Victorian Transport Digital Engineering

As-Built Pilot Final Report – Glen Huntly

VICTORIAN INFRASTRUCTURE DELIVERY AUTHORITY

VICTORIA State Government

Department of Transport and Planning

REPORT CONTROL AND AMENDMENT

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Prepared By	Checked By	Date Approved
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Preface

The content of this document has been taken directly from a Level Crossing Removal report produced by Southern Program Alliance. Any commercial in confidence content has been removed or modified for publication.

This report has been released to share insights and lessons learned from the delivery phase with industry and to promote discussion around innovation, digital solutions and continous improvement in this space.

The pilot was undertaken in conjuction with Victorian Department of Treasury and Finance and Victorian Transport Digital Engineering Transformation Project.

TERMS AND ACRONYMS

Acronym	Definition
ACC	Autodesk Construction Cloud
ALT	Alliance Leadership Team
AM	Alliance Manager
ARC	Architecture
AMT	Alliance Management Team
AWP	Additional Works Package
BAU	Business As Usual
BIM	Building Information Model
CF	Change Form
CNOP	Construction Non-Owner Participants
CMAC	CMAC includes representation from all Alliance Participants and is generally AMT level
CRS	Comment Review Sheet
CSR	Combined Services Route
CPS	Construction Phase Services
DCR	Design Change Request
DE	Digital Engineering
DEMP	Design and Engineering Management Plan
DMS	Document Management System
DNOP	Design Non-Owner Participants
GMR	Global Minimum Requirements
IFC	Issue for Construction
IWP	Initial Works Package
JCC	Joint Coordination Committee
KRA	Key Result Area
KPI	Key Performance Indicator
LXRP	Level Crossing Removal Project
MOC	Management of Change
MTM	Metro Trains Melbourne
NCR	Non-Conformance Report

O&M	Operations and Maintenance
PAA	Project Alliance Agreement
PRS	Project Requirements Specification
PTV	Public Transport Victoria. The statutory authority responsible for managing Victoria's train, tram and bus services
RFI	Request for Information
SDR	Shop Detailing Review
SPA	Southern Program Alliance
State	The Government of the State of Victoria, or Victorian Government
TLS	Terrestrial Lidar Scanning
TOC	Target Outturn Cost
WPT	Wider Project Team

Contents

1 Executive Summary

INTRODUCTION

The application and maturity of 3D geometric design information in the development and design of the Level Crossing Removal Project (LXRP) has contributed to the successful design and construction of individual projects within the program of works. The projects consist of the significant changes to the alignment and gradient of longitudinal infrastructure of road and rail. The Digital Engineering Joint Coordination Sub-Committee (SJCC) with LXRP, recognised that there was an opportunity to understand challenges, recommend improvements and realise the benefits of further application of 3D geometric design information after Issue for Construction (IFC) stage.

In response to the growing need for advancement the application of 3D geometric design information IFC and quality improvements in As-Built documentation, as well as LXRP's opportunity to support the Department of Transport and Planning Victoria (DTP) shape their future handover requirements for As Built BIM models, LXRP initiated the Glen Huntly Pilot (known herein as the 'Pilot').

PILOT OBJECTIVES

The primary objective of the Pilot was to test the feasibility and effectiveness of maintaining 3D models and drawings throughout the CPS (Construction Phase Services) by making continuous updates to the 3D models based on site feedback, including RFIs (Requests for Information), and point cloud surveys.

The Pilot aims were:

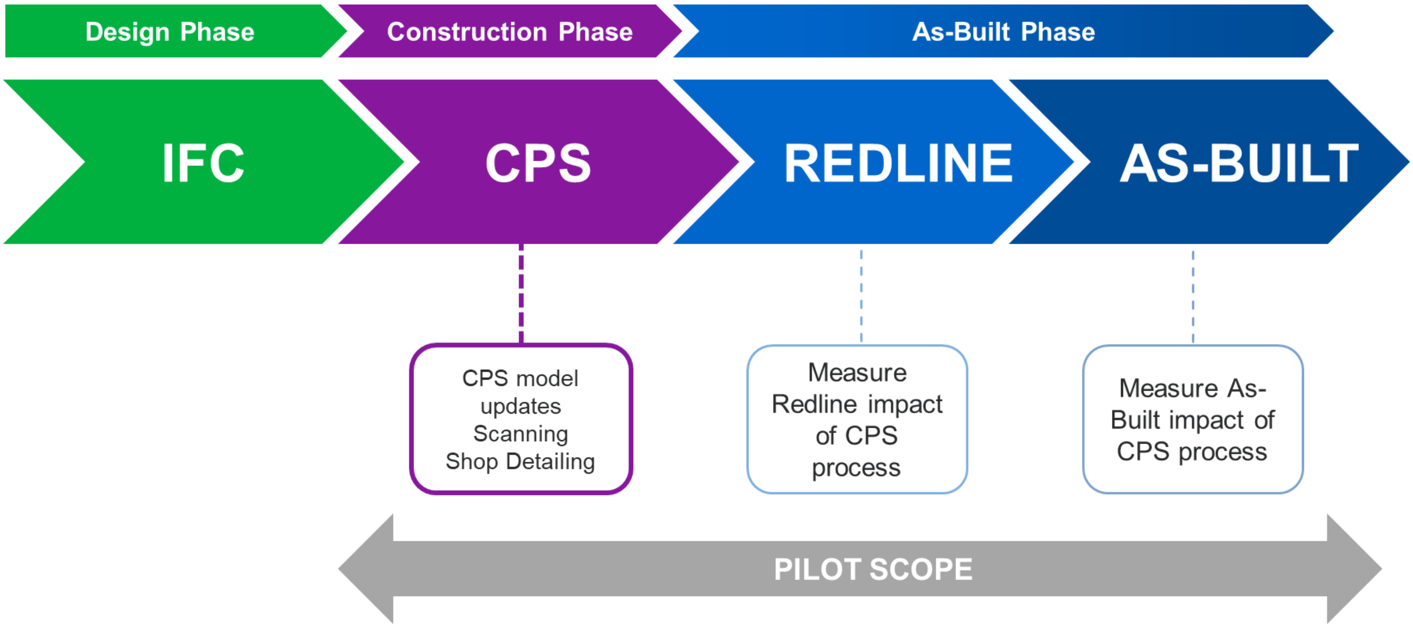
Primary Objectives	Planned Impact
CPS	
Models updated during CPS improving coordination and clash risk – reducing extension of time risk	Risk reduction
Construction Management and Design DCR/RFI reductions through coordinated model	Cost reduction
Redline	
Redline mark-up effort reduced through model updates and As-Built Scanning during CPS, during As-Built	Cost reduction
As-Built	
Model updated during CPS and As-Built to reduce As-Built drawing effort	Cost reduction

A secondary objective was to document lessons learned during this process and making recommendations for future projects.

PURPOSE OF THIS REPORT

The purpose of this report is to deliver the results, data and findings of the Pilot and make recommendations to all stakeholders involved to better implement process improvements relevant to the appropriate stakeholders.

SCOPE



The Pilot scope entailed the continuous updates of 3D models after IFC stage and capture any benefits in reducing effort in producing As-Built, which included:

- Updating the Glen Huntly design models during the CPS phase with site information including RFI and site surveys in the form of point-cloud.
- Developing and Coordinating Shop Detail information.
- Coordinating information from site before construction to support the reduction of risk.
- Evaluating the impact of updated information during CPS on the red-lining effort.
- Assessing the impact of updated information during CPS on the As-Built documentation effort.

The LXRP deliverables included:

- SPA to document lessons, benefits, and report project status monthly.
- Submit As-Built 3D models and As-Built survey in Point-Cloud format at project Handover.
- Submit a Final Report on the Pilot outcomes, lessons learned and recommendations for future projects.

The Pilot project was to be delivered in parallel with the on-going Glen Huntly construction and was planned not to impact the Practical Completion of Glen Huntly and the SPA performance ratings. The scope excludes the works being carried out as part of the Caulfield rationalisation the Glen Huntly project.

The scope was based on the level of detail as at the design Issue for Construction (IFC) state and did not require further information to be added to the models.

The scope also acknowledged that not all elements could be laser-scanned during the construction survey due to the pace of construction.

METHODOLOGY

The methodology employed in the Glen Huntly Pilot involved several approaches revolving around specific assumptions in the scope, testing against set metrics.

1. CPS
    - CPS Model Updates: The planned process for updating the models during CPS included a dual process of updating design IFC models with the latest RFI information and survey point-cloud information while continuing the business-as-usual RFI responses to construction. Models would be updated, reviewed and shared for coordination and review before RFIs were closed. Revised drawings, derived from the updated models, were required to be re-issued ahead of redline updates.
    - The speed of construction restricted access to the survey team for point-cloud surveys, models were not be updated accordingly during CPS. The Pilot team instead focused on RFI model updates and reducing risks through model clash detection before construction.
    - Shop Detailing Integration: The Steel Shop Detailers were engaged to provide detailed models early in the process, aiming to reduce the number of RFIs and streamline construction activities.
    - Scanning technology: The survey team pivoted from the plan to use an X7 scanner and deployed Drone surveys as well as Matterport during CPS to speed up the capture of site progress.
2. Redlining
    - Digital Surveying Tools: Advanced tools such as drones, Matterport, and Propeller were utilised to capture time-based survey data, which was used as desktop site analysis during redlining with the aim of reducing site attendance and the risks associated with it.
3. As-Built
    - As-Built to Survey: The Architecture team supported the testing of an As-Built procedure where point-cloud data were reviewed against redlines and the latest CPS BIM models. The aim was to adjust the models as close to as-built as possible and prevent potential for multiple As-Built review cycles.

FINDINGS

The Glen Huntly Pilot yielded several key findings, revealing both successes and challenges in implementing BIM workflows:

1. Continuous Updates in CPS: The Pilot encountered significant obstacles in maintaining continuous model updates during CPS. These included challenges related to the Quality Assurance process for strict versioning of drawings, clarity of scope demarcation and change management of Pilot activities, and difficulties in adapting processes to the rapid pace of construction. **The Pilot was able to ascertain that 85% of RFIs were not 3D geometry related, therefore the implementation of BIM during CPS would not significantly reduce the amount of RFIs generated on Projects.**
2. Impact on Risk Mitigation: The Pilot demonstrated that continuous model updates and coordination efforts during CPS could effectively mitigate risks. **Pre-site coordination was shown to reduce the potential for on-site clashes, and the Pilot calculated savings in the order of $1.3 million in unmitigated risks which were avoided on Glen Huntly.**
3. Cost Savings through Digital Capture: **The use of drone scanning provided substantial cost savings, with the Survey team saving 1620 hours of scanning by reducing the need for manual surveys** and excavation reporting. Additionally, the reduction in site visits due to the use of Matterport and Propeller viewers contributed to enhanced safety for field personnel around plant.
4. Limitations in Redlining: The Pilot revealed that **while digital tools could reduce the effort required for Redlining in some cases, these benefits were not universally applicable across all disciplines**, the majority needing to be on-site for physical checks or live survey tracking.
5. As-Built Processes: The assumption that maintaining up-to-date models during CPS would significantly reduce the effort required for As-Built documentation was challenged by the complexity of DMS compliance and the nature of changes during CPS. **The Pilot deduced that only 10% of the As-Built preparation effort is related to geometrical content that could be impacted by 3D model updates.**

The 3D issues found in the scans compared to the redline information, were not significant to redlining and represented extra work for the Architecture modelling team. Further pilot findings suggest that 3D model updates in line with As-Built survey data would be an additional effort to a Project business as usual, which would incur additional cost.

In developing As-Built information, for some disciplines, particularly those using CAD-based tools, the traditional process of modelling directly from survey CAD files proved more efficient than updating existing models.

RECOMMENDATIONS

Recommendations for Industry and Government

1. **Quality Assurance Process for drawings:** The current Quality Assurance procedures around drawing approval requirements for Redlining and As-Built requires a separate review to understand how 3D Model procedures could be incorporated for improvement in workflows and the barriers found on Glen Huntly can be alleviated.
2. **Model first approach:** The Pilot found barriers to a model first approach in the infrastructure industry in Australia, due to those disciplines and authoring tools that focus on CAD based processes instead of BIM. Clients should consider their need for BIM outcomes prior to starting a project and incorporate requirements for a model first approach for selected disciplines as mentioned in recommendation 4.
3. **Risk Reduction Targets:** A focus should be given on Risk reduction targets to measure the impact of BIM on projects instead of reduction in RFIs or Drawing Production issues.
4. **Identify High ROI disciplines:** When planning a project, clients are recommended to focus BIM implementation on selected disciplines that will add value to their asset portfolio or carry highest amount of risk during the asset's life. For example, BIM related CPS risk reduction targets and As-Built requirements of system critical or higher maintenance disciplines such as Combined Services Routes or underground services, would return more value for money than applying the additional costs and processes to all project disciplines.

Recommendations for Project teams

Based on the lessons learned from the Pilot, the following recommendations are proposed for future projects:

1. Role Definition and Accountability: Clearly define roles and responsibilities at the outset of a project to ensure that each team member understands their specific tasks and is accountable for their execution. This is particularly important for managing critical activities such as RFI responses, where delays can impact the entire project timeline.
2. Continuous Stakeholder Engagement: Maintain regular engagement with all stakeholders throughout the project lifecycle. This includes providing ongoing education about the project's goals, especially in pilot initiatives, to ensure buy-in and understanding at all levels. Support from leadership is crucial to ensure that the correct processes and procedures are in place and that the objectives are met.
3. Change Management: Implement robust change management strategies to support the adoption of new processes and technologies. This includes clear communication about the benefits and impact of changes, as well as training and support to ensure smooth implementation.
4. Focus on High-Impact Disciplines: Prioritise high-impact disciplines such as CSR, Utilities and Civil Structures for early coordination and model updates. These disciplines carry significant risks and costs, and ensuring their accuracy and coordination during CPS and As-Built processes can greatly reduce overall project risks.
5. Early Risk Assessment and Scope Definition: Conduct thorough risk assessments and clearly define the project scope before initiating any pilot or new process. This includes establishing selection criteria for what is included in the scope versus BAU and ensuring that all stakeholders understand the scope and objectives.
6. Further recommendations were made to implement similar scope within a seven-step process on future projects:
   - Step 1: Develop a project plan during the TOC phase, consisting of scope, agreed procedures, project team responsibilities and clear KPIs.
   - Step 2: Develop the budget with the end in mind during the TOC phase.
   - Step 3: Revisit the project plan at each project phase to adjust and review it in-line with the project goals.

- Step 4: Procure Shop Detailers between Gate 2 and IFC on the project and coordinate them closely with the Design team.
- Step 5: Conduct Construction-led constructability workshops during the IFC phase, including the coordination of Construction team-developed 3D models, such as rebar and conduits.
- Step 6: Implement model-based coordination with As-Built high-impact disciplines during CPS.
- Step 7: Use survey-aligned 3D models for high-impact disciplines at project handover.

CONCLUSIONS

The Glen Huntly Pilot provided valuable insights into the practical challenges and potential benefits of integrating BIM workflows into construction projects. While the Pilot achieved several of its objectives, including risk mitigation and cost savings, it also highlighted the need for the Quality Assurance Procedures to be reviewed, Model first approach requirements to be considered, application of requirements on selected disciplines allowed for from TOC phase, and risk reduction targets to be added to projects.

It is further recommended for future project teams to have greater clarity in scope definition, more effective change management, and careful consideration of the tools and processes are used during the design phase. These lessons have been instrumental in shaping the approach to a further pilot and will continue to influence the strategic direction of future projects for DTP, LXRP and SPA.

2 About the Glen Huntly Level Crossing Removal Project

In April 2021, the Level Crossing Removal Project awarded the Southern Program Alliance the Additional Works Package 4 contract to remove the level crossings in Glen Huntly, Melbourne (known hereon in as the Glen Huntly Project).

The Glen Huntly Project's scope included:

- Removing two level crossings at Glen Huntly Road and Neerim Road
- Building a new, modern Glen Huntly Station, along with station car parking
- Enhancing intermodal connections (Glen Huntly train station to the tram route on Glen Huntly Road)
- Constructing a new pedestrian and cycle path connecting Ormond and Caulfield

Early development started in 2019, the major occupation was completed in 2023, and practical completion was achieved in 2024 with a total estimated project value of $600m.

3 About the Glen Huntly As-Built Pilot

In 2022, LXRP requested (via their LXRP Digital Engineering Joint Coordination Committee [JCC]) that SPA undertake a 3D model As-Built Pilot to:

- inform the value of developing the 3D model post IFC and,
- to validate future changes to the PRS and LXRP Digital Requirements regarding 3D model delivery across all Alliance work packages.

A Scope Variation Report was developed by SPA for ALT endorsement and submission to the Project Owner, proposing the delivery of an As-Built 3D model and monthly lessons learnt/value-add opportunities reporting on Glen Huntly.

With LXRP Alliances are currently delivering IFC models in Design Phase, it was recognised that there were no formal DTP requirements for submission of 3D As Built models. The coordination of 3D information post IFC was therefore limited, 3D information delivered to LXRP did not reflect As-Built conditions, meaning information cannot be utilised within LXRP/VIDA systems to provide further value. SPA identified that the lack of development and management of the model post IFC, contributes to mismatch of information between models and As Built documentation.

The ALT Scope Variation was endorsed and released to the SPA teams on 25 May 2022. The CPS phase on Glen Huntly started on 16 July 2021.

3.1 Project Scope

The Pilot focused on delivering an As-Built model for the program of works covered within the Glen Huntly Additional Works Package – Glen Huntly. The Pilot aimed at testing and validating the assumption that when the 3D model is updated post IFC through to As-Built, it reduces effort in the following:

- RFIs generated during Construction Phase Services (CPS) – specifically Shop Detailing RFIs.
- As-Built redline markups – specifically effort from Site Engineers marking-up 2D drawings.
- As-Built Drawings – specifically the effort to capture changes during CPS and As-Built conditions onto a 2D drawing.

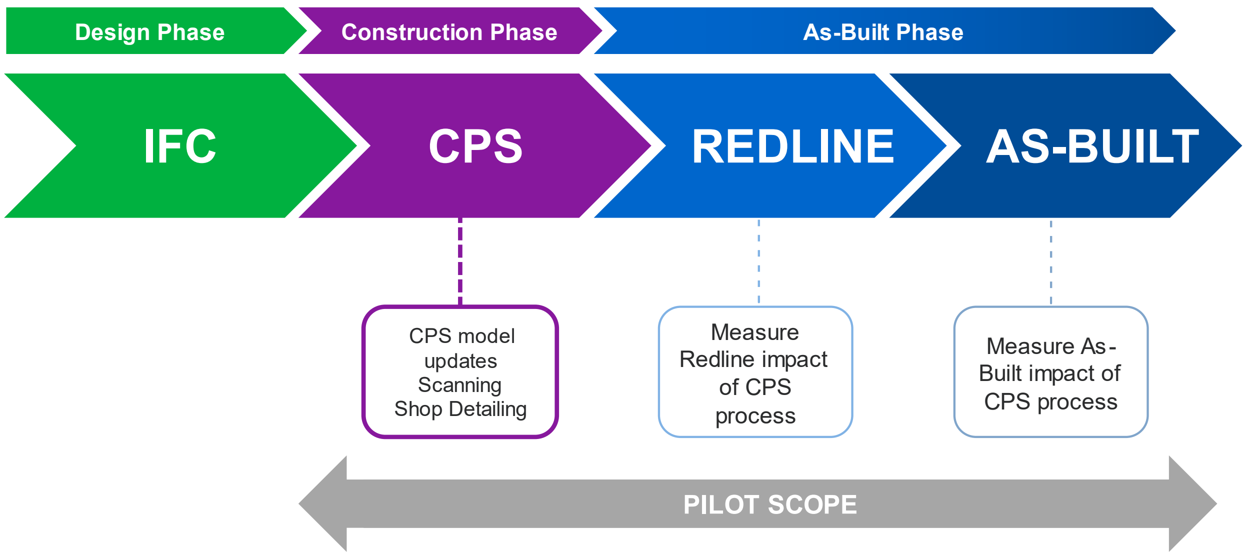


Figure 1 Project Timeline

The Pilot scope entailed:

- Developing and Coordinating Shop Detail information
- Coordinate information from site before construction to support the reduction of risk
- Evaluate the impact of updated information during CPS on the redlining effort
- Assess the impact of updated information during CPS on the As-Built documentation effort
- Document lessons, benefits, and report project status on a monthly basis
- Submit As-Built 3D models and As-Built survey in Point-Cloud format at project Handover; and
- Submit a Final Report on the Pilot outcomes, lessons learned and recommendations for future projects.

3.2 Scope Disclaimer

The Scope Variation Report noted that the scope of the Pilot shall not affect the following requirements set out in the PAA and PRS:

- Practical Completion for Glen Huntly (this scope and its deliverables will not form part of the practical completions delivery for Glen Huntly); and
- SPA KRAs (this scope and its deliverables will not impact on SPA's KRAs or performance ratings for the Glen Huntly package of works).

This scope is considered as a test pilot and separate from the delivery of the Glen Huntly Project, however the scope of the Pilot seeks to provide value to the Glen Huntly Project.

3.3 Scope Exclusions and Clarifications

The following exclusions and clarifications are applicable:

- The Pilot scope excludes the works being carried out as part of the Caulfield rationalisation that forms part of the Glen Huntly project.
- There is no requirement to update or modify element attributes during the Pilot, however element attributes shall align to the structure set-out in the Glen Huntly Project– Model Production Delivery Table
- In certain circumstances not all required model elements will be captured with the 3D laser scan – in particular, hidden building services and areas that are not visible at constructed As-Built status, due to the fast-paced nature of the construction program and the ability of the survey team to be present during occupation (especially nightshift). In this event the Pilot team shall utilise redline mark-ups from the Construction team to inform updates to the As-Built 3D model; and
- All 3D model elements must achieve the minimum Level of Development (LOD) at IFC, which has been set out in the Glen Huntly Project – Model Production Delivery Table.

3.4 Project Objectives

The primary purpose of the 3D As-Built scope is to provide lessons learnt and value for money from updating the IFC 3D model through CPS to As-Built status. A 3D model shall be delivered as close to the accuracy and requirements set out in the Scope Variation Report.

3.5 Objectives

At the commencement of the Pilot, the Pilot objectives were defined by the Pilot Project Sponsor in collaboration the client to set targets for the Pilot teams based on the project scope as listed in the Scope Variation Report. The Pilot consisted of Primary and Secondary objectives. The Primary Objectives have been defined for each project phase which were:

Table 1 Pilot Primary Objectives

Nr	Primary Objectives	Planned Impact
	CPS	
1A	Model updated during CPS improving coordination and clash risk – reducing extension of time risk	Risk reduction
1B	Construction Management and Design DCRs/RFI reduction through coordinated model	Cost reduction
	Redline	
2	Redline mark-up effort reduced through model updates and As-Built Scanning during CPS, during As-Built	Cost reduction
	As-Built	
3	Model updated during CPS and As-Built to reduce As-Built drawing effort	Cost reduction

The Secondary Objectives were to document the lessons learned and the impact of the implementation of activities to:

1) report the outcomes to the client monthly,
2) develop a final report to outline the lessons learned and make recommendations for future project implementation.

SPA elaborated on the objectives by developing the following questions as Metrics for the purpose of this report, to test and validate the Pilot assumptions as listed in the Project Scope and report:

Table 2 Pilot Metrics

Metric #	Initial Metric
1A	Assumption: In the Pilot, clash RFIs will be reduced due to model clash detection.
1B.1	Would coordination with Shop Detail models reduce Shop Detail RFIs on the Glen Huntly Project?
1B.2	Would the Pilot cause a reduction in RFIs as result of the modelling being updated during CPS?
2.1	Would model updates responding to RFIs during CPS reduce redlines?
2.2	Would the model updates with scans reduce redlines?
3.1	Would model updates during CPS reduce As-Built drawing effort?
3.2	Would model updates during CPS and As-Built reduce the number of revisions on drawings in As-Built?

3.6 Project Team and Responsibilities

The Pilot org chart was presented at the Pilot kick-off with the Project Sponsor and Project Manager leading the Pilot, reporting to the Alliance Sponsor and the Client and Owner. Each discipline had a lead and supporting role from management to ensure the implementation ran smoothly.

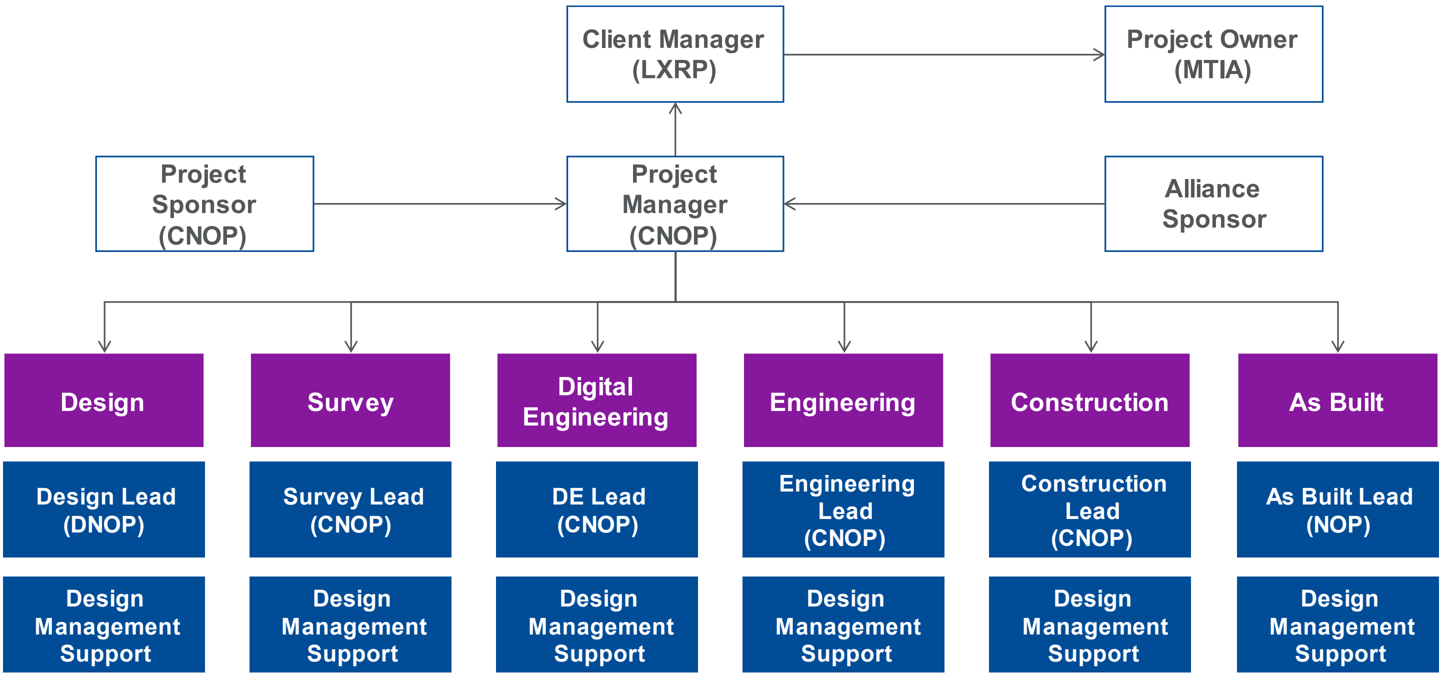


Figure 2 Pilot Org Chart

The following table lists the responsibilities of the discipline as presented at the Pilot kick-off.

Table 3 Pilot Personnel and Responsibility

Discipline	Responsibility
Project Manager	Management of the Pilot including coordination, budgeting, cost-tracking and monthly reporting on the progress status.
Design	Capture changes during and after CPS, updating as well as demonstrating that the discipline specific 3D models meet the minimum LoD set-out in the model production delivery table. The Pilot's design team will also incorporate the Pilot cloud data into their native platform and make appropriate updates to the 3D model.
Survey	Regular scanning of required element areas including processing, indexing and verifying data as well as attending regular coordination meetings to establish specific priority areas of scanning.
Digital Engineering	Support management and Coordination of 3D models through the CDE to delivery, set-up and management of validation dashboard, manage federated model data including monitoring issues and communication through iModel environment. The DE Pilot Team will also monitor and support the RFI adjustment process to inform 3D model updates, as well as supporting the As-Built update process.
Engineering	Support the Pilot and regularly meet with the Project Manager to coordinate requirements as well as provide specific support in the review and coordination of RFIs requiring 3D model updates during CPS.
Construction	Support the Pilot and regularly meet with the Project Manager to coordinate requirements as well as provide specific support in the review and coordination of the Shop Detailing process, survey and redline mark-up effort reduction. The Construction Team will also provide support relating to the logistics of the site access and site management.
As-Built	Work closely with the Pilot project manager to set requirements of the As-Built team on realising the value of 3D model updates. They will also collaborate with the design pilot team to generate 2D drawings from the 3D models at completion dates during CPS and specifically at completion of updates at As-Built.

3.7 Project Systems

Table 4 Project Systems

System Application	Description
TeamBinder	Internet-based document control and records management collaboration system for housing Project correspondence, transfer and storage of redline markups, formally transmitted draft/final As-Builts, RFIs and DCRs, along with other Project systems and quality documentation between SPA, MLXRT, VicRoads and other stakeholders.
ProjectWise	Applied for the development, storage, tracking and reporting of As-Built drawings within the SPA Design team.
iTwoCX	The Project Management and collaboration system for internal Project correspondence, transfer, and storage of redline markups, RFIs, and DCRs.

PowerBI	Dashboarding of RFIs statistics
iModel	Federated environment to review latest model updates.
iTwin	Communication platform to capture time and lessons learned from the design team.

3.8 Design Model Status at IFC

The following table lists the status of the IFC 3D models for each discipline at the Pilot kick-off. Included in the list is the authoring software used by the Design team, and whether this tool supports a BIM or CAD workflow. The difference between the two is, with a BIM workflow, 3D models and 2D drawings are directly related to one another meaning that the geometrical content is the basis of the 2D drawing. One change in the 3D model makes an automated change in the 2D drawing. Whereas a CAD workflow has the 3D model and 2D drawing separated with a model developed in one authoring tool, and 2D drawings in another. Although this workflow also supports a 3D base for 2D drawings, they are not interconnected which means, at any given time, the 2D drawings can progress without the need for the model, and vice versa. This is important to note for reference further in this report. The Level of Detail (LoD) on Glen Huntly during the design phase was in-line with the BIM Forum Specification 2021.

Table 5 Design Model Status at IFC

#	Discipline	Design Package Number	3D Model Title	LOD at IFC	Authoring Tool	Supported Workflow
1	CSW	059-19-CSW-6003	GLENHUNTLY TRACK DRAINAGE PUMP STATION & STORAGE TANK	300	Bentley OpenBuildings	CAD
2	SBS	059-19-SBS-8701	GLENHUNTLY BRIDGE CONCOURSE STRUCTURE	300	Autodesk Revit	BIM
3	CDR	059-19-CDR-6601	GLENHUNTLY STORMWATER MAIN DRAIN	300	12d	CAD
4	CBR	059-19-CBR-5501	GLENHUNTLY ROAD BRIDGE	300	OpenBridge	CAD
5	CSW	067-19-CSW-6002	GLENHUNTLY TANKING SLAB	300	Bentley OpenRoads	CAD
6	CSS	067-14-CSS-4701	SIGNAL STRUCTURES	200	MicroStation	CAD
7	CPW	067-19-CPW-4201	GLENHUNTLY 3D HORIZONTAL RAIL STRINGS	100	Bentley Rail Track	CAD
8	CSR	067-19-CSR-4601	GLENHUNTLY 3D CSR ALIGNMENT	200	Bentley OpenRoads	CAD
9	ETN	067-19-ETN-4903	GLENHUNTLY PERMANENT WORKS OVERHEAD WIRING	200	Bentley OpenBuildings	CAD
10	CSW	067-19-CSW-6001	GLENHUNTLY RETAINING WALLS	300	Bentley OpenBuildings	CAD

11	CRG	059-19-CRG-6902	GLENHUNTLY ROAD AND CARPARK DRAINAGE	300	Bentley OpenRoads	CAD
12	CRG	059-19-CRG-6902	GLENHUNTLY CIVIL ROAD GEOMETRY	300	Bentley OpenRoads	CAD
13	CSW	067-19-CSW-6002	GLENHUNTLY TRACK DRAINAGE	200	12d	CAD
14	CPW	067-19-CPW-4201	GLENHUNTLY CFD RAILS AND SLEEPERS	100	Bentley OpenRail	CAD
15	CPW	067-19-CPW-4201	GLENHUNTLY CFD BALLAST AND CAPPING	100	Bentley OpenRail	CAD
16	CRG	059-19-CRG-6901	GLENHUNTLY ROAD TRAFFIC SIGNAL	300	Bentley OpenRoads	CAD
17	BSG	059-19-BSG-8301	GLENHUNTLY STATION ELECTRICAL SERVICES	300	Autodesk Revit	BIM
18	BSG	059-19-BSG-8301	GLENHUNTLY STATION HYDRAULIC SERVICES	300	Autodesk Revit	BIM
19	BSG	059-19-BSG-8301	GLENHUNTLY STATION MECHANICAL SERVICES	300	Autodesk Revit	BIM
20	SBS	059-19-SBS-8701	GLENHUNTLY STATION STRUCTURAL	300	Autodesk Revit	BIM
21	ARC	059-19-ARC-7601	GLENHUNTLY STATION 3D MAIN MODEL	300	Autodesk Revit	BIM
22	ARC	059-19-ARC-7601	GLENHUNTLY STATION 3D LIFT CORE MODEL	300	Autodesk Revit	BIM
23	ARC	059-19-ARC-7601	GLENHUNTLY STATION 3D TOILET BLOCK MODEL	300	Autodesk Revit	BIM

4 Construction Phase Services (CPS)

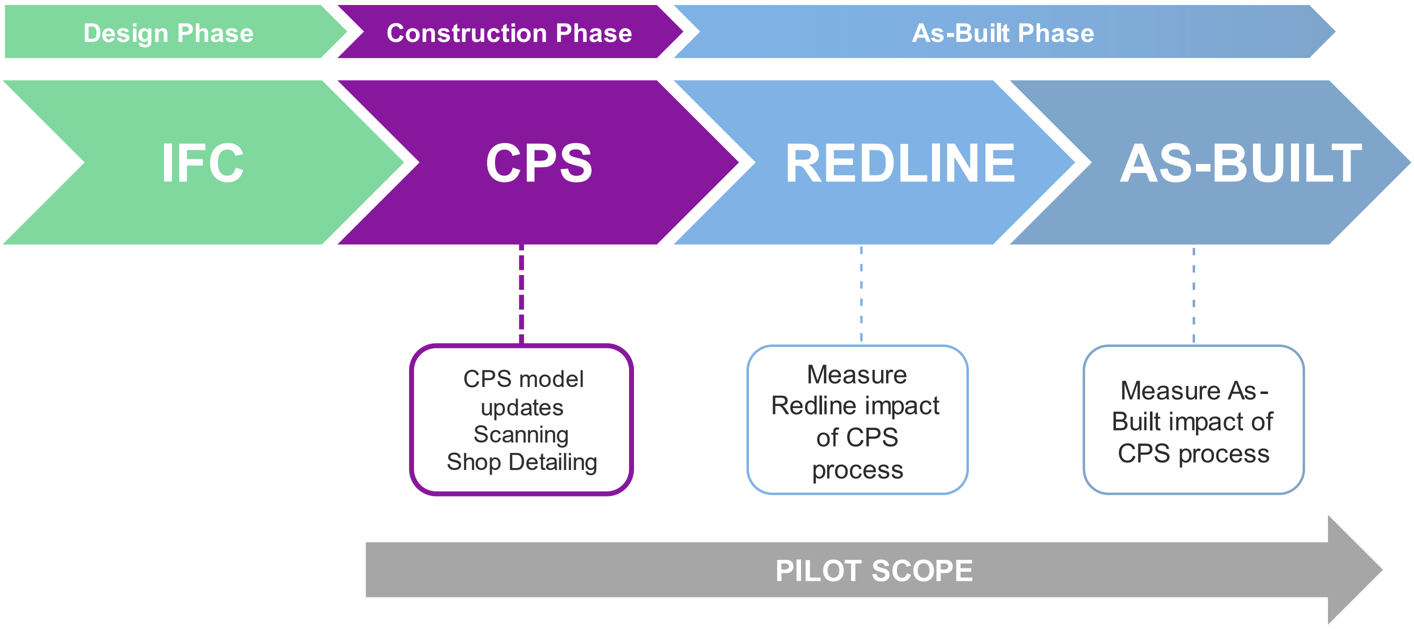


Figure 3 Project Timeline: CPS Phase

4.1 SPA Business as Usual CPS Processes

The purpose of this section is to demonstrate the SPA standards and protocols that drive decision-making processes from CPS to As-Built. This section is summarising the procedures as set out in the Glen Huntly Design and Engineering Management plan and related SPA standards, as listed in the references.

4.1.1 Quality Assurance Procedure

This section provides an overview of the quality assurance procedures for drawings during IFC and CPS. This process is crucial to ensuring that a construction project is built according to the design and that any changes are accurately documented and communicated.

IFC (Issued for Construction)

The IFC stage represents the point at which drawings and models are finalised and approved for construction. These documents are used by contractors and construction teams to build the project as designed.

Quality Assurance Procedure:

- Review and Approval: Before drawings are issued for construction, they undergo a rigorous review process. This includes checks for accuracy, completeness, and compliance with design standards and regulatory requirements.
- Sign-Off: The Design team, often including Architects, Engineers, and Project Managers, sign off on the drawings, indicating that they are ready for construction.
- Document Control: Once approved, IFC drawings are controlled documents, meaning any changes or updates must follow strict procedures. These documents are distributed to all relevant parties, including contractors, for use during construction.

CPS (Construction Phase Services)

During the construction phase, CPS involves ongoing support from the Design team to address issues that arise, respond to RFIs (Requests for Information) or DCRs (Design Change Requests), and make necessary updates to the construction documents.

Quality Assurance Procedure:

- Document Updates: Any changes to the drawings during CPS must be carefully documented. Updated drawings are issued as revisions, often labelled with a revision number, and are distributed to all stakeholders.

- Coordination: The Design team coordinates closely with the Construction team to ensure that updates are accurately reflected on-site. This involves regular meetings and site visits to verify that construction is proceeding according to the updated drawings.

4.1.2 RFIs, and DCR Procedure

It is important to manage design change during construction to ensure that approved documentation is always in place for construction purposes. The following procedures are outlined in the Design and Engineering Management Plan (DEMP) for changes to the IFC Design Documentation:

- Requests for Information (RFIs):

RFIs are used to obtain missing information, to clarify inconsistencies in any documentation, or to obtain additional information or advice. It is not uncommon for RFIs to request a small change that has no impact on the design intent. Any change will need to follow the Level Change Procedure. RFIs are to be submitted, responded to, and managed through the collaboration system in accordance with the RFI Procedure.

- Design Change Request (DCR)

DCRs are used by Engineering or Design personnel to request a design change that is expected to impact the original design intent or may be used as a vehicle to close out IFC drawings with unresolved items (hold clouds on drawings that have significant change to the design intent). A DCR should be used:

- Where changes are proposed, either at pre or post IFC stage, which involve a significant change to the original design intent.
- To gain approval to either modify IFC design documents or to construct something that varies from the IFC drawings or scope/requirements.
- To allow the issue of IFC design drawings with some unresolved items (hold clouds) where there has been significant change to the design intent.

