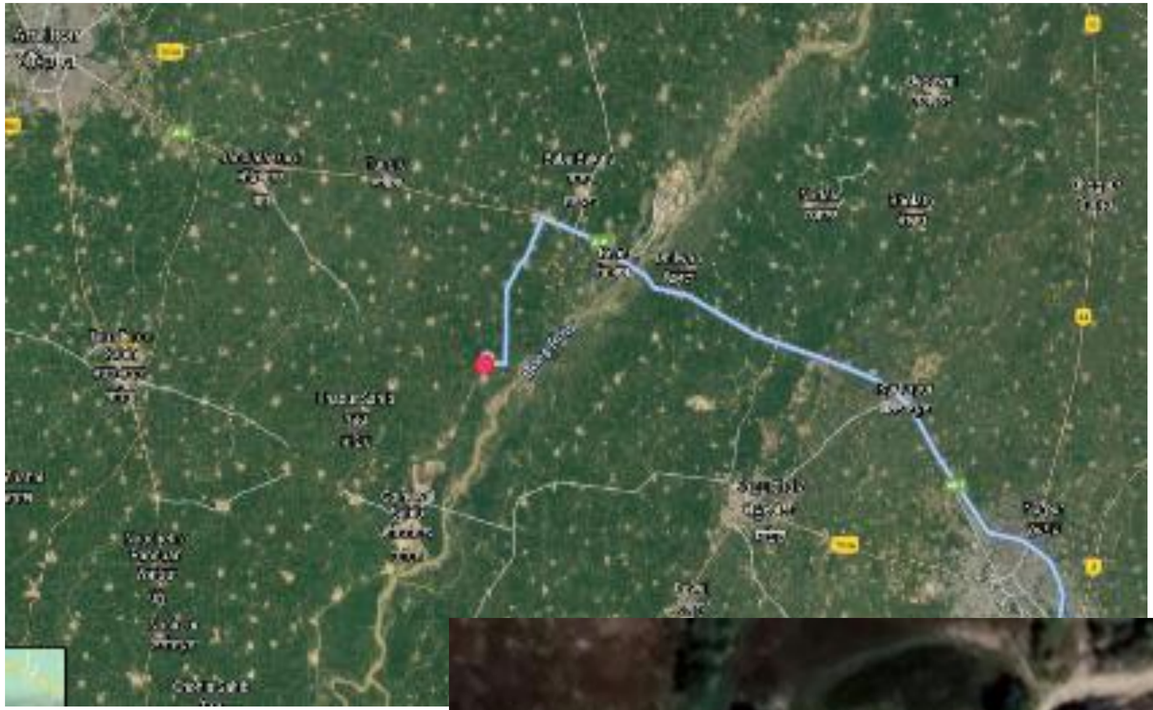
Chief Project Director/TMS

Copy:

1) AM/CE, Railway Board for information and necessary action please.
2) PCEs all Zonal Railways, for information and necessary action please.
3) CAO/Cs all Zonal Railways, for information and necessary action please.
4) MD/CRIS, Chanakyapuri, New Delhi for information and necessary action please.

STEEL GIRDER BRIDGE INSPECTION USING PHOTOGRAMMETRY AND LIDAR

Bridge Workshop, Jalandhar Cantt, NR
Rukon Rail Solutions, India
Yarra Drones, India, Australia



SETTING THE CONTEXT

Bridge No.63

BACKGROUND

Conventional means of bridge inspections	Digitised means of bridge inspections
Labour intensive	→ Minimises manpower requirement
Time consuming	→ Time consumed reduces progressively with each subsequent inspection
Subjective (dependent on staff skills)	→ Objectivity is increased as methodology and analysis tools are standardised
Non-auditable	→ Results and analysis can be viewed as many times as possible without need of returning to the site

CURRENT AND PROPOSED APPROACH OF DIGITISATION

There has been some effort in using technology for bridge inspections in Indian Railways culminating in the RDSO guidelines. This is a comparative analysis of major factors.

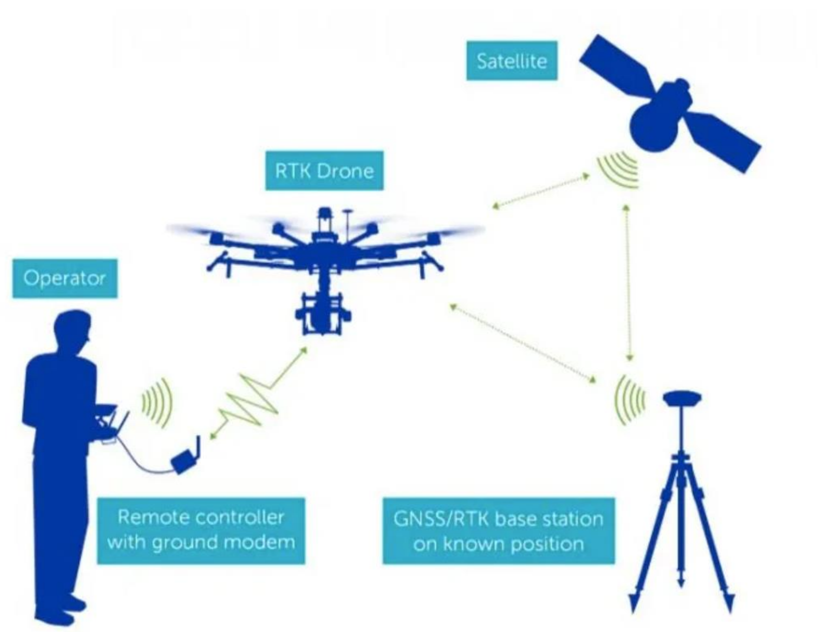
	Current Guidelines	Approach used in Proof of Concept
Key objective	Capture photos using drones as an aid to manual inspections	Have an inspection regime that is capable of replacing manual inspections
Focus	Focus only on visual elements, and no measurements possible	Focus on getting a high fidelity digital model that can be utilised in a number of ways including measurements
Additional advantages	Still photos do not give any addition advantage to manual observations	3D models can be rotated and sliced to get at any section, measured and analysed; that is not possible in the field

PROOF OF CONCEPT - FIELDWORK

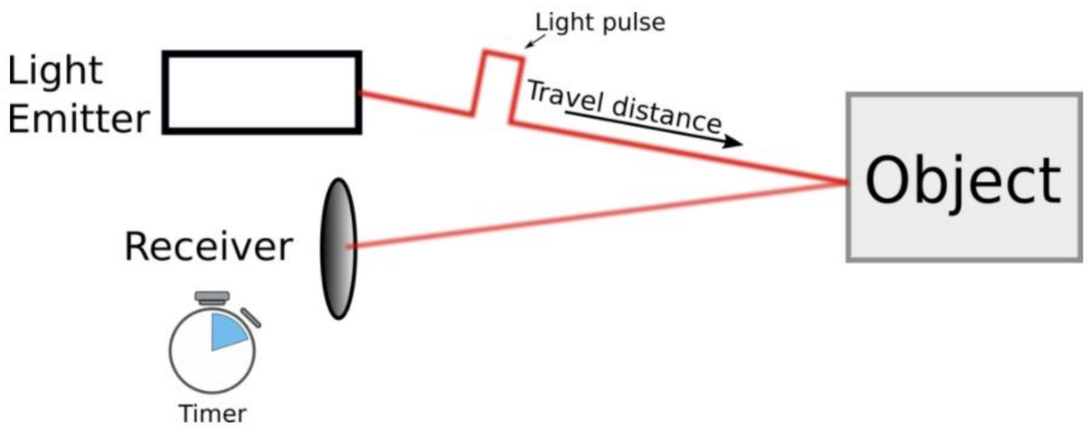
Equipment used at site

TECHNOLOGY - LIDAR AND DRONE WITH RTK

Drones with RTK (Real time Kinematics) significantly improves drones positioning to sub-centimeter level accuracy

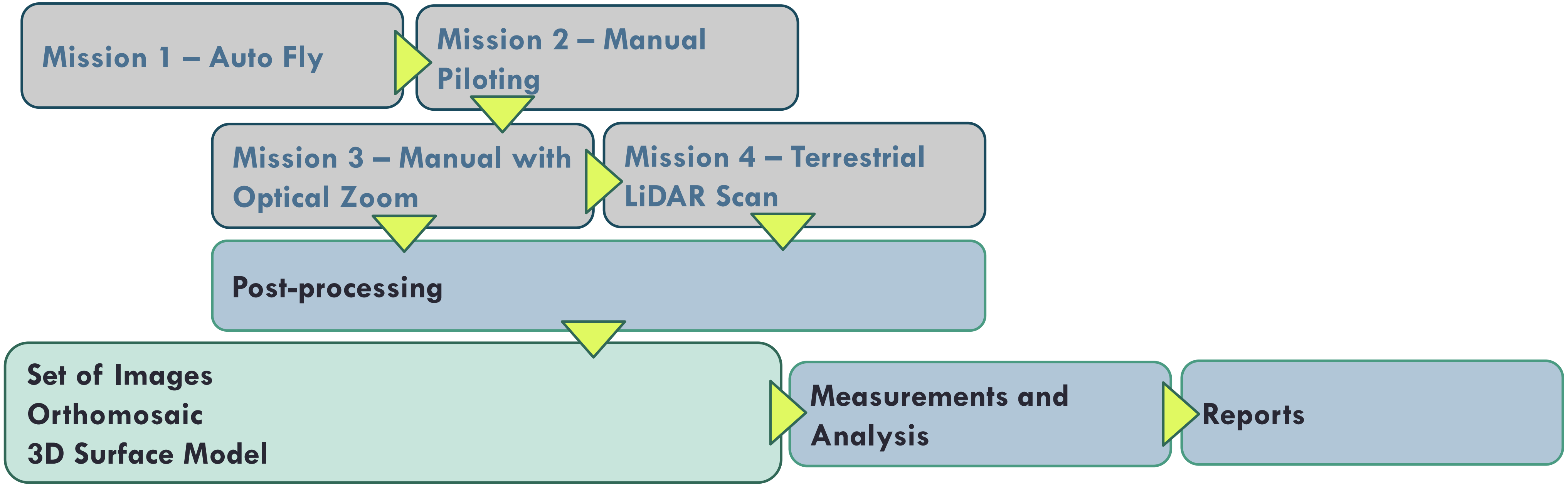


LiDAR stands for light detecting and ranging. LiDAR scanner sends million of light pulse and on reflection, records the distance in form of point cloud of the scanned surface. After rendering, surface is created from point cloud.

