1. INTRODUCTION

PROJECT:	**Predictive Maintenance of Turnouts from Data Capture of Expanded Detailed Inspections**
ENTRANT:	**Plateway Pty Ltd**
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2. Project Summary

The Detailed Turnout Examination aims to identify failures arising from several root causes with multiple variables. It is a time consuming and complex examination which traditionally produces a series of paper-based forms containing individual parameter assessment, but are not searchable or easily archivable.

The historically qualitative inspection is fit for a reactive run-to-failure maintenance strategy choice. However, for an asset where procurement of wear components involves a long team time, this reactive maintenance strategy is not optimal. A predictive maintenance strategy is required so that the remaining asset life is quantified and planned intervention made.

The challenge in selection of examination methods and reporting leads to:
- Variability between recording methods, standards and experience from inspectors and asset managers resulting in different inspection outcomes.
- Skills shortages where inspection and repair training are separate.
- Frameworks for analysis of the large amount data are generally unavailable.

This entry presents a framework for the data collected during the Detailed Turnout Examination including a greater degree of physical measurement, and quantification of asset condition. The data collected is then modelled enabling the root cause analysis, adjustment to repair procedures and prediction to inform a proactive-preventative maintenance strategy. The aim is to reduce operational disruption, improve safety and reduce cost.

This entry is split into two parts. The first addresses the judging criteria, and the second offers a discussion on the project method and results obtained.

3. Part 1 – Judging Criteria

• Difficulties Overcome

The project faced the following difficulties in the design and implementation of the detailed inspection methodology and data processing;

- The design of an expanded detailed inspection method was dictated by limited track possession windows on high volume traffic sections. This required a highly mobile inspection method that can be carried out by a small crew and without impacting train running. The project team was able to design an inspection method which required, on average, 30 minutes of track possession per turnout.
- As the expanded inspections were not supplementary, but rather formed, the annual track inspections for the network, the project team faced difficulty in incorporating existing fault reporting requirements into the outcomes of the expanded inspection method. This was compounded by the limited track time available between trains.
- Existing inspection data was not being used for works planning beyond fault reporting.
- A large number of parameters in typical turnout inspection forms are tick boxes which cannot be used to quantify wear or predict maintenance requirements. The project team developed methods of measuring data in a quantifiable and reportable format.
- The long transferal of data from field measurements to a searchable asset database has long been a barrier in digitising track inspection measurements. The project team overcame this difficulty by developing a tablet-based application that could record in-field measurements and visual assessments, and several macros to incorporate track geometry and rail profile data into a searchable asset database. This is a significant improvement over traditional, paper-based, inspection forms.

• Contribution / Impact to Rail

The primary benefit of an integrated inspection to maintenance and renewal works forecast process is a certainty in track possession and budget expenditure. Additionally, the following benefits were found to be an outcome of the process;

- Informing regular asset maintenance crews of impacts to asset condition i.e. adjustments to rail grinding and turnout tamping programmes as a result of the findings of the detailed turnout examinations.
- A traceable asset register and condition index.
- Development of a track condition register which allows traceability of ‘institutional knowledge.’
- No interruptions to rail traffic – inspections were completed as traffic allows.
- Turnouts are a major source of in-service failures. This approach targets reduction of failures, in particular, points detection failures.

• Technical Input

Inspection standards were benchmarked against several Australian and International turnout inspection standards, including Network Rail, Transnet, ASA and ARTC. Several stakeholders were engaged throughout the project including;

- Track inspectors were engaged to aid in identifying pre-existing asset condition issues and inspection methods.
- Track engineers were consulted to identify renewals and maintenance processes as current and aid in identifying root cause of turnout failures.
- Network standards engineers were consulted to aid in identifying suitability of standards on turnout components and how these standards were developed to prevent failure. This was critical in understanding component wear rates against risk profile.
- The project team also had discussions with turnout manufacturers to identify turnout failure modes and likely causes.

The turnout asset requires consideration of the impact on the total rail system, including;

- Wheel: wear, profile, flange condition and depth in both new and worn profiles.
- Rail: wear and profile.
- Points Detection and motor/rodding performance.

All of these inputs were considered in the assessment methodology.

The compatibility of the worn turnout asset with new wheels was considered. A major risk identified, was that the tolerable headwear in stockrail/switch assembly was far less than the tolerable wear in plain rail.