Due to the official nature of change in a DCR, DCRs require a budget separate from CPS, which is managed separately. DCRs require official drawing and model updates as part of BAU and have therefore been excluded from the Pilot.

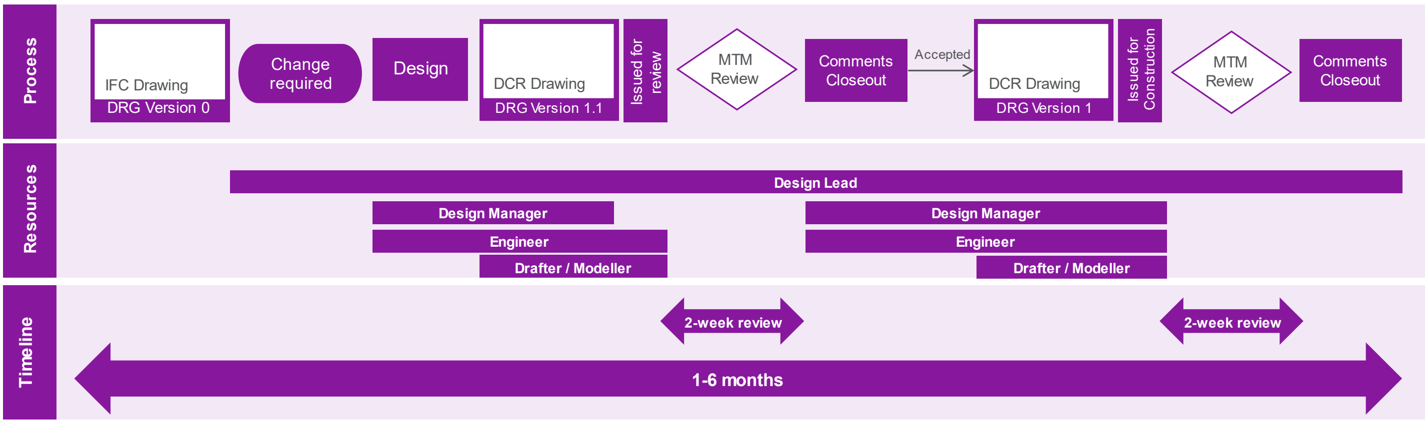


Figure 4 DCR BAU Procedure

4.1.3 RFI Response Process

As part of BAU, the Design teams will respond to RFIs in the collaboration system, such as iTWOcx on this project, with either a text response, a sketch, schedule, or specification. Because drawings cannot be updated without formal approval, drawings are not updated during RFI responses.

However, on SPA there are a few disciplines that develop their drawings directly from models – these are mainly disciplines working in Revit, such as Architecture, Building Structures, and Building Services, who develop their sketches in their model and drawing environment. In this Pilot, it was assumed that disciplines working in Revit will be excluded from the CPS part of the Pilot, as they are modelling and developing sketches as BAU, although in a CPS model separated from the IFC model.

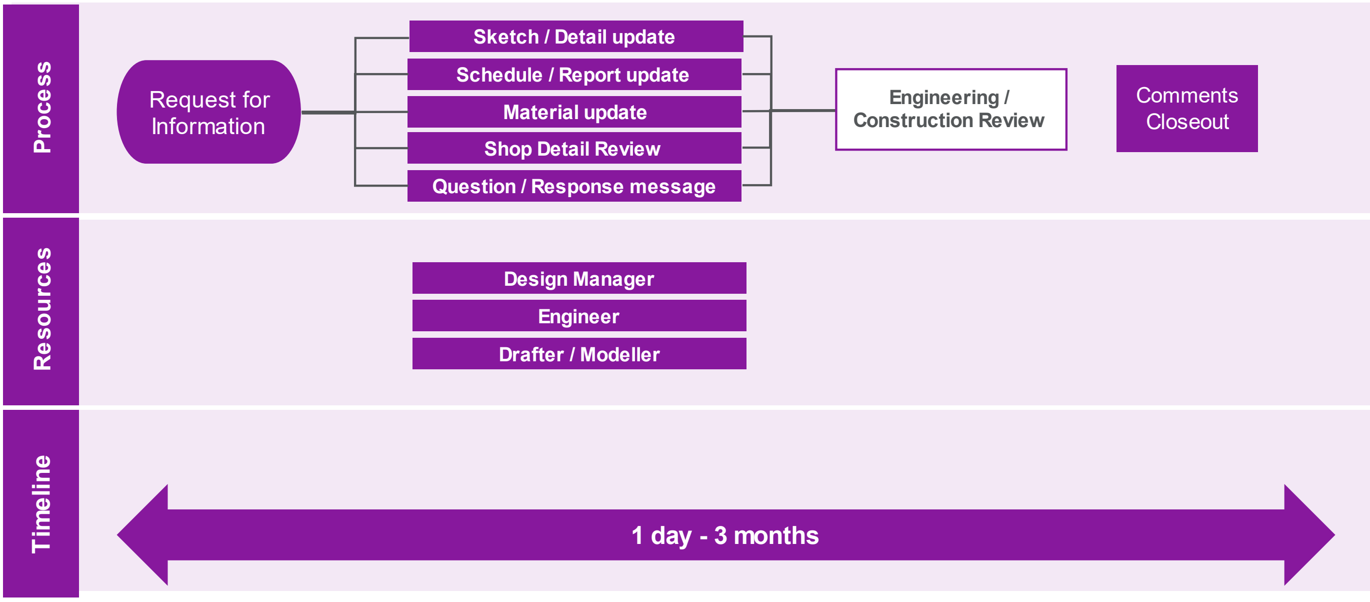


Figure 5 RFI BAU procedure

4.1.4 Level Change Procedure

As per the Change Management Procedure on SPA, the table below shows the procedure that applies to decision-making criteria and the authorities for requesting change after IFC. During CPS, the Pilot relied on the Engineering team to make decisions around which RFIs should be contributed to the Pilot or not. It is important to note that the cost of Pilot effort which includes Design Engineers, Drafting Technicians and Modellers updating information, could result in a change from RFI to DCR, or updates to be preferred in As-Built instead of CPS. This helps Engineering Managers keep to budget and reduces impact on the program.

The process and trigger for a change is made based on time, cost and information needed:

Any effort over eight hours should be upgraded from RFI to Construction Change Notice (CCN). Normally this is only done when there is a change to the design. CCN is a mechanism to agree to and go through a change that is documented. DCR requires update of incomplete information from design that requires a reforecast.

4.1.5 Coordination During CPS

A. Design

There are no documented procedures for coordinating RFI responses with other disciplines. However, it is the responsibility of the Designer to ensure that the design is fit for purpose and is coordinated.

B. Construction (on-site)

There are no documented procedures for coordinating information from Shop Detailers within Engineering during CPS. It is however required that Shop Detailers request design review of their work from the Design team who will approve adherence to the design intent.

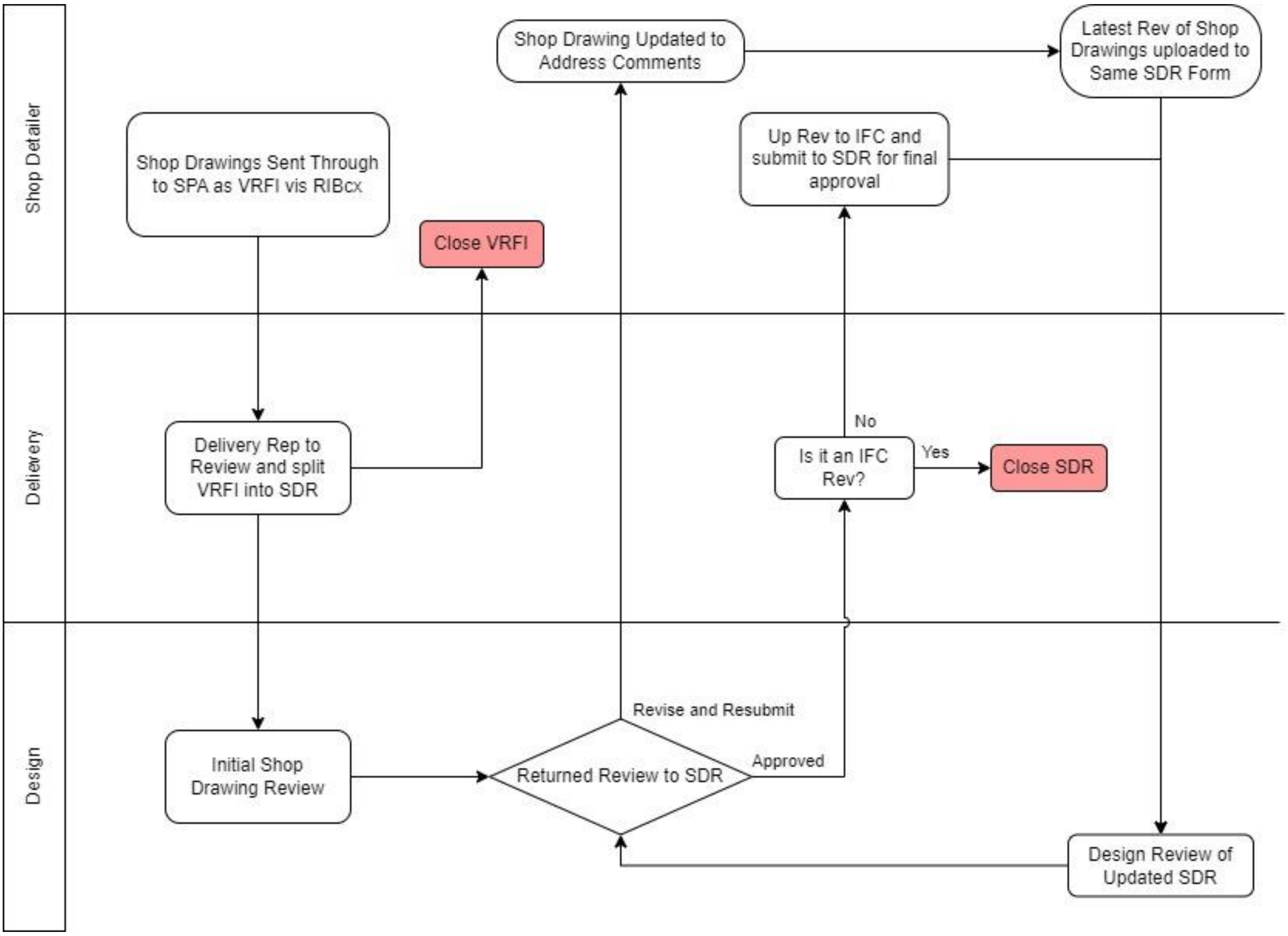


Figure 6 Shop Drawing process on SPA

4.2 Initial Planned Pilot Processes/Requirement

The following processes are cited from the Scope Variation Report as planned requirements for the Pilot during CPS phase:

Federated Model

- Manage federated model data from IFC to As-Built status, monitoring issues and communication in the Pilot iModel environment.

RFIs

- To capture changes during the CPS derived from RFIs in the 3D Design models and keep information up to date.
- Updates to the model shall be managed by the Digital Engineering Pilot Lead. The Engineering team shall review RFIs and provide guidance to the Design team modellers on what changes are required.
- Monitor and support the RFI adjustment process to inform 3D model updates. Three-tiered approach to model update requirements from RFIs (1. No update/2. Update not urgent/3. Update urgent), collaborating with Pilot Project Manager and Engineering Manager to validate requirements for Design team update during CPS.

Survey

- To capture changes after construction by incorporating the 3D point cloud As-Built model and updating the discipline-specific 3D model.

- As-Built point cloud data shall be provided to the Design team via ProjectWise. The Design team shall incorporate the point cloud data into their native platform and make the appropriate updates to the 3D model.
- The Design team shall export 2D drawings at IFC (PDF and .dwg) as usual. The Design team shall export 2D drawings at the completion of CPS and at the completion of the 3D As-Built process. The exported updated drawings at completion of CPS shall reduce the effort of redline marking. The exported updated drawings at completion of the 3D As-Built process shall reduce the effort of the 2D drawing As-Built process.

Shop Models

- The Engineering team shall coordinate with Shop Detailers on the integration of shop models during CPS phase and management of updates from Design/Construction to Shop Detailers.
- Construction team shall provide specific support in the coordination of the Shop Detailing process, requirements, and deliverables from Shop Detailers.
- An opportunity was identified to reduce effort during design by limiting the number of drawings required to communicate to Shop Detailers on design intent. Station structural and architectural elements have been identified and reduction of drawings and collaboration of models shall support the reduction of effort.
- Further information shall be gathered by the Pilot Project Manager to identify value realised and future value when structured into design program delivery.

4.3 CPS Process Pivot

This section will assess the changes made while pivoting away from the planned processes or scope as outlined in the Scope Variation Report.

4.3.1 CPS Model Updates

1) Original assumption or requirement: RFIs 3D model update procedures during CPS

The planned process for updating the models during CPS included a dual process of updating design IFC models with the latest RFI information. This process was planned to be done at intervals as design resources were freed up from other works packages. Models would be updated, reviewed and shared on PW before RFIs were closed. Revised models were required then to be re-issued. This update would also coincide with updates made based on survey scan data once the information was available from site but should be done before redlining. The presented process of the above is shown in the image below.

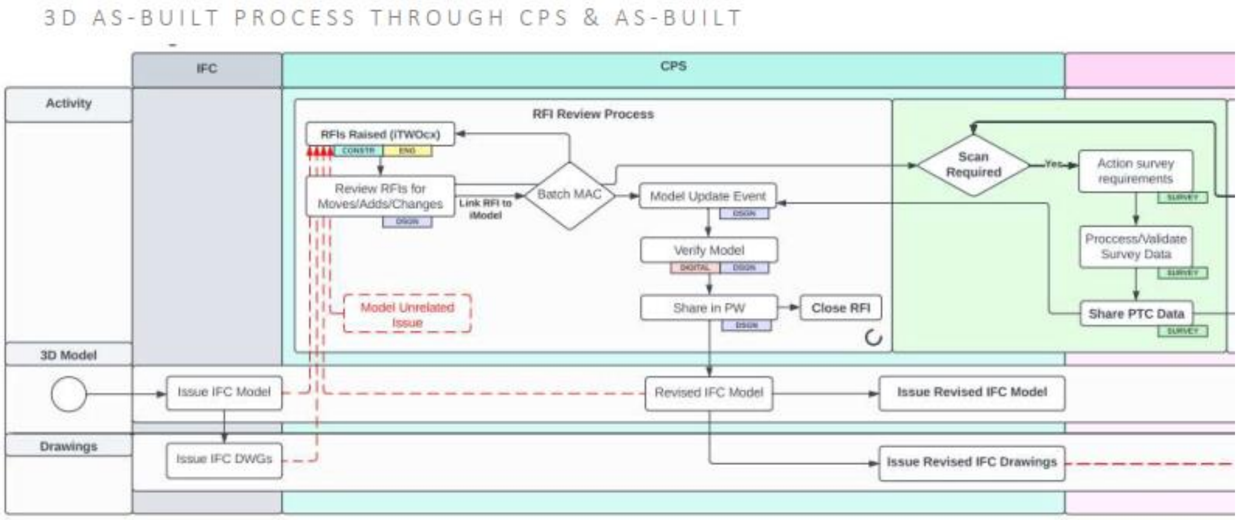


Figure 7 Process Extracted from the Pilot Kick-off

2) What caused a need for change?

   a) Speed of construction and RFI response requirements.

Depending on the RFI, information requested from the RFI would often require urgent response and open RFIs could sometimes lead to claims. Therefore, RFIs needed to be dealt with in a timely manner and information therein closed out.

At the time there was an agreement to keep the Pilot RFIs open until the model updates had been completed. However, this required a change management process so that responders didn't fall back into business-as-usual practices.

b) One model impacts other models.

Upon adjusting the first models, the team soon realised that the cost of the Pilot could exponentially grow due to the interface between disciplines. Once one model was updated and the RFI answered, further RFIs could get generated to clear up coordination with models, and more disciplines and resources would be needed to clear a RFI in full. This raised the question whether delays would occur while implementing this process, or if the process would create efficiency on site.

c) Quality Assurance process for drawings.

Another issue with the process is that IFC models needed to be re-issued for the use of redlining. According to the Quality Assurance procedures, redlining can only be done on IFC drawings. The above-mentioned process didn't account for the delay that would be caused if all the drawings that were impacted by Pilot model updates were required to be re-approved by third party approvers and MTM, and re-issued. This process alone takes between 1-3 months. The cost of this review and approval process plus the delay on redlining could have had adverse effects on Glen Huntly's construction progress.

d) Change management of staff resources, budget and time.

The Pilot was always going to be a parallel process from BAU and therefore the timeline and budget reflected the incremental changes during As-Built. Change management from BAU SPA and MTM procedures through CPS and to As-Built was not planned or included in the Pilot.

e) Update of selected models not drawings.

The assumption for the abovementioned process would have been that drawings are connected to the models. Therefore, once models are updated and re-issued after CPS, the drawings extracted from those models could be used for redlining. Unfortunately, not all drawings are connected to models, as shown in Table 5

For the reasons above, all the metrics on the Pilot had to be revised, and changes had to be made in process to test the value of 3D model updates throughout the life cycle.

3) The change in CPS.

To continue testing the benefits of model updates during CPS and its effects on As-Built, the majority of the original process remained intact except that some of models were updated after RFIs were closed out, and models and drawings were not re-issued during CPS except where required for a DCR.

The Pilot team developed a map of the full project process to understand where Pilot initiatives were planned to be initiated and where Pivots had to be made, see Appendix C.

4.3.2 Shop Detailing

1) Original assumption or requirement.

In the Scope Variation Report, it was assumed that all shop detailers procured on Glen Huntly would be included in the Pilot.

2) What caused a need for change.

The table below shows the procured suppliers on Glen Huntly that had shop drawing scope. Most of the suppliers had already been appointed by the time the Pilot got signed-off, missing the opportunity for SPA to amend their contract for model inclusion.

Table 6 Timetable of the TLS Scan

Procured Supplier Discipline	Appointment	Contract	Shop Drawings in Contract	Model Required	Pilot	Justification
Precast	Jul-21	Supply	y	n	n	Procured before the Pilot

Electrical	May-21	Supply and install	y	n	n	Procured before the Pilot
Lifts	Jan-22	Supply and install	y	y	y	
Metalworks	Feb-21	Supply and install	y	n	n	Focus on modelling the main steel
Structural Steel	Feb-21	Supply and install	y	y	y	

3) The Change

SPA was able to negotiate an amendment to the Steel Sub-Contract to include the development of a 3D model for coordination and drawing production for shop drawings.

4.3.3 Scan to Building Information Modelling (BIM)

1) Original assumption or requirement.

   a) Regular 3D scanning of required areas at Glen Huntly, including processing, registration, and verifying data, to be uploaded to ProjectWise for integration into 3D model updates.

SPA employed Terrestrial Lidar Scanning (TLS) as the primary method for capturing progress during the CPS phase, utilising the Trimble X7 purchased prior to this Pilot. This decision was made due to the Trimble X7's streamlined workflow, which allows non-survey-trained personnel to easily undertake the capturing task, thereby not overburdening the survey resources. Further, only minimal assistance from the survey team was required to establish survey targets from point cloud coordination and geo-referencing purposes.

In this case, SPA utilised Digital Engineering personnel for the As-Built capture, leveraging their expertise to efficiently manage the process and ensure accurate data collection.

The flowchart below illustrates the workflow of the Trimble X7, detailing the process from initial data capture to final decision-making.

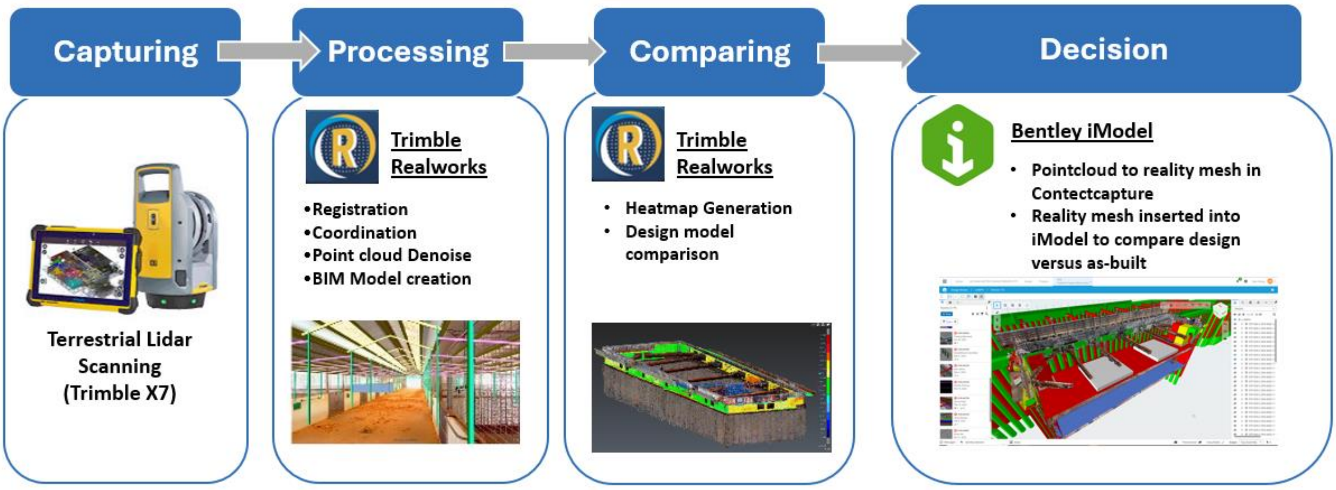


Figure 8 Trimble X7 Process

   b) Attend regular coordination meetings to establish specific priority areas of scanning.

Regular coordination meetings took place between the Engineering, Design, and Delivery teams to establish and identify specific priority areas for scanning.

   c) Provide additional survey data to the Pilot team when areas are unable to be 3D laser scanned.

Where the 3D laser scanner could not effectively capture areas due to obstructions, inaccessibility, or other limitations, supplementary survey data was provided. This additional data helped bridge the gaps left by the laser scanning process, ensuring that all critical areas of Glen Huntly were documented.

2) What caused a need for change?

   a) A terrestrial scan was undertaken, the post processing completed, and comparisons completed, however the turnaround time to complete this task was unfavourable for effective use of models during CPS. The process and details were as follows:

The initial lidar scan of a 400sqm storage tank was completed as planned. This scan mostly consisted of structural elements. Figures below show the point cloud results from the terrestrial scanner.

Figure 9 Terrestrial Scanner results

The scanning was performed at two levels: Level 1 used high HDR settings, while Level 2 used lower capture settings due to safety concerns. In total, 55 minutes were spent on doing this one-off scan.

Table 7 Duration of the TLS Scan

Tanking Scan	No of Scans	Scan time	Total scan time
Level 1	5	10 min	50 min
Level 2	8	2.5 min	5 min

The point cloud was geo-located using 4 control points placed on site as shown in Figure 10.

Figure 10 Scanning Control Points

The post-processing of the point cloud scan was done in Trimble Realworks and took over 48 hours to complete. Within Trimble Realworks, the team was also able to produce a deviation analysis, by visually comparing the As-Built point cloud with the design model, focusing on the capping beams as per Figure 11. This was done to provide extra information to the Engineering Managers on accuracy of the build, and guide decision making.

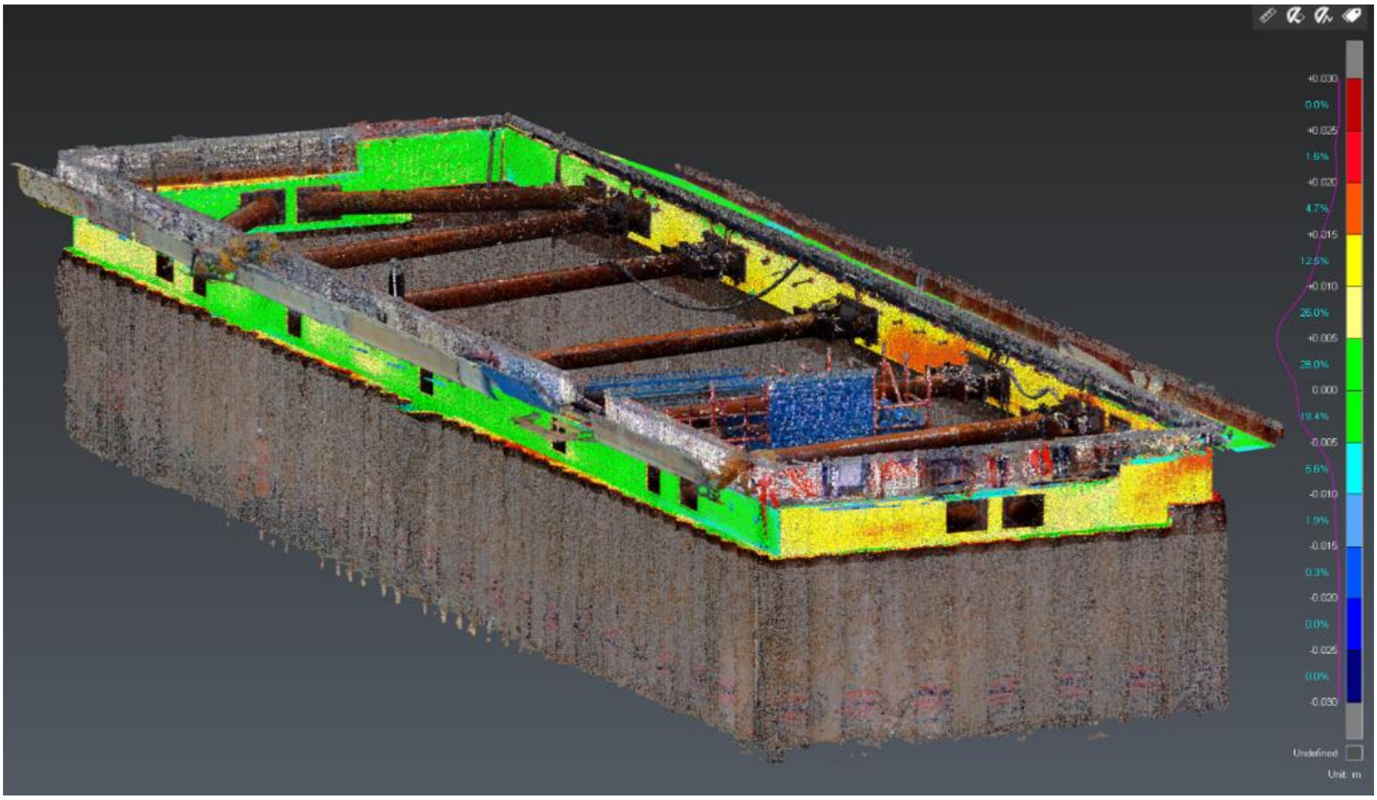


Figure 11 Point Cloud/Model Comparison

Thereafter, the point cloud was shared to the Design DE Lead in ProjectWise, who uploaded the information to ContextShare, and linked it directly to the federated model in iModel for review.

However, due to the deviation of information between the point cloud scan and the 3D model being within a 20mm tolerance, the Design team required the point cloud in their authoring software to achieve this level of accuracy in the scan. So, an extra step in the process was required to convert the point cloud to mesh format before sending the information to the Design team. This would then extend the processing time by another 2 hours. Thereafter the Design team would spend anything from 1-3 days (depending on resource availability) to update the models for coordination and information sharing with the Engineering Manager.

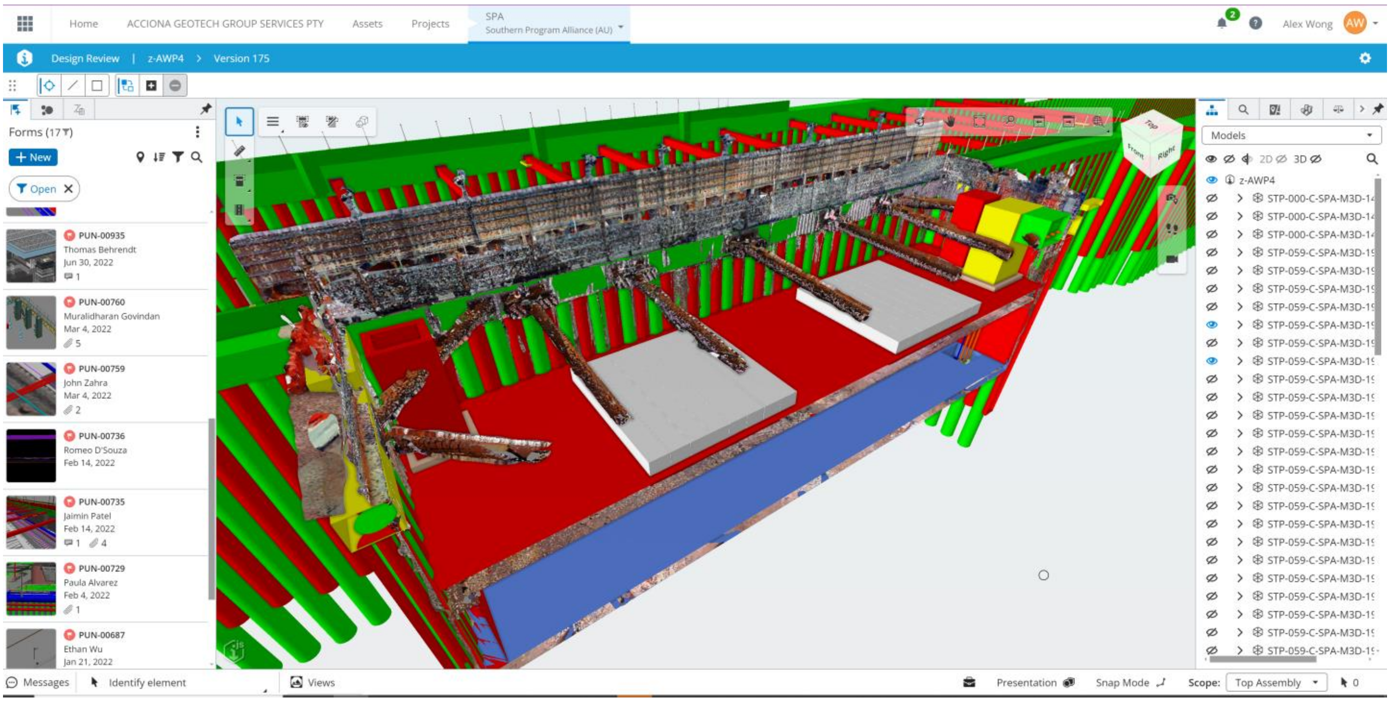


Figure 12 Reality Mesh Overlay on Models

The total time for scanning, post processing, design model amendments and engineering feedback, could take around 7 business days for a small area such as a tank, with hardly any obstruction to clean during post processing, and with only one design discipline covered.

Most of the station areas that had to be covered by this process would be far more detailed, and physically constrained with less site accessibility, which would increase scanning, processing and feedback time, add pressure on resources, increase risks of delays and increase safety concerns for the Survey teams. This would ultimately lead to information not being available to the Engineering Managers when required. Therefore, the Engineering Manager deemed this process not effective to support CPS processes. As a result, the Pilot pivoted from the plan to provide scan data during CPS directly into the design models for adaption.

3) The Change

The team had to continue the effort of scanning to achieve the requirements for As-Built, and therefore reviewed the process, focussing on the time it took to provide scan information.

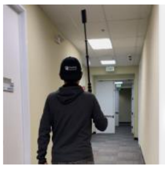
One of the key challenges is that a construction site evolves rapidly, therefore, planning and executing scans can be difficult due to shifting temporary support structures, ongoing work, and the need to adjust scanning strategies frequently. Additionally, safety concerns play a significant role in determining what can and cannot be scanned. For instance, areas with active construction, hazardous conditions, or limited access may restrict the ability to safely perform scans, impacting the comprehensiveness and accuracy of the captured data.

The Pilot team decided to pivot away from using the X7 scanner and sought to improve the time for Scan-to-BIM processes based on the search criteria below:

- **Efficiency and Turnover Over Time:** By seeking a different integrated technology platform, the objective is to speed up the integration of scan data into the BIM model, to enable quicker review and decision-making during the CPS.
- **Streamlined Workflow:** By adopting more efficient data capture and processing tools – preferably cloud processing to reduce bottlenecks and delays associated with the scanning process – a smoother transition from data acquisition to BIM integration will be facilitated.
- **Adaptability to Changing Conditions:** Seeking a more flexible scanning device will help to accommodate the rapid changes in site condition and construction progress.
- **Improved Collaboration:** By seeking an integrated cloud platform that is both user-friendly and capable of enhancing the viewing experience, improved collaboration and communication through measurement and annotation tools will be facilitated.
- **Technology that Fits Within Budget:** An integrated platform that fits within the available budget and fulfills key search criteria will be sought.

A technology review was undertaken to find a new solution. Below is the list of technology platforms that the Pilot investigated during the CPS phase.

Table 8 Scanning Technology Review

No.	Features	Trimble X7, X9, X12	Matterport 3	Geoslam Web Horizon	NavVis	Cupix
						
1	Point cloud resolution	2mm @ 10m	20mm @10m	300,000 per second	2 x 600,00 per second	not comparable
2	Capturing mode	360 image/TLS	360 image/TLS	SLAM	360 image/SLAM	360 videos
3	Camera image quality	3 x 10MP (x7) 3x 10MP (x9) 80MP (x12)	5 x 25MP	4K	4 x 20MP	6k
4	Range	0.6m to 80m (x7) 0.6m to 150m (x9) 0.3m to 250m (x12)	Up to 100m	Up to 100m	Up to50m	Up to 30m
5	Accuracy	Survey Grade	Less accurate	Survey Grade	Survey Grade	Least accurate
6	Person blurring	Physical cleaning	Possible	Not applicable	Not applicable	Possible
7	Point cloud file format	E57, LAS, LAZ, PTS	E57 only	E57, LAS, LAZ, PLY, TXT	E57	N/A
8	Colourised	Yes	Yes	Yes	Yes	N/A
9	Geo-referenced	Targets	3rd party app, not recommended	Targets	Targets	Targets
10	Indoor/outdoor capture	Indoor/Outdoor	Indoor/ Outdoor	Indoor/ Outdoor	Indoor/ Outdoor	Indoor/ Outdoor
11	Privacy/face blurring	No	Yes	Yes	N/A	Yes
12	Cloud processing	No	Yes	Yes	Yes	Yes
13	Processing/Turn over time	48+ hours	24 hours	10 hours	24 hours	24 hours
14	Post processing clean up	40 hours	Not applicable	10 hours	Not applicable	Not applicable
15	Capture time	10 days (x7)	120 mins	40 mins	45 mins	30 mins

		7 days (x9) 3 days (x12) (station only)	(station only)	(station only)	(station only)	(station only)
16	Static setup location constrains	Yes	Yes	No	No	No
17	Scanner orientation	Upright only	Upright only	Any orientation	Upright only	Any orientation, preferably upright
18	Resources hardware	High end computer	iPad with internet access	High end Computer with internet access	In-built hardware/ internet access	Phone/iPad with internet access
19	Resources personnel	2	2	1	1	1
20	Does this support the Scan to BIM process?	Yes	Yes (in theory)	Yes	Yes	Yes
21	High level price for solution	\$65,000.00 (x7) \$100,000.00 (x9) \$170,000.00 (x12)	\$25,000.00	\$105,000.00	\$115,000.00	\$10,000.00

The Survey team recommended Matterport as it offers an easy-to-use, all-in-one platform for creating high-quality 3D virtual tours and digital twins. Its user-friendly interface and cloud-based processing provide a comprehensive and efficient solution. Additionally, Matterport is versatile across various applications and allows for seamless sharing and collaboration, making it a practical choice which fits within the available budget. Matterport's cloud service includes the ability to export in the E57 format, saving time and resources on in-house processing while providing additional flexibility and compatibility for various applications.

As these changes to the Pilot technology were made after construction started, the Pilot team needed to understand which disciplines would benefit from scan data and what other stakeholders would require.

While the Matterport scanner proved to be effective as a workflow streamlining device, it was not suitable as a primary progress capture device for the entire project. To address gaps, aerial capture through drone scans was incorporated. SPA's adoption of a drone processing platform with rapid data turnaround proved particularly useful for overall progress reporting, especially during occupation periods that required tight coordination daily.

The table below outlines the mode of capturing required to support each discipline's use.

Table 9 Ideal Survey Capturing

Discipline	Ideal Survey capturing	Justification
Architecture	Matterport and Drone Scan	Improved efficiency with Matterport compared to TLS.
Structure	Matterport Scan	Improved efficiency with Matterport compared to TLS.
Building Services	Matterport Survey	Reflective surface of building services distorts scanning results, therefore traditional surveys are required for main runs. Matterport could be used to locate equipment and devices.
Bridge	Matterport Scan	Improved efficiency with Matterport compared to TLS.
Track	Drone Scan	Improved efficiency with drone scan compared to TLS.
Combined Services Routes	Survey	Using drone or point cloud scans for underground services are not ideal, and the teams require traditional survey with data points and drawings.

Ultimately, the pivot for the Pilot team was that the scans were no longer to be used during CPS to update models to the As-Built survey scans during CPS, but rather incorporated into the federated models for coordination purposes.

4.4 CPS Updated Pilot Metrics

Although the planned processes during CPS were pivoted from, the metrics that were aimed at were not changed.

Table 10 CPS Metrics

During Construction		
CPS		
1A	Model updated during CPS improving coordination and clash risk – reducing extension of time risk	Risk reduction
1B	Construction Management and Design DCRs/RFI reduction through coordinated model	Cost reduction

To measure the above-mentioned metrics, SPA has set out to answer the following questions in this report:

Table 11 Updated CPS Metric

Metric #	Intial Metric	New Metric
1A	Assumption: In the Pilot, clash RFIs will be reduced due to model clash detection.	No change
1B.1	Would coordination with Shop Detail models reduce Shop Detail RFIs on Glen Huntly?	No change
1B.2	Would the Pilot cause a reduction in RFIs due to modelling being updated during CPS?	No change

4.5 CPS Pilot Outcomes

This Section will address the Pilot processes implemented during CPS and respond to the metrics to understand the benefits and value achieved in this time.

4.5.1 Pilot Processes Implemented

1) Pilot Triggers and Process

As shown in the process flow in Figure 13, a workflow was implemented to capture 3D model updates required as part of the Pilot.

When an RFI was raised on iTwoCx, the Engineering Manager would review the contents of the RFI and decide whether an update to the 3D model would be required. If the 3D model update was required and would improve coordination on site, the Engineering Manager would select a tick box in the iTwoCx RFI form. This tick box notified the Design team that a model update was required as part of the Pilot and the Design DE Lead would begin the process of coordinating the model updates with the Design team.

The initial trigger to include an RFI as part of the Pilot lay with the Engineering Manager. There were no specific criteria outlined for the Engineering Manager to follow that would initiate a Pilot trigger, and it was left up to his discretion, knowing the Pilot scope.