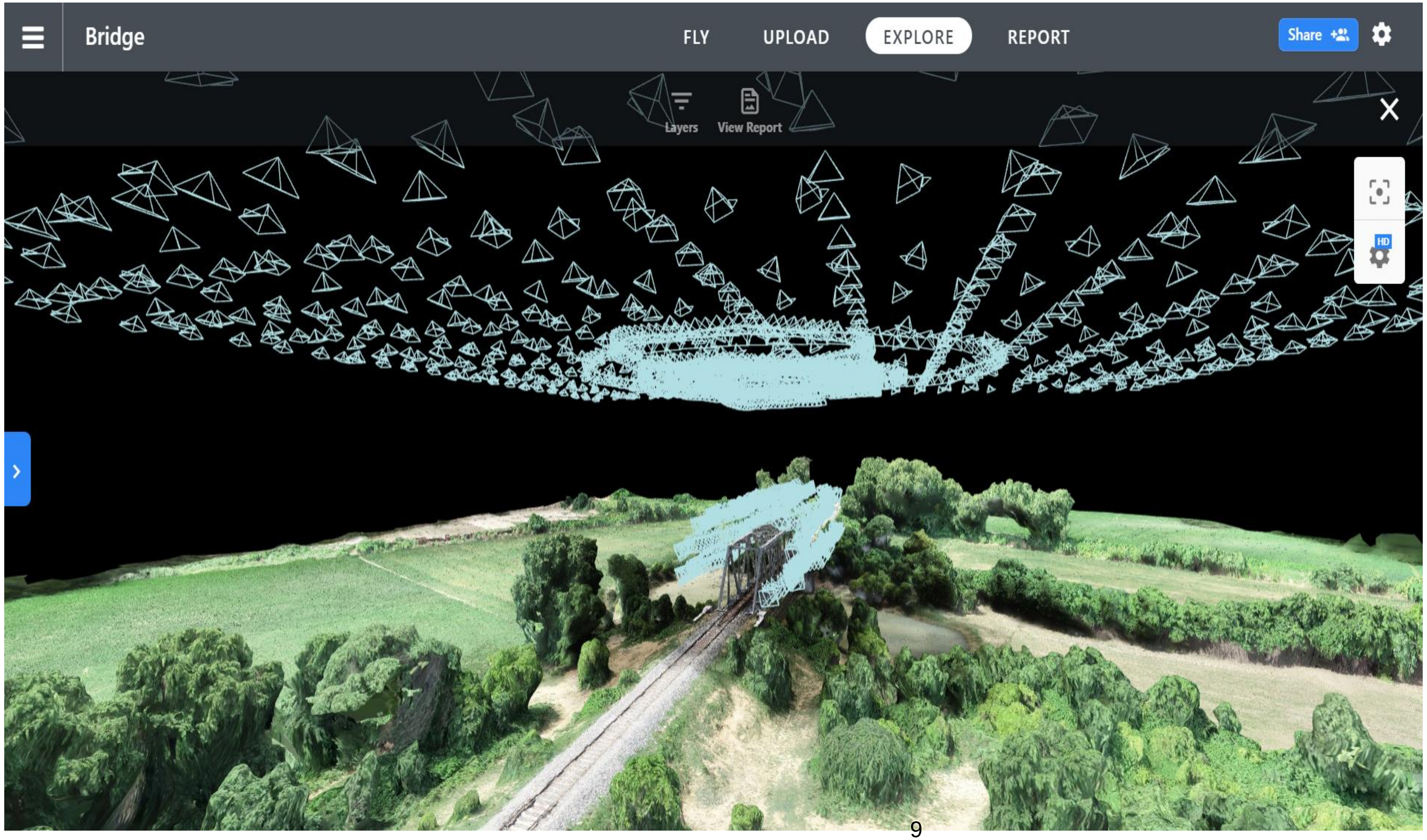


MISSION PLANNING

Used UAV for RGB photography and terrestrial LiDAR scanner for point cloud LiDAR data