- **Degree of Innovation in Rail Aspects**

Standard detailed turnout inspections on networks across Australia rely on a qualitative assessment of the condition of the asset. This is suitable for low volume networks where the asset condition is not expected to undergo significant change between detailed inspections allowing the maintenance and/or renewals branches to plan works. This relies on a qualitative assessment of multiple data sources, often including anecdotal data points and reliance on 'institutional knowledge'.

For example, the network engineer will look at track geometry recordings, rail profile recordings, quality assurance reports and historical data, and from this, form a qualitative assessment of the maintenance requirements of the asset.

In high traffic volume networks where the asset experiences high rates of wear, this approach is highly inefficient.

The detailed inspection method, the data collected, and the processing model that Plateway has developed utilize the following data inputs;

- Track geometry from a track geometry trolley with measurements taken every 0.1m
- Rail wear measurements recorded on stockrails, switch rails and turnout crossings
- Ballast depth measurements
- Qualitative assessments of turnout components that have been assigned a value and scored to form an asset condition index
- Traffic Volumes

This project brought innovations to the detailed turnout inspection process by quantifying the parameters of standard turnout inspections, and generating a searchable asset database. This data was then used to develop a data-driven maintenance and renewal plan which incorporates forecasted traffic volumes to estimate remaining asset life.

This methodology results in a more consistent set of results for asset inspections that are less subject to the variance in the skill and experience of the track inspectors.

- **Contribution to Safety**

Network Rail have identified key failure areas associated with switch fit, stockrail height/wear and switch rail climb angle. These were specifically targeted in the methodology developed.

This project resulted in the following improvements in safety;

- A detailed turnout inspection methodology was developed and risk assessed which minimised time spent on track.
- The asset database can be used to predict failure before a defect is formed. In comparison to other track assets, turnouts pose a high consequence and risk of failure and hence identifying when assets will be life expired is critical in high volume traffic networks wherein turnouts can undergo significant changes between inspections.

- **Systems Assurance**

Previous inspections have focused on technical discipline-specific issues rather than considering the role of the turnout assembly within the wider railway asset system. Turnouts are at the intersection of;

- the track and signalling systems;
- the rollingstock and signalling systems, and;
- the rollingstock wheel and rail interface.

This methodology uses the traditional detailed track inspection scope and expands on it to include the performance of the other elements of the turnout asset, such as wheel and rail interface, performance of the switch fit/detection system and condition of the IRJ's, both in terms of physical condition and their in service geometry features under load.

The project was intended to advance RAMS engineering on the network, by;

- Better understanding of the **reliability** of the turnout assembly and when they were expected to fail.
- Increasing track **availability** and rail traffic volumes by decreasing time required on track to perform detailed turnout inspections, and reducing unplanned possessions for maintenance tasks.
- Allowing easier **maintainability** of the network by establishing a set maintenance and renewal procedure, and predicting these maintenance and renewal cycled prior to a fault being identified.
- Improving **safety** on the network by reducing unplanned track possessions and improving knowledge of turnout assets prior to a fault forming.

- **Commercial Benefits**

The outcomes of this project were used to form the rolling 5-year maintenance and renewal plan for turnouts on the network. This will result in less unplanned maintenance, and critically, result in a more accurately scoped project in a high traffic volume network.

This will lead to the following commercial benefits;

- Less unplanned interventions, effectively increasing rail traffic through the network
- Timely removal of failed components from service
- A reduction in spare inventory levels as stock required can be sourced in advance of expected works, hence fewer spares are required for unplanned works.

The model assigns each parameter a weighting that can be adjusted to target specific configuration changes or maintenance needs. The model and methodology that was developed can be easily customised to suit turnout asset configurations.

4. Part 2 – Discussion

Background

A detailed turnout inspection methodology was required to be developed for use on a high traffic volume freight network in Australia. Data management of the existing turnout examinations being carried out was not sufficient to inform the short-term asset management planning due to the size and traffic volumes on the network. The asset database was to be used to develop a rolling 5-year turnout maintenance and renewal plan.

The project team completed a total of 215 inspections on various turnout configurations and formed a database and data processing stream to predict the maintenance and renewal timing and scope for each turnout on the network.