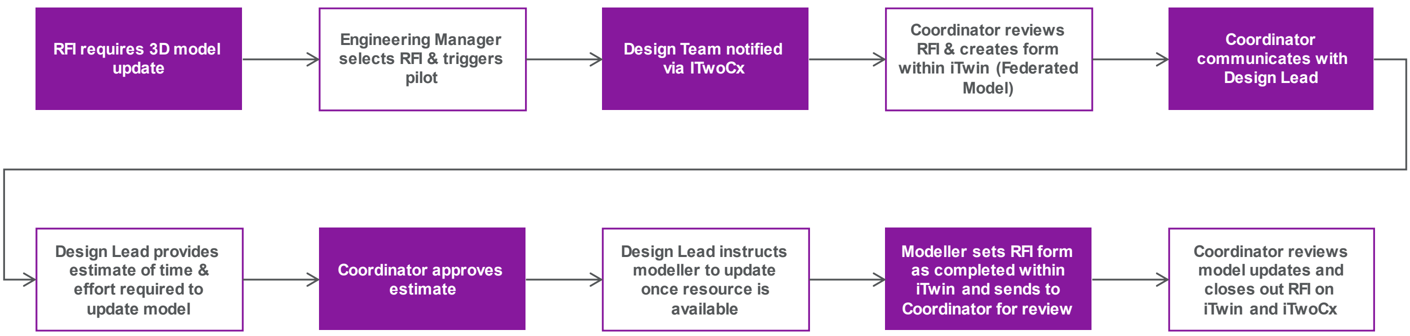
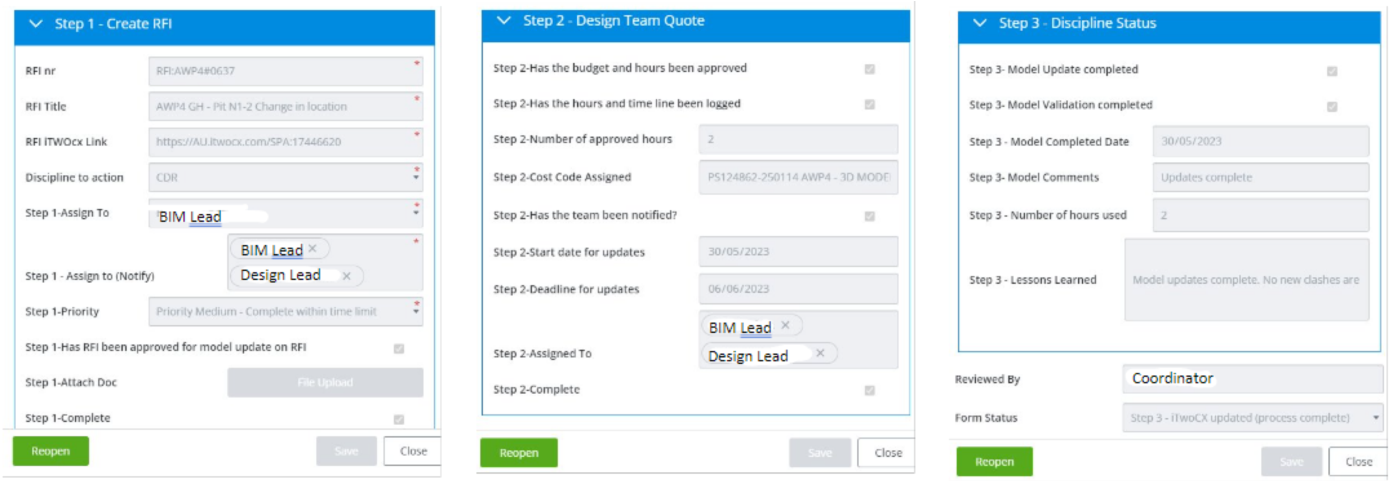


Figure 13 RFI Pilot Process

2) Updates and coordination

To track and manage all the RFIs that were selected to be part of the Pilot, the Design Coordinator utilised the federated model within iTwin (iModel) and created an RFI form. This form could be geo-referenced to a location or specific element within the federated model to allow for ease of identification of the affected design elements. This form was broken down into 3 stages to track effort and lessons learned as the RFIs got closed out.



Step 1 - Create RFI

RFI nr: RFI:AWP4#0637
RFI Title: AWP4 GH - Pit N1-2 Change in location
RFI ITWOcx Link: https://AU.itwocx.com/SPA:17446620
Discipline to action: CDR
Step 1-Assign To: BIM Lead
Step 1 - Assign to (Notify): BIM Lead, Design Lead
Step 1-Priority: Priority Medium - Complete within time limit
Step 1-Has RFI been approved for model update on RFI
Step 1-Attach Doc: File Upload
Step 1-Complete
Reopen | Save | Close

Step 2 - Design Team Quote

Step 2-Has the budget and hours been approved
Step 2-Has the hours and time line been logged
Step 2-Number of approved hours: 2
Step 2-Cost Code Assigned: PS124862-250114 AWP4 - 3D MODE
Step 2-Has the team been notified?
Step 2-Start date for updates: 30/05/2023
Step 2-Deadline for updates: 06/06/2023
Step 2-Assigned To: BIM Lead, Design Lead
Step 2-Complete
Reopen | Save | Close

Step 3 - Discipline Status

Step 3- Model Update completed
Step 3- Model Validation completed
Step 3 - Model Completed Date: 30/05/2023
Step 3- Model Comments: Updates complete
Step 3 - Number of hours used: 2
Step 3 - Lessons Learned: Model updates complete. No new clashes are
Reviewed By: Coordinator
Form Status: Step 3 - iTwoCX updated (process complete)
Reopen | Save | Close

Figure 14 CPS Design Updates Tracker Form

Step 1: Creating the RFI within iTwin

The first step for this process was for the Design Coordinator to review the RFI to ensure the scope of the required changes was fully understood. This involved ensuring that all affected models and disciplines were highlighted and included in the iTwin RFI form. The form also contained a link to the original RFI on iTwoCx, as well as the assignees, and the priority of the required updates – whether it was critical for the updates to occur to allow work to continue on-site, or if it was something that could be addressed later.

Step 2: Design team review and estimation of effort

Once an RFI had been assigned to a member of the Design team, the process of reviewing the effort required began. This involved consultation between the Design Coordinator and the BIM and discipline leads. This step was implemented to manage the budget and ensure that the amount of effort required to update the models was understood from the outset. Once a reasonable estimation had been agreed on, the Design team began updating the models.

Step 3: Discipline Status and Review

When the BIM Lead had completed their model updates, they could select a box on the form to send the model updates for review. This would trigger the Design Coordinator to re-sync the affected models with iTwin to ensure the latest information was showing. The Design Coordinator would then utilise the federated model to review the changes that had occurred. If further changes were required, the form could be sent back for review to the BIM Lead which would begin Step 3 again, until the models had been updated correctly.

The DE Coordinator would also conduct a high-level clash review in the federated model, around the RFI area that was flagged to the Design team that could influence RFI responses.

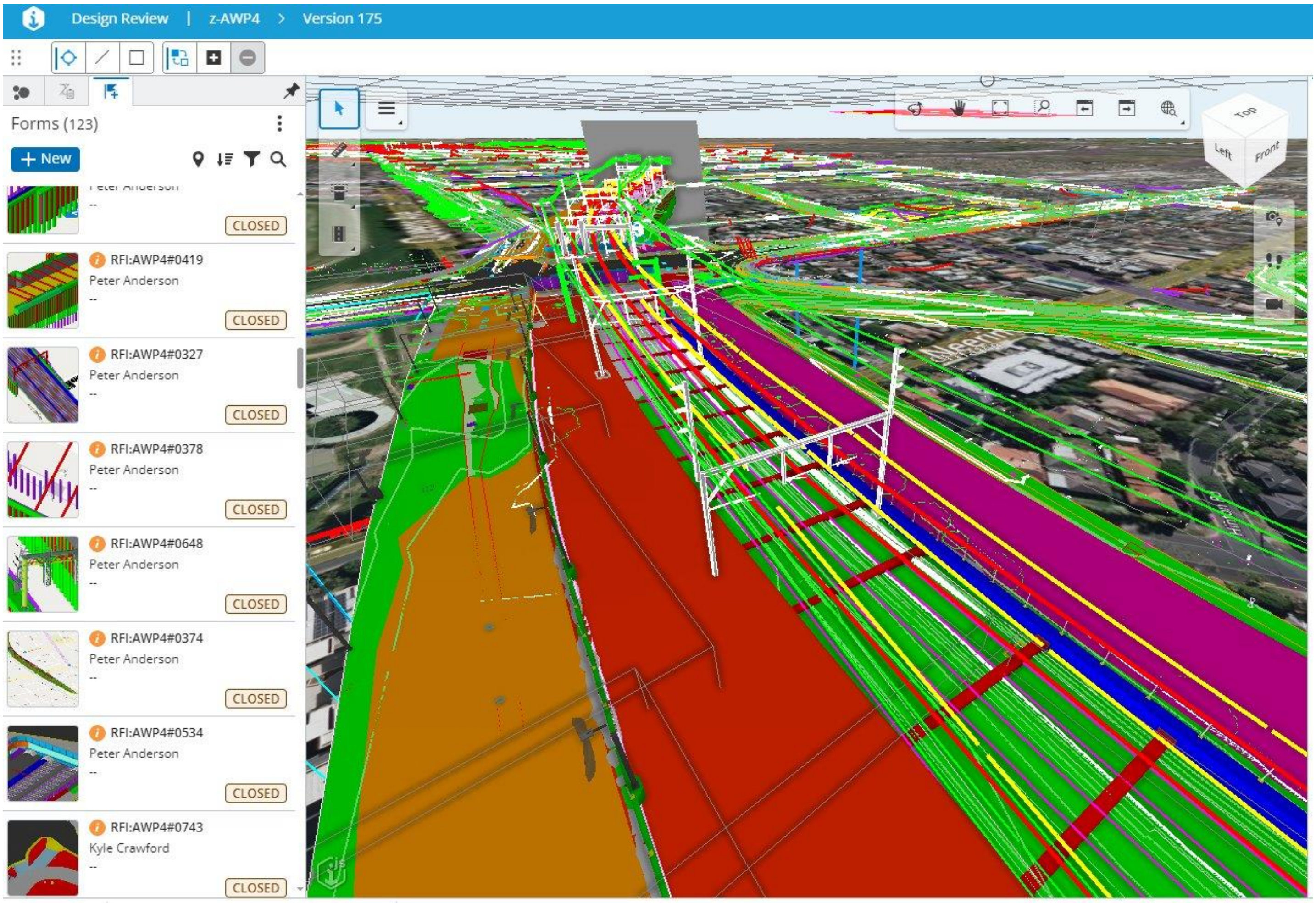


Figure 15 iTwin Review of Changes

3) Close-out of RFI

Once the Design Coordinator had completed their review of the model updates within the federated model and was satisfied that all the changes had been captured correctly, they could close out the RFI form on iTwin and iTwoCx which would then inform the whole team that the model updates had been finalised. The RFIs could clearly be identified within the federated model, and the status as closed was easily identifiable as shown in the image above.

4.5.2 Outcomes

The Glen Huntly Project produced 941 RFIs in total, as shown in Table 12. These RFIs will be referenced in the following section to reveal the impacts of the Pilot on the Glen Huntly CPS phase.

Table 12 Number of RFIs on Glen Huntly

Discipline	Number of RFIs
Civil	230
Civil Structures	75
Signalling	143
Stations	408
Track and Rail	68
Utilities	1

Electrical	16
Grand Total	941

1) RFIs as Key Performance Indicators (KPIs)

During the Pilot, the team realised that the nature of RFIs needed to be acknowledged before they could be used as a Key Performance Indicator (KPI). An RFI is a business process used in construction to request clarification about documents, drawings, specifications, or other project conditions. RFIs are used to resolve information gaps, eliminate ambiguities, and capture and share specific decisions during construction. What is less commonly considered is that the amount of RFIs in their nature are directly related to human and business-related variables. For example, human-related examples include:

- It is often assumed that providing a 3D model will reduce the number of questions and ambiguity for reviewers, however the opposite is sometimes true, where more questions are asked around more detail, which may have not been previously considered in conventional drawing reviews.
- RFI communication depends on reviewer personalities, where one reviewer of information would prefer asking multiple questions in a single RFI, while others may create an RFI per question. This could influence the amount of RFIs generated on the project.

A business-related example include:

- The procurement contract between sub-contractor and the contractor states that RFIs are to be used to clarify design information. However, the scope of the sub-contractor was not clearly defined and the gaps between the design and the sub-contractor's scope had not been highlighted at procurement. This would lead to more RFIs generated on the project.

2) In selecting which RFIs would form part of the Pilot:

The Engineering Manager's primary focus was to enable the construction team to complete their planned works within the limited time of the occupation. A major focus was given to activities that would benefit the quick turnaround for site progress.

As a result, RFI's were selected to form part of the Pilot where a quick turnaround in updates would have been made, however where additional time and resources were required, some potential for model updates may have been excluded from the RFI selection process. The Pilot team occasionally conducted RFI reviews and would retrospectively request RFIs to be included. Although it may have supported the future As-Built update process, the Pilot team have missed opportunities to measure impacts of keeping the models up to date during CPS for coordination and site impact purposes.

3) Updating models for RFIs:

During CPS, SPA had four running projects between design and CPS phases, and the Design resources were under pressure. Securing resources to update models proved challenging and updates were often delayed, which impacted the possibility of coordination reviews, and prevented the Pilot team from picking up potential risks.

Where models were amended to answer RFIs as part of BAU, the BAU communication and processes did not include the Pilot team, which prevented the team from keeping track of all the changes that occurred.

The Pilot team had on various occasions made retrospective updates when resources were available. However, the team was able to manage coordination for a few key disciplines while answering RFIs, which helped us to track the impact of the updated models.

4) The following model updates were completed during CPS:

See Appendix A for the full list of RFIs on the Pilot and models amended. In total, the Design team has spent 122 hours during CPS to update 49 models. As shown in the chart below, the majority of RFIs on the Pilot were assigned to CDR – Civil Drainage.

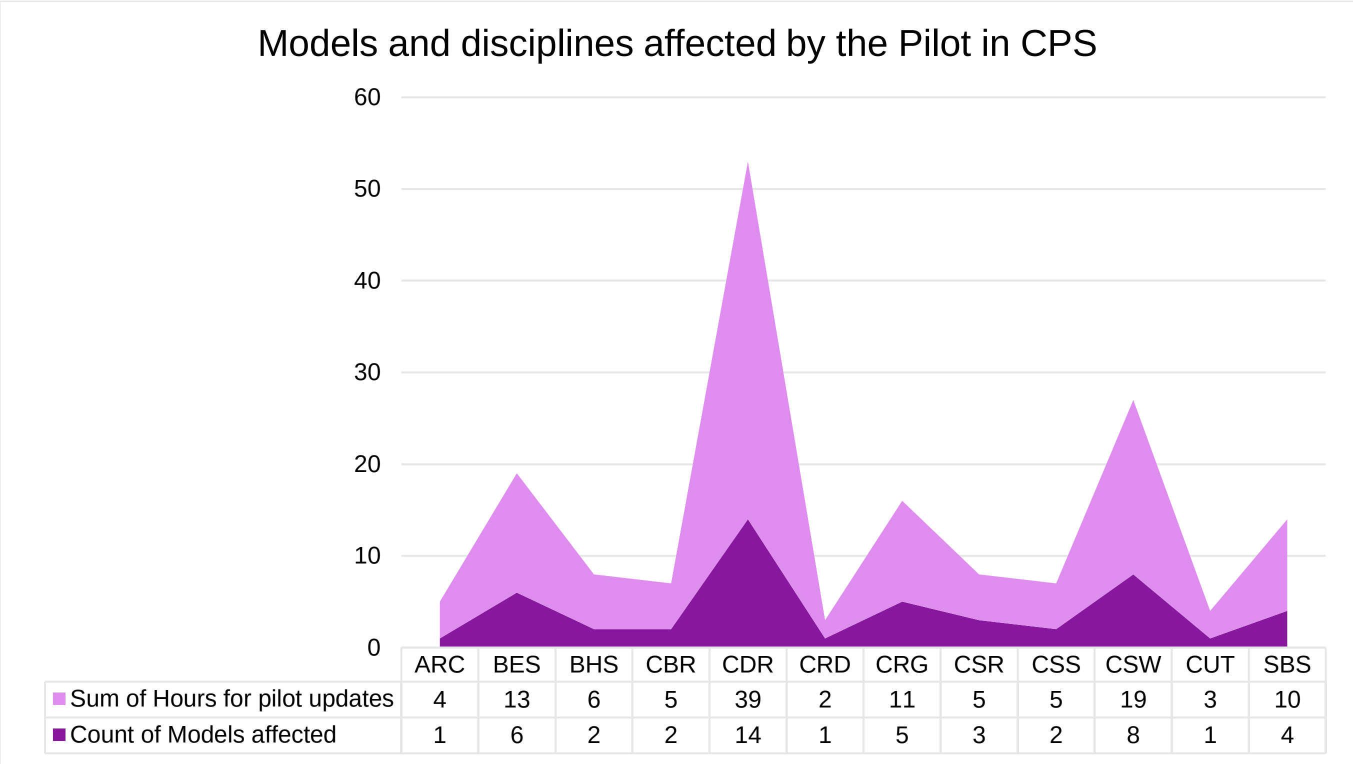


Figure 16 Models and Disciplines affected by the Pilot in CPS

4.5.3 Findings

1) Reviewing Metric 1B.2: Would the Pilot cause a reduction in RFIs due to modelling being updated during CPS?

As result of the analysis of the Glen Huntly Project's RFIs generated through CPS, categories were assigned to each RFI to understand the ratio between RFIs where models were updated as part of BAU and in the Pilot, as well as the percentage of RFIs that would not require model updates. When RFIs do not require model updates, it is mainly due to the nature of the RFI, including queries around details, schedules and materials that are normally not modelled.

Table 13 Categorisation of the Glen Huntly Project's RFIs

Discipline	Number of RFIs	Count of Actual Model Update
Pilot	48	5%
BAU	25	3%
DCR	11	1%
No Model Updates	802	85%
Shop Model Updates	55	6%
Grand Total	941	100.00%

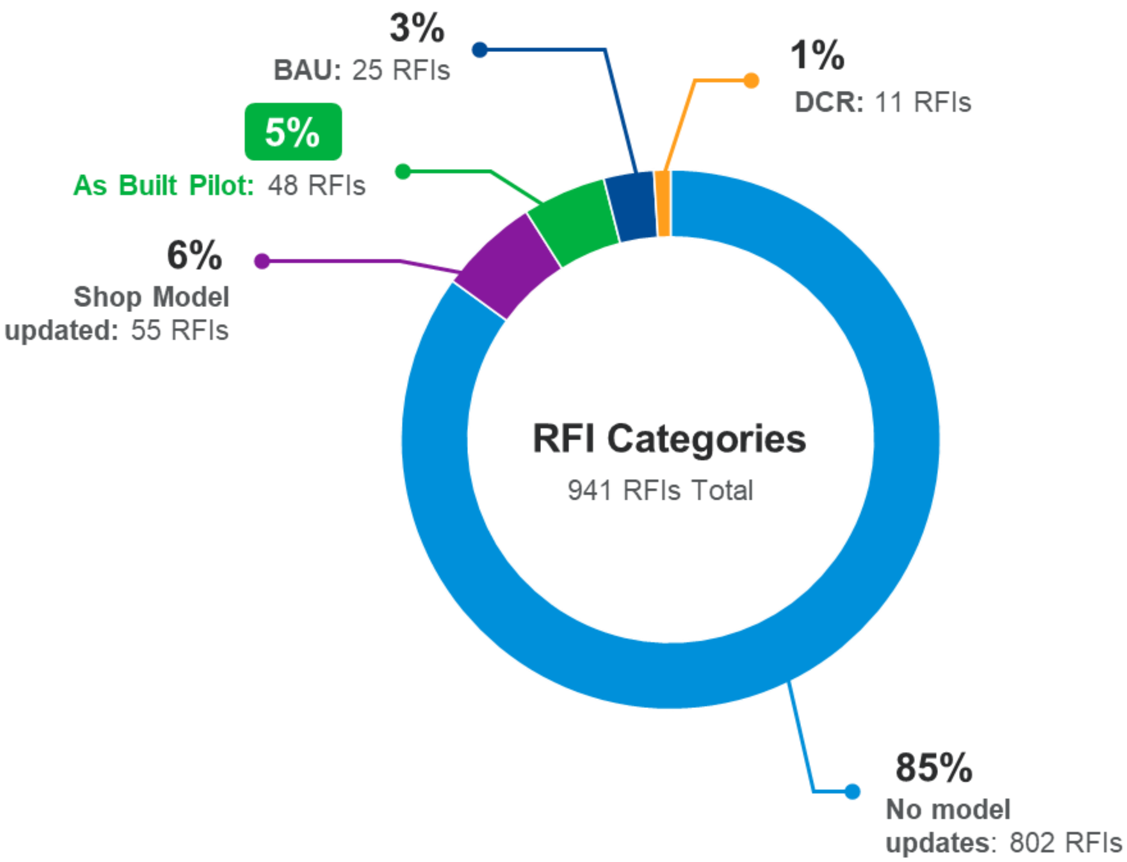


Figure 17 RFI Categories Chart

This analysis shows that the majority of RFIs on a project are attributed to queries that do not result in model updates, with only 5% of the total project RFIs having been included in the Pilot, and 3% of RFIs to see models updated as part of BAU.

The answer to this question is that if models are kept up-to-date, it would only impact marginal amounts of RFIs due to their nature. Therefore, the benefit and value of models updated in CPS should not be tied to RFI reduction but rather its impact on risk reduction. See Section 4.5.4 for the risks reduced through the process.

2) Reviewing Metric 1A: In the Pilot, clash RFIs will be reduced due to model clash detection.

There was a total of 18 RFIs on the Glen Huntly Project relating to clashes related to Drainage, Signal Structures, Bridge Structures, and Structures disciplines. Only 24% of these were attributed to the Pilot, with 18% of the total resolved as part of BAU. Although, 53% of the clash RFIs did not require model updates due to the nature of the RFIs.

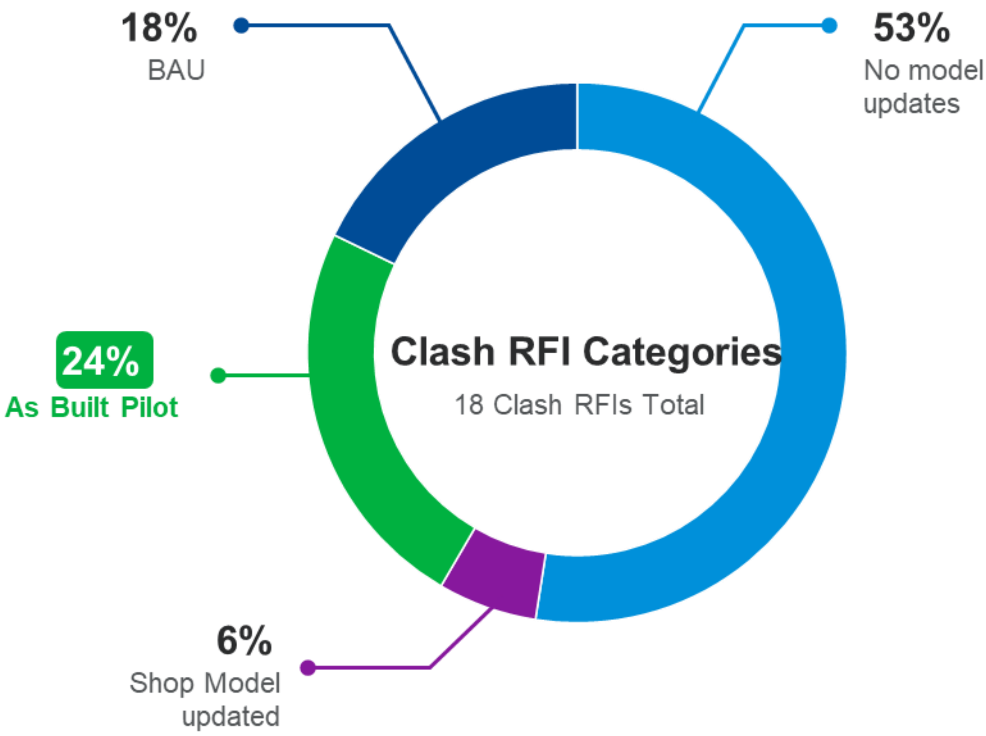


Figure 18 RFI Clash Chart

The majority of the RFIs that didn't result in model updates were due to the requested subject items not being required for modelling in 3D during design. This included clashes with rebar or conduits that were not a scope requirement during IFC Design modelling.

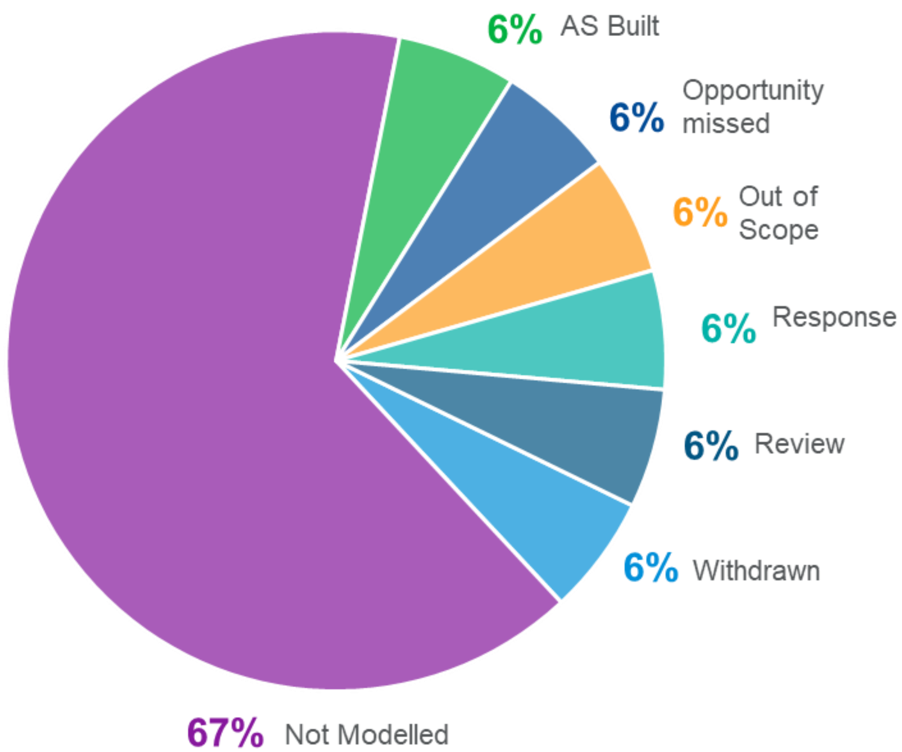


Figure 19 Model updates not required Chart

Although it is true that BIM models could support a reduction in clashes on site, this review has highlighted that not all clashes can be prevented with BIM. This is due to the level of detail of models that are not required to convey design intent during the design period but are required for construction. Depending on the value of the impact, it is recommended that Construction teams develop models through the shop detailer or internally to bridge the gap between design intent and construction level of detail.

1) Assumption: Disciplines working in Revit are amending their drawings and models during CPS as BAU

To examine the assumption that working in Revit will keep models up to-date as part of BAU, the analysis is focused on the Architecture (ARC) discipline's RFIs received in CPS.

Of the 76 RFIs received, only 4% of the RFIs required teams to keep models and drawings up-to-date as part of BAU. Only 3% of the ARC RFIs were attributed to the Pilot and 1% converted to a DCR. The majority of the RFIs were related to Shop Model updates (24%) which were not owned by the Design team and 68% of the RFIs did not require model updates.

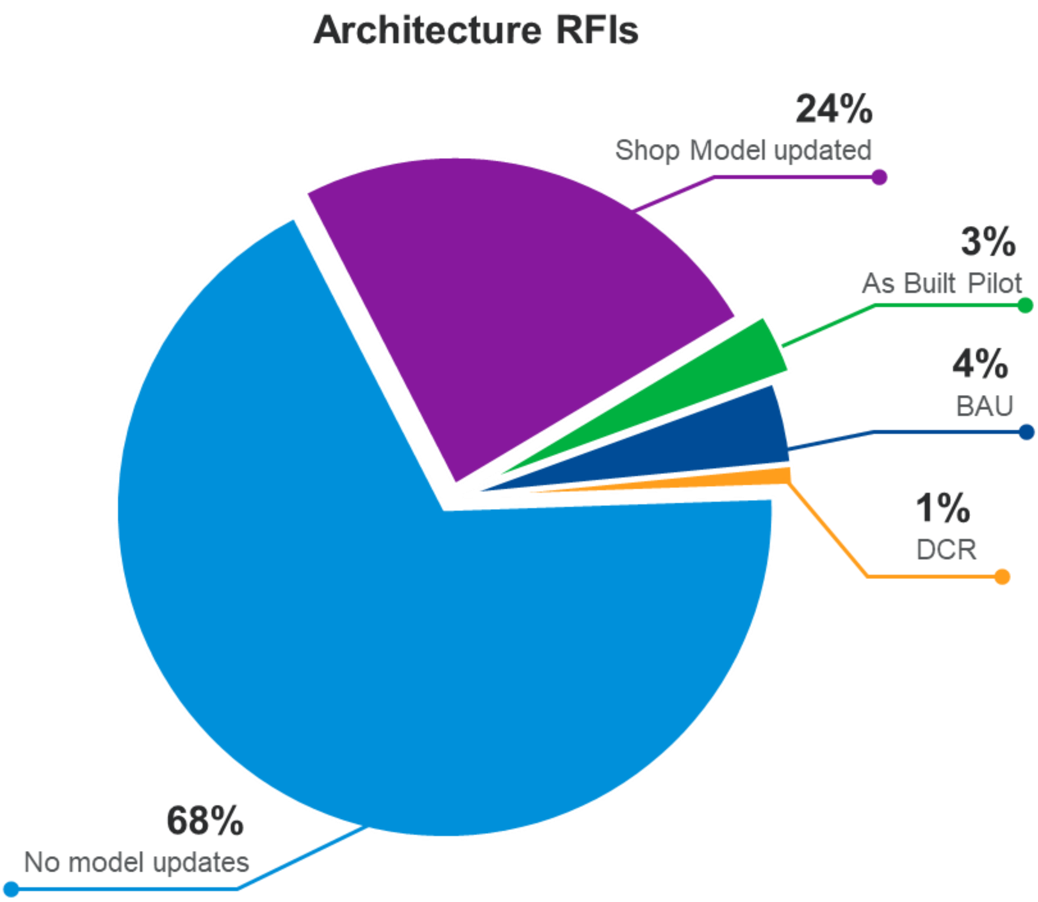


Figure 20 Architecture RFIs chart

To understand why no model updates were required for ARC, the chart below shows that out of the 52 RFIs that were tagged for no model updates, 45% were related to material queries, and 37% related to updating details, which are developed in 2D (as typical details) and had no connection to the models. Only 2% of these RFIs resulted in a missed opportunity for inclusion in the Pilot, as it was decided at the time there were no coordination benefits to updating these during CPS and that they would be updated during As-Built.

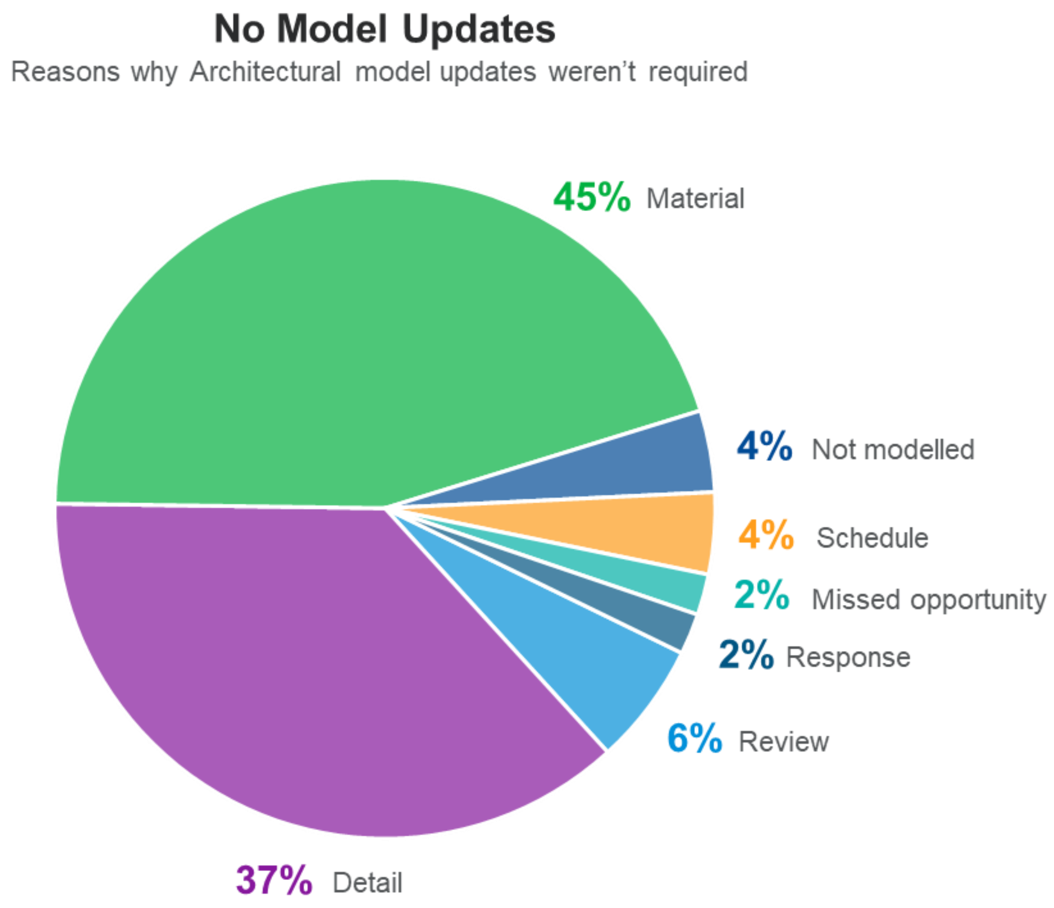


Figure 21 Architecture Updates not required chart

The data from the Architecture analysis shows that even with the use of models during CPS to update files for responses to RFIs, most of the RFIs would not be answered through 3D or did not require updates of 3D models. This meant that most changes in the design in CPS would have impact purely on 2D aspects of drawings and schedules, and not 3D geometric content.

2) Impact of model changes for RFIs on DCR drawings and official versions:

When teams started updating their models and drawings to respond to RFIs as per the planned Pilot process, a couple of process issues came to light.

In the example below, the impact that RFI drawing, and model amendments have on other design drawing processes in CPS arose. Here, the Civil Structures team were amending piles and retaining walls as part of DCRs and at the same time answering RFIs in the same area. The below quote is from the Civil Engineer that had to respond to the queries.

Example from RFI 0145: Glen Huntly Project: Change in retaining wall alignment in the station:

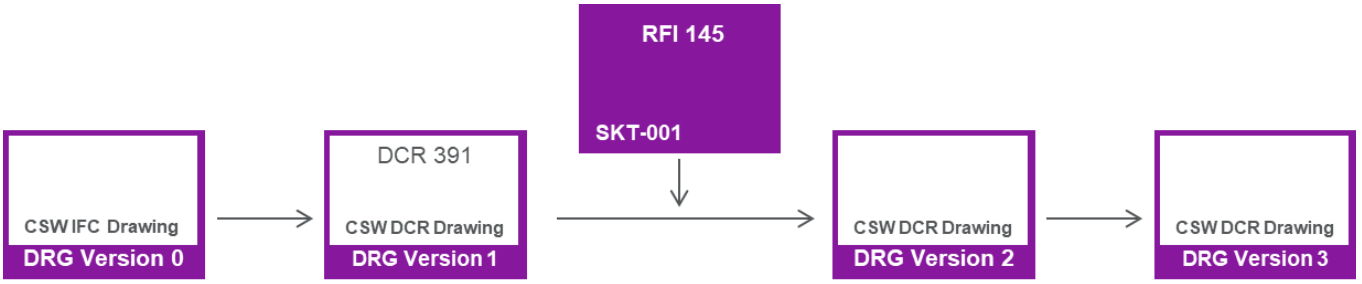


Figure 22 RFI 0145 Documentation Example

“During CPS, the drawings are reviewed by external stakeholders under DCR391 and are likely to be at IFC by end of the month. Updating the model and drawings at this time will result in the stakeholder’s receiving drawings that include the RFI update which will differ slightly to the Information for Review (IFR) drawings, which is a formal third-party review process part of design. Admittedly, this change is not very significant and typically would be resolved through redline markups, however, this may cause some issues with the reviewers. In this example, the IFR drawings show that 4 piles are to be removed as part of the re-alignment of the piles via DCR 391, however, when the reviewer receives the final drawings for IFC stamping (which includes the RFI update), they may notice 10 piles being removed, which is the change requested by RFI 145. This will incur variations as well as delays in submission due to the additional time for review.”

The approval and formal process design drawings followed during CPS were not known by the Pilot team at the start of the Pilot. Therefore, change management processes weren’t developed and implemented to mitigate these situations. At the time, a solution was to tag the RFIs in the drawings, however, the third-party approvers for the DCRs were not cognisant and involved with the Pilot and therefore it created a risk of rejection and delay of the next DCR that the teams were unwilling to test.

3) Impact of model changes for RFIs on DCR drawings and official versions:

Shortly thereafter the following situation came to light, noting at the time, the Design and Design Management teams were all under the impression that our goal was to keep CPS information like the models and drawings live.

A constructability issue was found which required the Design team to re-setout 2km of piles. If the RFI was answered by conventional methods, communication on iTwocx would have stated that the change would be adapted during As-Built.

However, an RFI was raised to include this change to the Pilot to ensure the information was kept live. A change notice CCN was created to make the change to the piles, but it was later withdrawn because the change did not alter the design intent. The decision was made to put the RFI driven changes on the Pilot budget. At the time, the Pilot team had not been involved with the decision-making and response to the RFI, as decisions were made at Engineering Management and Design Management level.

DCR 441 was raised to document updating of the model which changed the drawings that needed to be reviewed again and was completed in 2 months. Because of these changes, interfacing structures also required a change which led to a similar DCR process. DCR 466 was created and was completed in 2 months.

Retrospectively, there should have been a constructability workshop to address this issue instead of going directly into a DCR.

It was noted the time and cost impact of this minor update caused teams to be more averse to the Pilot updates during CPS, to avoid potential delays and cost overrun.

4.5.4 Benefits and Value

This section covers some of the benefits and value findings and shares some examples of RFIs that were included as part of the Pilot.

1) 1) Potential risk reduction during the Pilot

In typical BAU workflows, once the Design Package had reached IFC, the 3D models were only updated if there was a specific need based on a DCR. Any responses to RFIs were usually completed on 2D drawings or using uncontrolled sketches. By continuing coordination through the CPS phase and keeping the 3D models updated, the team was able to find some examples of areas where the project may have benefited from risk reduction associated with improved and ongoing coordination.

The example below of RFI 602 demonstrates the importance of continued coordination using 3D modelling applications during CPS. Further examples are contained in Appendix B – CPS Risks Mitigated.

2) Further detail around RFI 602

RFI (602) was raised to relocate a Drainage pit after it was noted that the proposed pit was going to clash with As-Built CSR and the existing feature survey drawing that wasn’t considered.

The 3D Drainage design model was updated in-line with the original RFI instruction.

Once the Drainage model had been updated and shared to the 3D federated model, it was noted that the new location of the pit was clashing with some proposed utilities (Water and Gas).

The Utilities Lead informed the team that they would be proceeding with the original Utilities design intent and that the Drainage team would need to find another design solution.