FLIGHT PLAN – SPATIAL REPRESENTATION



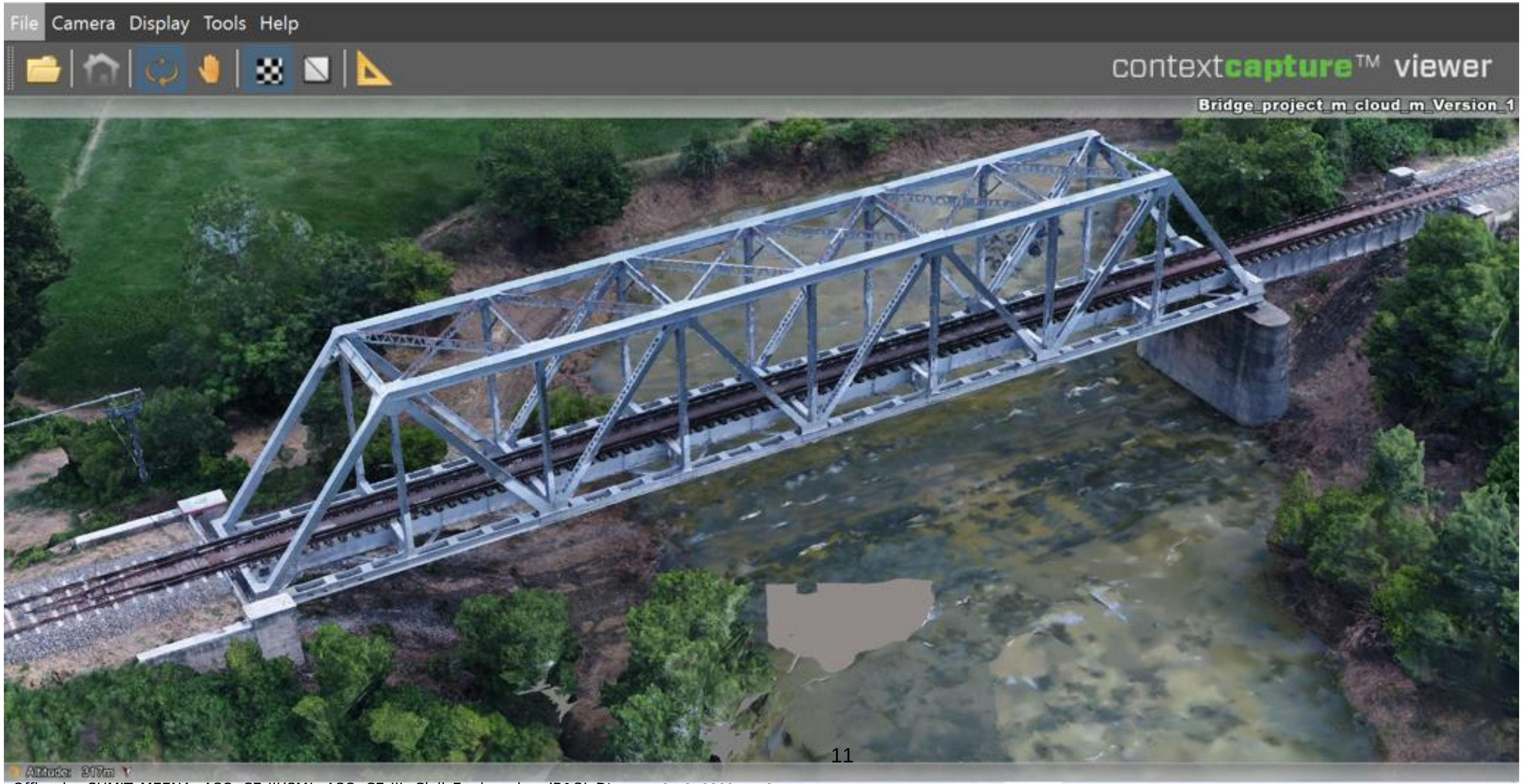
Inspection under the Bridge

Top Chord visual inspection

PROOF OF CONCEPT – POST PROCESSING & ANALYSIS

3D Mission

PHOTOGRAMMETRY



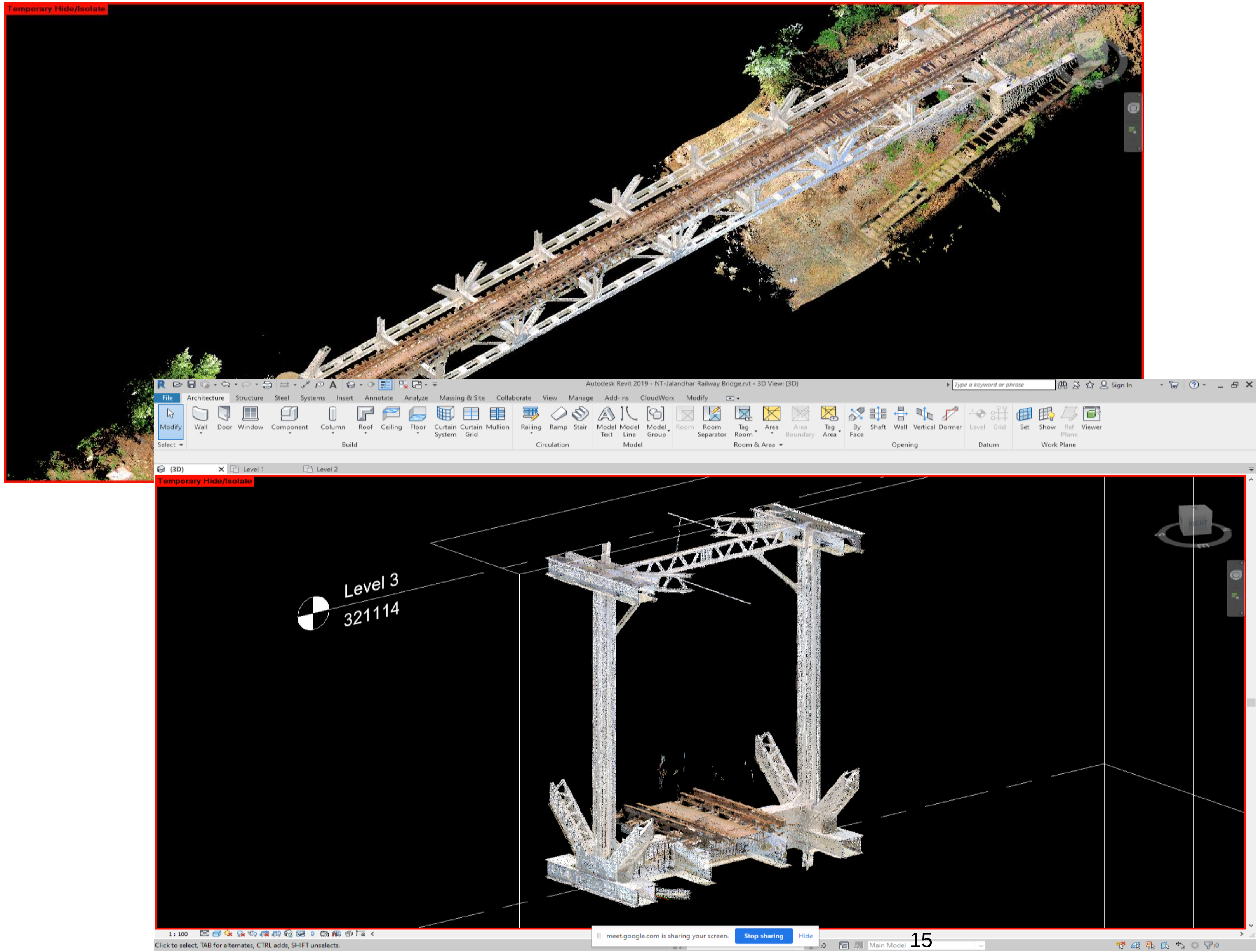
LIDAR POINT CLOUD

MERGED


File Camera Display Tools Help
contextcapture™ viewer
Drone_Bridge

3D CAD MODEL


FRONT
Home
Fit
Orbit
Pan
Zoom
First Person
Measure
Section
Explode
Markup



CONCLUSION

Cross-sectional views

PROOFS FROM THE PROOF OF CONCEPT

The proof of concept project has conclusively proven,

that measurements of all parameters normally required for ascertaining the health of the bridge can be taken from the digital method.

that the accuracy of measurements on the bridge structure fall within ±5mm which is equal to or better than manual measurements.

that the digital method allows quantitative analysis of important parameters of a bridge's health that are not possible to be undertaken by conventional manual means.

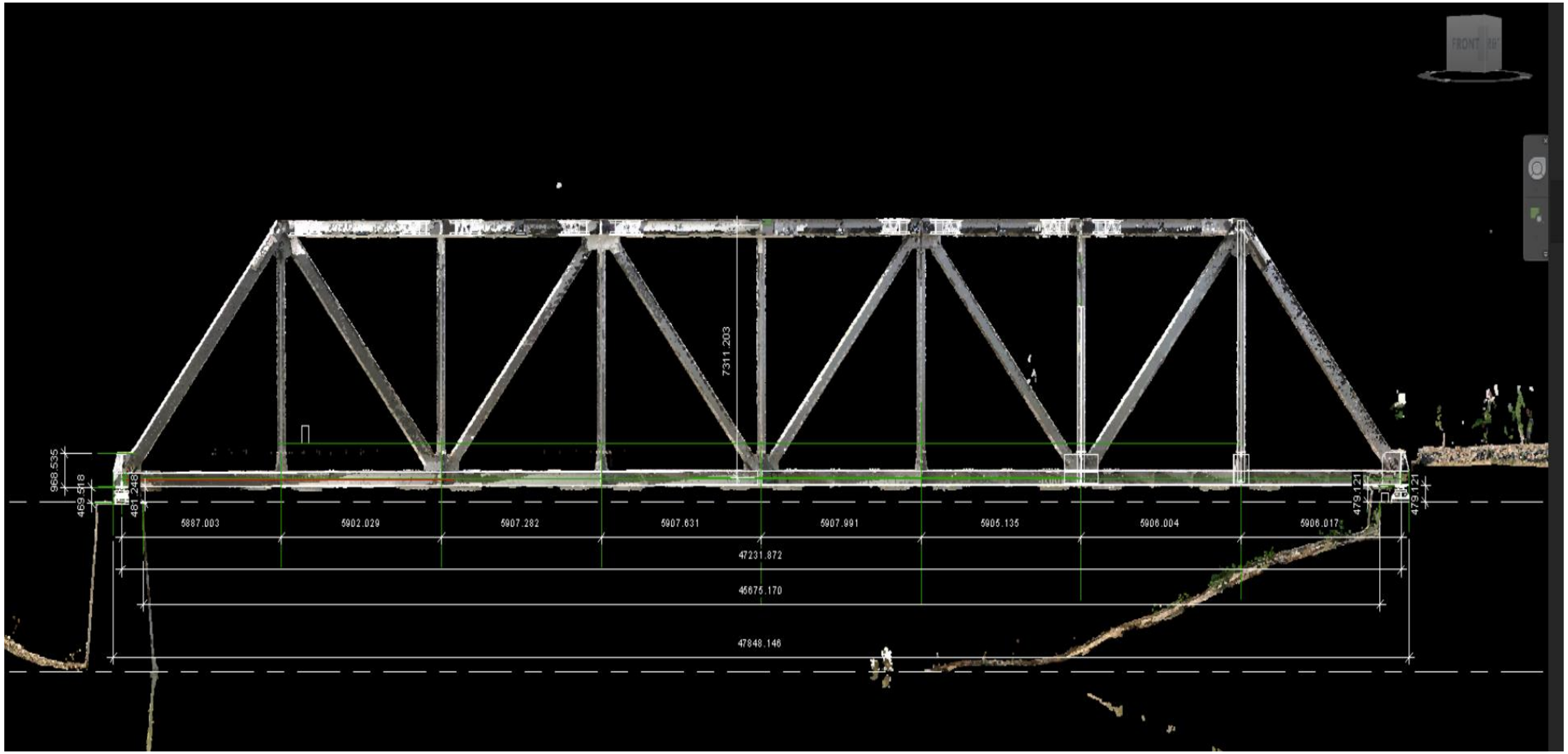
that the advantages envisaged for digital method (flexibility, repeatability, traceability etc) are present and true.

that the level of details available in high resolution images is sufficient for visually ascertaining the defects, or otherwise.

that all parts of bridge can be scanned and modelled by one or the other method, or a combination thereof.

RESULTS – BRIDGE DIMENSIONS (FOR SOD)

Elevation



RESULTS – BRIDGE DIMENSIONS (FOR SOD)

Dimension	As per RDSO drawing (mm)	Manually Measured (mm)	Measured on Digital Model (mm)
Overall Length	47850	47840	47848
Centres of Bearings	47240	47235	47231
Clear Span	45700	45660	45676
Bearing Height	406	480	479
L0-L1 (TTO End)	5905	-	5887
L1-L2	5905	-	5902
L2-L3	5905	-	5907
L3-L4	5905	-	5907
L4-L5	5905	-	5907
L5-L6	5905	-	5905
L6-L7	5905	-	5906
L7-L8 (BEAS End)	5905	-	5906

RESULTS – BRIDGE DIMENSIONS (FOR SOD)

Cross-section

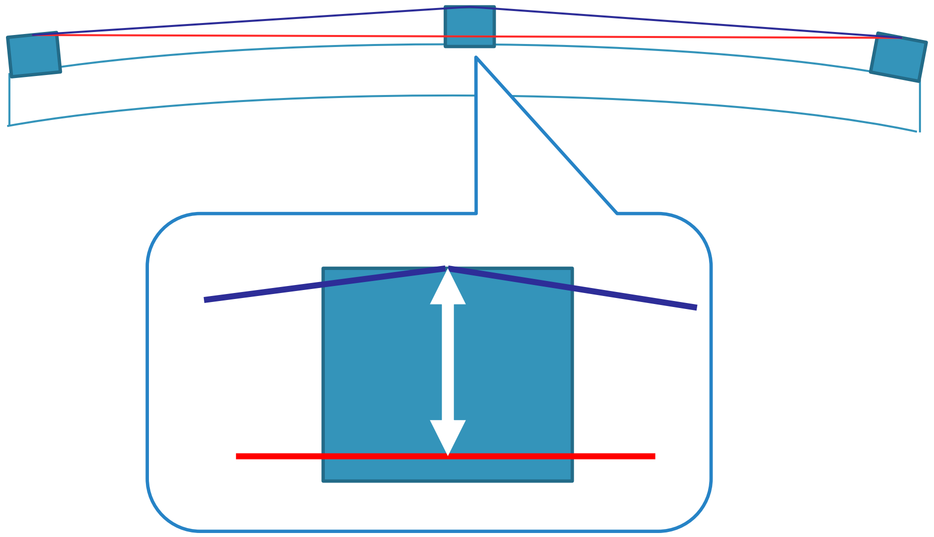
Dimension	As per RDSO drawing (mm)	Measured on Digital Model (mm)
Track Gauge	1676	1674 to 1678
Centres of Intersections	7315	7237.5
Inner width	4725+	4795
Centres of Main Girders	5180	5177
Contact Wire Height	Varies	5340 (5675 at catenary)
Sleeper height	950	950
Distance between knee bracings at contact wire height	N/A	3459.68

RESULTS - CAMBER

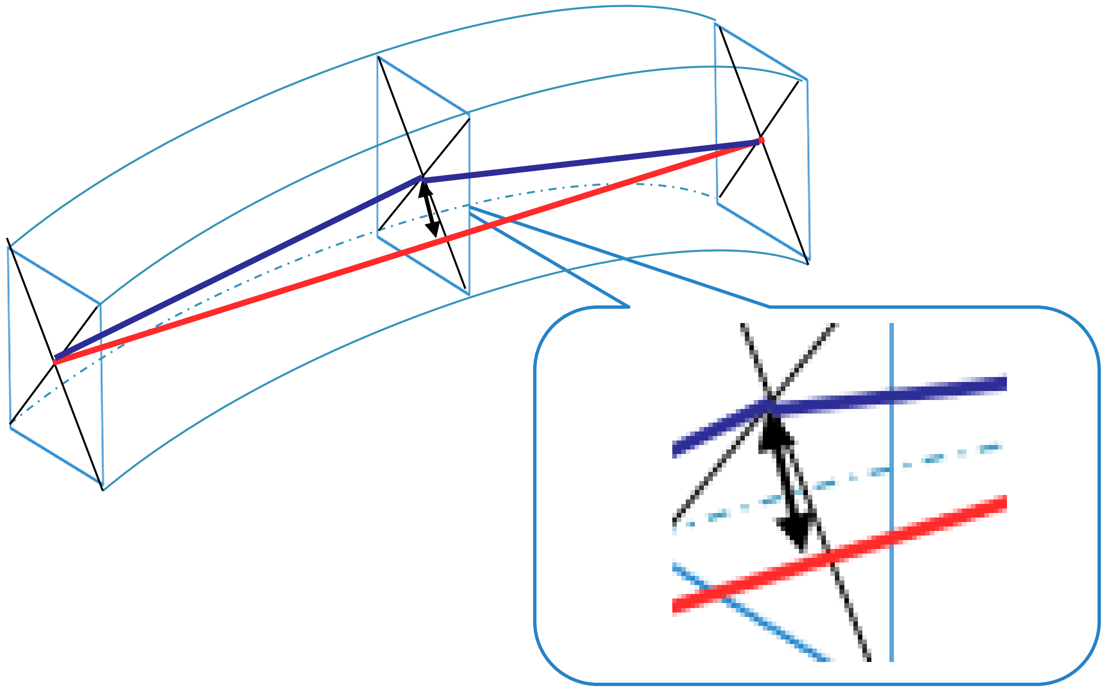
Camber was measured by two methods:

1. Method 1 - Differential of top of cross girders levels
2. Method 2 – Offset from chord joining the centre of cross-sections of a member

Method 1

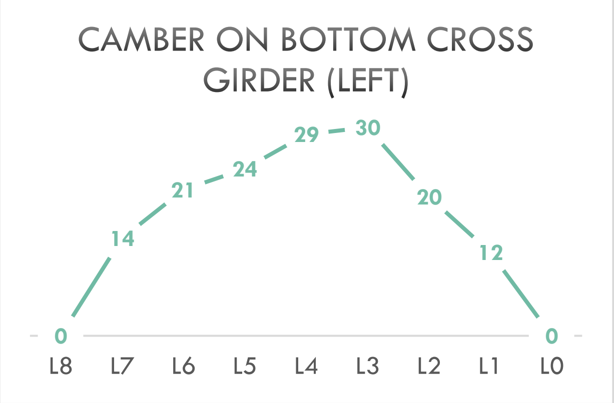


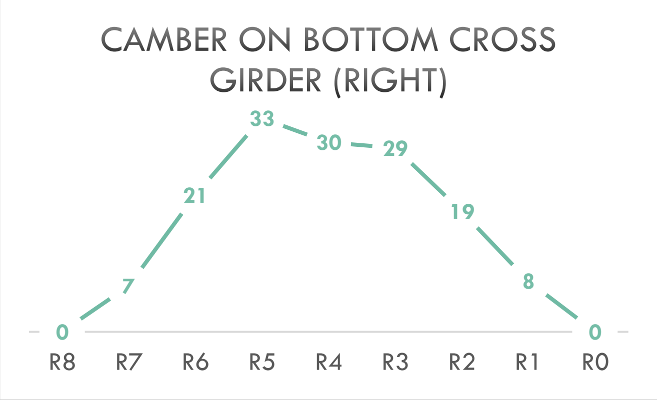
Method 2



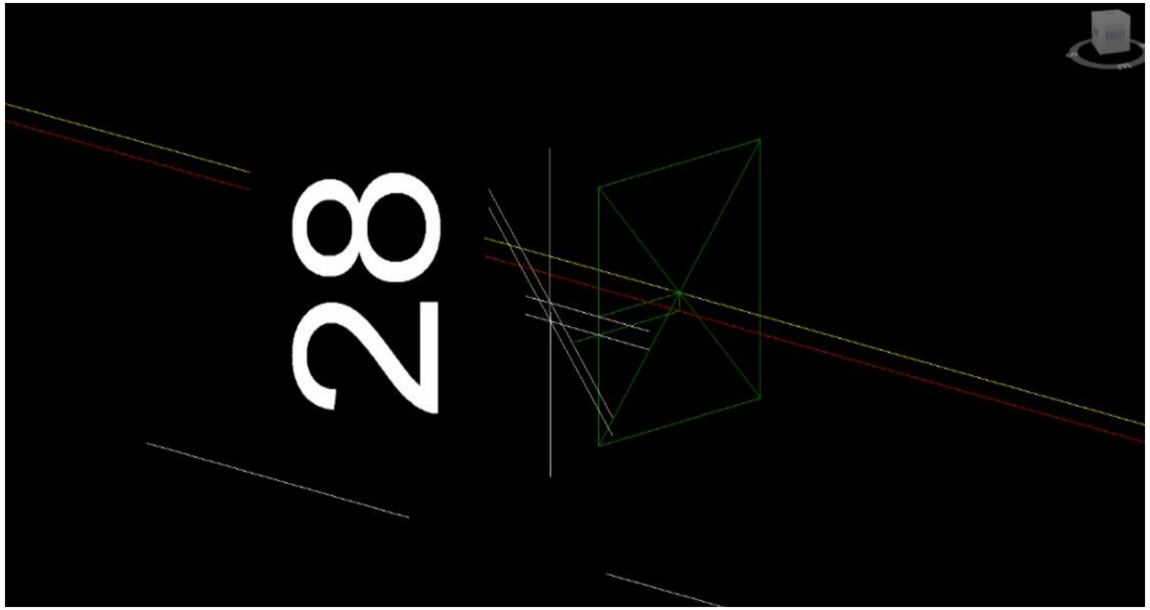
RESULTS – CAMBER METHOD 1

Joint #	2011	2016	May-21	Aug-21	PoC Camber Result	Manually reverified on 27th Aug 2021
L0	0	0	0	0	0	0
L1	10	10	9	10	12	10
L2	23	20	20	23	20	21
L3	38	32	30	33	30	29
L4	35	35	35	36	29	35
L5	35	30	28	27	24	25
L6	30	20	20	23	21	22
L7	20	10	10	11	14	12
L8	0	0	0	0	0	0
R0	0	0	0	0	0	0
R1	10	10	10	8	8	8
R2	20	20	18	19	19	20
R3	38	35	36	33	28	33
R4	35	38	36	34	30	35
R5	38	35	34	31	33	28
R6	35	20	22	21	21	20
R7	20	10	10	8	7	8
R8	0	0	0	0	0	0





RESULTS – CAMBER METHOD 2



This method better aligns with the engineering concept of camber.

However it cannot be undertaken in the field and cannot be compared with the indirect method (method 1).

But, once digital method is used repeatedly we will get sufficient data to see if the girder is really settling.

Value of camber measured at L4 for left bottom girder by this method came out to be 28 mm as against 29 mm through conventional method.

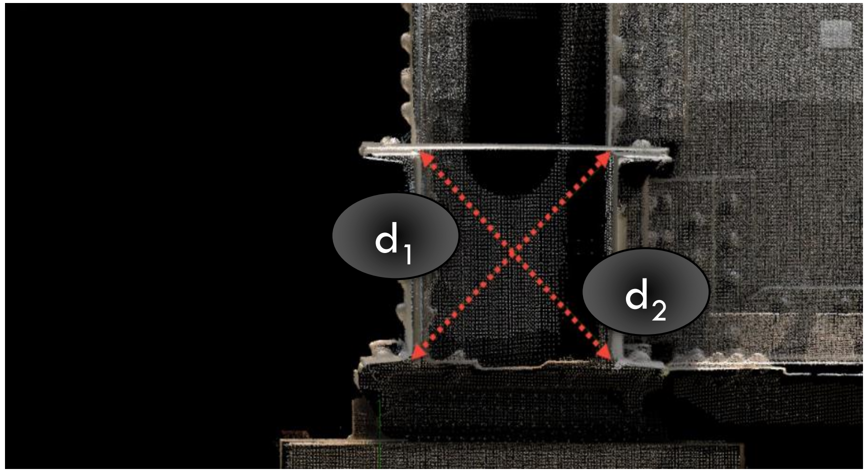
RESULTS - DISTORTION

Distortion measured in the field is essentially **lateral distortion.**

Distortion measured through digital method includes **torsional distortion,** something that is considered more severe.

Torsional Distortion

Measured using the length of diagonals at different cross-sections of a member.
Any significant difference in the length of diagonals (d1, d2) will show a suspected case of torsional distortion.
Once that is found, it may be further investigated using instrumentation.