Workshops were held with multiple disciplines including Civil, Drainage, Utilities, CSR and Traffic Signals to find a suitable solution. Through coordination and input from Construction, Engineering and Design teams utilising 3D modelling applications, the team was able to provide a solution that reduced the risk to the project.

3) Estimated Cost of doing model updates

The total hours spent updating models as part of the Pilot was 122 hours.

Table 14 Estimated Pilot Cost over BAU

	% cost over BAU
Architecture	0.3%
Landscaping	-
Civil	3.5%
Civil Structures	0.3%
Station Structures	0.9%
Station Services	2.2%
Rail	0.6%
Total	0.8%

It is important to note that this figure relates only to the time spent by the modeller updating the 3D model. The associated coordination, management and design work required to close out the RFIs is calculated separately and is included in the BAU cost.

The table below shows two examples of RFIs that demonstrate the additional cost over BAU to update 3D models during CPS. It also estimates the potential risk mitigation benefits regarding avoiding the worst-case scenario outcome. Further examples can be seen in Appendix B.

Table 15 Risk Mitigation Example during the Pilot

RFI No.	Description of Issue	Solution without Modelling	Adopted Solution	BAU RFI response hours	Pilot Model updates hours	Worst case scenario	Approx. cost to construct	Worst case scenario Risk Cost
0060	Pit MD01-5 is clashing with the existing drainage	Rework with adopted solution	Pit MD01-5 to be moved approximately 1.2m South to avoid clashing with the existing drainage	3*	1*	$35,000	$3,000	$30,000
0773	Issues encountered on pit GH05-1 due to the	Rework with adopted solution	Pit location installed further north to avoid clashing with	4*	3*	$177,000	$5,000	$170,000

	positioning of the gas main. The pit was installed 600mm further north than planned to maintain a safe clearance. Consequently, the grate opening is now positioned behind the kerb, within the crossover	and APA Gas main recoating (6m)	the gas main. The repositioned pit shaft is then fitted with a Class D grate for 100 years ARI storm

*Hours represented are standard consultant hours.

These examples show that through coordination in CPS, the Design team was able to provide solutions that reduced the overall risk to the Glen Huntly Project.

In conclusion, services that have lower tolerance for change in construction like track, OHW, and Structures (civil and buildings) could find more benefits from proper coordination during IFC production, including shop detail coordination during this time, as they are built accurately on site. Whereas, services disciplines, especially those underground like CSR and Drainage, or those covered like building services, would benefit from coordination during construction using surveys with CPS updated models.

4.6 Shop Detailing Outcomes

Shop Detailing Process and 3D Model Integration: SPA has developed a workflow and established a method of collaborating with the Steel Shop Detailer through coordination of the Shop Detailing Model. SPA has a clause in its 'Minor Services Agreements' with this vendor to enable the reduction of effort and lead-in time through sharing 3D Design Intent models with Shop Detailers.

The Structural Steel Shop Detailer produced eighteen models which form part of the 3D model deliverable.

4.6.1 Pilot Processes Implemented

The workflow required the Steel Sub-Contractor to develop a 3D shop model, using Tekla, at fabrication level of detail. The models were first checked for model quality and coordinates before being shared on ProjectWise. Thereafter, the models would be federated in the CPS federated model (iModel).

Reviewers would access the shared model and the federated models to compare the shop information with the IFC drawings to coordinate and agree on design intent (see Figure 12). Once approved and coordinated, the reviewers would allow shop detail drawings to be developed for formal approval.

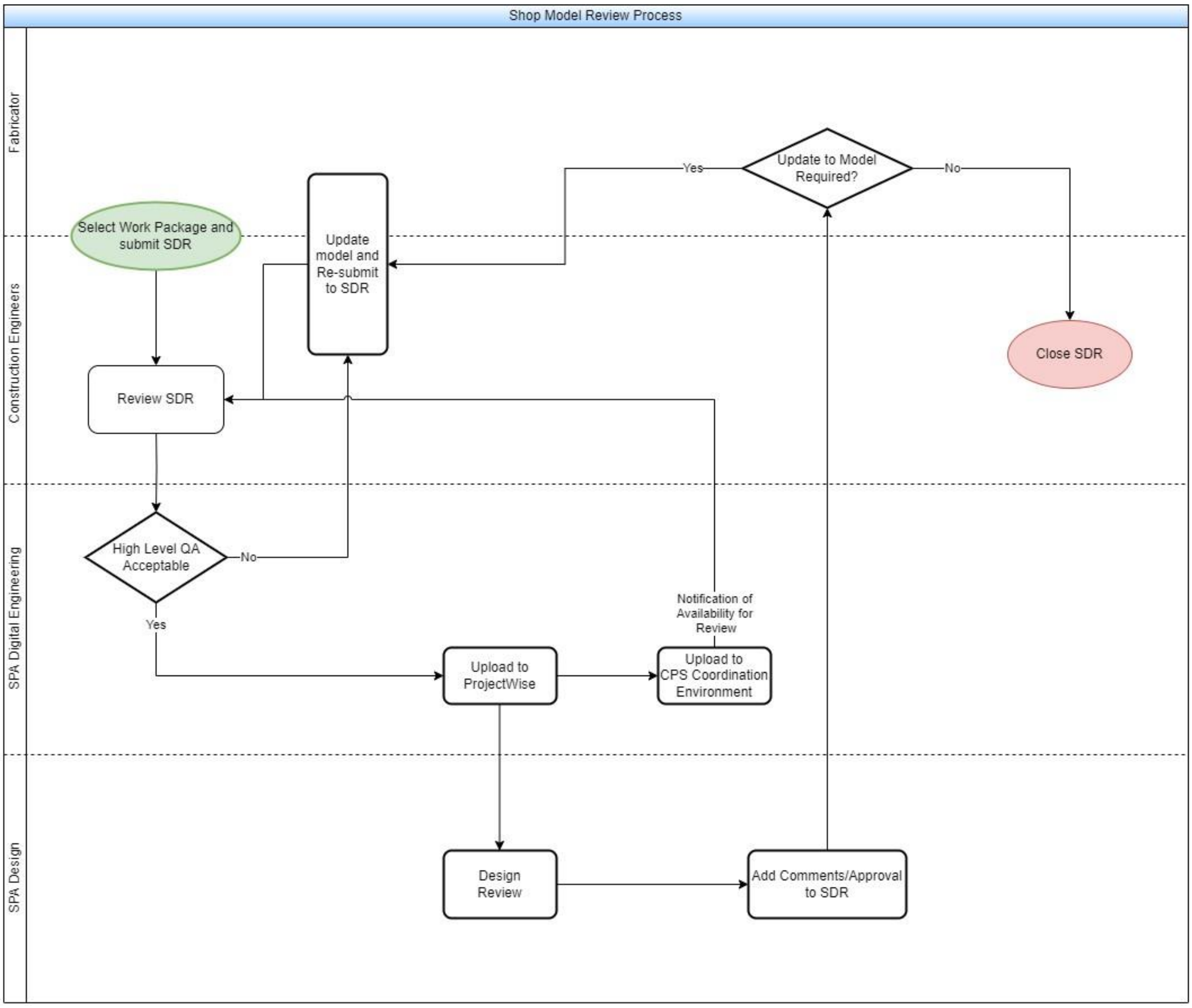


Figure 23 Shop Detailing Process

4.6.2 Findings

1) Outcomes of the shop model process compared to conventional shop detail drawings:

The process of hosting a Shop Drawing Review session before drawings have been created has seen significant improvement in reviewing times. This process has picked up clashes in structural details that wouldn't be picked up in IFC because shop drawing LOD is not required in IFC design. As an example, see Figure 24, where a capping and secondary steel item clashed. This process also picked up where typical detail didn't work for specific areas, prompting a design change before any shop drawings had been completed.

The time spent on the effort has not been documented by the Pilot team. However, the Shop Detailing review team on SPA has estimated the potential that this process should be saving based on calculations elsewhere on SPA. This includes:

- A potential for a 30% increase in efficiency to find coordination issues, because the model reveals interfaces between the shop detail and the design intent much better than drawings.
- A potential for a 25% increase in efficiency in review time for Engineers in total.

Therefore, the risk of clashes on-site has been reduced.

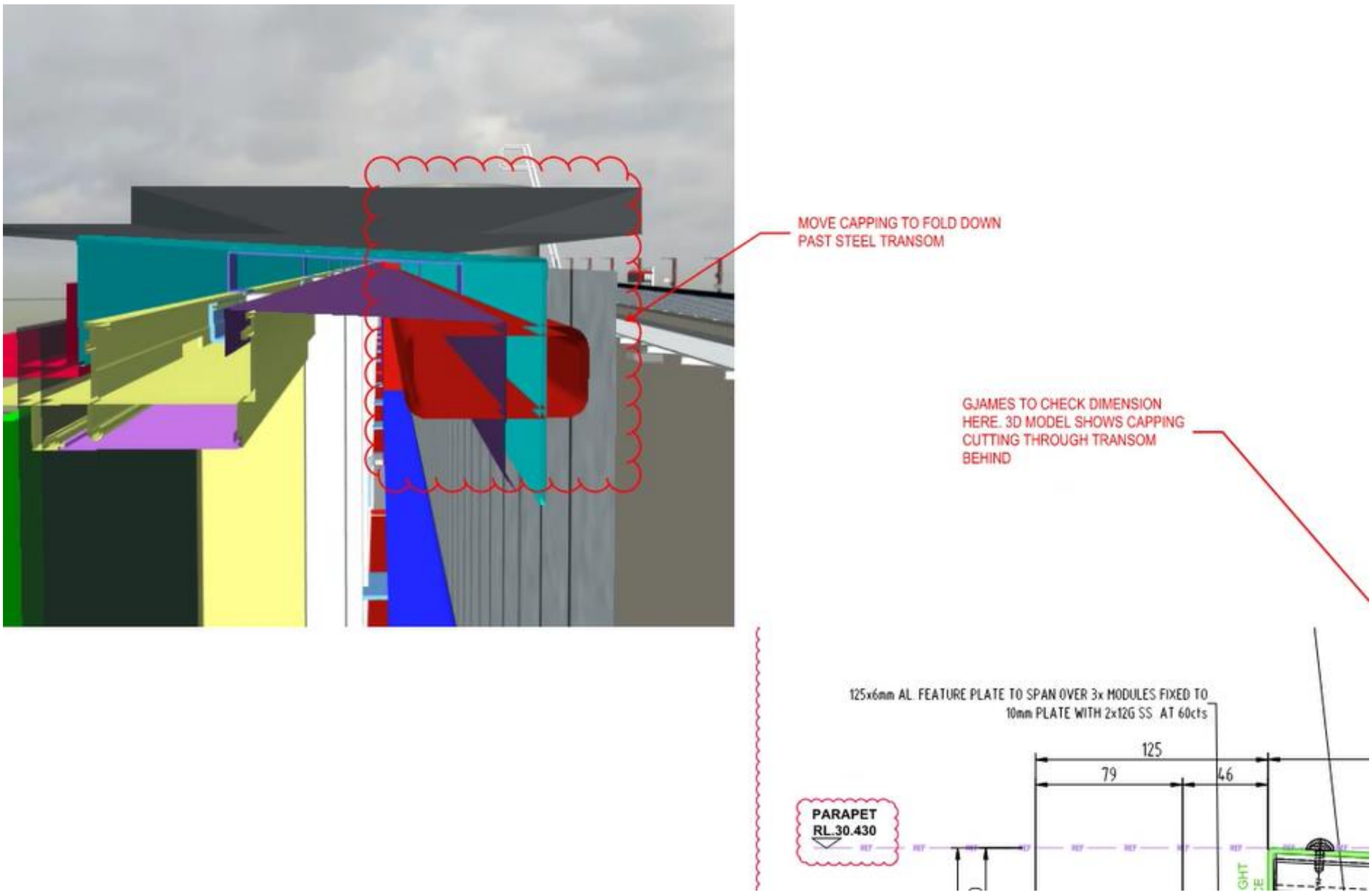
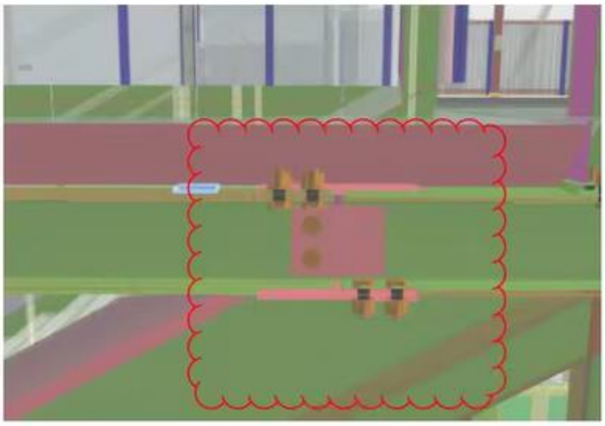


Figure 24 Shop Detail Clash

Below is an example of the SDR review between the model and the design details from IFC.



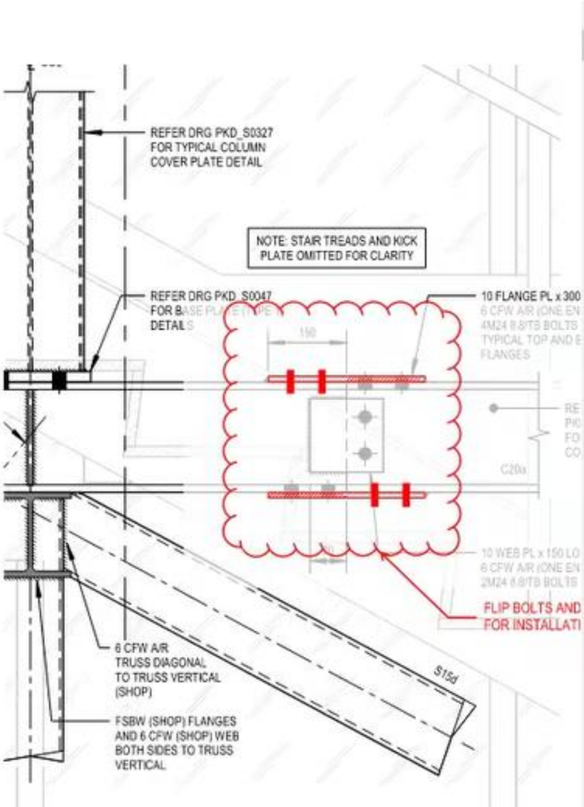


Figure 25 Shop Detail review against the design details

Compared to conventional Shop Detailing, the effort of developing the drawings would not be reduced, however, the reviewing of information in this context is improved, and the risk of finding costly issues on site is reduced. Further, any RFIs resulting from issues on site would have also been avoided.

2) Reviewing Metric 4.4 - 1B – Would coordination with Shop Detail models reduce Shop Detail RFIs on Glen Huntly?

To analyse this question, the RFIs related to steel and lifts between Chelsea Station and Greensborough Station (both from previous projects) were compared with the Glen Huntly Station RFI data. Neither Chelsea nor Greensborough implemented a 3D shop model process, whereas Glen Huntly has.

Table 16 Reduction of RFIs on Glen Huntly

	Total Station SBS and ARC RFIs	Steel/Metal	% of SBS RFIs	Lift	% of SBS RFIs
Chelsea	194	18	9%	11	6%
Greensborough	182	28	15%	15	8%
Glen Huntly	187	7	4%	6	3%

The results show a reduction in RFIs relating to steel and lifts. However, there are various efficiencies gained by doing multiple projects one after the other, and therefore there would have been many variables that needed to be considered before attributing the reduction of RFIs to the Shop Detail model coordination alone.

4.6.3 Opportunity

Although improved coordination with the Shop Detailers does save time during CPS, SPA believes that procuring suppliers and detailers between Gate 2 and IFC would be more beneficial. This would allow more efficient review of scope gaps between the design and procured supplier, and more detailed coordination before documents are issued for construction. This would ultimately reduce rework and administration during CPS and save resources from being idle while waiting for information.

4.7 Scanning Outcomes

In this section, the outcomes of the Matterport and drone lidar scans that were completed of the Glen Huntly Station and concourse are discussed.

4.7.1 Pilot Processes Implemented

Matterport is a three-dimensional system that allows users to create realistic, fully immersive digital twins of any space. Matterport consists of hardware, in the form of capturing equipment and software proprietary solutions for reading and using the data. Once a space is scanned by the Matterport capturing device, it generates a virtual 360-degree walk-through for the space. Matterport requires detailed scanning of a space, and it may take one hour to scan a 150 m2 space.

Drones, particularly those utilising the Propeller platform, complement the Matterport scanner by providing comprehensive aerial views, and capture data for larger and hard-to-reach exterior areas.

The process below was implemented on the Pilot.

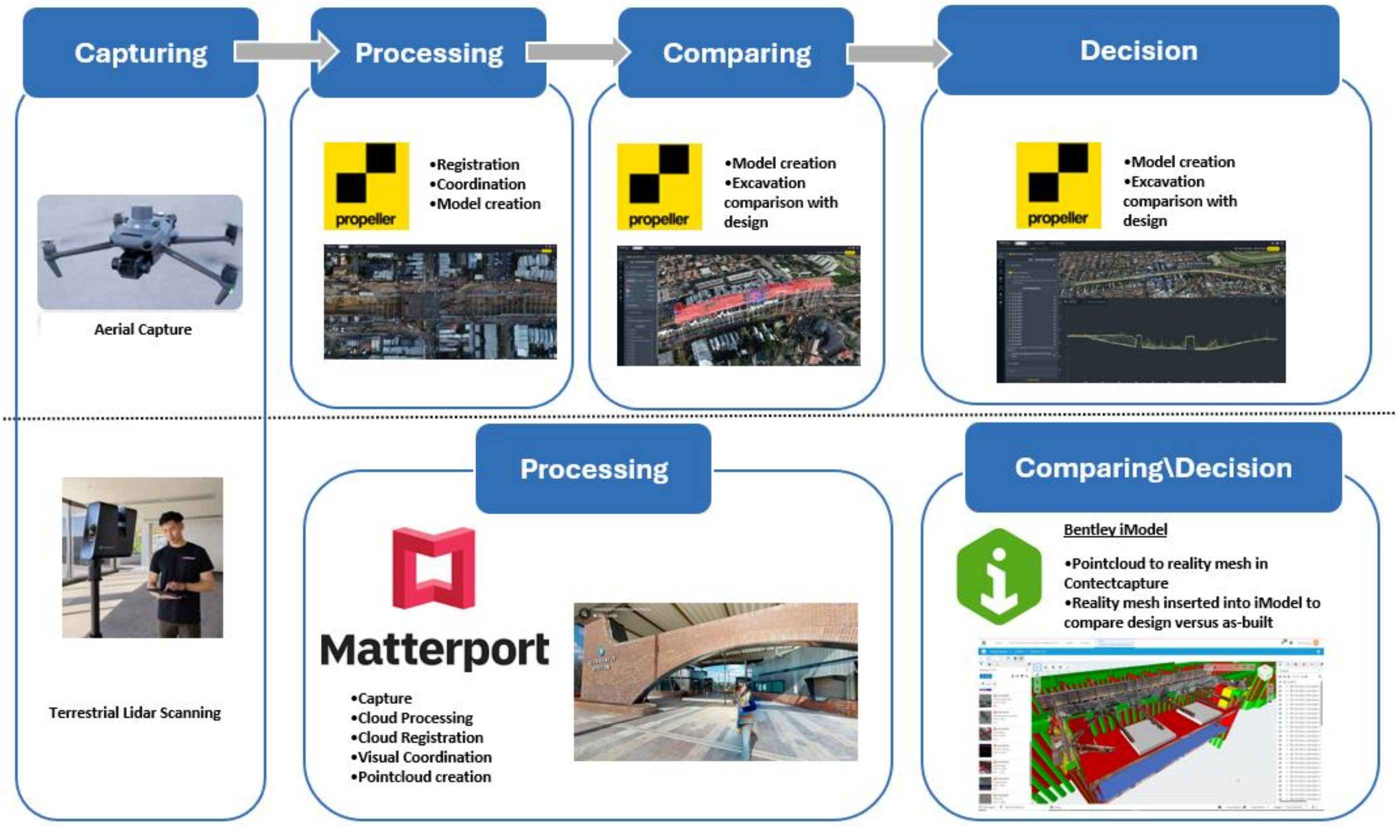


Figure 26 Scanning Process

Once the Matterport and drone scans were processed, the information was added to the Pilot's federated environment, iModel, for coordination and use during CPS. As most of the scans could not be completed in time for coordination for RFI responses, the scans were mostly used by the Engineering Manager and delivery team to review site progress and develop progress reports.

4.7.2 Findings

1) Scanning technologies used on the Pilot and their purpose.

Matterport is ideal for detailed interior scans, creating immersive 3D environments, and enabling users to take precise measurements within the cloud platform. However, it has limitations in capturing areas that are difficult to reach or covered entirely.

To address these gaps, aerial capture using drones was integrated into our workflow.

Drones, particularly those utilising the Propeller platform, complement the Matterport scanner by providing comprehensive aerial views and capturing data for larger and hard-to-reach exterior areas. Drone captures excel in capturing extensive exterior areas and providing a bird's-eye view of the site. This capability is particularly useful for monitoring large construction sites, tracking overall progress, and identifying areas that may require attention. The Propeller platform allows for rapid processing of the captured data, enabling quick turnaround times for analysis and reporting.

Together, Matterport and drone technologies offer a robust solution for comprehensive site survey and progress tracking.

Table 17 Drone vs Matterport comparison

	Aerial Capture/Propeller Aero (DJI M3E-RTK)	Matterport
		
What does it capture?	Outdoor only	Indoor/Outdoor
Static setup location constrains	No	Yes
Capture time	3 hours (entire site and station exterior)	120 mins (station only)
Cloud processing	Yes	Yes
Processing time	Within 24 hours	Within 24 hours
How is the data accessed?	Cloud platform	Cloud platform
What is it used for?	• Tracking general progress • Site measurement • Measuring earthwork stockpile • Monitor progress and changes	• 3D virtual tour • Tracking general progress • Record keeping • Collaboration tool for general discussion
What can this be used for?	• Aerial map production • Low density point cloud production • Quality assurance for design • Quality assurance for engineering • Quality assurance for survey • Historical record keeping • Coordination with the CPS design information	• Training and onboarding • 360° imagery produced can be extracted from the E57 to be used on external platforms such as Autodesk ReCap or Cloudcompare • Historical record keeping • Coordination with CPS design information

By integrating both Matterport and Propeller technologies, the Pilot surveys enhanced accuracy by combining detailed interior scans with exterior views for a complete representation of the site. Additionally, the rapid data processing and turnaround times improved efficiency, facilitating timely progress reports and informed decision-making. The integration allows for precise interior measurements with Matterport and large-scale site measurements with Propeller, enhancing overall site management.

Due to the timing of the scans and change of process, the Pilot team was unable to track design coordination between 3D models and the scan in iModel during CPS. It is therefore unknown if coordination with the point cloud scans were completed while responding to DCRs and RFIs.

2) Effort of survey scans on Glen Huntly:

The initial scans that were done on-site as listed in the table below, met the accuracy targets as set out in the Scope Variation Report. However, due to the capture duration, it became harder to get site access at the right time to scan every discipline as required for As-Built. The fast-paced construction and site obstruction also started making these site visits unsafe the below table shows the initial scans taken with the planned TLS process.

Table 18 Initial TLS Survey time

Location	Type of Survey	Capture Type	Frequency	Anticipate Accuracy	Average Capture Duration	Post Processing Time
Neerim Rd Deck	TLS survey	Exterior	One off	5-8mm	Pivoted to drone capture	
Glen Huntly Road Deck	TLS survey	Exterior	One off	5-8mm	Pivoted to drone capture	
Area 1 - Northern Tie-in to Neerim Road	Drone survey	Exterior	Daily - weather dependant	2-5 cm	All areas captured as one within 3.0 hours	Within 24 hours
Area 2 - Neerim Road to Northern Platform	Drone survey	Exterior	Daily - weather dependant	2-5 cm		
Area 3 - Northern Platform/GH Rd to Southern Platform	Drone survey	Exterior	Daily - weather dependant	2-5 cm		
Area 4 - Southern Platform to Southern Tie-in	Drone survey	Exterior	Daily - weather dependant	2-5 cm		
Area 3 - Concourse	TLS	Exterior	One off	5-8mm/ 2-5 cm	48 hours	1 week
Glen Huntly Station	TLS	Interior	As required	5-8mm/ 2-5 cm		
Glen Huntly Flood Tank	TLS	Interior	One off	5-8mm/ 2-5 cm	55 mins	48 hours

Despite taking time on-site, the team had to also complete manual post-processing which for the single Flood Tank scan alone took 48 hours. This was due to the post-processing steps involved in scan registration, georeferencing, noise cleanup, and final quality checks, as well as addressing any errors that may have required rescanning before issuing the final product.

With Matterport implemented, the table below summarises the capture that was conducted during the CPS.

Table 19 Matterport survey time

No	Location	Date	No of Scan/Images captured	Average Capture Duration (hrs)	Post Processing Time (hrs)
1	Storm Water Storage tank	23 May 2023	15	1.5	4
2	Glen Huntly Station	06 Jul 2023	105	2.5	24
3	Glen Huntly Station	10 Jul 2023	145	3.5	24
4	Glen Huntly Station	13 Jul 2023	200	5	48
5	Glen Huntly Station	14 Jul 2023	140	3.5	24
6	Glen Huntly Station	17 Jul 2023	150	3.75	24
7	Glen Huntly Station	20 Jul 2023	132	3.0	24
8	Glen Huntly Station	21 Jul 2023	104	2.5	24
9	Glen Huntly Station	24 Jul 2023	106	2.5	24
10	Glen Huntly Station	26 Jul 2023	171	4.2	24
11	Glen Huntly Station	28 Jul 2023	200	5	48
12	Glen Huntly Station	30 Jul 2023	103	2.5	24
13	Glen Huntly Station	11 Aug 2023	114	2.85	24
14	Glen Huntly Station	18 Aug 2023	98	2.45	24
15	Glen Huntly Station	24 Aug 2023	205	5.125	48

The results show a vast improvement in scanning times on site, which helped the Survey team to access the site more regularly. The processing times using Matterport were reduced by using cloud computing instead of manual processing. The table below shows the comparison between the planned TLS process and the actual implemented effort using Matterport and the drone with Propeller.

Table 20 Planned vs Actual Scanning Solution

During CPS only	Planned	Actual	
	TLS (x7 mid setting)	**Matterport**	**Propeller Drone**
Number of scans of externals			48
Time per flight			3h
Number of scans of station in CPS	42	14	
Average scan no. per station	120	120	
Time for scan setup	120s	30s	
Time per scan	150s	30s	
Total time scanning (hours)	378	28	144

Post-processing	126	2.24	7.68
Total (Hours)	504	30	152

Besides the reduced cost of Matterport compared to the TLS planned solution, the comparison above demonstrates the quick turnaround of Matterport on site, which was the main driver for implementing this solution.

Table 21 Reduction in physical site attendance

Action	Team	Scan Information	Cost/Time Savings
Savings in effort comparing to physical presence on site. **Saving in effort for data sharing and consumption.**	Delivery team, Design team, Completion team, Survey team	Averaging 120 scans for Glen Huntly Station. 3 minutes saving per scan. Plus 3 hrs saving for post-processing per capture. 14 captures conducted over the Glen Huntly Station	14 capture x [3minsx120 scans + 180mins] = 7,650mins = 7,650min/(7.6hr x 60min) = 17 days = 1 surveyor x 17 days

3) How did Matterport support the Engineering team?

During CPS, Matterport can rapidly create a time-based platform to support the Engineering team and their stakeholders in the following ways:

- **Streamlined Workflow**: Integrating Matterport into the workflow can streamline project management from capturing, cloud processing to sharing of output, reducing errors, and enhancing overall efficiency.
- **3D Visualisation**: Matterport creates accurate, high-resolution 3D environments of physical spaces, allowing engineers to visualise projects in detail and collaborate with their stakeholders without needing to be on-site.
- **Enhanced Collaboration**: The platform enables easy sharing of 3D models and virtual tours, facilitating better communication and collaboration among team members and with other stakeholders.
- **Improved Project Documentation**: Matterport provides a comprehensive, high quality visual record of a site, useful for documentation, progress tracking, and reference throughout the project life cycle.
- **Remote Inspections**: The Engineering team can conduct remote inspections and assessments, saving time and reducing the need for frequent site visits.

Therefore, with technology such as Matterport, the Engineering team can achieve accurate, efficient, and collaborative project outcomes.

4) Unexpected impact of the drone capture on Glen Huntly.

To support the CPS process, the plan was to conduct a daily drone scan of the site to not only aid in developing progress reviews, but also build up a dataset for the final point cloud deliverable. As data became available to the Engineering, Survey and other teams during CPS, the use of the drone data through Propeller proved more widespread than initially thought.

One well documented use was within Civil Earthworks. The conventional survey process included using Total Station for surveying excavation calculations. This process involved on-site risks for the survey team and was time-consuming not only on-site, but also in the processing of the data and report development. Due to the plant movement, the Survey team would usually be unable to reach all areas of the site, reducing the accuracy in the dataset.

The drone data available on Propeller supplemented this conventional survey and reporting, effectively saving time as shown in the table below. But, more importantly, it reduced the safety risks for the Survey team on site.

Over the full Level Crossing Removal Program, there have been around 36 safety incidents that have occurred around plant, with most of these incidents involving surveyors. This reduction in site attendance for the survey team was a critical outcome for the team.

Table 22 Drone Survey Savings

Action	Team	Scan Information	Cost/Time Savings
Savings in effort comparing with convention survey method using Total Station.	Survey team	3 surveyor per shift, 2 shifts per day, 30 days during occupation/CPS	1440 hours

A second example of Civil Earthworks benefits during CPS using the drone, was in the Civil Earthworks site's progress reporting process. Conventionally, the Engineer is required to calculate excavation volumes and extract information from excavation dockets and truck record/timesheets, and crosscheck these with the conventional survey capture. However, with Propeller, the Engineer had access to a time-based desktop solution that allowed for excavation measurement which automated these checks once an excavation template was provided. This saved the Engineer a significant amount of time to complete his reviewing and reporting task.

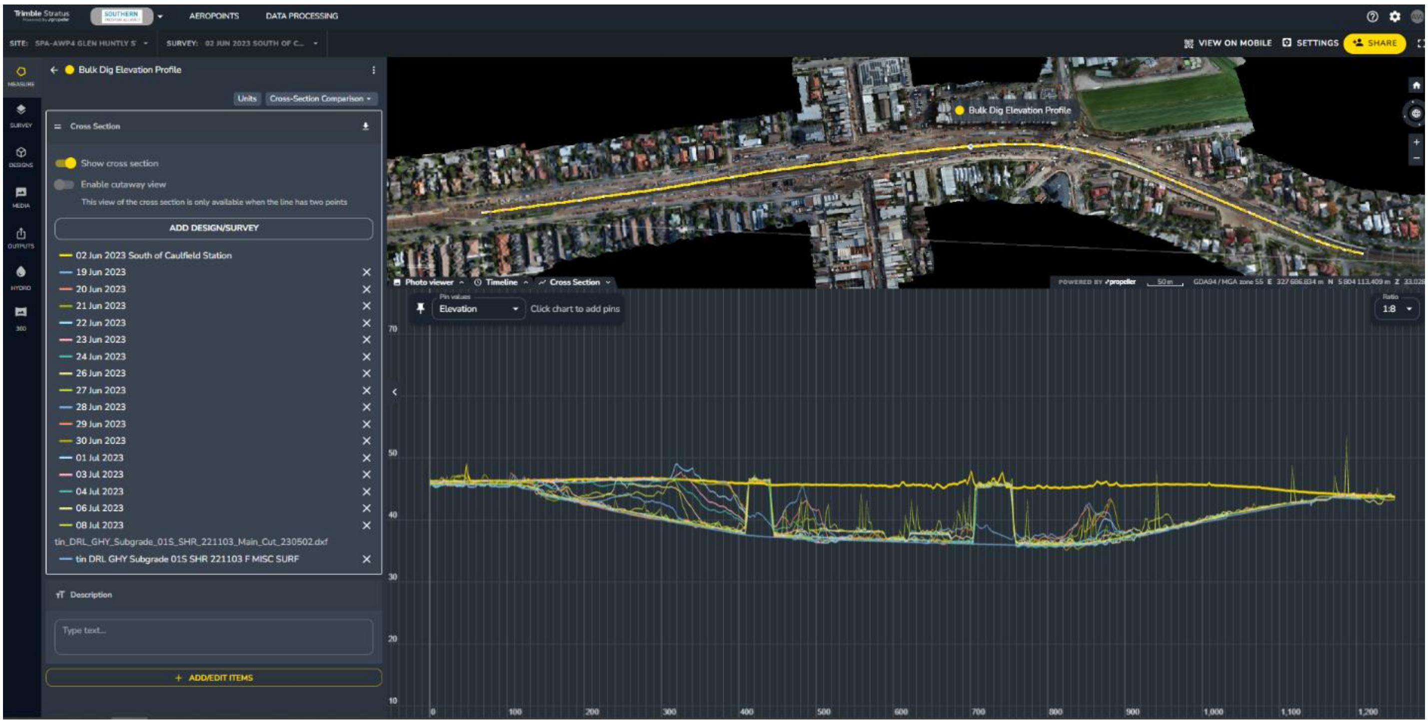


Figure 27 Excavation Measurement in Propeller

Table 23 Civil Earthwork Propeller Savings

Discipline	Platform	Findings	Savings
Civil Earthwork	Propeller	Automated progress measurement reporting tool over the 60-day occupation period. Saving of 3 hours per day on earthwork progress reporting. Note: The hours saved did not consider the savings in capturing, and the conventional processing effort.	180 hours

Total amount of savings during CPS on Glen Huntly due to the drone implementation is 1620 hours.

5) Stakeholder analysis and quality needed.

Different technologies are required at different project phases to ensure precision, efficiency, and comprehensive documentation. Throughout all phases, Matterport is essential for creating detailed 3D models and virtual tours, enabling stakeholders to visualise, plan, and track progress accurately. Drone capture is also vital from the early stages, providing extensive aerial views and creating initial detailed records of the project's extent, which are essential for planning and monitoring large areas during construction. For the final completion phase, accurate Terrestrial Laser Scanning (TLS) is indispensable, offering the highest level of detail and precision to capture the exact state of the finished project. Additionally, SLAM (Simultaneous Localisation and Mapping) technology can enhance real-time mapping and navigation, especially in complex or indoor environments. To efficiently manage and process this extensive data, Cintoo provides a robust platform for managing 3D laser scan data, and facilitating visualisation, analysis, and integration with other technologies like Matterport, drones, and TLS. By integrating these technologies at their respective stages, the project benefits from a comprehensive and detailed record, facilitating better decision-making, coordination, and project success.

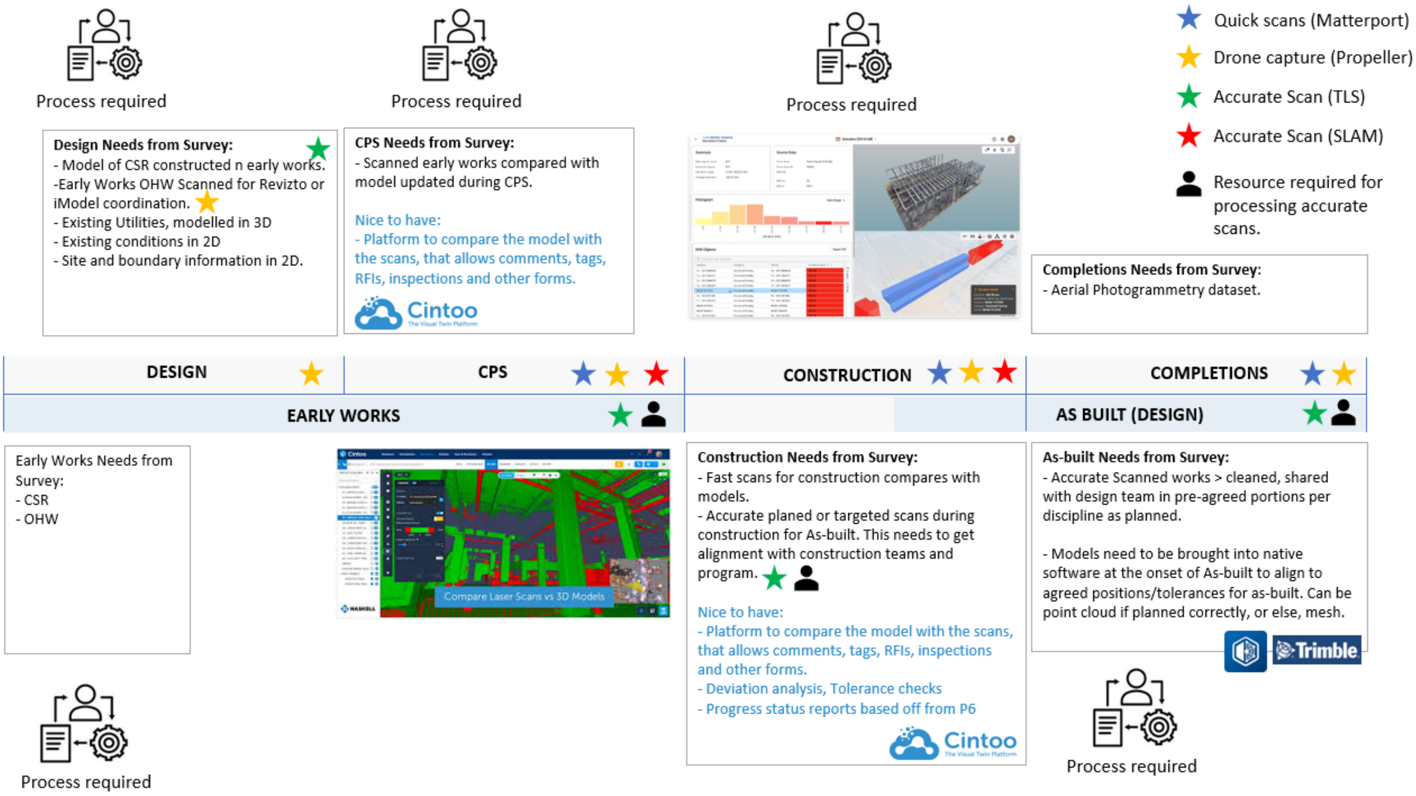


Figure 28 Stakeholder Analysis

4.7.3 Opportunity

1) Quality and Completion Propeller for asset and drawings.

Propeller enhances the quality and completion of asset and drawing management through its advanced aerial data processing capabilities. By providing high-resolution aerial imagery and rapid data turnaround, Propeller ensures accurate and detailed asset documentation. This comprehensive data helps in producing precise and up-to-date drawings, improving overall project accuracy and efficiency.

2) Final point cloud deliverable.

The opportunity to combine aerial capture with point cloud data using Bentley ContextCapture aka iTwin Capture Modeller, allows us to produce a final, comprehensive point cloud deliverable. By integrating the detailed aerial photogrammetry data captured from drones with the precise point cloud data from TLS, a unified and highly accurate 3D model of the entire site can be created. This final point cloud deliverable provides a complete and coherent representation of both interior and exterior spaces.

4.8 CPS Summary

The Pilot implementation was planned to focus on keeping 3D models and drawings alive during CPS, by making continuous adjustments as feedback from site came in, in the form of RFIs and point cloud surveys. The aim of the process was to improve coordination before and during construction, as well as reduce the effort of drawing and modelling during As-Built preparations. This required minor changes to the RFI business as usual process to allow the Pilot team to manage, coordinate and record model updates as well as uncover any lessons learned.