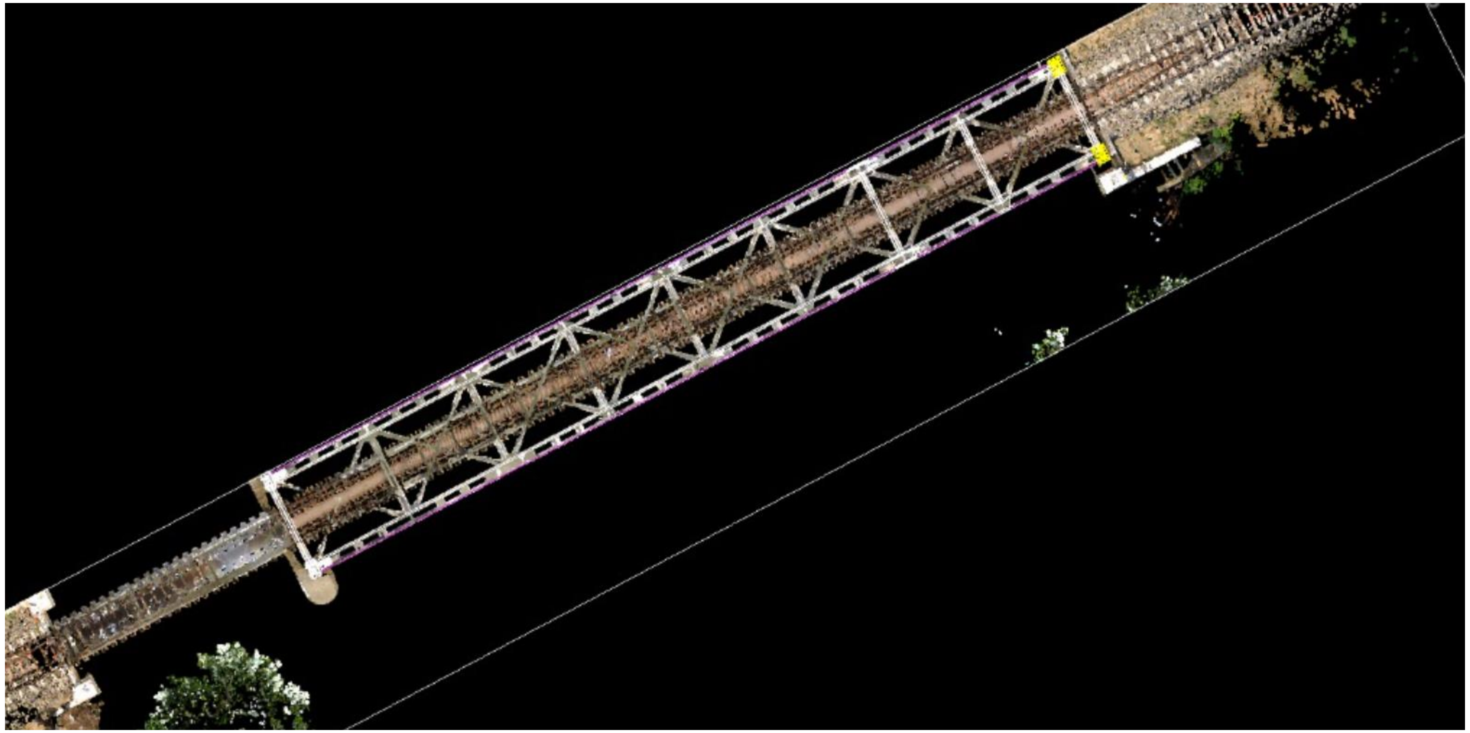


	d_1 in mm	d_2 in mm
1st x-section	569.320	569.320
2nd x-section	572.349	568.153
3rd x-section	565.00	565.00
4th x-section	564.875	564.210

RESULTS - DISTORTION

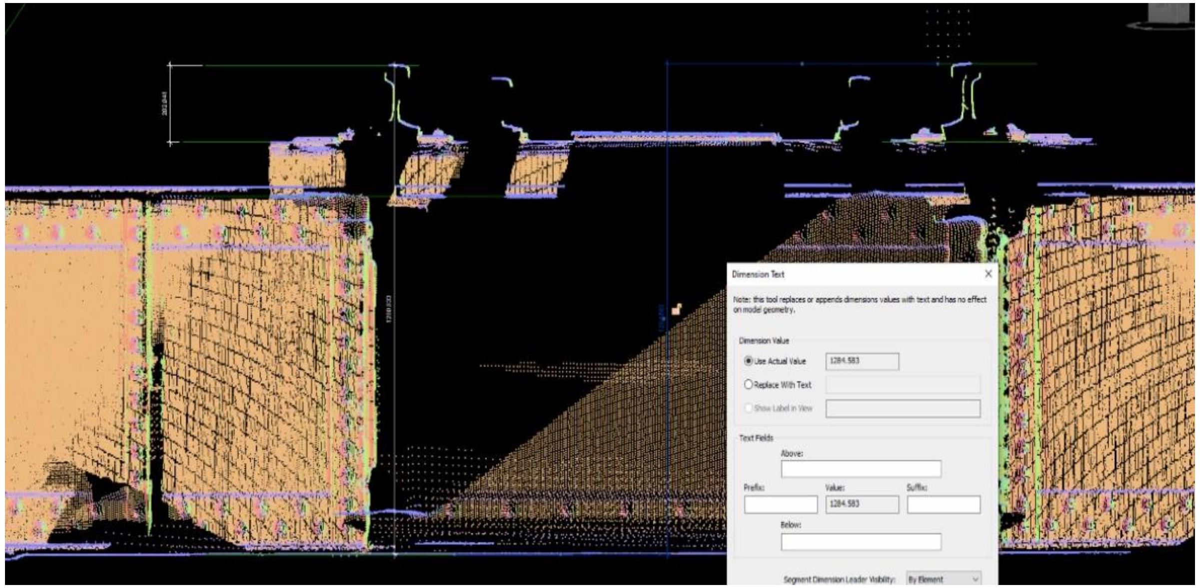
Lateral Distortion

	Distortion in mm
R0 TTO End	0
R1	-15
R2	-8
R3	-6
R4	-2
R5	-2
R6	4
R7	6
R8 Beas End	0

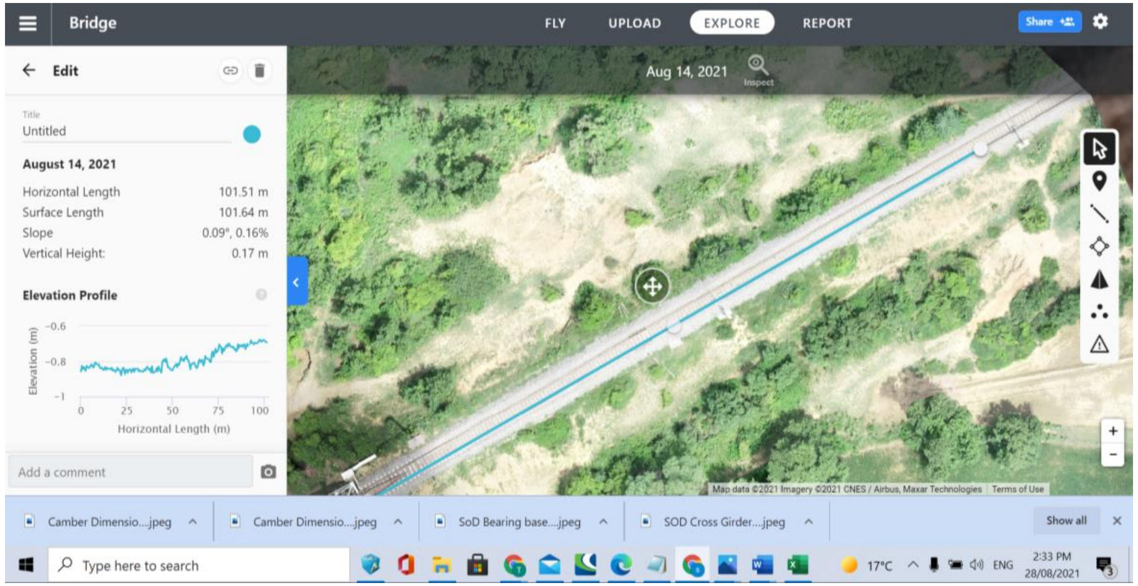


RESULTS – RAIL LEVELS

Dimension		Manual reading by BWS/JRC (mm)	Measured on Digital Model (mm)
Top of rail to top of pier	Beas End	1750	1755
	TTO End	1762	1763



RESULTS – 100M L-SECTION

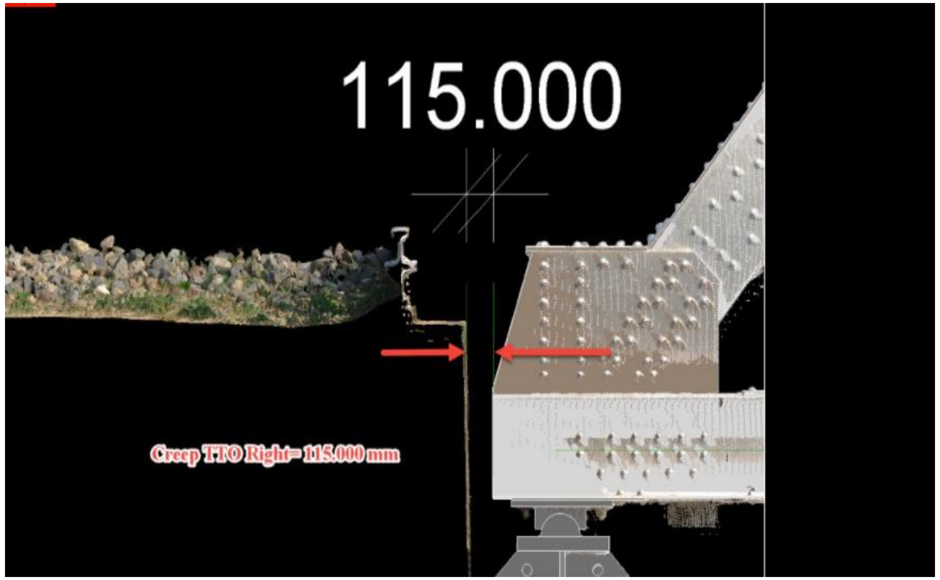


Beas End

	BEAS (Manual)	BEAS (PoC)
100 m	160 mm	170 mm
0 m	0 mm	0 mm

RESULTS – CREEP

	Manually Measured	Measured on Digital Model (mm)
Beas end left	105mm	108 mm
Beas end right	102mm	115 mm
TTO end left	170mm	187 mm
TTO end right	170mm	185 mm



RESULTS – OWG BRIDGE ASSEMBLY TWIST

This is again an item that is not usually measured in the field and cannot be easily measured either. But, with the digital method it is a very simple matter.