Secondary to the above process, Shop Detailers were required to provide a model to support in the reduction of RFIs from Shop Detailers.

Upon starting the updates, the teams faced various challenges, including clarity of scope demarcation, people challenges, as well as the Quality Assurance Process for versioning drawings during CPS, which required the team to deviate from the planned model and drawing update process. Further, challenges with access to site and the speed of construction forced a pivot in the approach to the point cloud scan process.

The Pilot revealed a deeper understanding of the nature of RFIs, and the outcome showed that using RFIs as a Key Performance Indicator for improvements made in CPS through BIM workflows, would not be a successful measure. Further, the Pilot uncovered the need for other stakeholders outside of Design and Construction to also be included during CPS, as changes to drawings during this period had a detrimental impact on time and approvals of packages.

However, the outcome during CPS showed that significant gains can be achieved during this project phase by implementing model updates and coordination. In this section the team has revealed some examples where risks were mitigated through pre-site coordination, in response to RFIs, as well as in Shop Detail model reviews.

In addition to the improvements in coordination and model updates, the pilot also highlighted how the implementation of technology significantly mitigated safety risks by reducing the need for physical presence on-site. By leveraging remote collaboration tools, fewer personnel were required to be physically present at the construction site. This reduction in on-site staff effectively minimised the risk of accidents related to plant and equipment contact, as fewer people were exposed to hazardous conditions. The use of technology not only streamlined processes but also enhanced safety by limiting the potential for dangerous interactions between workers and machinery, thereby contributing to a safer working environment.

Furthermore, an unexpected cost saving also presented itself through the implementation of drone scanning, saving the team 1620 hours in manual survey and excavation reporting. Another critical outcome was the reduction in site visits, which involves a large safety risk for the surveyors who work near plant.

5 Redlining

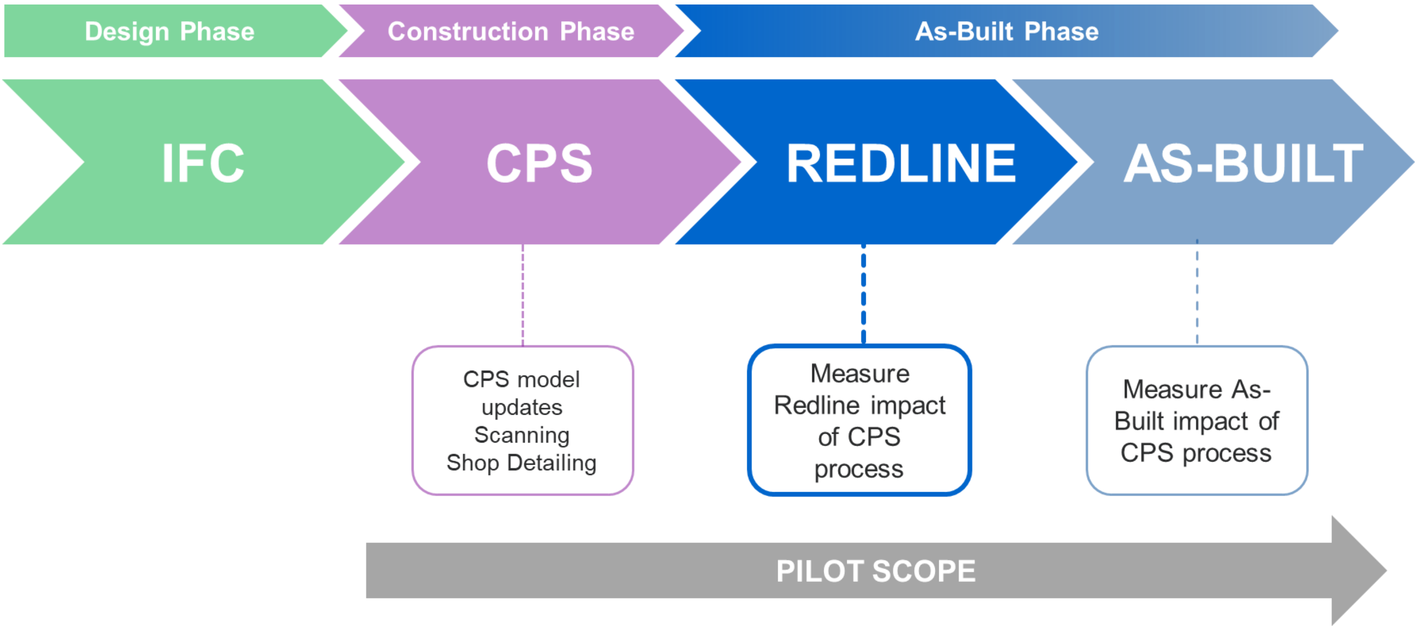


Figure 29 Project Timeline: Redlining Phase

5.1 SPA Business as Usual Redlining Process

5.1.1 Quality Assurance Procedure

Redlining refers to the process of marking up drawings to reflect changes or deviations that occur during construction. These redlines are essential for creating accurate As-Built documents.

Quality Assurance Procedure:

- Mark-Up: As construction progresses, any deviations from the latest IFC drawings are marked up on the drawings, usually in red ink or electronically using redline tools. These mark-ups may be done by the Construction team or the Design team, depending on the process.
- Review: The redlined drawings are reviewed to ensure that all changes are accurately captured. This review often involves both the Design and Construction teams.
- Documentation: Redlined drawings are retained as part of construction project documentation and are used as the basis for creating As-Built drawings.

5.1.2 SPA Redline Procedure

As per the SPA Redline Procedure: The construction records for non-signalling works must include a current version of the IFC Design Documentation with 'As-Constructed' changes (including repaired defects) marked up to scale, commonly referred to as redline drawings or redline markups (RLMUs).

Table 24 BAU Redline Process Inputs

Process	Description
Mighty Films Timelapse Camera	Utilising a timelapse camera to capture construction from a bird's eye view outside, and viewing via the cloud platform, which helped the reviewers to access time-based information imagery of construction of the area or discipline in review. This camera does however not capture everything and cannot be used by all reviewers.
Physical Site Visits	Conducting regular visits to the site for inspections and updates. For many reviewers, part of the review is to complete physical testing on systems and therefore requires site attendance.

Physical Survey Pickup	Relying on manual surveys to gather site data.
Drawing Mark-Ups	Supervisors marking up changes and updates to the latest IFC drawings and data. This can be done manually using a pen and paper, or electronically.
RFI Register Referencing	Constantly referencing the Request for Information (RFI) register to track queries and changes that may not have been provided on the IFC drawings.

Drawing mark-ups is often largely a desk-based exercise, which means staff must spend time visiting the site, conducting tests, and then travelling back to their desk for change reviews.

5.2 Initial Planned Project Processes / Requirement

The following process is cited from the Scope Variation Report:

1) The Design Pilot team shall export 2D drawings at the completion of CPS and at the completion of the 3D As-Built process. The exported updated drawings at completion of CPS shall reduce the effort of redline marking. The exported updated drawings at completion of the 3D As-Built process shall reduce the effort of the 2D drawing As-Built process.
2) The Construction team shall collaborate with the Pilot team to support the process of redline markup effort reduction.

5.3 Redlining Process Pivot

1) Original assumption or requirement

Key Metric: Redline markup effort reduced through model updates and As-Built scanning during CPS.

It was assumed that models and drawings were connected, and any updates made to the models when responding to RFIs or DCRs, or when updating models with scanned data, would automatically keep drawings updated and these drawings could be used for redlining, which would ultimately reduce the redline effort.

2) What caused a need for change?

As discussed in section 4.3, the drawing updates that could not be updated during CPS phase had a knock-on effect in testing the reduction of effort in redlining. This was due to the following reasons:

- As part of the quality assurance procedures on projects, redlines can only draw on official drawing versions such as approved IFC drawings or approved DCR drawings. Therefore, even if drawings were kept up to date during CPS through RFIs and scan data, redlines couldn't be done on these drawings.
- The key metric assumed that all disciplines were working in a full BIM environment, such as Autodesk-based software where model updates have direct connection with each drawing, forming the backdrop of the drawings. However, only the Stations teams were working on Autodesk based software and the rest on Bentley and 12D software. Bentley and 12D authoring tools do not maintain a drawing to model connection by default and it is up to the drafters and their workflows as to whether the drawings have a model backdrop or not. During the time of this project, some Bentley products had limitations to modelling and model drawing extraction.

Therefore, the Pilot team had to pivot away from the initial workflow that relied on updated CPS drawings and come up with a new opportunity to reduce effort.

3) The changed process

The Pilot team decided to make use of Matterport as a tool for the redline reviewers to use to aid their redlining efforts, by reducing their need to conduct physical inspections. Redline reviewers required to report any feedback on their experience and note if they would use the tool again in the future.

Instead of Mighty Films, Matterport was used as a desktop review tool aiming to reduce physical site visits. Matterport would then in essence replace the manual survey pickup. The Redline Engineers were still required to continue the BAU Drawing mark-up and RFI review as well as provide feedback to the Pilot team on their experience with the Pilot process.

As Matterport training started for redlines, Propeller was also included in the process as the content in Propeller (aerial capture) covers more of Glen Huntly scope than the Matterport scans, but the process and outcomes are similar.

5.4 Updated Pilot Metrics for Redlining

The following table shows the change made to the metric after the Pilot Pivot in Redlining.

Table 25 Updated Redlining Metric

Metric #	Initial Metric	New Metric
2.1	Would model updates responding to RFIs during CPS reduce redlines?	Would the use of technology such as Matterport and Propeller save redlining time by reducing site visits?
2.2	Would the model updates with scans during CPS reduce redlines?	Metric removed, as process was not implemented.

5.5 Redlining Outcomes

5.5.1 Pilot Processes Implemented

The plan was to use Matterport and Propeller instead of Mighty Films, to see if these tools supported a desktop review process with the aim to reduce physical site visits. Matterport and Propeller would then in essence replace the manual survey pickup for some disciplines. However, drawing mark-up and RFI review was still required as part of a Redlining Engineer's process. Through the Pilot, the Redlining Engineer was requested to report any feedback on this process to the Pilot team.

Table 26 Redlining Process Implemented

BAU Redlining Inputs		Matterport Redlining Process	
Process		**Process**	**Description**
Mighty Films Timelapse Camera	>	Matterport and Propeller	Utilising Matterport to give access to time-based site imagery, allowing measurements used to compare drawings with site activity. Matterport and Propeller would also replace the need for physical survey for some disciplines. The tool is aimed for use in reviews where site visits could be avoided.
Physical Survey Pickup	>		
Physical Site Visits	>		
Drawing Mark-Ups	>	Drawing Mark-Ups	Continue as BAU
RFI Register Referencing	>	RFI Register Referencing	Continue as BAU

5.5.2 Findings

1) Does availability of scans for online review reduce redlining effort?

Because redlining must be done on official IFC (or revised DCR, also called updated IFC) drawings, the physical effort of marking up drawings is not reduced when using Matterport. To reduce the drawing mark-up effort, official drawings would need to be kept up-to-date post IFC and redlines should be completed on the most up-to-date version of the drawing.

Where Matterport can support the Redline Engineer, is by reducing the number of site visits required and provide time-based information about the construction of the subject matter. This may reduce the hours spent on redlining in total. This will be examined in subsequent sections.

2) Does the use of Matterport improve efficiency in the redlining process?

The efficiency most likely to be gained using Matterport is reduction in site visits. By the time the Pilot team completed the implementation process of Matterport with for the redline reviewers, which included training and process meetings, a few disciplines had already completed most of their redlines. However, the Pilot team was able to track redlining processes and effort for 8 disciplines. The table below shows the feedback from the disciplines.

Table 27 Findings of Matterport and Propeller

No	Discipline		Findings
1	ARC	Architectural	**Matterport**
			Matterport was implemented when the Redline Engineer had already completed 92% of the redlines. Using Matterport has saved 2 hours in completing the remaining 24 pages of redlines due to reviewing of historical construction on a desktop application.
			Propeller
			Not applicable for ARC trades as aerial photography could not capture any objects undercover.
2	ETN	Train Electrical Network	BAU is based on physical construction and commissioning of the signalling system, checking everything is working physically. Then, physical redline mark-up with stamps is required for sign-off.
			Matterport did not manage to capture all the OHW construction due to time constraints.
			Propeller captured information lacking details, to assist with redline mark-up.
3	AUD	Urban Design and Landscaping	BAU is based on survey live tracking assisted by the Survey team, and any defects are fixed on the spot, with redline signed off either instantly or via the RFI process.
			Matterport where captured, used for reference only.
			Propeller used for reference only.
4	CS	Bridges, Structural Wall Signal Structures	BAU is based on survey tracking and reporting, or physical site visit for redline mark-up verification and clarification.
			Matterport where captured, used for reference only.
			Propeller used for reference only.
5	CSH	Civil Overheads	BAU is based on survey tracking and reporting or physical site visit for redline mark-up verification and clarification.

			Matterport did not manage to capture all the Overhead Wiring construction due to time and access constraints. **Propeller** captured information lacking details, to assist with redline mark-up.
5a	CSV	Civil Tanking Slab	**Matterport** did not manage to capture any of the tanking slab construction due to safety, time, and access constraints. **Propeller** captured sufficient details to assist with earthworks excavation progress reporting. See Section 4.7.2.
6	LTC	Telecommunications	Using Matterport has saved 40 hours in completing the 80 pages of redlines due to reviewing of historical construction on a desktop application.
7	RTC	Rail Track Civil	BAU is based on survey live tracking assisted by the Survey team, and any defects are fixed on the spot, with redline signed off either instantly or via RFI process.
8	SBS	Building Structure	The Matterport capture did not yield satisfactory results for comprehensive use, as it failed to capture all necessary details as shown in Section 6.3 D. Propeller also lacked details, to assist with redline markup.

The feedback demonstrated that most disciplines are required to be on-site for physical checks or live survey tracking, and the use of the desktop tools had only supported the process for a small number of disciplines.

Based on the feedback, the Telecommunications team benefited the most from a desktop-based review process. Because the Propeller results achieved similar outcomes to those of Matterport, the perceived reduction in site visits were included in the savings report.

Table 28 Telecommunications savings

Discipline	Platform	Findings	Savings
Telecommunication (MTM)	Matterport	Completed 80 pages of redlines due to reviewing of historical construction on a desktop application, avoiding frequent site visits.	40 hours

In conclusion, the integration of Matterport and Propeller technologies into the redline BAU process will only have a marginal impact on redlining. This is due to the discipline's need for physical testing on-site and conventional 2D points-based survey information.

During the Pilot process, the team was unable to calculate how much effort was spent on redlining drawings compared to other redline effort not previously considered, such as physical testing of equipment. It can be assumed that redlining effort that includes drawing markup would only be a portion of the overall effort and it would vary between disciplines.

Based on the Pilot outcomes, it is not certain whether the significant effort of keeping drawings and models live during CPS, to reduce redlining effort, would yield the expected efficiencies. Especially, when looking at rail infrastructure disciplines such as ETN and Track, where the Redline Engineers spend most of their time on physical testing on site rather than marking up drawings. In this example, drawing Redlining would be done regardless of survey and RFI 3D model updates during CPS, therefor not changing the effort required in As-Built.

3) Reduction of safety risks in redlining.

Another potential risk that is mitigated when reducing site visits is that of safety. During this Pilot period, the Telecommunications review team was able to avoid any hazards and kept their safety score in check. Examples of risks reduced for this team are detailed below:

- Hours of Driving: Engineers often need to drive long hours from site to site. This extended travel time can lead to driver fatigue, increasing the risk of accidents and impacting overall productivity. The time spent traveling also reduces the time available for on-site work and other project tasks.
- Accessing Hazardous Environments: Construction sites can pose numerous hazards, including uneven terrain, heavy machinery, and ongoing construction activities. Team members must navigate these dangerous environments to perform site inspections, surveys, and redlining tasks. This exposure increases the risk of injuries, which can lead to project delays and increased costs due to potential medical treatments and downtime.
- Examples of Previous Hazards: Slip and Fall Incidents – on previous projects, team members have encountered slippery surfaces or tripped over construction debris, leading to injuries.
- Exposure to Harmful Substances: Certain construction sites involve hazardous materials, such as chemicals, which pose health risks if not handled properly.
- Equipment-Related Accidents: There have been instances where team members were injured by operating machinery or being in proximity to heavy equipment without adequate safety measures.
- Environmental Hazards: Adverse weather conditions, such as extreme heat, heavy rain, or wet conditions, have previously created unsafe working conditions, leading to delays and increased safety risks.

5.5.3 Benefits and Value

1) Metric 2.1: Would the use of Technology such as Matterport reduce or save redlining time by reducing site visits?

The table below shows the total hours spent on redlining on Glen Huntly, with the Telecommunications team's time spent and hours saved during the redlining process using Matterport.

Table 29 Estimated Telecommunications Hours Saved

Team	Tool	Project Total hours on Redlining	Discipline Time spent on Redlining	Hours reportedly saved using Tools	Package Number
Telecommunication (MTM)	Matterport	401.4	25	40	19-LTC-8601

Although the time spent by the Telecommunications team was only 25 hours, which is 6% of the total redlining time, it is down from the potential 65 hours that were planned on being spent by this reviewer. However, this saving cannot be scaled to the entire project, as site visits depend on the nature of the discipline and the requirements for site testing and checks. However, there is an opportunity for the tool to support reviewers in reducing unnecessary site visits.

5.5.4 Redlining Summary

The knock-on effect of not updating drawings and models during CPS as planned in the Variation scope, required the team to pivot their approach to test the impact scan data in desktop applications like Matterport and Propeller had on the effort of redlining, with the aim to reduce the amount of site visits for each Redline Engineer.

The outcome of the Pilot was that the Telecommunications team saved 40 hours by reducing the need for site visits. Although the team was successful in achieving savings during Redlining, this effort could not be scaled up to the entire project to achieve a similar result.

The findings during the process implementation were that most disciplines require physical testing on-site during the redline period. Furthermore, some disciplines produce redlines on information that would not be affected by a 3D model. Therefore, the Pilot team is questioning whether the updates of the model and drawings during CPS would in fact reduce effort in As-Built as assumed for disciplines such as ETN, Track and Civil Overheads.

6 As-Built

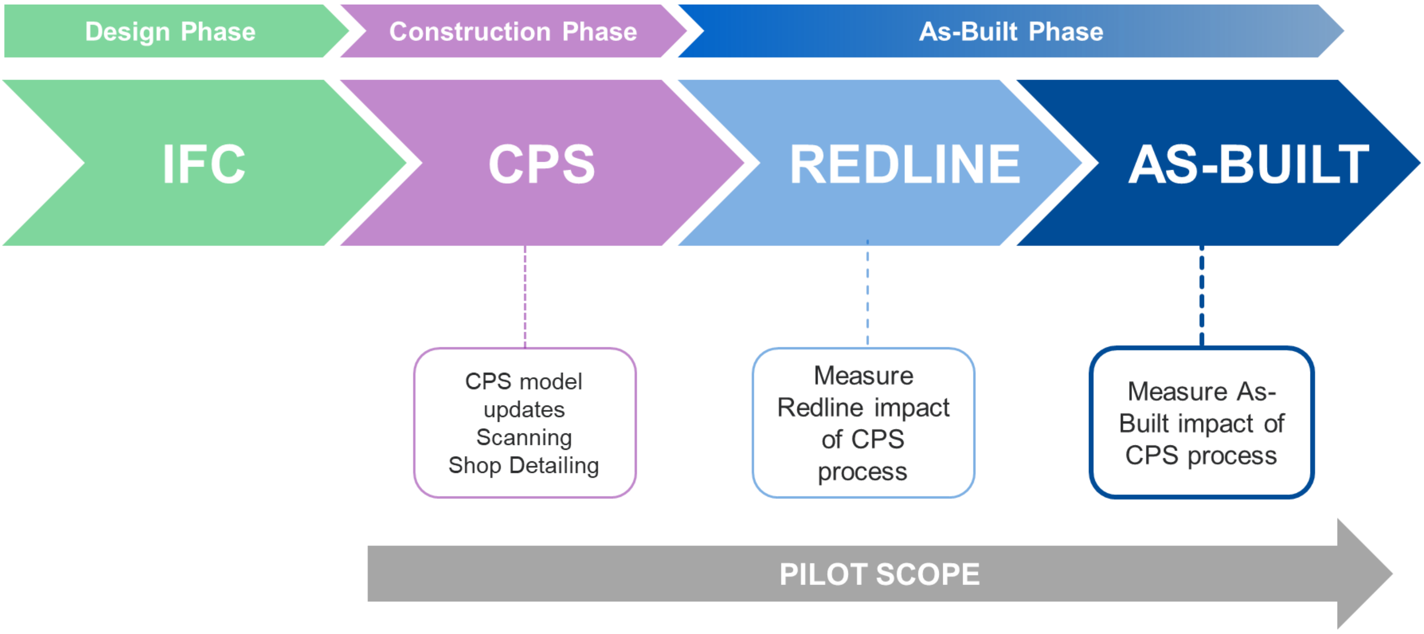


Figure 30 Project Timeline: As-Built

6.1 SPA Business As Usual As-Built Process

6.1.1 Quality Assurance Procedure

As-Built drawings are the final set of drawings that reflect a project as constructed, incorporating all changes made during construction.

Quality Assurance Procedure:

- **Compilation**: As-Built drawings are compiled using the redlined drawings and any other documentation that captures changes made during construction. The Design team or a designated As-Built team typically undertakes this process.
- **Verification**: The As-Built drawings are verified against the completed construction to ensure that they accurately represent the built structure. This may involve site visits, surveys, or comparing the drawings to other documentation, such as photographs or 3D scans.
- **Final Review and Approval**: The final As-Built drawings undergo a review process to ensure they meet all required standards and accurately reflect the constructed project. These drawings are then approved and archived for future reference.
- **Handover**: The As-Built drawings are handed over to the client and relevant stakeholders, such as Facility Managers, who will use them for maintenance, operation, and future modifications.

6.1.2 The SPA As-Built Procedure

The SPA As-Built Procedure (Non-Signalling) states:

In accordance with the Alliance’s philosophy of targeting completion from the start, all design documentation will be kept up-to-date, with any changes proposed during construction being documented as the change is approved.

The construction team will be responsible for maintaining detailed records in an appropriate format (for example redline drawings) of As-Built features for all elements of the program. The collaboration system will also be used to retain a record of all RFIs and associated DCRs which document any changes throughout the construction process.

As completion is achieved in each area of the program, these records will be returned to the Design team for incorporation and re-issue of the IFC drawings as an “As-Built” record. This process will commence as works become complete and continue through until the completion of construction to ensure that handover documents are finalised at program completion. As-Built drawings will be checked and signed off by the Construction team and then passed to MTM for review and acceptance prior to MTM submitting to DMS. It is important to note that other authorities may also be included in the review process, depending on the scope.

Further details of the processes that the Alliance will follow to ensure accurate As-Built information is entered into the DMS are included in the CPS Plan.

6.1.3 Design Team BAU Workflow

The process for starting preparations for As-Built depends on each discipline, and often, on the authoring software they use to develop drawings. As shown in the timeline below, for the disciplines that have drawings disconnected from models, such as the workflows used predominantly by Bentley users (e.g. CSR) the As-Built pre-work starts during CPS. However, the BIM workflow for disciplines using Revit (e.g. ARC), where the models are connected to the drawings, has a more linear process and follows the Glen Huntly phases.

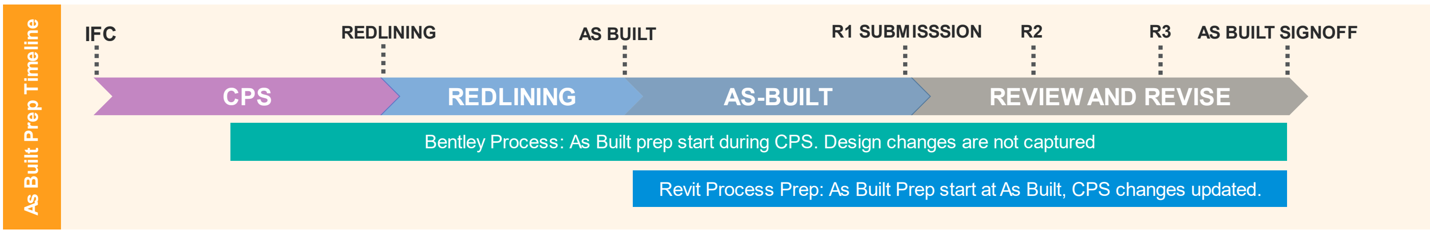


Figure 31 As-Built Prep Timeline

The main difference between the two workflows, is that the As-Built team with the CAD workflow starts copying the latest IFC files to the As-Built Environment in ProjectWise, during CPS, and starts drawing and model preparations, including the application of DMS standards. Ultimately, this results in disconnecting the models and drawings from any CPS updates including DCRs or RFIs. In comparison, in the BIM workflow, models and drawings that are used in CPS are continuously updated until the As-Built preparations start. An As-Built model will then be saved, and As-Built work will continue in this file until drawings are exported to CAD for DMS compliance.

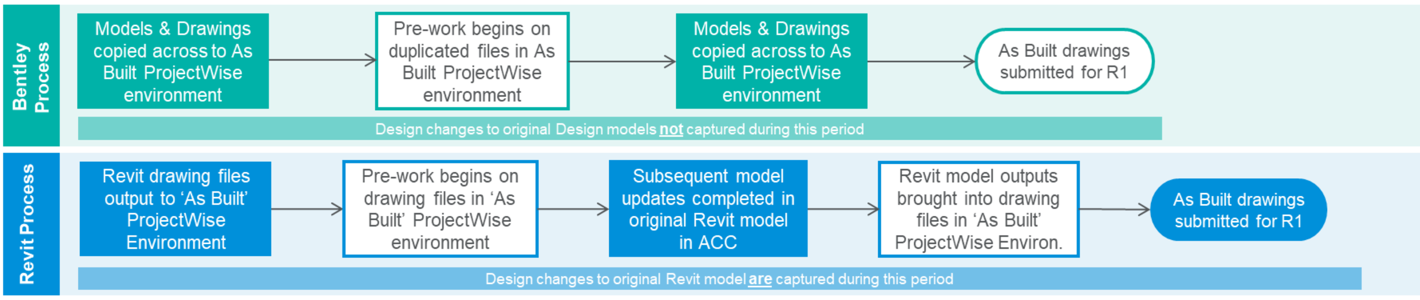


Figure 32 Revit vs Bentley As-Built Prep Process

In both scenarios, once drawings are exported for DMS standards application, they will rarely go back to model backgrounds. This means that once drawings are submitted for Revision 1 (R1) of MTM reviews, they are all disconnected from the models. As-Built teams have between the closeout of Redlining and the submission of R1 to make any changes to the models. Most disciplines will get feedback on their drawings, and most will be related to DMS compliance, including but not limited to, title block information, line styles or comments on details between redline drawings and As-Built drawings. This will send most disciplines to Revision 2, which requires adjustments and drawing re-submission. Further revisions on more complex disciplines are not uncommon. Each revision cycle requires resources and could be costly. Therefore, teams aim to reduce these cycles as much as possible, through DMS templates, and lessons learned through previous SPA project.

6.2 Initial Planned Project Processes/Requirement

The following process is cited from the Scope Variation Report:

- The As-Built team will collaborate with the Design Pilot team to generate 2D drawings from the 3D models at completion dates during CPS, and specifically at completion of 3D updates at As-Built. Focus will be on the reduction of effort of the As-Built team completing 2D deliverables.
- Support As-Built update process, from point cloud data received from Survey to Design team updates, through to As-Built model delivery.
- The Pilot team shall provide 2D drawings upon completion of CPS 3D model updates and at completion of As-Built updates to minimise the effort of redline markups.

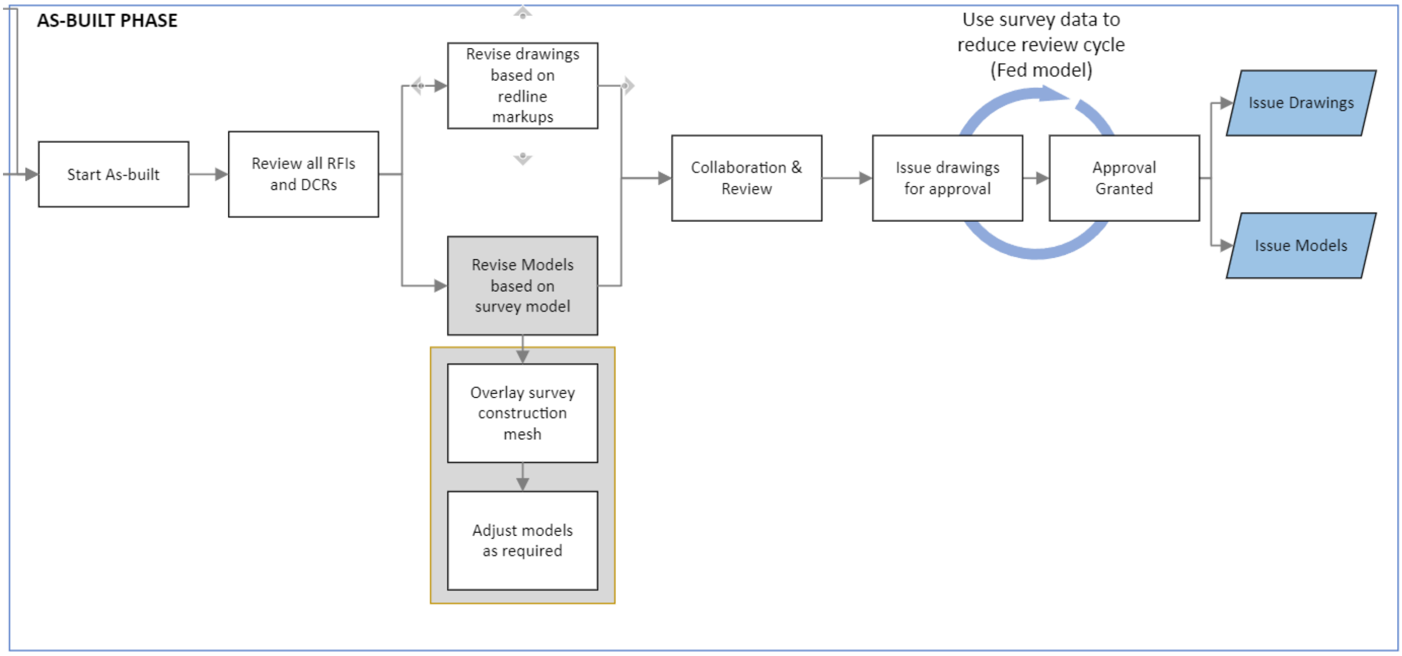


Figure 33 As-Built Process

6.3 As-Built Process Pivot

1) Original assumption or requirement

As stated in Section 6.1, the assumption was that 2D drawings would be generated through updated CPS models and used for redlining, and 2D As-Built updates. This process would result in reduced redlining and a reduced number of drawings to be updated during As-Built. This assumption would have been measured by comparing the hours and cost spent by the As-Built team.

In the Scope Variation Report, reference was made to hours spent by the As-Built teams in AWP2, and a targeted reduction of 50% of the hours spent in the As-Built phase at Glen Huntly.

Table 30 Effort of As-Built Model Updates

Team	Task	AWP2 hrs	50% Time reduction (hrs)
Construction Team	Redline mark-up and review	802.8	401.4
As-Built Team	Drafting and CAD management	31883	15941
	Designer input (RL review + As-Built + review + closeout)	1024.4	Not Reduced

2) What caused a need for change?

   a) Lack of 2D drawing updates during CPS and its use in redlining.

As mentioned in Section 4.3 CPS Process Pivot, SPA was unable to implement the process of updating 2D drawings during CPS and use these for Redlining and As-Built updates. Therefore, the estimated 50% reduction of As-Built effort could not be tested.

   b) As-Built prep/pre-work

Looking at the planned process for developing As-Built drawings from 2D drawings updated by models in CPS, as per Section 6.1, there is an assumption that all drawings are cut from the models. However, at the time Glen Huntly was designed, Bentley authoring tool maturity and workflows, and the processes for developing drawings within the Design team, did not always allow for the drawings to be cut from the models. This meant that various disciplines had their models and drawings divorced from one another. Consequently, the same procedures were used when updating models and drawings during CPS, and ultimately As-Built.

Further, when preparing drawings for As-Built DMS compliance, the As-Built team often divorced the As-Built information from CPS as highlighted in Section 6.2.1 SPA As-Built Procedures.

   c) Measurement of the benefit of As-Built updates with scans.

When the target was developed, it did not account for the continuous improvement of the Alliance due to lessons learned and Alliance efficiency improvement objectives. It also did not consider the differences in scope between the two projects. The initial target assumed there would be a 50% reduction in As-Built effort of the stations due to model updates. However, as shown in Table 31, comparing the hours spent between AWP2 and Glen Huntly, there was a natural increase in efficiency of 49%. This highlights that there will always be multiple contributing factors in efficiency, which may or may not be attributed to the use of BIM in Construction. A key factor in the reduction of hours was the difference in scope, with AWP2 involving three stations, while Glen Huntly had only one.

Table 31 Efficiency gains in Glen Huntly

Team	Task	AWP2 hrs	GLEN HUNTLY Hrs	Natural increase in Efficiency
Construction Team	Redline mark-up and review	802.8	440	54.8%
As-Built Team	Drafting and CAD management	31883	16360	49%
	Designer input (RL review + As built + review + closeout	1024.4	934	9%

3) The Change

   a) Measuring the effort of aligning models to scanned data.

Because the As-Built team could not update drawings from 2D information developed through CPS, the SPA Pilot team decided to pivot, and measure the effort of aligning the As-Built models and drawings to scanned data before reaching As-Built Revision 1.

Scanning was continuously done throughout construction, and the Pilot team started testing the conversion of the Matterport scans to meshes, required for incorporation into the Design BIM models. This step was tested on the Structural Discipline models and was created as a process to reduce the risk of hardware and software issues when working with heavy Point Cloud data.

However, it was noted that the quality of the scan was insufficient for the Structures team to adjust models accurately as required for As-Built. This was due to the point cloud level of accuracy being inconclusive instead of the 20mm accuracy required.

Figure 34 Scan to BIM Structure Point Cloud

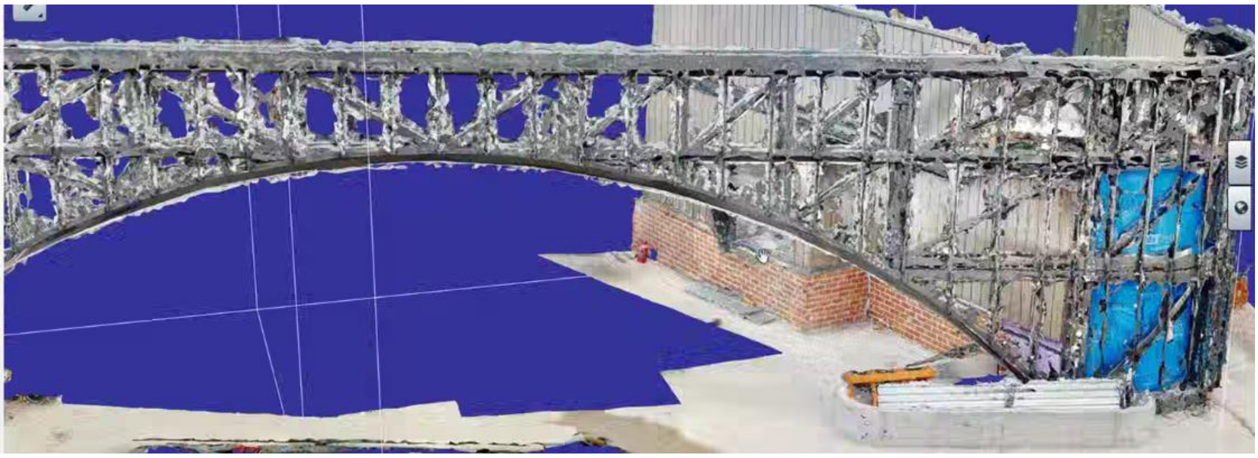


Figure 35 Structure Scan to BIM Mesh Quality

The Pilot team had to abandon this workflow to measure As-Built effort using scans, as all of the point cloud scans to date were done through Matterport.

b) Focus on Architecture for the As-Built amendments on the Pilot.

Next, the Pilot team reviewed all the scan data and decided to focus their efforts on Architecture, as most of the scan data covered the main station. By the time the scans were completed, redlining had already started for Architecture. The pivot in process then, was to compare the redlining information with the retrospective Trimble X7 scan and BIM model in

Revizto to understand if the redline process had missed anything that could result in additional revisions during As-Built. Therefore, Metric 3.2 was changed to accommodate a new measure of effort during As-Built.

c) Consider a new measurement of the benefit of As-Built updates with scans.

Furthermore, the Pilot team proposed a measure as part of the lessons learned by analysing the effort of developing As-Built documentation to understand where model updates would potentially reduce the As-Built effort.

6.4 Updated Pilot Metrics for As-Built

The following table shows the change made to the metric after Pilot Pivot in As-Built.

Table 32 Updated as As-Built Metric

Metric #	Initial Metric	New Metric
3.1	Would model updates during CPS reduce As-Built drawing effort?	No change
3.2	Would model updates during CPS and As-Built reduce the number of revisions on drawings in As-Built?	Would adapting As-Built information before As-Built Review 1 reduce the number of revisions in As-Built?

6.5 As-Built Outcomes

6.5.1 Pilot Processes Implemented

The process implemented to measure Metric 3.2: Would adapting As-Built information before As-Built Review reduce the number of revisions in As-Built?

The Pilot team developed a federation of the latest CPS 3D model and the As-Built scans for Architecture, and reviewed the differences between the redlines on drawings with the scan and the model, to pick up any missed issues during redlining. The following process was agreed on and applied by the Architecture As-Built teams. This process was implemented in parallel with the As-Built preparation and was to be completed before the drawings were exported to CAD for DMS compliance preparation and the first revision. The timing was critical because once the drawings were exported to CAD, the models would be abandoned to complete the drawing approval through the revisions.

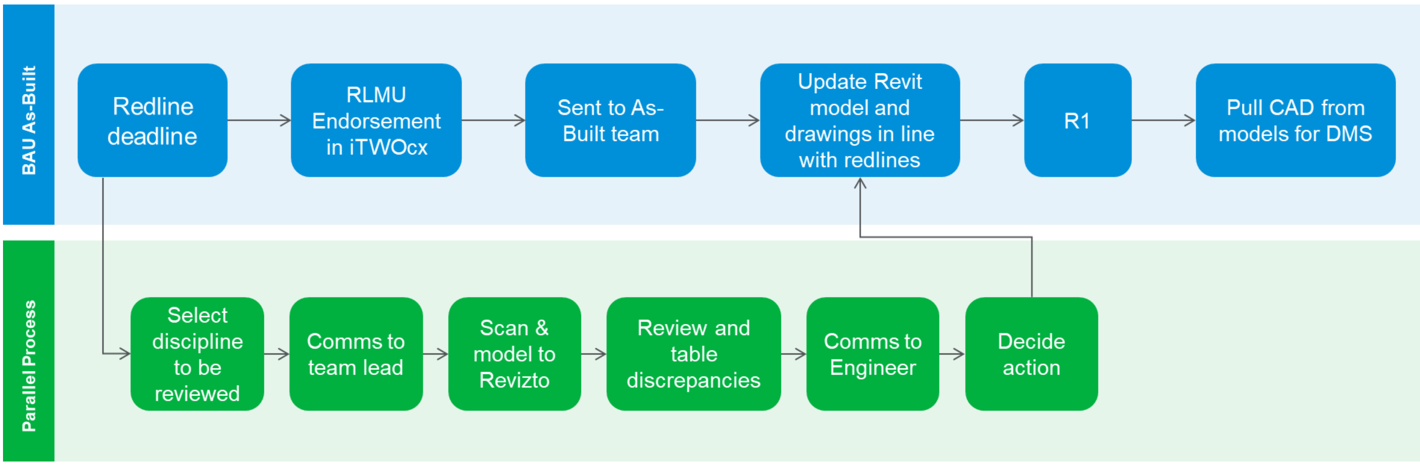


Figure 36 Architecture Redline / Scan Review Pilot Process

Any new issues discovered by the parallel process would not have been updated in the 3D model if the Pilot was not in place and would ultimately improve the accuracy of the final overall 3D model deliverable.

6.5.2 Findings

This section will review the findings of the processes implemented and answer the Pilot metrics.

1) Reviewing Metric 3.2: Would adapting As-Built information before As-Built Review 1 reduce the number of revisions in As-Built?

The table below shows the revisions of all the drawings in the 102 design packages across all disciplines on the Glen Huntly Project. Most of the design packages went through to R2 during As-Built, with only 6% of drawings reaching R4.

Table 33 As-Built Design Package and Drawing Revision Tools

As-Built Design Package and Drawing Revision Totals					
Accepted	**@R1**	**@R2**	**@R3**	**@R4**	**Total**
Design package quantity	05	63	29	05	**102**
% of design packs	5%	62%	28%	5%	**100%**
No. of drawings all disciplines	12	2,751	868	238	**3,869**
% of drawings	0.3%	71%	22%	6%	**100%**
No. of drawings for architecture	0	314	0	0	**314**
% of drawings	0	100%	0	0	**100%**

2) To answer the Metric 3.2 question, Architecture's As-Built results will be reviewed through answering the following questions:

   a) What was the result of the implemented scan to redline review process?

During the review of redlines, point cloud scans and the Architecture models, there were a total of 21 discrepancies found. To understand if anything was missed during Redlining that could impact As-Built, these 21 discrepancies were categorised as per the chart below. Most of the discrepancies found, were caused by the level of Shop Detailing (43%) that is not present in design intent or IFC models, and minor position changes (38%) that are all irrelevant for redlining. Refer to Appendix C for a detailed list of the As-Built/Redline Review Findings.

Ultimately none of the discrepancies found had any impact on As-Built and they would not have been considered for comments during As-Built reviews.

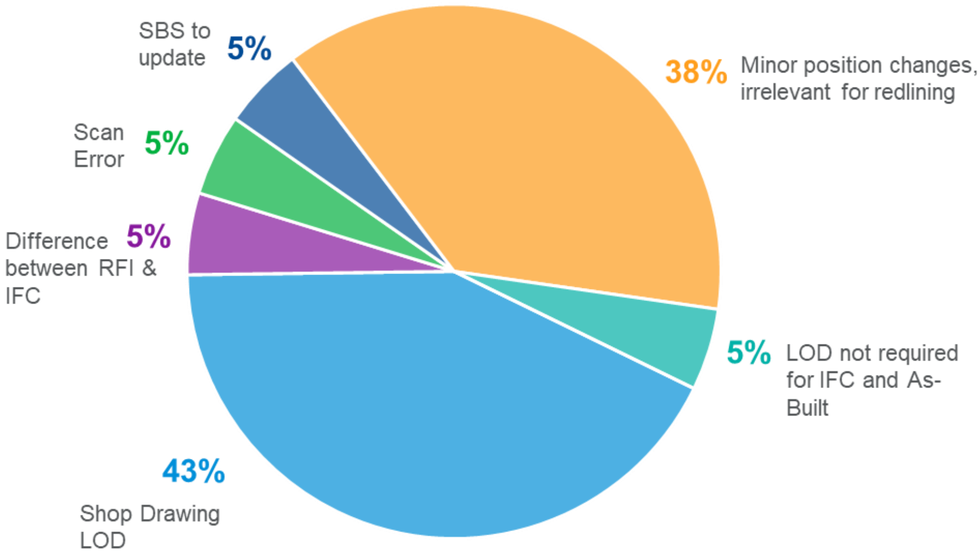


Figure 37 Redline/Scan Review Findings

Examples of the findings are shown in the images below. Figure 38 shows the minor position change of the ticket machine. This would not be picked up in Redlining because the redline check is related to whether the element has been constructed and is in working condition, rather than accuracy of the position based on the IFC drawing.

Figure 39 shows a slight change in angle of a wall that was built at the entrance of the station. Again, this is not something that would be picked up with the naked eye during a site inspection.

Further, Figure 40 shows floating lights in the model that would not be updated during CPS, as the Shop Detailing was focussed only on the structural steel and its details, and there was no impact on site for not coordinating the model at the time.

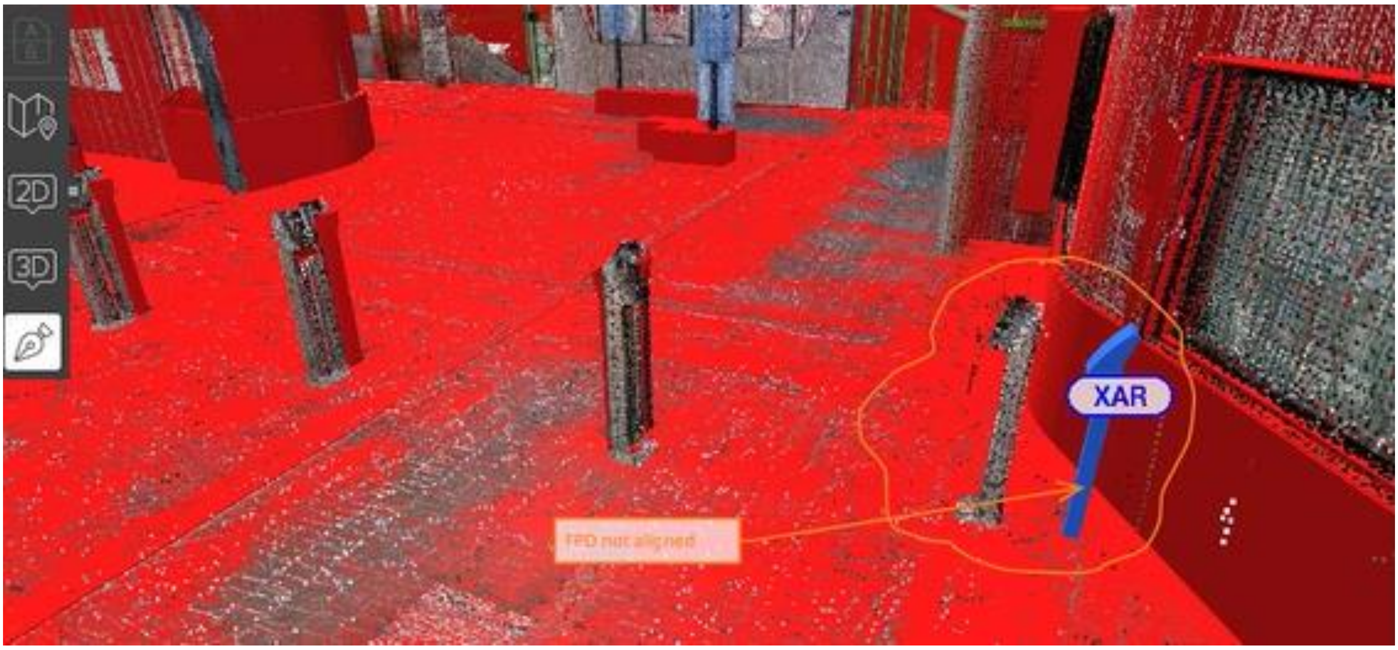


Figure 38 Minor Position Change of Ticketing Machine

Figure 39 Entrance Wall Differences

Figure 40 3D Model Light Positions

All adjustments were made in the models, which ultimately impacted 203 Architecture drawings.

b) Do the model comparisons with scan data reduce the number of revisions of As-Built?

Despite knowing the discrepancies that were found, and still updated in the models before R1, would possibly have no significant impact on As-Built reviews, the Pilot team aimed to quantifiably review the results to determine if any possibility existed for a reduction in effort.

To answer this question around reducing the revisions, focus was given to Architecture as it was the only discipline that made As-Built updates in-line with the scans before As-Built submission.

All the Architecture drawings went to R2, which is not dissimilar to the Architecture As-Built result from Chelsea Station project, with the same As-Built team and similar project scope. When compared, the number of comments between Chelsea and Glen Huntly had reduced during the 2nd cycle of reviews. The focus here is on the comments around geometrical content, because these types of comments can be prevented through accurate As-Built drawings.

Table 34 Architecture Revision comments Totals Comparison

Architecture Revision Comments Totals Comparison							
	Drawing No	**Content comments**	**TC @ R1**	**TC @ R2**	**TC @ R3**	**TC @ R4**	**Content comments %**
Chelsea Total Revision Comments	387	43	0	176	0	0	24%
Glen Huntly Total Revision Comments	314	11	0	91	0	0	12%

It is worth noting that the Architecture team always submits a full package of drawings, regardless of the number of drawings that have a revision up from R1. This is due to the difficulty in tracking which drawings have possibly been affected by updates to the 3D model. To avoid the risk of missing certain drawings that have been updated, the team submits the full package.

The table above shows a reduction of 12% of geometrical content comments between Chelsea and Glen Huntly.

Whilst this appears to be a marked improvement, it is difficult to attribute this reduction to any singular source. There are many variables which can impact the number of comments that drawings receive, including the efficiency in the As-Built process through learning from package to package. As the Design and As-Built teams improve their processes through each subsequent project, the number of comments could reduce given the greater understanding of the design, the reviewers, and the project.

Another factor which needs to be considered is that the number of comments raised can also be impacted by the person who is doing the reviews. Some design aspects may be open to interpretation and are therefore at the discretion of the reviewer to comment on or accept. As an example, some reviewers may have several queries but comment within one review comment, where others would create one review comment per query, resulting in more comments.

In conclusion, the findings are inconclusive. As a result, the implemented process would have most probably not resulted in a reduction of review comments for the Architecture team during As-Built, because the discrepancies found in the comparison between the scan and redlines were negligible. Also, due to the many variables contributing to As-Built reviewers' comments during As-Built reviews, a successful reduction in reviews would be difficult to attribute solely to a more accurate 3D model by using point-cloud scans.

3) Reviewing Metric 3.1 Results: Would model updates during CPS reduce As-Built drawing effort?

   a) Does working from updated CPS drawings reduce the As-Built preparation effort?

The only drawings that are updated during CPS are drawings that have been formally submitted through a DCR process. This is a separate process to the works undertaken as part of the Pilot. Therefore, the Pilot was unable to test the impact of updated CPS drawings on As-Built. Review Section 4.3 for more information.

   b) Did the CPS 3D model updates reduce the As-Built drawing preparation time?

As mentioned in Section 6.3, the authoring software used to develop the design has a big impact on how As-Built preparation is done. To understand this impact, Architecture, representing Revit-based workflows preparation, will be compared with CSR As-Built preparation, representing Bentley-based workflows.

Updates on Revit-based models used in Architecture, are connected to the drawings, so the updates must occur on the model information to produce the drawings. This means that updates done during CPS for RFIs or DCRs did have a potential impact on As-Built drawing preparation effort.

CSR models (Bentley) are copied across by the As-Built team into a separate ProjectWise folder specifically for the As-Built phase and converted to 2D data at the first submission gate for As-Builts. Any subsequent updates are only done on those disconnected 2D files, so no reduction in time can be attributed to RFI model updates in CPS.

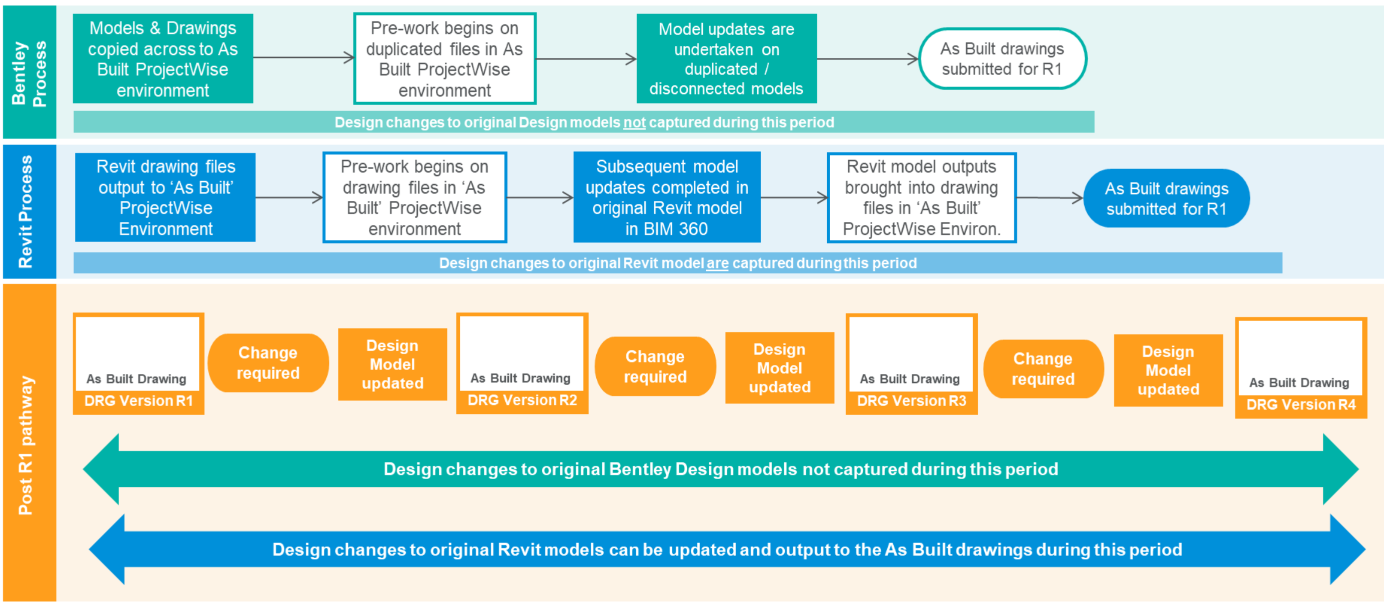


Figure 41 Revit and Bentley Authoring Tool As-Built Prep Process

Ultimately, the reduction in effort depends on authoring software and the As-Built team's preparation process. Reduction in effort is not easy to measure as there are many variables to the effort required during As-Built preparation, including RFI, DCR reviews, DMS compliance, drawing and modelling.

On this Pilot, the Architecture and other Revit teams have mentioned improvements, but the improvements weren't documented or accurately measured during the Pilot. Further, the disciplines using the Bentley authoring tool did not see any reduction in effort. Therefore, the results are inconclusive. Based on the Pilot experience, there will be a direct correlation between As-Built effort saved and the effort in updating the models over BAU in CPS which can be seen in Section 4.5.4.

c) Replace the STR Steel Design model with the Shop Detail model for As-Built.

Another test during the Pilot was to understand if shop detail models could replace As-Built design models, as they are more detailed, coordinated, and more up-to-date than IFC design models. The Pilot team had a workshop with the Station Structure Design team to understand the impact if the Structural Steel Shop Model produced on the Pilot could be used to replace the Structural Steel IFC model for As-Built.

The outcome of the session concluded the following impact on As-Built effort for structural steel:

- Because the Structural Steel IFC models were created in Revit, where the drawings are connected to the models, the replacement of the model would require a full redraw of 2D information on drawings, and this would not be feasible during As-Built.
- As-Built reviewers will reject the drawings because the detail is significantly different from the drawings used for Redlining and IFC.

Due to the above-mentioned reasons, the Pilot abandoned this option to improve As-Built update effort for structural steel.

6.5.3 Benefits and Value

1) The value of Metric 3.2: Would adapting As-Built information before As-Built Review 1 reduce the number of revisions in As-Built?

   a) Was there a reduction in effort in developing As-Built drawings based of the scanned model?

To measure reduction in effort in developing drawings, one needs to assume that the workload decreased. This would have only been the case if the official drawings (IFC and DCR) were kept up to date with As-Built information during CPS and Redlining. Based on the process implemented in the Pilot, this couldn't have been achieved. Therefore, there were no reductions in effort.

It is important to note however that adjusting the models in-line with scanned data during As-Built increases the effort for the team, due to an increase in accuracy not picked up during Redlining.

This means there was a 41.5% increase in effort and cost to align As-Built information to scanned data. Looking at the specific information that did require an adjustment, the changes were all minor, and will not impact maintenance on the facility, see Appendix C.

A Pilot recommendation would be to focus on disciplines with services underground, and disciplines with key equipment or data points that are digitally controlled. From our experience on SPA, any As-Built 3D models that are passed down for refurbishing or upgrades of a facility during its life, may be helpful to achieve a conceptual design, but may not reduce the future effort for new surveys and models to be developed to progress a design.

2) The value of Metric 3.1 Results: Would model updates during CPS reduce As-Built drawing effort?

   a) Had the Pilot been implemented in full, and all models and drawings kept up-to date, what would the potential reduction in effort have been?

In the table below, the actual geometrical content-related comments during As-Built in Glen Huntly have been compared with the drawing-related comments to see which disciplines could benefit from implementing model updates during CPS, what information is required for successful As-Built, the ratio of comments during review, and the potential cost savings per discipline.

Table 35 Actual Potential for Influence on As-Built Cost

Architecture Revision Comments Totals Comparison

Discipline	Authoring Tool	Would updated models have	# of comment	Content	Drawing	Other	Package code	Max. potential influence on cost on As-Built
Architecture	Revit	Yes	109	27%	67%	6%	19-ARC-7601	2.3%
Structure	Revit	Yes	133	3%	92%	5%	19-SBS-8701	0.5%
Building Services	Revit	Yes	61	9%	87%	4%	19-BSG-8301	1.4%
Railway Track and Civil	Open Rail	No	487	9%	58%	33%	Multiple	5.3%
							Total	**10%**

As shown in this table, the maximum potential influence on cost for effort during As-Built preparation on Glen Huntly would have been around 10% of the As-Built budget but realistically, it would have been much lower. This is due to the portion of work that needs to be done on the drawings for DMS compliance, CPS change reviews and other variables that would not have changed if a model was kept up to date with As-Built scans during CPS. The potential is less than 10% of the As-Built budget, making the target of reduction in effort on this project less probable.

The baselining of the cost of As-Built should be compared with projects that are identical in scope. It should then be considered that only a portion of the effort in As-Built is adapting geometric content that relates to Redlining. Most of the As-Built effort is spent on amending drawings for DMS compliance. Many of the comments after R1 also relate to DMS compliance rather than accuracy of geometric content for most disciplines.

It is also important to note that As-Built reviewers use the latest version redline drawings to compare As-Built drawings. Any discrepancy in the location of items or changes that may have occurred after Redlining which are not captured in a redline, is subject to reviewer rejection. In the Architecture package's case, this would result in re-issuing the full pack. So, if As-Built models were to align with survey scans, the information may be more accurate, but the As-Built documentation process may be subject to an increase in the time, effort and review cycles before As-Built is approved. The recommendation would be to ensure that all stakeholders on a project are part of the process, and a change management process is implemented across the board to reduce the rejection of information and potential rework during As-Built.

In conclusion, an estimated 10% of As-Built time is spent on adjusting geometric content-related information; the rest of the time is spent on other As-Built effort, including the review time for changes during CPS, which will not be affected if CPS models were adjusted to As-Built scans before the As-Built team started preparation. As such, the impact of changes during CPS and Redlining processes would perhaps not have the large impact on the reduction of As-Built effort assumed. With a large majority of effort in As-Built being spent on change reviews and DMS compliance, a recommendation would be to test solutions to support the reduction on effort here instead. However, the Pilot would suggest ensuring that models are kept updated at As-Built, with the latest survey information to support the data's ongoing use in a project life cycle.

6.5.4 As-Built Summary

An assumption as set out in the Scope Variation Report was, if models were kept up-to-date with the As-Built scans during CPS, the effort would be reduced during the As-Built phase. Due to challenges implementing the planned process in CPS, the team had to pivot their approach to improve the accuracy of the models for As-Built. Further challenges arose when the team discovered that the BAU As-Built preparation varied between authoring tools, with Bentley based disciplines' workflows divorcing models from As-Built drawings much earlier than the Autodesk based disciplines, and before red-lining was complete, ultimately leaving them out of the Pilot for testing. Further, the only completed point cloud scans that covered an entire discipline was the station's Architecture, which made them the focal point for Pilot investigations. The process implemented was to compare redlines with scan data to see if anything was missed in Redlining, with the hope to reduce the revisions in As-Built reviews.

The outcome of the investigation was that the Architecture team did identify some efficiencies in As-Built preparation, but the team was not able to quantify this efficiency. Further, the findings of the scan to redline comparison was inconclusive, because not only were the 21 discrepancies negligible for Redlining purposes, but the drawing package required a re-submission for As-Built due to DMS compliance, rather than accuracy of the content of the drawings.

Even though measuring the improvements of geometric content comments between the Chelsea Station project and Glen Huntly proved a 12% reduction in geometric content comments, the improvements could not be attributed solely to the Pilot due to many variables involved in reviewers' comments.

For Architecture on the Pilot, there was a 41.5% increase in effort, without any efficiency gains in the As-Built process. Based on the experience on this Pilot, it is concluded that amending models to scans is an additional effort, regardless of project phase. Furthermore, with the drawing version restrictions placed on projects due to the Quality Assurance procedures, adapting models and drawings in CPS carries a risk of delays and costs.

In this report it was determined that less than 10% of the budget for As-Built would have been a target for reduction in effort if the Pilot was implemented through CPS, Redlining and As-Built as planned. This is since only a portion of the As-Built effort is spent on the content of the drawings, with most time spent on DMS compliance and CPS change reviews.

The two main recommendations for increasing efficiency on As-Built production are:

- To focus As-Built process enhancements on disciplines such as Drainage and CSR, specifically due to their authoring tools and BAU processes, but also due to their impact on the asset life cycle changes and maintenance for the Operator and Client.
- To ensure that all stakeholders on a project are part of the process, and a change management process is implemented across the board to reduce the rejection of information and potential rework during As-Built.

7 Project Wide Outcomes

7.1 Project Wide Outcomes

This section summarises the tangible outcomes of the Pilot project.

7.1.1 Pilot Metrics Outcome

The table below summarises the outcomes of the Metrics established to meet the Pilot Objectives.

Table 36 Metric Outcome

Metric #	Metric	Outcome
1A	Assumption: In the Pilot, clash RFIs will be reduced due to model clash detection.	The Pilot has highlighted that while BIM models can support a reduction in clashes on-site, not all clashes can be prevented with BIM. This is because the level of detail required in the models for construction coordination is much higher than the level of detail required in the design phase to convey design intent. Relying purely on the design intent models for coordination, would not be sufficient to find all clashes that could possibly occur on-site.
1B.1	Would coordination with Shop Detail models reduce Shop Detail RFIs on Glen Huntly?	The results show a reduction in RFIs relating to steel and lifts. However, there are various efficiencies gained by doing multiple projects one after the other, and therefore there would have been multiple variables that needed to be considered before attributing the reduction of RFIs to the Shop Detail model coordination alone.
1B.2	Would the Pilot cause a reduction in RFIs due to modelling being updated during CPS?	If models are kept up to date, it would only impact marginal amounts of RFIs due to their nature. Therefore, the benefit and value of models updated in CPS should not be tied to RFI reduction but rather its impact on risk reduction. See Section 4.5.4 for the risks reduced through the process.
2.1	Would the use of technology such as Matterport and Propeller save redlining time by reducing site visits?	Savings were found for the Telecommunications team using Matterport but this saving cannot be scaled to the entire project, as site visits depend on the nature of the discipline and the requirements for site testing and checks. But there is an opportunity for the tool to support reviewers in reducing unnecessary site visits.
3.1	Would model updates during CPS reduce As-Built drawing effort?	An estimated 10% of As-Built time is spent on adjusting content-related information, the rest of the time is spent on other As-Built effort such as CPS change reviews and DMS compliance, that would not change if CPS models were adjusted to As-Built scans before As-Built documentation preparations As such, the impact of changes during CPS and Redlining processes would not have the large impact on the reduction of As-Built effort as assumed. With a large majority of effort in As-Built being spent on change reviews and DMS compliance, a recommendation would be to test solutions to support the reduction in effort here instead. However, the Pilot would suggest ensuring that models are kept updated at As-Built with

		the latest survey information to support the data's ongoing use in a project life cycle.
3.2	Would adapting As-Built information before As-Built Review 1 reduce the number of revisions in As-Built?	The findings are inconclusive, as a result, the implemented process would have most probably not resulted in a reduction of review comments for the Architecture team during As-Built, because the discrepancies found in the comparison between the scan and redlines were negligible. And, due to the many variables contributing to As-Built reviewers' comments during As-Built reviews, a reduction in reviews would be difficult to attribute to the success of a more accurate 3D model by using point cloud scans.

7.1.2 Value for Money Results

Due to the Pilot processes, Glen Huntly was able to prevent various risks on site during its CPS phase. These are not direct savings and would not reduce the cost of construction or CPS but are rather reductions in unmitigated risks. As tabled, the documented risks avoided include:

Table 37 Value of Unmitigated Risks avoided

Phase	Risk Avoided	Report Section	Value
CPS	Coordination issues resolved before construction	Section 4.5.4	$ 1.3M
CPS	Surveyor safety risks avoided around plant	Section 4.7.2	Reduction in safety incidents for Surveyors
Redlining	Utilities safety risks avoided on Site	Section 5.5.3	Reduction in safety incidents for Utilities

It is important to note that not all the risks avoided could be calculated with a monetary figure, but their value far outweigh the direct cost savings on Glen Huntly. For those where a figure was provided, the figure would be a calculation of the worst possible outcome.

7.1.3 Budget Management

During CPS, the Pilot budget was managed by the Engineering Manager, who also assumed the role of the Pilot's Project Manager. Like most of the Pilot team, the Engineering Manager's Pilot responsibilities were carried out alongside their responsibilities as Engineering Manager for the Glen Huntly Project. Consequently, there were beneficial overlaps, notably the same person leading RFI activities during the both the Pilot and delivery of the Glen Huntly Project.

Due to the unknowns of a new pilot scope and process, and the cost impact it would have on the stakeholders involved in CPS, the Pilot team was unable to accurately forecast the effort required to deliver the Pilot outcomes. As a result, they held off from booking their management time to the Pilot.. Therefore, the money spent on the Pilot would not reflect the true cost of the implemented process.

This cost also does not include the indirect cost of the Pilot team, including managing the Pilot, the implementation of the Pilot processes, clarifying project scope, and reporting on Pilot progress.

After CPS, the remaining DNOP budget was rearranged to equalise the amounts to be used for the As-Built budget.

Like CPS, the Pilot team refrained from booking to the Pilot during the As-Built phase to ensure that all deliverables could be met.

7.1.4 Opportunities Found

Despite facing challenges and needing to pivot from the initial plan, the Pilot found several opportunities for improvement and risk reduction through this type of 3D model process implementation, supported by quantifiable results:

1) Potential for risk reduction in CPS:

- Early works and underground: Due to the sequence of works, especially early works construction , there is a need for instant turnaround of As-Built model development of Utilities, Drainage and CSR information for coordination and risk assessment. This coordination would provide significant value in reducing the risk of strikes on site. This process would require a dedicated modeller to model and share information as soon as it is surveyed, with the stakeholders accessing these models through the project federated model. These models should be at an appropriate level of detail to capture all elements that are existing on-site. A construction process that should be implemented alongside the BAU Before-You-Dig process, would consist of a review and coordination of this federated model before works commence on site.
- Shop Detailing: Although the models provided a benefit to coordination and reviews of Shop Detailing information, this process did not reduce the time the reviewers were idle while waiting for information, or the risk of scope gaps between the design and the procured specialist scope. There is an opportunity to procure the Shop Detailers during the design period, preferably between Gate 2 and IFC, to coordinate in full and deliver IFC and Shop Detail drawings in short sequence. This will iron out any gaps and speed up the approval of the Shop Detailing information.

2) Latent value of time-based point cloud data.

The value of the Matterport and Propeller data captured during construction will not be understood for a long time, but some of the latent benefits of the data includes:

- Matterport helps the Completions team to find covered pipes from the capture during the CPS. These scans show exactly where the pipes are located, days or weeks after they're buried or covered. The team can do virtual walkthroughs to check for any issues without being on-site. This makes it easier to catch mistakes, collaborate with others, and keep a record of construction for future reference. One example was determining if a pipe (Drainage) was installed and what its location was. The survey was not only able to prove it had been installed but able to provide indicative measurements for the Engineers on-site to locate.

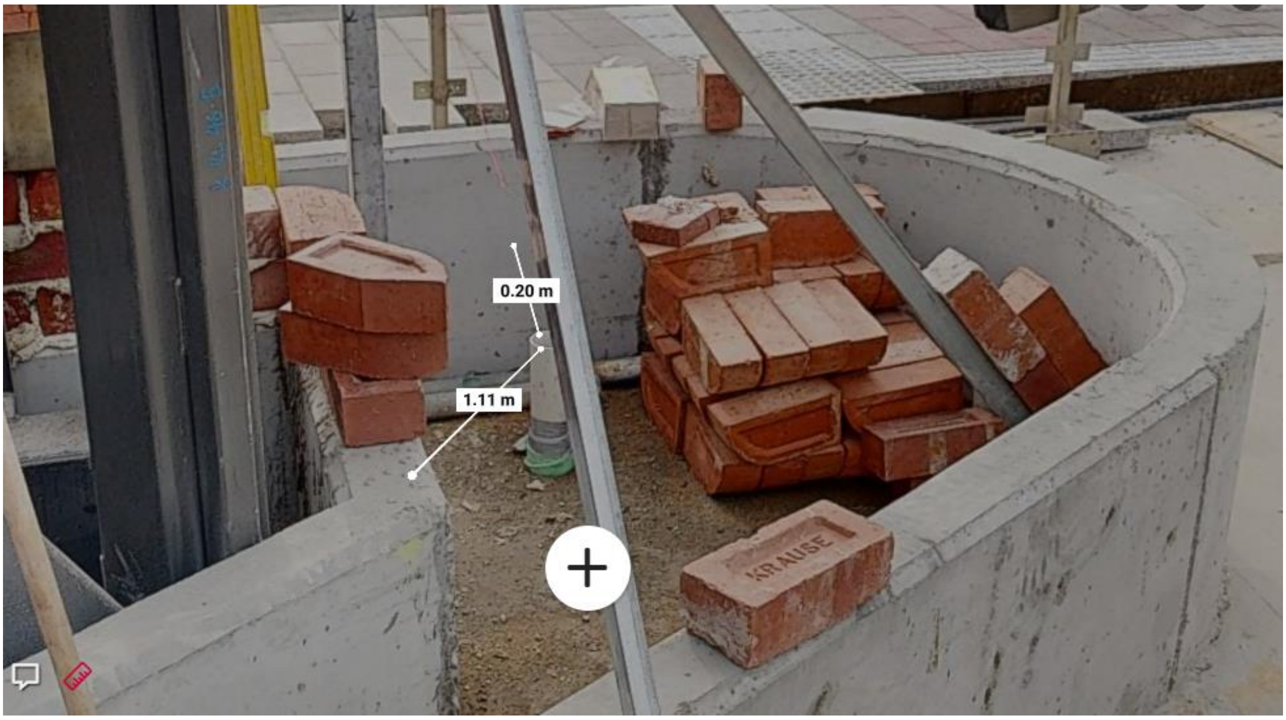


Figure 42 Measurements in Matterport

- We're currently assisting an insurance claim on behalf of LXRP to cover the delays and damages caused by the rain during last year's May, June, and July occupation. This claim, centred on weather-related disruptions, is supported by comprehensive drone flyover videos and detailed footage. These resources will provide an in-depth analysis, ensuring the claim is backed by the most relevant and precise information available.
- The Glen Huntly data can be made available to LXRP for their record at Completions.

7.1.5 Pilot Obstacles

The implementation of the Pilot process encountered the below obstacles which ultimately impacted the ability to derive value during the Glen Huntly project phases:

1) Change Management: The low level of Change Management on Glen Huntly pilot reduced the level of engagement of various stakeholders on the project throughout its lifecycle.
2) Impact on CPS Document Approval: The role of models in the Quality Assurance process for CPS drawings was not fully considered. This led to confusion and extended discussions to find solutions, without settling on a decision on the way forward. The absence of clear guidance and agreement among stakeholders caused some disciplines to pause model updates or reduce their involvement in the Pilot.
3) Documented BAU Processes: There were no documented processes for BAU activities related to the Design team's responses to RFIs, software requirements for DCRs, or coordination during CPS. In response, the Pilot team developed a process within iTWOcx to trigger notifications for the Design team's required updates. Once they received the trigger notice, the Design team would adjust their models but often did not share the information with the rest of the Design team or involve the Pilot DE team for coordination. This was because the DE team was not part of the BAU CPS or DCR process.
4) Speed of construction, and the low level of awareness from Construction, resulted in missed opportunities in scanning activities that could be performed to meet the planned procedures, causing the team to find new solutions.
5) During an occupation, there are time constraints to respond to RFIs, as works may be on a critical path. Teams need time to get resources, or models updated and coordinated, leading to extended response times to RFIs, which often holds the construction team up. Therefore, issues often had to be resolved on-site, resulting in retrospective updates where coordination in the model could not have been used to support the process.

8 People Factors Affecting the Pilot

This section will detail the people factors that impacted the pilot throughout the life cycle.

8.1 Change Management

Project Management, which focuses on the technical side of change, and Change Management, which focuses on the people side of change, both play critical roles in change success. The costs and risks of mismanaging change by ignoring the people side of change can be significant, impacting not just project outcomes, but timelines, budgets and more.

The implementation of the Pilot comprised mostly of communication of the Project Management and technical side of Pilot activities. The notice of the Pilot was given during the close-out of the development of IFC, in the Glen Huntly Design Phase. This communication was mainly in the form of presentations around the planned deliverables, and the planned team at each phase, with the targets that had to be achieved, as well as discussions around budgets. The Pilot project was only signed off for start after the CPS phase had already begun, giving the team a short notice of change.

However, Change Management is much more than communicating what is changing, such as the implementation of a BIM process. All stakeholders on a project must be supported through their transitions from the current state (BAU) to the future state, and understand what is needed to influence each person to embrace and adopt the change. In this way, a project can significantly increase the chances of success and their project investments paying off.

The Pilot missed the implementation of a plan to manage the people side of change. Ideally, all project stakeholders should have been involved in mapping out what BAU was and the various dependencies they had on one another. Then the team would list the improvements in the BAU process that were required, and where the implementation of a BIM processes could have supported this improvement. From here, a targeted process, as well as roles and responsibilities, should be created and assigned amongst the team to implement the change. One important role would have been a Change Manager, who would be responsible for keeping communication channels open between stakeholders and leading forums, to manage changes in process or tracking progress during a project life cycle.

This way of management would have:

- Improved the understanding between BAU and what is expected form the Pilot.
- Improved communication amongst the team.
- Integrated the DE team further into the BAU process of CPS, Redlining and As-Built.
- Increased the potential for opportunities to be developed for testing on the Pilot.
- Improved documenting and tracking of benefits and their reporting during the life of a project.

8.2 Staff Changes

During the life of Glen Huntly, the Pilot was subject to staff turnover, which impacted critical roles such as the Project Sponsor, the Project Manager, Leads, and Management Support roles. These changes sometimes occurred multiple times, and some roles were removed completely after staff left SPA. The org chart below demonstrates these changes, and the amount of role changes over time.

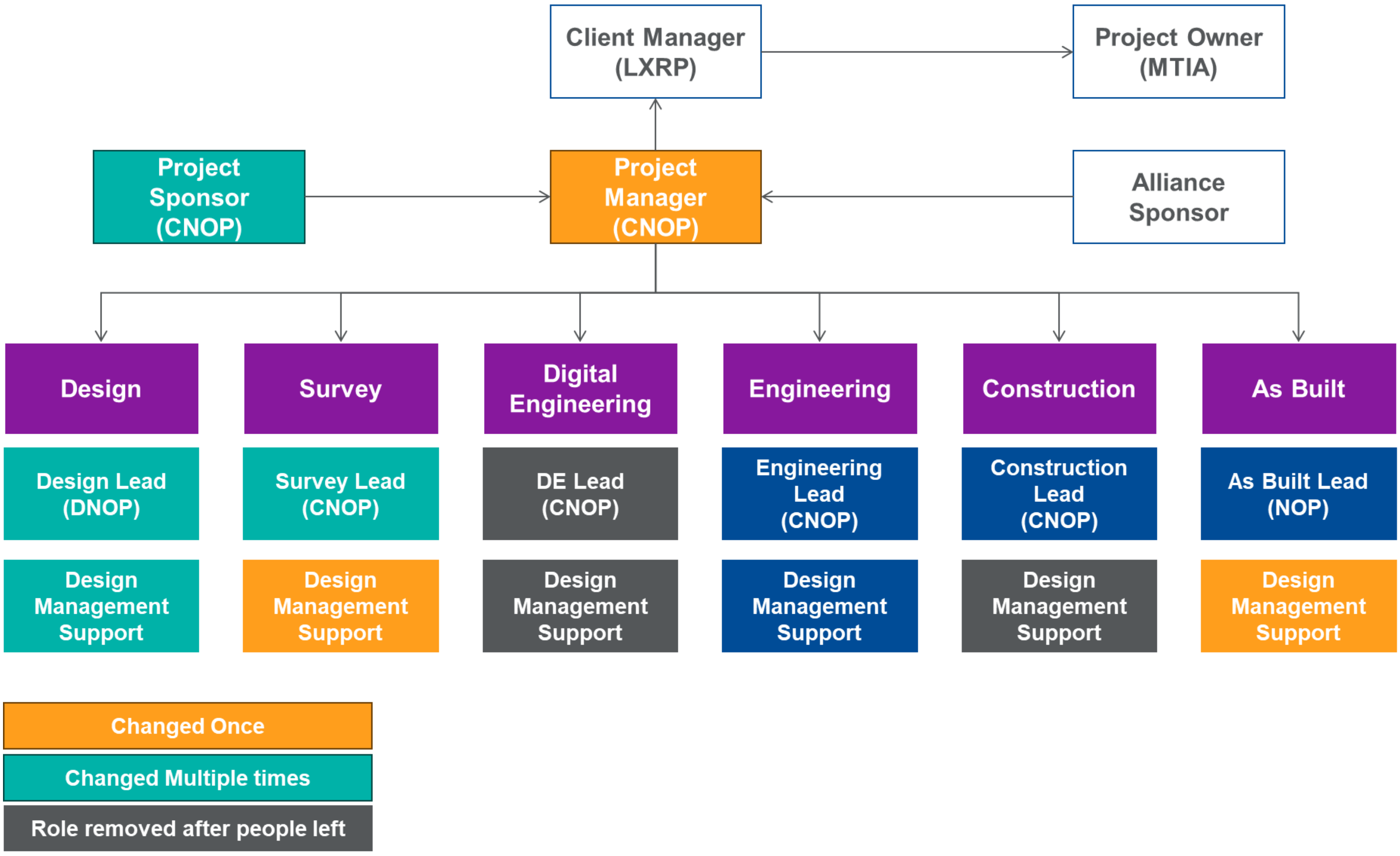


Figure 43 Staff Changes

The impact of the turnover on the Pilot depended on the role that changed. For instance, the Project Sponsor was a critical role on the Pilot, and it carried the history of the scope and agreements on process and budget. This however was hard to document and handover, especially if the role was not filled before the initial staff member left. This caused the remaining project team to be unsure of their roles, and the Pilot scope. This workload was also then picked up by others who were not previously aware of to the information required to effectively lead the Pilot.