	D_1	D_2	Difference
L7-R7	7763	7770	-7
L6-R6	7902	7905	-3
L5-R5	7895	7895	0
L4-R4	7915	7912	3
L3-R3	7895	7895	0
L2-R2	7920	7902	18
L1-R1	7778	7775	3

RESULTS – SAMPLE VISUAL INSPECTION

View of bearing from multiple angles

RECOMMENDED WAY FORWARD

Immediate

- Incorporation of lessons learned from the PoC into framing a rigorous set of specifications
- Extending this method's concepts to concrete and steel plate girder bridges
- Conduct bridge inspections using this method over a larger set of bridges of varying spans, lengths and construction to generate sufficient data for future development and advancement

Medium to Long Term

Development and use of
- Image analytics
- Machine learning
- Other imaging tools

Leading to

- Automation of measurements
- Automatic failure detection
- Automatic assignment of bridge health index
- System recommendation of inspection frequency
- Generation of maintenance job cards
- Failure predictions
- Long term bridge health analysis


Thanks

For official use only

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

Revised
Guidelines for
4D Bridge Information Modelling (BrIM) System and Digital Inspection of Railway Bridges Using Photogrammetry, LiDAR and Similar Techniques

November 2022

1.0 Abbreviations

UAV : Unmanned Aerial Vehicles

UAN : Unique Authorization Number

UAS : Unmanned Aerial System

LED : Light-Emitting Diode

BrIM : Bridge Information Model (Digital Twin)

GAD : General Arrangement Drawing

GCP : Ground Control Points

DGPS : Deferential Global Positioning System

CAPI : Critical Areas of Particular Interest

BMS : Bridge Management System

LiDAR : Light Detection and Ranging

2.0 Introduction

There are more than 1,50,000 bridges in Indian Railways including about 700 Important & 12000 Major bridges. All these bridges need regular monitoring, periodic inspection and maintenance to make railway operation fail safe. Monitoring strategies play a major role in achieving the target of service life of bridges. Currently, the inspections of these bridges are carried out by mobile inspection units, ladders, rope access etc. Regardless of the method used to carry out the inspection, the associated costs and dangers remain a challenge. Mobile inspection units require operation closures and blockage of routes, while inspection by ropes/ladders require a high level of training and expertise and still have issues related with resource availability, time needed and safety of the inspection staff.

Therefore, in most cases, these inspections are technically and logistically complex. The inspection of critical structural components and difficult spots that are hard to reach is mostly done by specially trained staff like industrial climbers or with large under bridge units, elevated platforms or other specialized equipment.

Remote controlled Unmanned Aerial Vehicles (UAV) equipped with high definition RGB and LiDAR cameras can simplify these difficult inspection tasks. This method provides an important contribution to monitoring strategies in terms of quality and efficiency. Unmanned Aerial System (UAS) commonly known as "Drone" is considered as an efficient tool for mapping, monitoring, inspection and planning for transportation corridors and projects.

Advancement of UAV (Drone) based photogrammetry and LiDAR technology has created a possibility to adopt indirect inspection techniques in digital environment for railway bridges. Apart from saving considerable manpower and other costs, it standardizes the approach as well as does away with the subjectivity related to skills of the technicians doing manual inspections.

3.0 Digital Twin - 4D BrIM, Bridge Information Model Integrated Drone Inspection

Bridges are constructed based on the GAD (General arrangement Drawing) & Detailed designs. These GADs are available in the form of 2D drawings printed on paper or scanned Pdf files, with railways for most of the bridges except the bridges those are very old. It is difficult to refer these traditional 2D paper or CAD drawing for the inspection & maintenance purpose. Moreover, the inspections records are not being linked with the designed elements of the Bridges and thus are hard to visualize, compare and comprehend. Regular Monitoring, Inspection & Maintenance management is a difficult and complicated task. The periodic inspection of the same Bridge and comparison of same is essential for holistic bridge maintenance.

In the 4D Bridge information modelling (BrIM) based approach a high fidelity 3D Model of the Bridge is developed from photogrammetry and LiDAR point cloud for managing and maintaining the inspection records. BrIM is essentially a federated model where inputs from various sources can be input and analysed for a better understanding of the health of the bridges.

4.0 Advantages of Digital Inspection:

a) Minimises manpower requirement

b) Time consumed reduces progressively with each subsequent inspection

c) Objectivity is increased as methodology and analysis tools are standardised

d) Results and analysis can be viewed as many times as possible without need of returning to the site

e) UAVs can be used in the field for bridge inspections safely. The risk to inspection personnel and public is very low.

f) UAVs can be used as a tool by bridge engineer to view and assess bridge elements conditions in accordance with the Bridge Standard.

g) Defects can be identified and viewed with a level of detail equivalent to a close-up photo.

h) UAVs can provide a cost effective way to obtain detailed information that may not normally be obtained during routine inspections.

i) Safety risks associated with train traffic, working at height, etc. could be minimized with the use of UAVs.

j) UAVs can be utilized as an effective method to determine stream or river bank conditions upstream or downstream of the bridge as well as capture large overall aerial maps of dynamic bank erosion and lateral scour conditions.

5.0 Advantages of 4D BrIM, Bridge Information Model Integrated Inspection:

a) 3D Model of bridge brings clarity & understanding of the bridge geometrical details.

b) Rich Visualization of any part of bridge including virtual reality interface.

c) Enables dissemination and sharing of information in the 3D environment.

d) Enhances communication and coordination among officials.

e) Base line Model to compare the periodic inspection records.

f) Web-based 3D technology to enhance the inspection records and its effectiveness.

6.0 Future Development

Adoption of this technology will enable further advances. It will lead to development and use of:

- Image analytics
- Machine learning
- Other imaging tools

Which will lead to:

- Automation of measurements
- Automatic failure detection
- Automatic assignment of bridge health index
- System recommendation of inspection frequency
- Generation of maintenance job cards
- Failure predictions
- Long term bridge health analysis

7.0 Objectives

a) To Develop 3D model (Digital Twin) of the Bridge from photogrammetry and LiDAR point cloud.

b) Capturing high resolution images of the critical areas of the bridge that can be linked to the 3D model and that can be used for ascertaining defects.

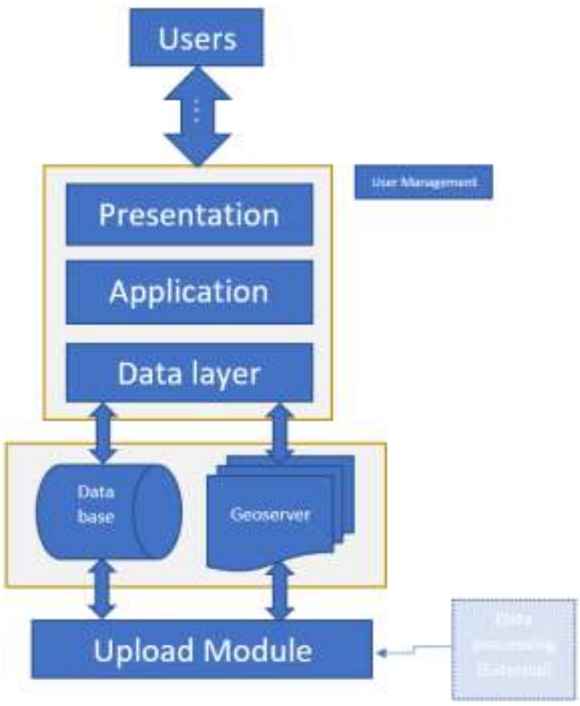
c) Web based BMS linked BrIM environment to enable railway officials to obtain an overview of the condition of the bridge and to compare it with past data to assess the deterioration. This will allow officials to plan the maintenance of the bridges in a better manner, plan ahead for refurbishments and overhauls, find gaps in maintenance and usher in a condition-based maintenance regime.

8.0 Functional Requirements of 4D BrIM Application

8.1 Proposed solution will be a single-page web application to provide geospatial and catalogue exploration capabilities together. Catalogue in this application will be railways bridges and catalogue items will be the data associated with bridges. It will be written in TypeScript and compiled to ECMAScript 5 to run in Firefox, Chrome, Safari or Edge having decent internet connection. Catalogues Function will allow parameterized service where user supplies the parameters and gets back some result.

8.2 4D BrIM will have following key functionalities:

1. Data hosting - 2D, 3D and associated technical data of bridges.
2. Data federation, visualization and analytics
3. Data upload



8.3 User classes

1. Admin
2. Users (Ordinary)
3. Users (With upload privilege)

Only authorized users shall be allowed to edit or upload after data is processed externally.

8.4 As size of each dataset per bridge is expected to be large, lazy loading techniques shall be used. All logical and memory intense operations must be run on application layer in the server end and minimal data is required to be downloaded by users

8.5 Key features of application include a React-based user interface designed to work on phone, tablet or desktop. Allow users to specify Web Processing Service (WPS) parameters from the UI and visualise the result in workbench. Compare datasets using the image splitter and date picker to compare data at different points in time, or different datasets.

8.6 Visualise data on 3D and fall back to 2D when not feasible or switch between them on the fly, based on Cesium and Leaflet. Easily analyse the underlying data from bridge features or external sources, using rich and interactive charts, and export the results.

8.7 The BrIM shall be accessible through suitable interface in BMS. However, BrIM shall be a separate application with its own database and structure.

9.0 Equipment Details

9.1 Purpose of these details is to standardize Rail-bridge inspection methodology using drones for consistent and comparable results irrespective of drone type, skill of operator and other site-based variables such as types of bridges, location and weather conditions.

9.2 Drones, camera and data processing technologies are evolving at rapid pace hence it becomes further more important to have uniformity. Following are the required specifications of the common equipment to be used. Additional equipment shall be used to meet the end purpose of digital inspection.

S.No.	Items	Details
1	UAS Type	Rotatory Wing
2	Number of Propellers	4 minimum (preferably 6)
3	Wind Resistance	5 m/s or higher
4	Flight Control System	Offer Critical systems redundancy
5	Operating Temperature	-10° C to 45° C
6	Hovering Accuracy (minimum)	Vertical: ±0.5 m, Horizontal: ± 1.5 m
7	GPS / GNSS	UAS must be fitted dual GPS/GNSS receivers to constantly provide feedback to Drone to correct its positional accuracy.
8	Position Correction	Drone must be equipped with RTK or similar technology to improve the positional accuracy of drone while airborne and avoid interference with steel structure and GPS 4 satellites are reachable.
9	Geotagging	Photos captured by RPA must be geo tagged to position recorded by RTK.
10	Operating Frequency of Remote Controller	5.725 GHz to 5.825 Ghz; 2.400 Ghz to 2.483 Ghz or DGCA Compliant
11	Flashing Lights	Flashing lights, anti-collision strobe lights with heading indicator
12	Aircraft Colour	Any colour except red and green, or as per regulations
13	Obstacle avoidance	Should be equipped with obstacle

		avoidance.
14	Low Battery Charge	Must have low battery audio warning to warn operator below 30% charge.
15	Image Resolution	Minimum 20 MP (preferebly 40 MP)
16	Photo Format	JPEG, TIFF or similar
17	Field of View (FOV)	60° or higher
18	LiDAR	Minimum sampling rate 150,000 pulses per second

10.0 Bridge Inspection Methodology

10.1 Introduction

10.1.1 The methodology of digital inspection will be a Seven-stage process.

a) Planning & Preparation
b) Site Assessment
c) Data Acquisition
d) Data Processing
e) Measurement and Analysis
f) Data Upload to BrIM

10.2 Stage 1: Planning & Preparation

10.2.1 This stage will comprise of the steps taken to get apprised of the general and special features of the bridge under inspection and planning for the inspection to fulfil the goals of the assignment. It will entail study of the plans and drawings of the bridge, historical inspection records, failure reports, repair and rehabilitation records and other pertinent information that may have a bearing on any special requirement of inspection of the bridge.