Any change in process during a project is often driven by the Project Manager, therefore when a change in this role happened, there was always a reduction in effort towards the Pilot. Additionally, those who remained driven, struggled to deliver value, affecting team morale.

Further, the supporting roles were important to guide the Pilot team around the activities and processes undertaken by the various teams in CPS, Redlining and As-built. With these roles changing, communication between the Pilot teams and the Delivery teams reduced, impacting their effectiveness in delivering the Pilot outcomes.

8.3 Roles and Responsibilities

As mentioned previously, the low change management resulted in reduced clarity around the roles and responsibilities of not only the Pilot team, but also all other stakeholders interfacing with the Pilot in Design and Delivery.

The impact thereof was far-reaching, and included the below:

- Complete handovers were not done when staff changes occurred because staff were not aware of their expected responsibilities.
- Teams were not aware of the dedication required for certain tasks, resulting in a decreased engagement in the Pilot.
- Some inconsistency in the approach to Pilot tasks, as teams implemented what they saw fitting in their own context and experience, instead of what would be important for reaching the Pilot goals. This also impacted the consistency of outcomes that could be documented and measured.
- Meeting goals with the end in mind, reduced the Pilot's efforts in implementing processes that could impact subsequent phases, ultimately reducing the Pilot's performance.
- Increase in cost of tasks, as it was hard to distinguish roles between the Pilot tasks, and those of BAU.

- Decreased effort to find value during CPS, as teams were unsure what their involvement in the Pilot was, and who they should speak with if they did have any opportunities to discuss.

8.4 Project Assumptions on Processes

The Scope Variation Report lists various targets required to be met, assumed a process for implementing tasks such as RFI activity and assumed the impact that would have on subsequent project phases.

Stakeholder analyses weren't done before project initiation to check the soundness of the assumptions when the scope was created. As a result, official project procedures, such as the Quality Assurance Procedure, were missed, which had a big impact on the implementation of the Pilot activities in CPS. This then had a knock-on effect on the ongoing project's success for reducing effort in As-Built.

8.5 Pilot Trigger Events

A Trigger Event in a project is a specific event or set of circumstances that signify the need for action. Agreed trigger events are important as they serve as a warning sign or a signal that prompts Project Managers to initiate predefined actions to mitigate risks, address issues, or take advantage of opportunities.

When the Pilot kicked-off there was only one trigger event defined, and that was the planned process for notifying the Design team of an RFI for inclusion on the Pilot during CPS, using iTWOcx. Although an RFI open and closeout process was presented and planned initially, this process did not include the selection criteria for the Pilot Project Manager to use when making decisions around what should be included in the Pilot or not. The lack of the selection criteria proved to have a big impact on what was included and as mentioned, caused teams to make decisions based on their immediate needs on the Glen Huntly project, instead of the Pilot life cycle.

Further, trigger Events for Redline start, and As-Built process start was assumed to coincide with the As-Built program. And, as the outcomes of the Pilot heavily relied on the outcomes of CPS, the Pilot teams kept focus on the CPS procedures and updates and started planning on Redline and As-Built a month before the scheduled start of these phases. Unfortunately, because the Pilot Leadership teams were disconnected from the As-Built and Redline teams, they were unaware of some of the processes within As-Built that start earlier during CPS, such as the preparation of the CAD workflows for Bentley users on Glen Huntly. Further, due to a pivot in process after Redlining started; the team missed out on measuring the outcomes of the pivoted process for many of the disciplines.

This resulted in a lesson learned in understanding all the procedures and stakeholders before a project starts. As a result, the team recommends mapping out the full life cycle of a project and all the stakeholders involved in the three project phases at the start of a project and developing a communication plan and trigger events that are agreed upon by all stakeholders on future projects.

9 Lessons Learned

The following table lists all the lessons learned throughout the Pilot, and direct recommendations for future projects. The table has been structured to categorise each lesson and establish a root cause, whereafter an analysis is done on the dominating factors that impacted the Pilot implementation. The recommendations listed per lesson will be summarised in Section 10 Recommendations.

Table 38 Lessons Learned

Nr	Phase	Category	Lesson	Action Took	Root Cause	Recommendation
1	1. Pilot Start-up	People	Resourcing the 3D As-Built Pilot has been challenging due to the change in Workflow and the number of Additional Work Packages SPA are currently delivering.	DE team collaborated with the design team to action each RFI as required.	Resource Planning	**Recommendation 1:** Dedicated resources provided with allocation of hours to focus on specific tasks related to the pilot. Continuity of staff is essential.
2	1. Pilot Start-up	People	Establishing scope and approval from ALT and LXRP taken a long time to come thru, as result, CPS started and Shop Detailers were appointed before the Pilot commencement, reducing the implementation of the Pilot scope in these areas.	Pivot our approach and process to get a benefit from what was available at the time.	Timing	**Recommendation 2:** Establish processes and procedures for Shop Detailers to align with prior to contract award and commencement of the project.
3	1. Pilot Start-up	Process	Due to the timing of the pilot kicking off after IFC, design models were not 100% coordinated at the outset of the pilot. This made it very difficult to track if clashes were relevant or if they were the result of a knock-on effect of not being done correctly to begin with.	Models were audited and the model status was documented at IFC. Some models were updated to comply with the audit findings while others were not due to the requirements not being in place prior to the completion of IFC designs.	Timing	**Recommendation 3:** Ensure all scope requirements are agreed upon and in place prior to Design kick off.

4	1. Pilot Start-up	People	Identification of risks were not conducted before commencing pilot.	Pilot team had to constantly pivot processes to work around the issues.	Stakeholder Understanding	**Recommendation 4:** Clearly define roles and responsibilities prior to the outset of the project to avoid communication breakdown across stakeholders.
5	2. CPS	People	It has been identified that the knowledge of design processes, Engineering expectations and construction requirements in regard to the 3d model, has been disjointed.	Several Collaboration meetings have been established to highlight & mitigate some of the Communication breakdown.	Change Management	**Recommendation 4**
6	2. CPS	Process	Delineation between BAU and requirements of pilot regarding post IFC 3d model updates are being established. Discussion between RFI and DCR updates and how the 3d model reflects changes as part of BAU.	Process diagram developed to enable design team to understand what is regarded as BAU and what is part of the pilot has been established.	Process and Procedures	**Recommendation 4**
7	2. CPS	Technology	Early identification of how models are (in some areas, specifically Bentley open series) updated post IFC (i.e. MicroStation 2d updates) without the 3d model capturing changes.	A systems review was undertaken by the BIM team to establish gaps and mitigation processes are being reviewed.	Technology Process	**Recommendation 5:** Ensure that projects are implementing a model first approach to ensure drawings are extracted from the models. s.
8	2. CPS	People	Due to slow responses to RFI model updates, and the fact that the Engineering manager who is responsible for RFIs was the Pilot PM, less RFIs were added to the Pilot, as his perception of the value of model updates seemed to decrease.	A review of the criteria for choosing RFIs was undertaken and the complete list of RFIs was checked to see if any retrospective updates could be done to add value to the pilot process	Process and Procedures, Resource planning	**Recommendation 6:** Establish & produce guidelines to clearly define what should constitute a 3D model update arising from an RFI rather than leaving it open to interpretation.

9	2. CPS	People	Project Management couldn't focus on the Pilot, as their main focus was on construction of the project, resulting in monthly reports not being generated on-time and not documenting actual progress or issues on the Pilot.	PM of the Pilot was handed over to DE team who then took charge of managing the updates.	Roles and Responsibilities	**Recommendation 4**
10	2. CPS	Technology	RFI Reports were incorrectly reporting for 3 months due to RFI Reporting tool sync issues in SharePoint. Links between SharePoint and PowerBi needs to be reviewed regularly to ensure data is correct. This may have also been due to a user license issue.	Manual push from excel to PowerBi, and license issue has been resolved.	Process and planning	**Recommendation 7:** Reporting tools need to be quality checked on a regular basis.
11	2. CPS	People	Pilot leadership engagement: Challenge in maintaining regular Engagement with key Stakeholders throughout the Pilot	The DE Team took charge of the leadership of the Pilot and focused on implementing specific tasks to keep up the ROI.	Staff turnover, Roles and responsibilities	**Recommendation 5**
12	2. CPS	Process	Implementing model-based processes over BAU in construction phase services was met with reluctance. This is due to not having stakeholder buy-in from construction and clear change management to ensure the change is happening.	The Pilot team implemented parallel processes that didn't always meet a ROI.	Change management	**Recommendation 8:** Wider awareness of the pilot across the Project team. Support from the ALT to ensure the correct processes and procedures are in place.
13	2. CPS	People	Measuring ROI on the Pilot turned out to be complex. There is no exact way to measure the impact of BIM during CPS and Construction due to its risk reduction capability, and the human factors and overlapping efforts from BAU practice involved in	Retrospective KPIs were developed, and time spent on these efforts weren't always accurately measured.	Scope Clarity, Missing KPI	**Recommendation 9:** Develop clear and concise and measurable KPIs prior to the outset of a project and keep track of its progress monthly.

			the process. Further complicating the matter, the budget for the Pilot only applied to Pilot processes and not BAU, while BAU was not an actual documented process.			
14	2. CPS	People	Low understanding of the wider picture and how the pilot is tied to future development and Glen Huntly's construction because these phases of the projects are historically siloed in their approaches. The project missed the change management to improve this way of working.	The Pilot team took action on a case-by-case basis and tried to work with the teams as much possible to implement a process or technology to achieve value for the client.	Change Management	**Recommendation 4 & 8**
15	2. CPS	Process	Adjusting the RFI and DCR process to capture & identify model updates	Discussions & coordination meetings to understand the implications of changing the current redlining process led us to discover that the Quality Assurance process does not currently allow for redlines to be undertaken on uncontrolled versions of design drawings.	Change Management	**Recommendation 10:** Coordinate with all relevant stakeholders to map out any change in process required. Evaluate the Quality Assurance Procedure for future projects.
16	2. CPS	Technology	The team should have identified the 3d modelling disconnection from drawings in the Design Development phases and planned the CPS process accordingly.	Review of current modelling practices and discussions with all disciplines to understand the issues they are facing with model updates in CPS.	Timing, Process and Planning,	**Recommendation 11:** Appropriate authoring tools should be selected at the outset of the project design phase to achieve the project goals.
17	2. CPS	Technology	Scan data for 3D model updates: The time and resources it took to scan, process and integrate with the federated models, were underestimated, and we realised there was less chance of coordination	We pivoted to Matterport, focus to site reviews through Matterport for construction and new processes for redlining and as built.	Technology review and planning, Stakeholder Understanding	**Recommendation 12:** Develop a resource plan based on planned tasks. Select suitable hardware & software capable of completing the work.

			impact during CPS if the planned process was kept.			
18	2. CPS	People	Management of budget allocation between disciplines: Due to new/unclear scope, the first few RFIs saw a large budget spend which had to be rectified. This resulted in a reluctance to spend on the pilot as no one understood where the budget would be allocated to: Pilot or Project.	Most of the Pilot teams resorted to not book to the Pilot and let their cost be absorbed by the rest of SPA work, while doing Pilot work, for a fear of overspending.	Scope clarity, Process and Planning	**Recommendation 13:** Produce documentation that clearly outlines the differences between BAU and the Pilot.
19	2. CPS	Process	RFI: AWP4#0145 - Understanding scope of Pilot: Understanding of As-Built scope & process was unclear at the outset of this RFI. A DCR was created which in turn led to a cost overrun from what was initially expected.	The team became stricter on what RFIs were allocated to the Pilot.	Scope clarity	**Recommendation 13**
20	2. CPS	Process	RFI selection criteria: Criteria for deciding what should be considered as part of the As-Built pilot should be developed to give clear guidelines on what should be considered as requiring a model update to gain some value from the process. This will require collaboration between Design and Construction/Engineering teams.	A review of the criteria for choosing RFIs was undertaken and the complete list of RFIs was checked to see if any retrospective updates could be done to add value to the pilot process	Process and Procedures	**Recommendation 6**
21	2. CPS	Process	Tracking & quantifying actual effort: Through completing this RFI model update process and communicating with the Design team, we are realising that there are currently some model updates that are being done outside of the pilot. Teams tend	Improved communication between Design team and pilot team to better understand the processes that were in place. Review of models updates that	Change Management	**Recommendation 13**

			to update some models and book that time to CPS rather than including it as part of the pilot. This makes it difficult to track and quantify the actual time and effort associated with managing these updates post IFC.	were undertaken that could have added value to the pilot.		
22	2. CPS	Technology	Matterport E57 geolocation: The exported point cloud from Matterport lacks coordination, posing challenges for the survey team during the importation of the E57 file into their survey coordination software for further processing	Coordination with external software such as Trimble Business Centre	Technology constraint	**Recommendation 12**
23	2. CPS	Technology	The time it took to clean the point cloud to filter out unnecessary captures was underestimated. Such as foot traffic from construction personnel, to generate a more meaningful reality mesh that can be compared with the 3D design model	Manual cleanup which is very labour intensive	Technology review and planning	**Recommendation 12**
24	2. CPS	Process	Impact of RFI model updates on drawings. The current redlining process does not allow for redlines to be completed on uncontrolled drawings and must take place on the approved IFC drawings.	Discussions & coordination meetings to understand the implications of changing the current redlining process led us to discover that the MTM quality assurance process does not currently allow for redlines to be undertaken on uncontrolled versions of design drawings.	Process and Planning, Stakeholder Understanding	**Recommendation 10**
25	3. Scanning	Technology	Construction teams were under pressure on the program, as a result, not all areas and elements can be captured as part of the 3D scanning process due to missing support from	Process shifts to Matterport to improve scanning times	Process and Planning	**Recommendation 8**

			construction teams and lack of access during construction to specific areas and time it takes to do a scan with the Trimble X7.			
26	4. Redlining	Process	Change management and Process implementation: The perception that project phases are linear has impacted our ability to implement Matterport at the right time to ensure redlines will be part of them.	Review of technology & process. Document issues.	Change Management	**Recommendation 4 & 8**
27	5. As-Built	Process	While successful importation of the E57 point cloud file into Autodesk ReCap has been achieved, there is a need to structure the capturing/scanning sequence to ensure seamless registration of Matterport's E57 with Autodesk ReCap station.	Manual coordination with coordinated point cloud of other data source	Technology review and planning	**Recommendation 12**
28	5. As-Built	Technology	The transformation of the point cloud into a reality mesh requires a powerful and dedicated desktop processing system to ensure efficiency in processing and sharing of results.	None	Technology Constraint	**Recommendation 12**
29	5. As-Built	Process	As-Built team copied files to their environment long before the closing out of CPS. Even if files were kept up to date the As-Built team wouldn't have known about it and the CPS model updates wouldn't have been used for As-Built.	Discussions with As-Built team to understand the process so the disconnect could be documented	Process and Planning, Stakeholder Understanding	**Recommendation 14:** Review As-Built process alongside the pilot processes to ensure alignment between workflows.

30	5. As-Built	Process	CSR: It is more efficient to update models directly from survey CAD file than amending the existing CPS model when developing an As-Built.	All As-Built model to be done off the approved As-Built drawings and survey.	Process and Planning	**Recommendation 15:** Produce As-Built model from As-Built Survey model upon completion of construction. In the interim the As-Built survey model can be brought into the federated model to assist with coordination and clash detection.
31	5. As-Built	Process	Drainage: As-Built drawing and models are redone in accordance with an X-Ref survey file instead of redlines to provide a more accurate As-Built. This has been proven to be more efficient than amending the latest approved drawings or models.	None	Technology Constraint	**Recommendation 15**
32	5. As-Built	Process	Updating 3D models to reduce the number of Review iterations would only be relevant to Revit models (ARC, SBS, BES etc.). Subsequent updates on Revit based models are connected to the drawings so the updates must occur on the model information up to the first revision. All other models (Bentley etc.) are copied across and converted to 2D data during CPS - any subsequent updates are only done on those disconnected 2D files.	We focused our findings on Architecture to evaluate the impact that be achieved through this process.	Process and Planning	**Recommendation 5**
33	6. Project Wide	People	Support and understanding of the pilot from key stakeholders within SPA, has lost momentum. Due to not understanding future impacts / value	The DE Team took charge of the leadership of the Pilot and focused on implementing specific tasks to keep up the ROI.	Change Management, Staff Turnover	**Recommendation 4**

			and change in SPA stakeholder personnel.			
34	6. Project Wide	Budgeting	Pilot budget wasn't used or booked to the code because team members were cautious due to the budget overrun early in the pilot. The construction DE teams absorbed the cost.	Discussions with team to understand the hesitancy to book hours so that the reasons could be documented	Scope Clarity, Budget Forecasting	**Recommendation 16**: Ensure that the project team is aware of the breakdown of timesheet codes and their uses. Accuracy of time booked is essential.
35	6. Project Wide	Budgeting	DE Teams didn't book to the Pilot, to ensure there was enough money for the design and Engineering teams to complete the work	Discussions with team to understand the hesitancy to book hours so that the reasons could be documented	Scope Clarity, Budget Forecasting	**Recommendation 16**

9.1 Lessons Analysis

All the Pilot lessons listed in the previous Section in the can be categorised between Process, People, Technology and Budgets. As shown in the chart below, most lessons learned were around issues with people and process. This result is not surprising, as this report has already established the need for more detailed Pilot procedures and increased change management that has impacted the Pilot outcomes.

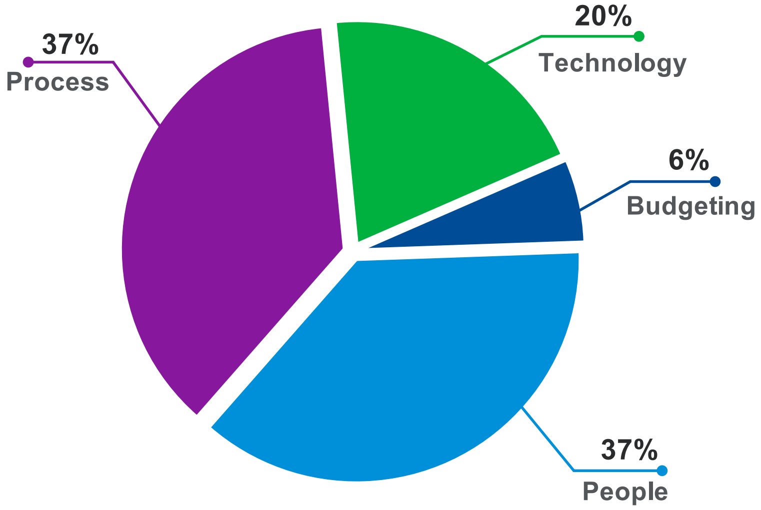


Figure 44 Lessons Category Chart

When looking at the root causes of the lessons, it can be deduced that planning and procedures, change management and scope clarity were the biggest contributors to issues on the Pilot. Had these three main root causes been addressed, other issues would have been caught early or addressed at an appropriate time to reduce the impact it had on the Pilot.

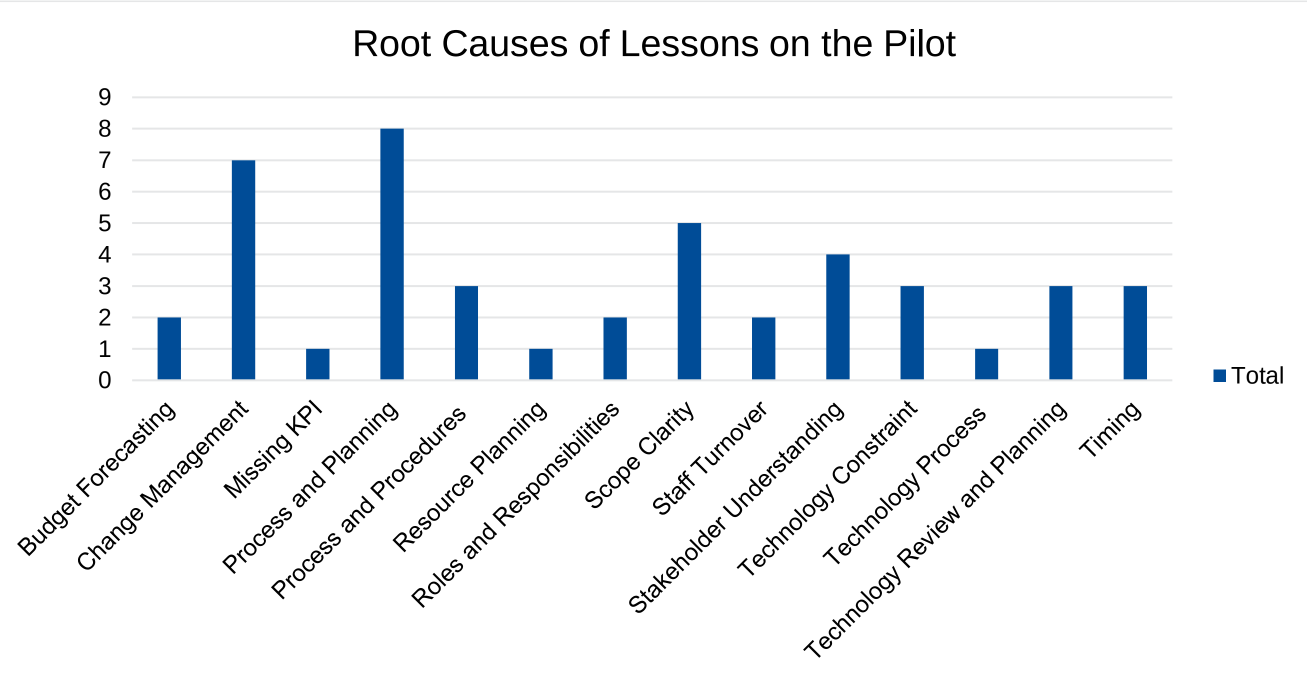


Figure 45 Root Cause Chart

Therefore, the recommendation for future projects is to focus on Scope Clarity, Planning and Procedures and Change Management. The following sections will go into more detail around some of the lessons learned and their impacts.

9.2 What Worked Well

Although the Pilot team learned various lessons throughout Glen Huntly, it must be acknowledged that there were many things that went well, which was why the team was able to reduce risks and make savings. These included:

1) **Monitoring and Adjustment**: The DE teams from both DNOP and CNOP consistently monitored project progress and promptly adjusted when goals were not met. This approach ensured the Pilot stayed on course.
2) **Importance of Coordination in the CPS Process**: Our active participation in the CPS process allowed us to track coordination efforts and understand their impacts, which directly informed our recommendations for future projects. This underscores the value of being closely involved in coordination activities.
3) **The Use of Unplanned Innovations**: Although initially unplanned, implementing the drone survey and Propeller provided valuable time-based survey data that benefited both the Survey and Engineering teams. Being open to incorporating new tools and technologies can lead to significant advantages, even if they are not part of the original plan.
4) **Continuous Feedback, Process Mapping, and Stakeholder Engagement**: Regular feedback during the Pilot led to actionable changes in the SPA BAU beyond the Glen Huntly project. Additionally, mapping out the full process and engaging stakeholders helped identify gaps that were later addressed in other projects. This approach not only enhanced SPA personnel's understanding of BIM's impact on their project scope, but also enabled the DE team to implement new procedures. Maintaining consistent communication, thorough process mapping, and active stakeholder involvement are essential for driving improvements and ensuring project success.

9.3 Project Process

1) **Timing of initiating the Pilot**: The pilot was initiated after the Issued for Construction (IFC) phase and months after CPS on early works started, resulting in design models that were not coordinated to the degree needed for coordination in CPS. This made it difficult to distinguish relevant clashes from those caused by initial coordination issues. Future pilots should be initiated earlier, ideally before the IFC phase, to ensure that models are fully coordinated and to avoid complications during the pilot.
2) **Clear scope demarcation**: There was a missing clarity in understanding the scope of the Pilot, leading to cost overruns and misaligned expectations. Clear scope demarcation is critical to avoid misunderstandings and to ensure that all involved parties are aligned on the objectives and boundaries of the Pilot from the outset. This includes establishing selection criteria for RFIs to ensure they are relevant and valuable to the Pilot.
3) **Delineation between BAU and Pilot requirements**: The distinction between BAU processes and the Pilot-specific requirements for post-IFC 3D model updates was not clearly defined. This resulted in confusion over which updates should be managed within the Pilot and which should remain part of BAU. Clear delineation between BAU and Pilot activities is essential to ensure that resources and efforts are appropriately allocated, and to prevent overlap or neglect of responsibilities.
4) **Impact of Design phase authoring tools on subsequent BIM processes**: The use of different Design phase authoring tools, such as Revit and Bentley, affected the BIM process during the Pilot. Revit-based models required updates that were linked to the drawings, while other models were converted to 2D data, limiting the effectiveness of subsequent updates. The choice of authoring tools in the design phase has a significant impact on the efficiency and accuracy of the BIM process. Future projects should consider the long-term implications of these tools on BIM workflows and ensure that all models are consistently updated.
5) **Timing and sequencing of processes implementation**: The perception of project phases as linear and the lack of proper sequencing impacted the timely implementation of tools like Matterport. This delayed the integration of redlines into the process, reducing their effectiveness. Proper timing and sequencing of process implementation are crucial to ensure that all elements of the BIM process, including redlining, are effectively integrated and add value to a project.
6) **Project Quality Assurance Process**: The Pilot DE team was historically not involved in the day-to-day activities of CPS, Redlining and As-Built process, and as result, they were unaware of the rigid quality assurance on projects that this process included.
7) **Effort of As-Built and DMS compliance**: The effort required for As-Built documentation and compliance with the Document Management System (DMS) was not reduced by maintaining up-to-date drawings during CPS. Additionally, As-Built teams found it more efficient to model directly from survey CAD files rather than amending existing CPS models. This suggests that current practices in As-Built documentation may benefit from a

reassessment, focusing on direct modelling from accurate survey data rather than relying on updates to existing models. Ensuring DMS compliance throughout a project life cycle is also crucial to avoid disconnects between different phases and teams.

9.4 Team Dynamics and Coordination

As discussed in Section 8, the people side of implementing new procedures is vital when making a change to a BAU procedure or implementing new ones. This Pilot has learned the following lessons:

1) **Resourcing challenges and dedication to the Pilot**: Effective resource allocation and dedicated focus are crucial for the success of pilot projects. The Pilot faced resourcing challenges due to competing priorities and additional work packages. Additionally, delays in obtaining scope and approval significantly impacted the Pilot's implementation timeline. Future pilots should ensure that resources are allocated with clear priorities and that necessary approvals are secured promptly to avoid delays.
2) **Roles and responsibilities**: Clear definition of roles and responsibilities is essential to maintain focus and accountability in pilot projects. The disconnection between design processes, engineering expectations, and construction requirements highlighted the need for better alignment across disciplines. The dual role of the Engineering Manager as both Pilot PM and RFI overseer diluted focus on the Pilot, resulting in reduced RFI management and documentation. In future projects, clearly defined roles with distinct responsibilities will help maintain attention on pilot objectives.
3) **Change management**: Effective change management is necessary to integrate pilot outcomes into broader project processes. The Pilot exposed the challenges of managing change within a historically siloed approach to project phases. Without a robust change management strategy, the benefits of the Pilot could not be fully realised across Glen Huntly's life cycle. Future efforts should prioritise change management to ensure new processes and technologies are seamlessly adopted and understood by all involved parties.
4) **Understand Stakeholders and their BAU**: Continuous engagement of stakeholders is vital to sustaining support for pilot projects. The Pilot experienced a decline in stakeholder support due to not communicating its future value and the changes in personnel. The difficulty in measuring the Pilot's ROI, and unclear budget allocations, further complicated stakeholder involvement. Future pilots should include ongoing stakeholder education and clear communication of how pilot outcomes align with BAU processes to maintain momentum and support.

9.5 Tools and Technology

1) **Tools and processes used in design phase have an impact on how disciplines update information after IFC:** The choice of tools and processes during the design phase significantly affects how disciplines update information after the IFC stage. Inconsistent updates between 2D (e.g., MicroStation) and 3D models, highlighted the need for a model-first approach that ensures 3D models are consistently updated alongside any 2D changes to maintain data integrity.
2) **Mapping of stakeholder needs at each phase impacts tool selection for scanning, surveying, and other processes:** Understanding and mapping stakeholder needs at each project phase directly influence the choice of tools used on a construction project including:

   a) Requirements for survey for Engineering Managers to coordinate and manage RFIs during CPS and construction.

- Requirements for Design teams to incorporate scan data into their models or drawings. This includes understanding the authoring tools used, data disciplines required to make decisions and the resources required to manage the process for Scan to BIM.

   b) Understanding the deliverables required at the end of a project and ensure that process and tools line up with the requirements.

- Requirements for the scanning team to effectively access the site, scan or survey, and resources required for post-processing.

9.6 Budget and Resourcing

1) **Underestimation of Resources for 3D Model Updates in CPS**: The time and resources required to scan, process, and integrate data with federated models was underestimated for coordination and RFI feedback. This

led to limited requests for this level of coordination and reduced impact of the Pilot during CPS. Accurate estimation of resources and time for scanning and data integration is critical to create an understanding of what it takes to execute such works. Once this process and timeline is understood, the team can make an informed decision to utilise this process on disciplines with high impact. Project Managers will also have the knowledge required to support the team in this process by getting Construction teams involved in the planning of such procedures.

2) **Resourcing Challenges in the Pilot**: The Pilot faced significant resourcing challenges due to changes in workflow and the high volume of additional work packages within SPA. This affected the team's ability to fully dedicate resources to the Pilot. Future pilots should ensure that resources are allocated with clear priorities and that necessary approvals are secured promptly to avoid delays.

3) **Staff Turnover and Documentation**: In a two-year project tenure after IFC, staff turnover can be expected. However, having clearly documented goals and an understanding of targets is crucial to ensuring project success despite changes in personnel. Proper documentation and resource continuity are key to maintaining project momentum.

4) **Delineation Between Pilot and BAU Tasks**: BIM tasks can easily become absorbed into general work activities, blurring the line between Pilot and BAU tasks. Clear delineation is necessary to ensure that resources and time are appropriately allocated and that contributions to the Pilot are accurately recorded.

5) **Impact of Early Cost Overrun on Resource Allocation**: Due to a cost overrun early in the Pilot, teams reduced their effort on the Pilot to avoid further overspending. This caution extended to the Pilot team, which led to inaccurate time allocation and made it difficult to track the actual effort spent on the Pilot. More robust budget management and communication about resource allocation is essential to prevent underreporting and ensure accurate tracking of efforts.

10 Recommendations

10.1 Recommendations from the Lessons Learned

These recommendations are designed to address the key lessons learned and help ensure the success of future projects by focusing on the critical areas of People, Process, and Technology:

10.1.1 People

1) **Clear Role Definition and Accountability**: Clearly define roles and responsibilities at the outset of a project, ensuring that each team member understands their specific tasks and accountability. This is especially important for managing critical activities like RFI responses, where delays can impact the entire project.

- **Continuous Stakeholder Engagement and Education**: Maintain regular engagement with all stakeholders throughout a project life cycle. Provide ongoing education about project goals, especially in pilots, to ensure buy-in and understanding across all levels. Support from leadership, such as the ALT, is crucial to ensure that the correct processes and procedures are in place and that all stakeholders understand the pilot's importance and objectives. This is essential to maintain momentum and support, particularly when implementing new technologies or processes.
- **Documentation and Continuity Planning**: Given the potential for staff turnover, ensure that goals, targets, and processes are clearly documented and communicated. This will help maintain project continuity and reduce the impact of personnel changes over a project's lifespan.

2) **Resource Planning and Allocation**: Allocate resources effectively, with a clear understanding of project priorities. Ensure that all teams are adequately resourced to meet project goals, and that any concerns about budget or resource constraints are addressed early to avoid underreporting of efforts or reduced participation.

10.1.2 Process

- Early Risk Assessment and Scope Definition: Conduct a thorough risk assessment and clearly define the project scope before initiating any pilot or new process. This includes setting clear criteria for what is included in the pilot versus BAU and ensuring that all stakeholders understand the scope and objectives.

1) Coordination and Sequencing: Ensure that project phases are well-coordinated and that the sequencing of activities (particularly technology implementation), is planned to align with project needs. Proper timing and sequencing are crucial for maximising the effectiveness of new processes.
2) Effective Change Management: Implement robust change management strategies to support the adoption of new processes and technologies. This includes clear communication about the benefits and impact of changes, as well as training and support to ensure smooth implementation.

- Model-First Approach: Ensure that projects adopt a model-first approach where drawings are extracted from the models. This maintains consistency across all project documentation and facilitates accurate updates during CPS and As-Built phases.
- Accurate Tracking and Reporting: Establish systems to accurately track and report all project efforts, particularly in pilot projects. Ensure that tools are regularly reviewed and maintained to prevent data sync issues and to ensure that reports reflect actual progress and effort.

3) Discipline Selection for High Impact: Select disciplines with high impact, such as Utilities, to support in achieving project goals. These disciplines should be prioritised for As-Built updates and coordination during CPS to enhance accuracy during construction and ensure precise data handover at As-Built, reducing the risk of future issues like utility strikes.

- Procurement and Integration of Shop Detailers: Establish processes and procedures to procure Shop Detailers during the design phase, ensuring they work alongside the Design team. This helps to avoid scope gaps between Shop Detailers and Design teams, improving the coordination and accuracy of the designs.

10.1.3 Technology

- Tool Selection and Integration: Carefully select and integrate tools during the design phase, keeping in mind their long-term impact on a project, especially post-IFC. Ensure that tools chosen for design and modelling (e.g., Revit, Bentley) are compatible with subsequent processes and that 3D models are consistently updated.
- Resource Planning for Technology Implementation: Accurately estimate the resources required for technology-related tasks, such as 3D scanning, point cloud processing, and reality mesh creation. Ensure that the necessary computing resources are available, and that sufficient time is allocated for these activities.

1) Hardware and Software Capabilities: Choose suitable hardware and software that are capable of efficiently meeting the Scan-to-BIM requirements. This ensures that the technology used is fit for purpose and can manage the demands of any project, particularly in terms of processing and integrating scan data.

- Adaptability and Flexibility in Technology Use: Be open to adopting new technologies even if they were not part of the initial project plan, as they can offer significant advantages. However, ensure that any new technology is thoroughly tested and that its integration into existing workflows is carefully managed.

10.2 Roll-Out to Future Projects

10.2.1 Goals for Future Projects

The Pilot was initiated to test the impacts of producing As Built 3D models and capture any subsequent benefits and reduced effort in producing As-Built documentation.

However, due to the rigid project delivery processes that follow the IFC phase—such as the quality assurance procedures during CPS and Redlining, as well as the DMS compliance requirements during As-Built—implementing any changes to these processes presents significant challenges.

As a result, the Pilot team will exclude any recommendations that would interfere with the existing quality assurance procedures during CPS and Redlining, as well as any changes to the effort involved in As-Built documentation. It is recommended that a separate Pilot is required to specifically address the challenges related to DMS compliance.

During the Pilot tenure, various project risks were identified that could potentially be mitigated or reduced through a robust BIM process and adequate change management. These risks included:

- Coordination risks during construction, specifically with high-risk disciplines such as Utilities and Civil Structures.
- Procurement risks with Shop Detailing
- Safety risks through site attendance

Therefore, the recommendations in this section were developed to address the following project goals for future projects:

- Goal 1: Implement a change management process to ensure buy-in for any BIM procedures on a project.
- Goal 2: Target high-impact disciplines to produce accurate information during the design phase and coordinate throughout CPS and As-Built to reduce construction and maintenance risks.
- Goal 3: Improve coordination for elements often not modelled during design to reduce the risk of clashes on-site.
- Goal 4: Enhance coordination with Shop Detailers to reduce scope gaps, idle resources, and coordination issues on-site.
- Goal 5: Reduce site attendance to minimise safety risks.

10.2.2 Recommendations

It is important to note that every project and team is unique, so the recommendations provided are high-level to ensure they can be considered in various project contexts.

To achieve the goals outlined in the previous section, it is recommended that Project teams follow the subsequent seven steps when implementing any DE related processes or Technologies on future projects:

- Step 1: Project planning during the TOC phase.
- Step 2: Develop the budget with the end in mind during the TOC phase.
- Step 3: Revisit the project plan at each project phase to adjust and review it in-line with the project goals.
- Step 4: Procure Shop Detailers between Gate 2 and IFC on the project and coordinate them closely with the Design team.
- Step 5: Conduct Construction-led constructability workshops during the IFC phase, including the coordination of Construction team-developed 3D models, such as rebar and conduits.
- Step 6: Implement model-based coordination with As-Built high-impact disciplines during CPS.

- Step 7: Use survey-aligned 3D models for high-impact disciplines at project handover.

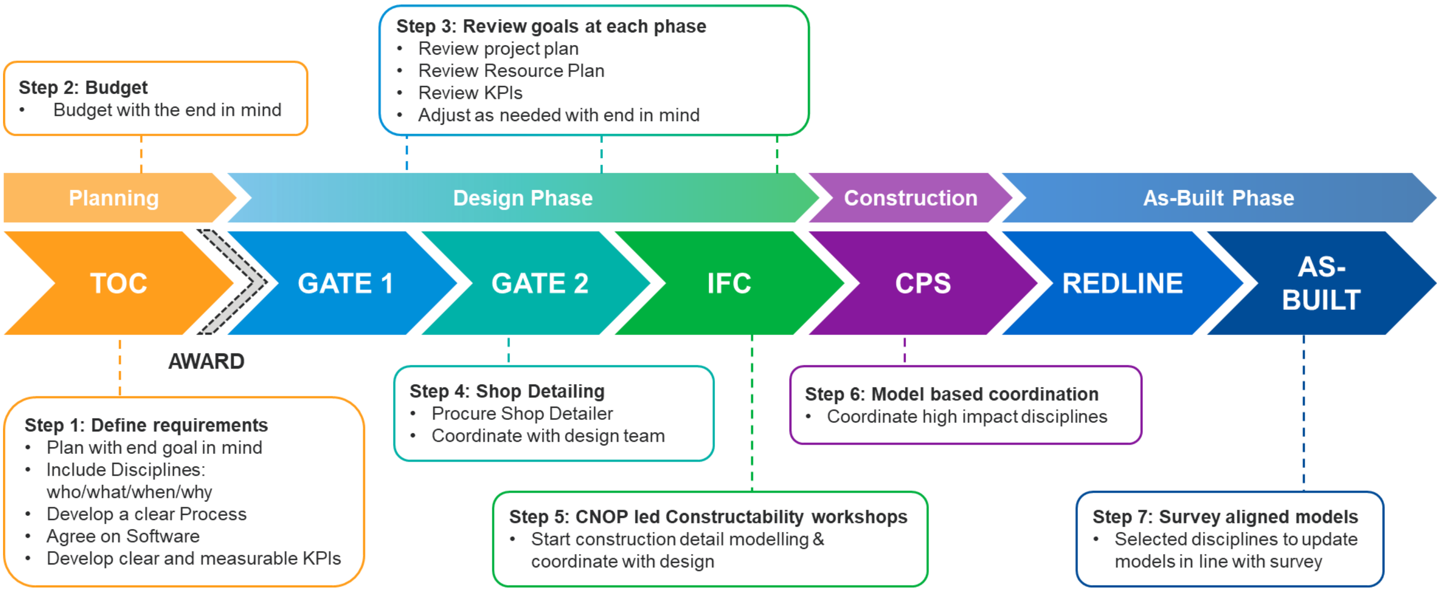


Figure 46 Recommended Seven Step Process

1) Recommended change management and project planning:

To influence any outcomes in CPS, it is recommended to initiate a project plan as early as the TOC phase as shown in Step 1. The reason for a TOC start is that most of the Design and Construction costs, specifically resource costs, are established during this phase. In this phase, it is important to plan with the end in mind and ensure that all stakeholders are involved in the planning process. It is recommended that the client forms part of this planning process to ensure that their goals for asset management are also met.

A project plan should address the “who, what, where, when, and why” factors and clearly define the project goals. Ideally, each stakeholder should map out their BAU procedures on projects and should coordinate them with the planned outcomes. When subject matter experts develop processes for the project, the amount of assumptions made on the project would be reduced. All project processes should be brought together and coordinated to develop the project plan. The last planner method should be used to develop a project plan with predictable workflows amongst all stakeholders to achieve reliable results.

A project plan is to include clear processes, developed by the stakeholders who are subject matter experts, to reduce the number of assumptions to be made. Further, an agreement should be made on the targeted disciplines and their deliverables at each phase, as well as agreement on hardware and software to achieve project goals at each phase. Finally, clear and measurable performance indicators should be developed to keep track of the effort and progress throughout the project phases.

As shown in Step 2, the budget should be developed during the TOC phase based on the agreed project outcomes, processes and resources at each project phase.

As per Step 3, at each project gate during the design and construction phases, the stakeholders should review the project plan in-line with the main project to ensure the goals will achieve the planned value, and if not, any adjustments should be made to improve on risk reduction. This could involve a review on resources, hardware, software, processes, KPIs and unplanned events. This step is also important to ensure that stakeholder knowledge of the project plan, and education around procedures are retained, even in the event of staff turnover.

2) Recommendations on targeted disciplines:

For each stakeholder, the risks pertaining to specific disciplines have different impacts to their requirements, and it should therefore be considered that there is no one-size-fits-all approach to reducing risk, and instead, stakeholders should participate in the planning process to ensure successful outcomes.

When starting a project plan in Step 1, it is recommended that the client, the operator, Construction team and Design team are part of the planning process. The concept is to use an 80/20 rule to focus on the disciplines that carry 80% of the project risk or cost and target those disciplines for meticulous planning to reduce project risk throughout project phases.

As an example, contractors may choose to focus on Civil Structures for early engagement in constructability and coordination with reinforcement, as well as Underground Services to ensure these are properly coordinated during the design phase and set-out is on-site by a surveyor as per the design. The client and operator may choose to focus on more accurate underground service As-Built information, to prevent any strikes or disruption to maintenance or future refurbishment works on the facility.

During the planning, stakeholders should work together, to devise a plan to pull coordination forward into the design phase, reducing the risks for disruption in construction. The recommendation for change is to develop As-Built, versioned drawings for some disciplines much earlier in the process and allow for coordination with As-Builts before the main occupation.

3) Pulling coordination effort forward

   a. Design Sequencing

In the seven recommended steps, the project process looks vary linear, but discipline works happen in various sequences based on the design and construction program. Typically, in a level crossing removal project, disciplines such as CSR and Track would complete early works in the design phase much sooner than most disciplines. Drainage and Civils would often follow suit and then most of the other disciplines in short sequence after, with their IFC close to the main occupation as shown in the figure below.

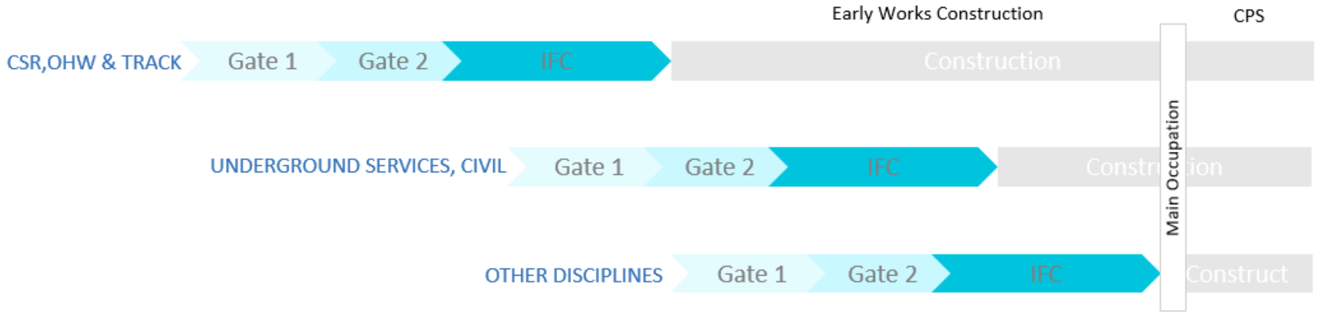


Figure 47 Design Sequence example

A drawback of this sequence of work is that CSR and underground services design would often finish before other disciplines that are more rigid in their location, meaning there is an understanding that changes to the location of these services may occur on site.

Our recommendation is to review the sequence of design work to enable better coordination before the main occupation. This needs to be meticulously planned in coordination with the Design team, Construction and the client.

Examples of what this entails on an Alliance are outlined in the following two scenarios that take two different approaches to coordination and sequencing during the design phase:

Scenario 1:

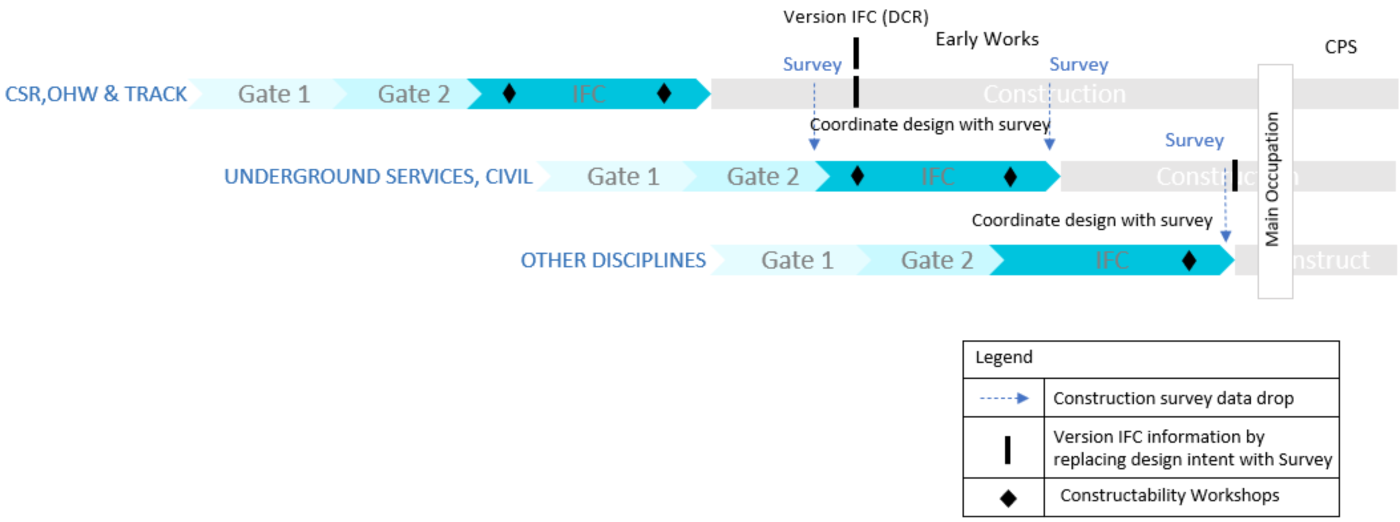


Figure 48 Design Sequence Scenario 1

The current sequence of works could be advantageous when considering that the construction of CSR would start during other disciplines' design phases, meaning that during the design phase teams can coordinate with the CSR As-Built survey, instead of their design intent information.

This process requires the Construction and Survey team to develop a plan in Step 1 to ensure construction of these disciplines starts timeously, and the Survey teams have access to the site regularly to gather the right information to feed back to the Design team. Ideally, before the main occupation of the site, the survey would replace the design intent information of CSR and Drainage and would require a formal version update of drawings. These drawings could then be used as reference in other discipline drawings. The change in reliance information should be planned in detail during Step 1 and 2 to ensure all stakeholders have buy-in to this process. The survey information would also be used for coordination and clash detection during the design phase with other disciplines.

This process does not replace the activities of CPS such as RFIs or DCRs but brings the coordination effort earlier into the design phase, reducing the risk of any clashes or the need for questions or changes during CPS.

Scenario 2:

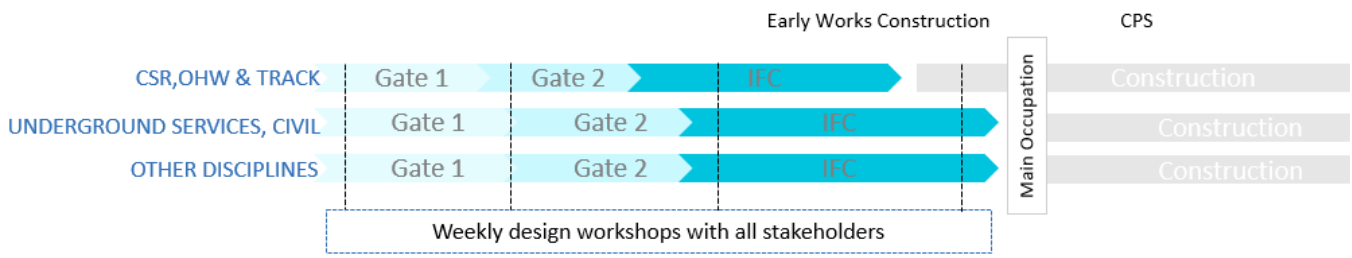


Figure 49 Design Sequence Scenario 2

In this scenario, all Design disciplines start at the same time and hold weekly integration coordination sessions with all stakeholders, including Construction, where the teams agree on locations of elements and sequences of work for that week. This process requires all disciplines to take a model-first approach to design. The information gets federated weekly and coordinated in these integration sessions in the 3D model environment. This scenario would require much more detailed upfront planning, and dedication during the design phase. However, if this is combined with the shop detailing and constructability recommendations below, there is a potential for this process to reduce a large amount of coordination risk during construction.

b. Shop Detailing:

Another coordination effort that should be pulled forward into the design phase is the procurement and collaboration of the shop detailers as mentioned in Step 4. Ideally, shop detailers should be appointed between Gate 2 and IFC when the design is close to being frozen. The Shop Detailer's contracts should also include their responsibilities for developing 3D models of their scope, adaptability in coordinating directly with the Design team and incorporating minor changes during the design phase and finalising the Shop Detailing drawings as soon as the design intent drawings are approved for IFC. This process will have a big impact on relieving coordination issues on site and the idle wait times for reviewers of shop detailing information during CPS.

c. Constructability Workshops

It is also recommended to change how constructability workshops are conducted during the design phase. Firstly, workshops should be led by the construction team at various intervals in the design phase. Currently, constructability workshops are led by teams who rely on assumptions on construction methods that may not be aligned to the actual construction plan.

Similarly to the shop detailing, it is recommended that the Construction team have a dedicated 3D modelling team that would develop construction level of detail models based on the design, during the design phase, and coordinate directly with the Design team. This will reduce the risk of clashes with these elements during construction.

d. As-Built Team Collaboration

Part of the coordination effort that needs to be pulled forward is the integration of the As-Built team in the project reviews of Step 3 in the design phase. Bringing the As-Built team onboard with decision-making on software, process and deliverables of the project goals, ensures that their own procedures could either be considered or adapted to achieve the desired outcomes at the right time.

e. Technology implementation for safety

Technology such as time-based drone captures, together with Propeller, is recommended to be used on construction projects to reduce site attendance where physical work would not be required, therefore inherently reducing the safety risks associated with site.

10.3 Barriers and Risks to Future Implementation

Implementing any kind of change requires a rigorous change management process. The following risks and barriers may impact future implementation of the seven recommended steps:

Step 1: Plan the Project During the TOC Phase

- Early Stakeholder Engagement: Ensuring that all relevant stakeholders are engaged early in the TOC phase can be challenging, especially if there are differing priorities or schedules.
- Misalignment of Objectives: If stakeholders are not properly engaged or if coordination is lacking, there is a risk that project goals may not be fully aligned, leading to issues later in the project.
- Inadequate Planning: Failure to adequately plan during the TOC phase could result in unforeseen challenges during later phases, leading to delays or increased costs.

Step 2: Develop the Budget with the End in Mind During the TOC Phase

- Budget Constraints: There may be limitations on available funds during the TOC phase, making it difficult to allocate sufficient resources for all anticipated needs.
- Uncertain Costs: Accurately predicting all costs associated with the project from the outset can be difficult, especially for complex projects.

Step 3: Revisit the Project Plan at Each Project Phase to Adjust and Review In-line with the Project Goals

- Resistance to Change: Teams may resist revisiting and adjusting the project plan, especially if they feel it disrupts ongoing work or creates uncertainty.
- Inconsistent Reviews: If reviews are not conducted consistently or thoroughly, there may be missed opportunities to address emerging risks or adjust the project course.

Step 4: Procure Shop Detailers Between Gate 2 and IFC, and Coordinate Them Closely with the Design Team

- Procurement Delays: There may be delays in procuring shop detailers, especially if there are contractual or market challenges.
- Coordination Challenges: Ensuring close coordination between shop detailers and the Design team can be difficult, particularly if they are not accustomed to working together from an early stage.

Step 5: Conduct Construction-Led Constructability Workshops During the IFC Phase

- Construction Team Involvement: Construction teams may not be fully engaged or available to lead constructability workshops during the design phase, especially if they are focused on other tasks.
- Resource Constraints: Conducting detailed constructability workshops requires time and resources that may be in short supply.

Step 6: Implement Model-Based Coordination with As-Built High-Impact Disciplines During CPS

- Technological Limitations: Existing modelling tools may have limitations that make it difficult to fully implement model-based coordination across all disciplines.
- Resistance to New Processes: Teams may resist adopting model-based coordination, particularly if it requires significant changes to their existing workflows.

Step 7: Use Survey-Aligned 3D Models for High-Impact Disciplines at Project Handover

- Data Integration Challenges: Integrating survey data with 3D models can be complex, particularly if the data is not aligned or if there are discrepancies between the survey and design information.
- Resource Requirements: Developing and maintaining survey-aligned 3D models requires specialised skills and resources, which may not be readily available.

11 How the Pilot Impacts Subsequent SPA Works

As the Glen Huntly Pilot progressed, the outcomes were regularly fed back to SPA ALT, Design Management, as well as Engineering Management. This created some awareness of the benefits of BIM procedures throughout the project life cycle, which ultimately influenced changes in the way SPA approaches projects. The following examples of changes in SPA's approach that were specifically attributed to the Pilot outcomes include:

- Other ongoing operations and maintenance initiatives, especially the MURL project has expressed a need for similar datasets to those currently in use. This request highlights the importance of data consistency and accessibility across different projects to ensure seamless integration and support for operational needs.
- Integration of DE in Design: the DE team's integration into the day-to-day activities of design has improved greatly. The DE team works closely with the Design team to continuously improve the way that models are developed and coordinated throughout the design phase, providing higher quality outcomes since Glen Huntly.
- Project Management, Design Management, Engineering Management and DE leads work together during the TOC phase to plan project goals, which include data for construction in models, coordination, and CPS coordination effort.
- Model requirements for shop detailing have been a standard practice since Glen Huntly. The Shop Detail reviewers have greatly improved their coordination and management of shop detail information since the Parkdale level crossing removal project. Further, on the Kananook project, the Design team engaged with the steel sub-contractor during the design phase to coordinate directly with them.
- Drone surveys are now a standard practice in SPA projects.
- Use of Revizto model federation and coordination of CPS works, managed by the Engineering Managers, has been initiated at Parkdale and will be continuously used on future projects.

11.1 Kananook Pilot

The Kananook Pilot approach was significantly informed by the lessons learned from the Glen Huntly Pilot. After a thorough review of Glen Huntly's lessons, the Kananook team made key adjustments to their execution strategy:

- Dedicated Leadership: A critical aspect of this plan was the selection of a Project Manager with a strong focus on project completions. This Project Manager's experience ensures that the end goal is consistently prioritised, aligning with the recommendation to plan with the end in mind, as emphasised in Glen Huntly's review.
- Targeted Scope: Prioritising areas with the highest return on investment, such as the train wash and maintenance facilities.
- Need for Clear Guidelines: Glen Huntly revealed the necessity for clear guidelines on when model updates are required for change management. The Kananook team developed a comprehensive execution plan to guide the Pilot which includes roles and responsibilities, and a clear process and project program.
- RFI Process Management: Glen Huntly's experience with increased RFIs and the impact of 3D modelling on response times led Kananook to keep the RFI standard practice, separate from the Digital Handover Pilot.
- Model Update Strategy: To address the difficulty of maintaining model updates during fast-paced construction, Kananook will not include CPS model updates. Instead, any geometry changes captured post-construction will be in a new scan vs model process that feeds into consolidated redline review pack.
- Point Cloud Management: The Pilot team will manage point cloud data staging to ensure that the As-Built team receives it before commencing As-Built drawings, avoiding the timing issues encountered in Glen Huntly.
- Coordination and Clash Detection: Coordination between discipline models and clash detection will continue during the design phase to fulfill DCRs, adhering to standard practice.

Appendices

Appendix	Description
Appendix A	RFIs and Models on the Pilot
Appendix B	CPS Risks Mitigated
Appendix C	Project Process Map
Appendix D	As-Built/Redline Review Findings
Appendix E	Survey

Appendix A – RFIs and Models on the Pilot

Reference	RFI Title	Models affected	Hours for pilot updates
RFI:GLEN HUNTLY#0024	(GLEN HUNTLY Glen Huntly Stage 1 CSR) - Combining ULX 12 & 14	STP-059-C-SPA-M3D-19-GHY-CSR-8001.ifc	1
RFI:GLEN HUNTLY#0060	GLEN HUNTLY- MD01-5	STP-059-C-SPA-M3D-19-GHY-CDR-7002	1
RFI:GLEN HUNTLY#0074	GLEN HUNTLY - Car Park Pits	STP-059-C-SPA-M3D-19-GHY-CDR-7002.ifc	6
RFI:GLEN HUNTLY#0075	GLEN HUNTLY - Irrigation control conduit for the GHY deck.	STP-059-C-SPA-M3D-19-GHY-BHS-1001.rvt	3
RFI:GLEN HUNTLY#0076	Glen Huntly RD Pits	STP-059-C-SPA-M3D-19-GHY-CDR-7002.ifc	4
RFI:GLEN HUNTLY#0090	GLEN HUNTLY CSR - Acquired Properties Cable Route Bore Type	STP-059-C-SPA-M3D-19-GHY-CSR-8001.ifc	2
RFI:GLEN HUNTLY#0103	GLEN HUNTLY - Glen Huntly - Lift Marshalling & Control Cabinet reposition	STP-059-C-SPA-M3D-19-GHY-BES-1001.rvt	3
RFI:GLEN HUNTLY#0145	GLEN HUNTLY Changes in RE wall alignment	STP-059-C-SPA-M3D-19-GHY-CSW-7001.ifc	DCR
RFI:GLEN HUNTLY#0175	Glen Huntly - Footpath Levels outside 1158 Glen Huntly Rd	STP-059-C-SPA-MFD-19-GHY-CRG-7000	2
RFI:GLEN HUNTLY#0182	GLEN HUNTLY - Glen Huntly - Station Service and pit relocation proposals	STP-059-C-SPA-M3D-19-GHY-BES-1001.rvt	3
RFI:GLEN HUNTLY#0191	GLEN HUNTLY Station Platform and pile clash	STP-059-C-SPA-M3D-19-GHY-SBS-0001.rvt	2
RFI:GLEN HUNTLY#0240	GLEN HUNTLY - Glen Huntly - Platform Light pole and Capping beam clash	STP-059-C-SPA-M3D-19-GHY-BES-1001.rvt	1
RFI:GLEN HUNTLY#0256	GLEN HUNTLY - Glen Huntly MD01-5 Pit Location	STP-059-C-SPA-M3D-19-GHY-CDR-7002.ifc	2
RFI:GLEN HUNTLY#0260	GLEN HUNTLY - Glen Huntly Lord Street Land Changes and Pipe Drainage Removal	STP-067-C-SPA-M3D-19-GHY-CDR-7003.ifc	BAU
RFI:GLEN HUNTLY#0280	GLEN HUNTLY Glen Huntly - Light pole Impacted by Guardrail	STP-059-C-SPA-M3D-19-GHY-BES-1001.rvt	2

RFI:GLEN HUNTLY#0327	GLEN HUNTLY End of retaining wall	STP-059-C-SPA-M3D-19-GHY-CSW-7001.ifc	3
RFI:GLEN HUNTLY#0337	GLEN HUNTLY Tension pile rectification CSW-AP0002	STP-059-C-SPA-M3D-19-GHY-CSW-7002.ifc	2
RFI:GLEN HUNTLY#0338	GLEN HUNTLY Tension pile CSW-AP0115	STP-059-C-SPA-M3D-19-GHY-CSW-7002.ifc	2
RFI:GLEN HUNTLY#0374	Signal Structure Piles - As Builts	STP-067-C-SPA-M3D-20-CFD-CSS-0301.dgn	3
RFI:GLEN HUNTLY#0378	GLEN HUNTLY Tension pile CSW- AP0121	STP-059-C-SPA-M3D-19-GHY-CSW-7002.ifc	3
RFI:GLEN HUNTLY#0387	- /GLEN HUNTLY/41/4120/412D	STP-067-C-SPA-M3D-20-CFD-CRD-8120.ifc	2
RFI:GLEN HUNTLY#0388	GLEN HUNTLY CSR ULX	STP-059-C-SPA-M3D-19-GHY-CSR-8001.ifc	2
RFI:GLEN HUNTLY#0419	SW CARPARK CAPPING BEAM LEVELS	STP-059-C-SPA-M3D-19-GHY-CSW-7001.ifc	3
RFI:GLEN HUNTLY#0423	GLEN HUNTLY - Glen Huntly - Thickening of Service building slab	STP-059-C-SPA-M3D-19-GHY-SBS-0001.rvt	2
RFI:GLEN HUNTLY#0473	GLEN HUNTLY - Glen Huntly - GLS-06 Waiting room louvre window frame clash	STP-059-C-SPA-M3D-19-GHY-ARC-0002.rvt	4
RFI:GLEN HUNTLY#0495	GLEN HUNTLY - North West Carpark (NWCP) Drainage - CSR Clash	STP-059-C-SPA-M3D-19-GHY-CDR-7002	5
RFI:GLEN HUNTLY#0521	South-West Carpark Light pole footing/CSR clash	STP-059-C-SPA-M3D-19-GHY-BES-1001.rvt	2
RFI:GLEN HUNTLY#0534	GLEN HUNTLY Service bridge upstands and services concrete encasement	STP-067-C-SPA-M3D-19-CFD-CBR-7001.ifc	3
RFI:GLEN HUNTLY#0562	GLEN HUNTLY - Approval of As built Capping Beam Scallop	STP-059-C-SPA-M3D-19-GHY-CSW-7001.ifc	3
RFI:GLEN HUNTLY#0596	GLEN HUNTLY GH - Neerim Rd Drainage - Pit N4-2 - Power Clash	STP-067-C-SPA-M3D-19-GHY-CDR-7003	2
RFI:GLEN HUNTLY#0602	AWP 4 - Glen Huntly Road Drainage MD01-10	STP-059-C-SPA-M3D-19-GHY-CDR-7001	6
RFI:GLEN HUNTLY#0625	GLEN HUNTLY -GHY -Additional conduit for OCS fibre to ICT rack on concourse	STP-059-C-SPA-M3D-19-GHY-BES-1001.rvt	2

RFI:GLEN HUNTLY#0631	GLEN HUNTLY - Glen Huntly - Public Building Planter box drainage	STP-059-C-SPA-M3D-19-GHY-BHS-1001.rvt	3
RFI:GLEN HUNTLY#0637	GLEN HUNTLY GH - Pit N1-2 Change in location	STP-067-C-SPA-M3D-19-GHY-CDR-7003	2
RFI:GLEN HUNTLY#0653	GLEN HUNTLY - Neerim Road Footpath Interface with Existing Telstra Manhole	STP-059-C-SPA-MFD-19-GHY-CRG-7000	2
RFI:GLEN HUNTLY#0655	GLEN HUNTLY - Neerim Road - Bus Stop Foot Path Clearances	STP-059-C-SPA-MFD-19-GHY-CRG-7000.ifc	2
RFI:GLEN HUNTLY#0689	- /GLEN HUNTLY/41/4180/4180	STP-059-C-SPA-MFD-19-GHY-CRG-7000.ifc	3
RFI:GLEN HUNTLY#0691	- /GLEN HUNTLY/41/4140/414B	STP-059-C-SPA-M3D-19-GHY-SBS-0001.rvt	3
RFI:GLEN HUNTLY#0692	Island platform precast frame - rag bolt & grout tube proposal - Glen Huntly	STP-059-C-SPA-M3D-19-GHY-SBS-0001	3
RFI:GLEN HUNTLY#0699	GLEN HUNTLY - GHY Storage Tank - Concrete Hob Detail around Risers	STP-059-C-SPA-M3D-19-GHY-CSW-7301.ifc	3
RFI:GLEN HUNTLY#0718	GLEN HUNTLY - Neerim Rd. - Southeast Footpath vs Gates	STP-067-C-SPA-M3D-19-GHY-CDR-7003.ifc	2
RFI:GLEN HUNTLY#0743	GLEN HUNTLY - Neerim SE Footpath Connecting to Bridge	STP-059-C-SPA-MFD-19-GHY-CRG-7000	2
RFI:GLEN HUNTLY#0744	GLEN HUNTLY - Neerim Rd. Drainage Clash NW Carpark - Kerb and Channel	STP-067-C-SPA-M3D-19-GHY-CDR-7003.ifc	1
RFI:GLEN HUNTLY#0773	GLEN HUNTLY - GH Road West Drainage Clash Pit GH05-1	STP-059-C-SPA-M3D-19-GHY-CDR-7001.ifc	3
RFI:GLEN HUNTLY#0787	GLEN HUNTLY - CIVIL / UTILITIES - Area 3 & 4 - Northwest Carpark Water Meter Interface	STP-059-C-SPA-M3D-19-GHY-CUT-2005.ifc	3
RFI:GLEN HUNTLY#0788	GLEN HUNTLY GHY - Royal Ave Stormwater Point of Discharge	STP-059-C-SPA-M3D-19-GHY-CDR-7001.ifc	2
RFI:GLEN HUNTLY#0796	GLEN HUNTLY- Capping Beam - Signal Bolt Set	STP-067-C-SPA-M3D-20-CFD-CSS-0301.dgn	2
RFI:GLEN HUNTLY#0841	GLEN HUNTLY - GHY - Carpark Drainage MD01-10 to SWCP01-1 & SWCP01-2	STP-059-C-SPA-M3D-19-GHY-CDR-7001	3

RFI:GLEN HUNTLY#0913	GLEN HUNTLY - Remove Junction box on GH Rd Northern barrier	STP-067-C-SPA-M3D-19-CFD-CBR-7001	2
Total amount of models adapted and total amount of modelling hours		**49**	**122**

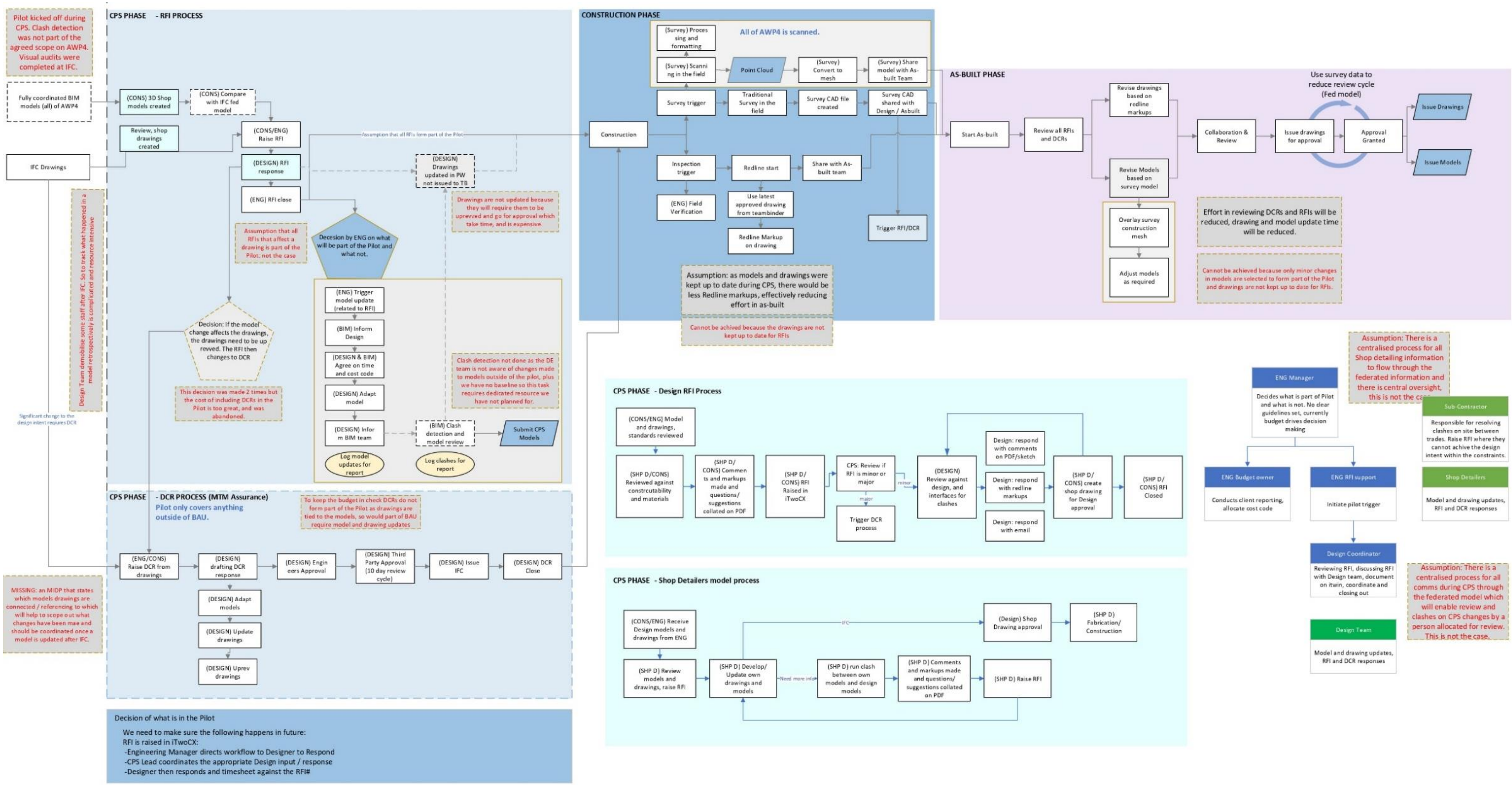
Appendix B – CPS Risks Mitigated

Item No	RFI No.	Cost Code	WBS	Description of Issue	Solution without Modelling	Adopted Solution	Worst Case Scenario
1	0602	4.3.2.1 Drainage – Stormwater	GLEN HUNTLY 41 Area 1 Glen Huntly 4110 Civil Works 411D Drainage	VicTrack power clash with utilities design	Relocation of utilities and disconnection of power service	Re-designed services in a congested area and assessed with modelling tools	$1,000,000
2	0060	10.1302 Drainage-Box and pipe culverts	GLEN HUNTLY 41 Area 1 Glen Huntly 4110 Civil Works Drainage	Pit MD01-5 is clashing with the existing drainage	Rework with adopted solution	Pit MD01-5 to be moved approximately 1.2m south to avoid clashing with the existing drainage	$35,000
3	0596	GLEN HUNTLY 4.3.2.1 Drainage – Stormwater	GLEN HUNTLY 41 Area 1 Glen Huntly 4110 Civil Works 411D Drainage	The drainage design for Pit N4-2, has an offset of 229mm from live power (UE) Constructions PTW (Permit to Work) around live UE assets require install of drainage pits with a minimum offset of 300mm from live power assets	Rework with adopted solution United Energy live-power cut over	Pit to be shifted minimum of 750mm further from the live power	$130,000
4	0637	GLEN HUNTLY 4.1.3.1 Power Relocation	GLEN HUNTLY 41 Area 1 Glen Huntly 4110 Civil Works 411D Drainage	Telstra under bore (live), was identified during drainage construction works, Pit 1-2 could not be installed in the design location, and a modified pit had to be installed	Rework with adopted solution	Install a new GSEP N1-2a, connect this to N1-2 (As-Built) and change the pipe connections of N3-1 & N2-1 to align with the As-Built N1-2	$25,000
5	0744		GLEN HUNTLY	Inadequate design of bike ramp resulting in potential water pooling	Installation with adopted solution	An additional GSEP (as per VicRoads standard	$15,000

			41 Area 1 Glen Huntly 4180 Landscaping and SUP 418C SUPs			SD1322) is installed, positioned on the updated kerb and at the base of the bike ramp an additional segment of Ø375mm class 3 pipe connecting from this pit into pit N2-3, laid within minimum grade 0.4%.	
6	0773	GLEN HUNTLY 4.3.2.1 Drainage - Stormwater	GLEN HUNTLY 41 Area 1 Glen Huntly 4110 Civil Works 411D Drainage	Issues encountered on pit GH05-1 due to the positioning of the gas main. The pit was installed 600mm further north than planned to maintain a safe clearance. Consequently, the grate opening is now positioned behind the kerb, within the crossover	Rework with adopted solution APA Gas main recoating (6m)	Pit location installed further north to avoid clashing with the gas main The repositioned pit shaft is then fitted with a Class D grate for 100 years ARI storm	$180,000

Appendix C – Project Process Map

Example of Project Process map developed during CPS



Appendix D – As-Built / Redline Review Findings

Nr	Disc	Description	Estimated number of sheets affected	Category
1	ARC	Issue: ID 5: The retaining wall at the entry of Glen Huntly Station concourse. A Design Change Request (DCR) was issued during the CPS phase, design and design drawings were updated; however, this was not updated in the model. Refer Figures 1 & 2.	20	Difference between RFI and IFC
2	ARC	Issue: ID 11, 28, 29, 30 & 32: The canopy roof structures at the platform. Two structural members are misaligned with their positions in the point cloud, and the other two members are not included in the model.	8	Shop Drawing LOD
3	ARC	Issue: ID 12: The stair handrails at both ends of the platforms 1, 2 & 3. The number, shape, and height of the handrails are misaligned with the point cloud.	6	Shop Drawing LOD
4	ARC	Issue: ID 13: The roof gutter system at the up and down track stairs. The length and width of the gutter are misaligned with the point cloud data, and a duplicated gutter has been identified on the top side of the stairs for both the up and down track stairs.	7	Shop Drawing LOD
5	ARC	Issue: ID 14: The panel frame between up and down track stairs at concourse level. The frame edge position is misaligned with the point cloud, approx. 175mm off.	9	Shop Drawing LOD
6	ARC	Issue: ID 16: The structural framing and panel system at the up stair at concourse level. The architectural columns are misaligned with the point cloud and the panel gaps also need to be filled.	9	Shop Drawing LOD
7	ARC	Issue: ID 17: The rail post at the up and down track stairs at concourse level. The positions of the rail posts are misaligned with the point cloud, approx. 180mm.	4	Shop Drawing LOD
8	ARC	Issue: ID 18: The ladders to the lift rooftop next to the up-track stair. The ladder angle and cage height are misaligned with the point cloud, and one side of the ladder has not been modelled with a cage.	6	Shop Drawing LOD

9	ARC	Issue: ID 19: The FPD at concourse area. The position of the FPD machine is misaligned with the point cloud.	6	Minor position changes, irrelevant for redlining
10	ARC	Issue: ID 20: The furniture at concourse level. The positions and shapes of facilities like rubbish bins and benches are misaligned with the point cloud.	5	Minor position changes, irrelevant for redlining
11	ARC	Issue: ID 21: The ticket machines at concourse level. The positions of ticket machines are misaligned with the point cloud by approx. 175mm.	4	Minor position changes, irrelevant for redlining
12	ARC	Issue: ID 25 & 26: The walls & stairs at the northern end of platform 3. The position and height of the system panels are misaligned with the point cloud.	15	Shop Drawing LOD
13	ARC	Issue: ID 27: The wall facing the up-track stairs on platform 1. The position and height of the system panels are misaligned with the point cloud.	4	Shop Drawing LOD
14	ARC	Issue: ID 31: The down track stair roof and the signage at the platform level. The roof level is misaligned with the point cloud data, and a clash between the signage at the platform level and the gutter has been identified.	14	Minor position changes, irrelevant for redlining
15	ARC	Issue: ID 33: Underneath both the up and down track stairs, 2 structural beams and covers are not included in the model.	0	SBS to update
16	ARC	Issue: ID 34 & 35: The information board, bench and signage on platform 3. The information board, bench and signage are misaligned with the point cloud data.	14	Minor position changes, irrelevant for redlining
17	ARC	Issue: ID 36: The penetration on platform 1. The penetration for the electrical pit is misaligned with the point cloud data.	4	Minor position changes, irrelevant for redlining
18	ARC	Issue: ID 37 & 41: The platform 3 floor level. The floor levels on both sides of platform 3 are misaligned with the point cloud data.	39	Scan data incorrect
19	ARC	Issue: ID 38, 39 & 40: The tactiles and hatch access on platform 3. The tactiles and hatch access on platform 3 are misaligned with the point cloud data.	24	Minor position changes, irrelevant for redlining
20	ARC	Issue: ID 42: The penetrations on platform 3. The penetration for the electrical pit is misaligned with the point cloud data and one penetration is not included in the model.	3	LOD not required for IFC and As-Built

21	BES	Issue: In comparing the model with the point cloud, various electrical fixtures that are outside of tolerance were found.	2	Minor position changes, irrelevant for redlining
			203	

Appendix E – Survey

Table below shows technical comparison between the two devices.

Feature	Aerial Capture (DJI M3E-RTK)	Matterport
		
Point cloud resolution	50mm overall	20mm @10m
Capturing mode	Photogrammetry	TLS
Range	100m	Up to 100m
Accuracy	Survey Grade	Less accurate
Person blurring	Not applicable	Possible
Point cloud file format	LAZ, LAZ	E57
Colorised	Yes	Yes
Geo-referenced	RTK, Ground Control Point	3rd party app, not recommended
Indoor/outdoor capture	Outdoor only	Indoor/Outdoor
Privacy/face blurring	N/A	Yes
Cloud processing	Yes	Yes
Processing time	24 hours	24 hours

Post processing clean up	N/A	N/A
Capture time	3 hours (entire site and station canopy)	120 mins (station only)
Static setup location constrains	No	Yes

END OF REPORT