10.2.2 The primary objective of this stage is to ascertain critical locations of the bridge in order to list down the Critical Areas of Particular Interest (CAPI) for the bridge, and to plan for the inspection including the requirements for equipment and any particular expertise. The Employer will provide all necessary documents and information for this exercise, as required.

10.3 Stage 2: Site Assessment

10.3.1 This stage is intended to identify potential risks such as near trees or traffic lanes to safely proceed with the drone-enabled inspection. Other benefits of performing a site risk assessment prior to conducting the inspection include identification of safe landing/take off zones, safe bridge approaching areas, and pilot risk minimization. Additionally, the legal regulations should be accounted for prior to establishing a flying strategy. Legal regulations vary from location to location.

10.3.2 The objective of the study will be to finalize operational parameters such as UAS take-off and landing zones, flight plan, traffic or power block requirements, GCP locations (if needed), requirements of observers and any other measures for safety of the men and material.

10.4 Stage 3: Data Acquisition

10.4.1 Once all the preliminary information has been gathered during the previous stages, the inspection using the drone can be conducted. During the operation of the drone, it is necessary to consider weather conditions such as wind, because it can negatively affect the performance of the drone. Aside from weather condition, the inspection plan should be performed as planned to avoid delays or damage to both the structure and the drone. It is recommended to capture the overall sections of the bridge, and then gather close-up or detailed information of each structural and non-structural component. It can be noted that current regulation does not allow drone operation over traffic, thus, the inspection of some sections (i.e., location over roadway) should be conducted accordingly. The Pilot-in- Command (PIC) should be continuously assisted by an observer to avoid distraction and possible accidents.

10.4.2 To perform the Drone Pre-flight Setup**:** It is recommended, to conduct a thorough inspection of the drone prior to the first flight of the day. Inspections of all the software and hardware including, but not limited to, propellers and rotors inspection, full charging of all instruments (e.g., a remote controller, storage batteries, and a monitor), remote controller adjustments, gimbal inspection, and firmware updates should be conducted. A compass calibration must be performed prior to flying at a new location to prevent GPS signal loss during a flight.

10.4.3 The whole length of the Bridge is to be inspected covering the Bridge structure, substructure and surroundings that include a zone of 100m toward increasing & decreasing chainage and 100m in upstream & downstream of the river/nalas/stream/road/canal etc. crossing the bridge. This coverage shall be done using the RGB as well as LiDAR camera. If the drone is capable of mounting both the cameras, the data shall be captured in a combined pass. Otherwise, there shall be two sets of data capture flights, once for visual spectrum the other for LiDAR. Further, in case terrestrial LiDAR is required due to the site or any other reason, terrestrial LiDAR shall be used.

10.4.4 UAS (Drone) with High resolution digital camera capable of collecting geo-tagged high-resolution images (at least 20 MP, preferably 40 MP resolution) fitted on 3-axis gimbal (Pitch, roll, yaw) is to be used for stable and clear data acquisition quality. Data acquisition shall be done in good photographic conditions and area must be free of fog, haze, dust, and smoke. Additionally, data is to be collected in good light conditions to ensure the images clear and sharp in detail. Close up/zoomed stable images will be taken for each CAPI to gather detailed information of structural and non-structural components. Depending on clearances, features of the RPA and weather conditions like wind, manual flight or still photography will be taken as an option, Some CAPIs may need flight paths that require traffic or power regulations and care needs to be taken for those locations. For areas inaccessible to RPA due to infringements or restricted clearances, the site personnel will resort to manual still photography to capture photographs with equivalent or better parameters as those for RPA mounted cameras.

10.4.5 High Resolution Geotagged Imagery for Orthophoto: Survey grade UAS (Drone) to be utilized to capture precisely geotagged low altitude Nadir aerial images. These images shall be captured from flight height of about 20-60m, as per requirement.

10.4.6 High Resolution Nadir & Oblique Geotagged Imagery for 3D reality Model: Oblique & Nadir photography to be done as per best practices (for best result) to meet the objective. Very low altitude flight height of about 20-60m, as per requirement should be used for clear capture of details.

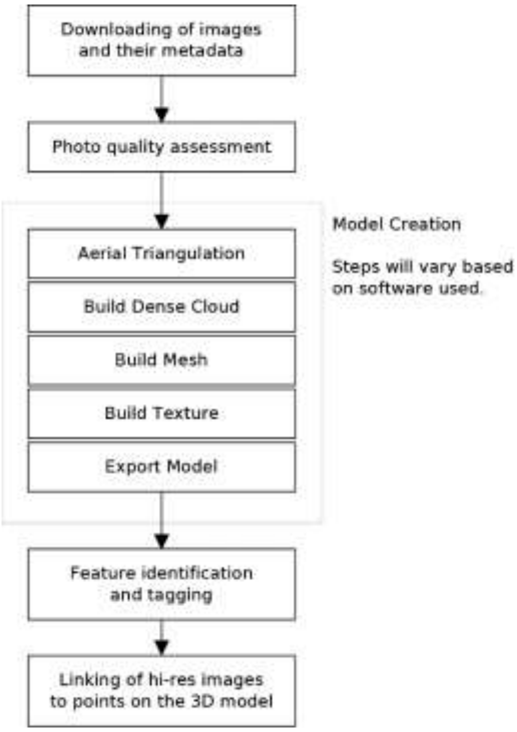
10.4.7 The images can be taken every 2 to 4 seconds (or as required for getting the necessary overlap), while drone follows the way points or circles the point of interest at a speed of 3 to 5 meter per second. Horizontal and vertical overlap between subsequent images should be at least 60%.

10.4.8 Subsequently, a preliminary general assessment of the images captured will be undertaken so that the gaps may be filled and re-plan of the flight is avoided. Integrity of data shall be ensured and, if possible, the data downloaded to a secure location that can be used for post-processing.

10.5 Stage 4: Data Processing

10.5.1 This is the stage where the images procured from the flights will be processed to get them ready for the next stage. It will be done broadly in two steps. First, creation of a virtual photogrammetric 3D model of the bridge. And second, collation and tagging of images pertaining to different CAPIs for further visual examination and analysis.

10.5.2 Following process flow will be taken up for creation of a 3D model:



10.5.3 These are some of the software packages that can be used:

- Bentley ContextCapture
- Autodesk Revit
- Autodesk ReCAP
- Agisoft Metashape
- AliceVision Meshroom
- Pix4D
- RealityCapture
- Trimble Inpho
- WebODM

– 3DF Zephyr

10.5.4 Images of CAPIs will be collected, tagged and renamed suitably. These images will also be linked to the 3D model to show their location in the overall bridge structure, for better appreciation. The images can also be processed for better clarity and contrast of the feature that is required to be analysed.

10.5.5 The 3Dmodels shall be linked with bridge inspection data for effective reporting of condition, maintenance needs, planned maintenance and other important decisions.

10.5.6 The images of CAPI intended to be used for visual inspection shall be tagged and set in suitable hierarchies for easy identification. These images will also be linked to the 3D model to show their location in the overall bridge structure, for better appreciation.

10.6 Stage 5: Measurement and Analysis

10.6.1 The 3D models shall be manipulated using appropriate CAD software for taking various measurements required for getting the parameters detailed in these specifications. The accuracy desired shall be ±5 mm and any discrepancies shall be brought out.

10.6.2 Following parameters shall be measured:

a) Bridge dimensions (including SOD diagram)
b) Camber
c) Distortion (for OWG bridges)
d) Track measurements including rail levels, level of track at 5th sleeper, sleeper spacing etc.
e) 100 m L-section
f) Creep
g) Bridge assembly twist

10.6.3 Following will be the areas for general examination which shall be examined and commented upon:

a) Bridge approaches for 100m in each direction (in addition to L-section)
b) 100m upstream and downstream in both directions (Water crossing bridges)

10.6.4 CAPI will be ascertained for each bridge from its history, environmental factors, experience etc. Following are the typical CAPIs for guidance:

a) For steel girder bridges:

S.No.	Area/Location	Remarks
1	Protection Works	Visual examination of hi-res photographs with an option of machine learning in future developments. Examination by comparison to drawings and earlier pictures to be examined.
2	Abutments	
3	Piers	
4	Bed Blocks	
5	Bearings & vicinity	
6	Lateral Bracing	
7	Sleeper Seats	

8	Flooring arrangement and connections with bottom chords, cross girders	
9	Gusset connection of top lateral bracing to top boom.	
10	Bridge Deck	

b) For concrete bridges:

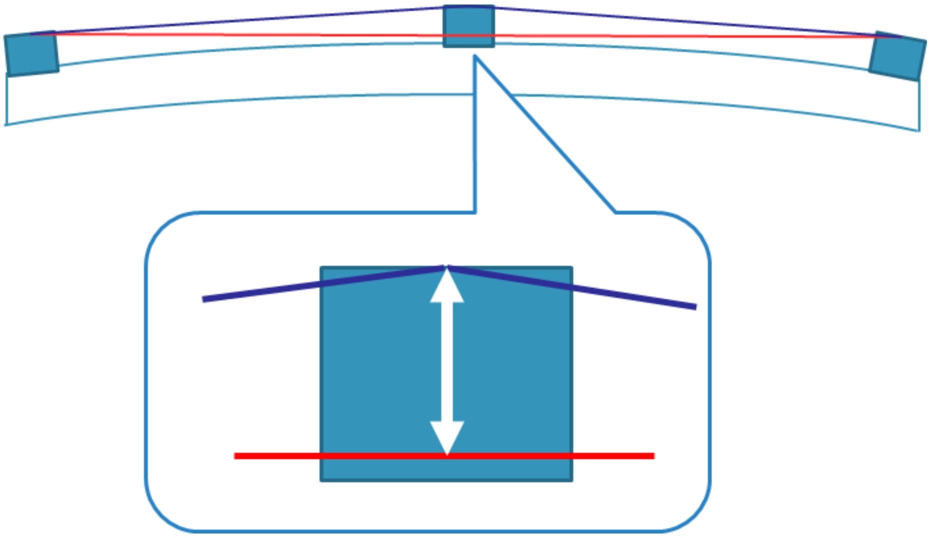
S.No.	Area/Location	Remarks
1	Protection Works	Visual examination of hi-res photographs with an option of machine learning in future developments. Examination by comparison to drawings and earlier pictures to be examined.
2	Abutments	
3	Piers	
4	Bed Blocks	
5	Bearings & vicinity	
6	Anchorage Zone	
7	Deck Slab	
8	Top and bottom flange of I-girder	
9	Bottom slab in box girder	
10	Webs	
11	Diaphragms	
12	Junction of slab and web	
13	Junction of precast and in situ cast elements	
14	Segmental Joints	
15	Expansion Joints	

10.6.5 **Bridge dimensions:** Measurements shall be taken from elevation, end view and cross-sections of the bridge. A comparison of these measurements with previous readings (manual or otherwise) shall be done. One of the important points required is that the measurements are required to prove the clearances required as per SOD. For this purpose, the kinematic envelope shall be developed in CAD and superimposed on the bridge cross-section.

10.6.6 **Camber:** Camber shall be measured for both the bottom chords (lower girders) at all panel points using two methods, and shall be taken at;

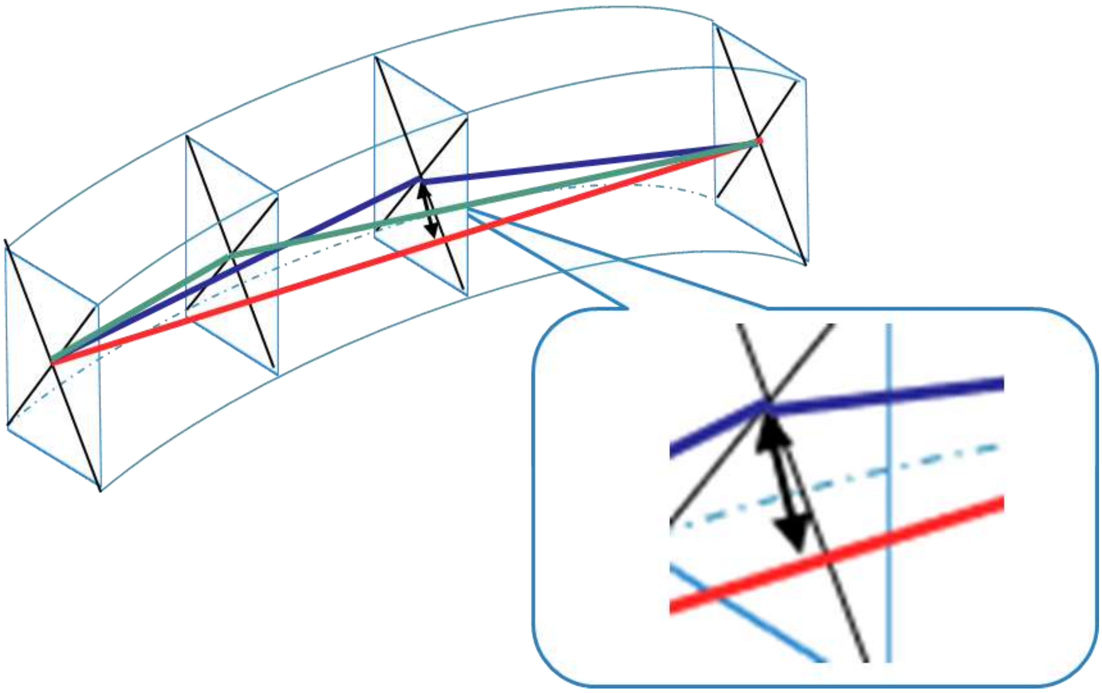
a) **Differential of top of girder levels.** This will be equivalent to the conventional method being adopted in the field and shall be compared with manual readings taken in the fields by the Employer. A table to the effect shall be prepared. An illustration of the method is given in Figure 1

Figure 1



b) **Offset from chord joining the centre of cross-sections of the bottom chord.** For this purpose, cross-sections of the bottom chord will be taken at the panel points (or points closest to the panel points) such that the corners of the flanges making the bottom chord can clearly be made out, and drawings necessary geometric chords joining the centres of the cross-sections. An illustration of the method is given in Figure 2

Figure 2



10.6.7 **Distortion:** Any deviation of a bridge member from the intended geometry due to bending or twisting is distortion.

a) In open web girders the following members are likely to show distortion.

- Top chord members carrying compressive stresses if not sufficiently restrained.
- Diagonal web members particularly if they are made up of flats and most likely at midspan due to stress reversal and vibration during passage of train.
- Bottom chord members which carry tension and longitudinal forces if not properly braced. The most likely location is near the bearings in case of frozen bearings.
- Top lateral and portal bracings are likely to distort due to excessive lateral forces.

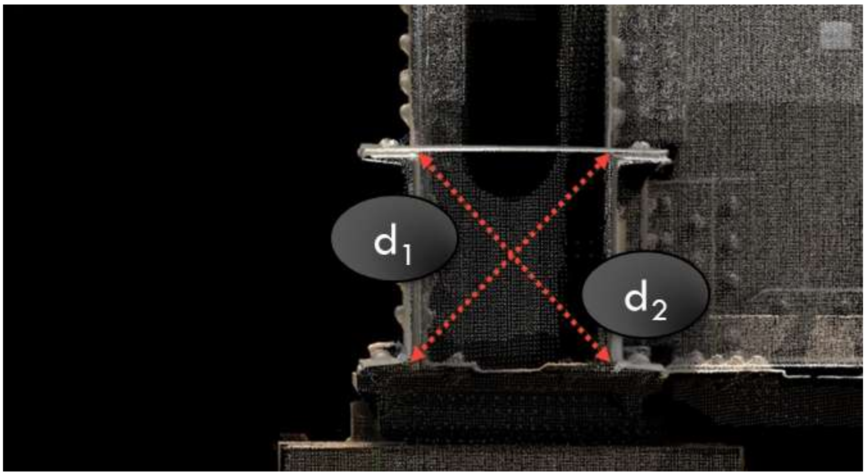
b) Distortion is also possible if longitudinal movement of girders due to temperature variation is arrested on account of frozen bearings. Sometimes web member i.e., diagonal, vertical and end rakers in through girder bridges are hit by moving loads due to shifting of load in wagons, particularly over dimensioned consignment (ODC).

c) For different members two types of distortions will be measured utilising two different methods. The members for which this parameter will be measured will be based on requirement and discussions with the Employer. It may not be required to measure it for each bridge member.

d) **Lateral distortion.** It shall be measured as the offset of the centre of a member from a chord connecting the end points of the same member. Normally it shall be measured at multiple points and tabulated to show the maximum value for each member.

e) **Torsional distortion.** It shall be measured using the length of diagonals at different cross-sections of the member. Any significant difference in the length of diagonals (d1, d2) will show a suspected case of torsional distortion that may be further investigated using bridge instrumentation (not part of these specifications). It will also be taken at multiple cross-sections. An illustration of the method is given in Figure 3.

Figure 3



10.6.8 Track measurements: Following track measurements shall be taken as a minimum;

a) Gauge
b) Rail levels at the bridge
c) Sleeper spacing

d) Level of track at the fifth sleeper.

10.6.9 **100m L-section:** On either side of the bridge at the approaches on the trackside for a distance of 100m, an elevation profile will be measured and generated to give the 100m L-section. For double line section, it will be separate profiles for each approach. The contractor shall use suitable software to measure and show the profiles. The accuracy of the measurements shall be comparable to the accuracies of measurements at the bridge structure.

10.6.10 **Creep:** Creep is the lateral movement of the bridge along the track. It shall be measured on both the ends of the bridge for left as well as right side of it.

10.6.11 **Bridge assembly twist (where applicable):** At different locations of the bridge cross-sections will be taken and diagonals marked and measured. Any significant difference in the diagonals at a particular cross-section will be indicative of twist in the bridge assembly.

10.6.12 **Bearings:** All dimensions of all bearings will be measured, along with any special features based on the bearing design.

10.6.13 **Visual inspection:** For each CAPI, the images captured will be visually inspected and analysed by an experienced engineer for any discrepancy, signs of failure or any abnormality. A report will be prepared for each wherein such discrepancies will be detailed assisted by relevant photographs suitably annotated. The report(s) may also carry possible causes and recommendations, if required by the Railways. Typical CAPI are given in preceding paragraphs.

10.7 Stage 6: Data Upload to BrIM

10.7.1 Processed data and reports etc shall be uploaded to BrIM by logging in through BMS and using the available BrIM interface modules. Raw data should be kept and handed over to the concerned railways on hard disks, if asked for.

11.0 Deliverables for Digital Bridge Inspection

11.1.1 After Stage 1 and 2, an Inception Report covering:

a) important parameters of the bridge as understood by the Contractor;
b) special features relevant to the job at hand;
c) list of CAPI;
d) features of the site mentioning special considerations with respect to Stage 3;
e) work plan for Stage 3 including assistance required from the Employer;

11.1.2 Images with markup of defects

11.1.3 Detailed Inspection report with measurements and analysis.

11.1.4 Cloud data hosting for one year license

11.1.5 2D Ortho-mosaic in TIFF/ECW format

11.1.6 3D point cloud data

11.1.7 3D Mesh

11.1.8 Annotated 3D model in suitable format that can be viewed through any freely available viewing software, and as per SOW

11.1.9 Geotagged images captured by UAV/RPA properly structured and named for easy identification

11.1.10 Final scaled and geo positioned Orthophoto Tiles in geotiff format of 2 cm resolution.

11.1.11 Interactive 3D model of the bridge in Obj/3mx/fbx format both in hard and soft copy

11.1.12 Assistance to concerned Railways in uploading the data to BrIM.

11.1.13 Raw data in suitable media, if required by the concerned Railways.