Equipment utilized

A key distinction in this detailed inspection method is the use of quantifiable data. This necessitated the use of a track geometry recording trolley and miniprof rail profile instrument to allow detailed asset condition data to be recorded and processed off-site.

Figure 1 - Miniprof rail profile instrument

The inspections were to be carried out between train running, as traffic permits. This required a suite of tools that were easy to mobilise, and data outputs that could be post-processed to integrate into an asset condition database. The track geometry trolley chosen for this application is the ABTUS 4530 track geometry inspection trolley as it fulfilled all criteria.

Figure 2 - ABTUS 4530 Track Geometry Trolley

In addition, the inspection team utilized standard track inspection tools such as insulated tapes, laser squares and feeler gauges.

Pre-Possession Planning and Inspection Items

It was imperative that the detailed inspections were completed with no disruption to rail traffic or other work activities. The inspection regime for the network was planned to run adjacent to other work parties wherever possible, this allowed the inspection team to take advantage of adjacent possessions, maximize crew safety, and minimise asset downtime.

As an outcome of a pre-work risk assessment, it was determined that several of the inspection items could be completed under Lookout working. This includes taking photos, measurement of ballast heights, rail profiles and switch and cross wear. Possession was required to take track geometry measurements and throw the turnout points and complete measurements for both switch rails.

By effectively utilising pre-possession ‘downtime’ and streamlining the inspection process, the project team was able to work to an average productivity of approximately 1 location per hour with a possession of 30 minutes.

Inspection Method Development

An inspection method was developed to comply with current detailed turnout inspection requirements on the Network. To streamline data entry, a tablet-based application was created, which allows for manual measurements and notes to be directly exported into excel format.

A track geometry assessment algorithm was developed to highlight track geometry faults in the data set, and to calculate a TQI value for each track geometry recording in accordance with the TQI formula used on the network.

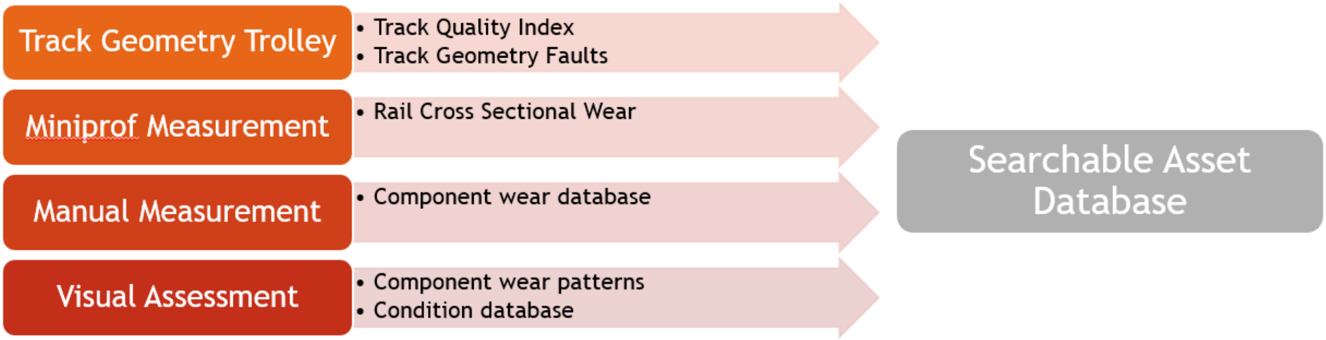
A miniprof measurement format was developed at locations which were identified as presenting significant risks at the rail/wheel interface. These locations are as follows;

- Stockrail 100m before point of switch
- 50mm within point of switch
- Stockrails in the body of the turnout
- Crossing nose splice rail ramp points as identified in manufacturer drawings

By utilizing the data obtained from these measurements, the project team was able to determine the expected asset life based on expected traffic volumes.

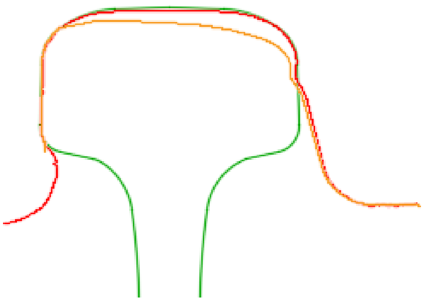
Data Processing

The key innovation in this project was the conglomeration of the various data inputs into an asset database designed to track asset condition for its life cycle.



The data from the track geometry trolley was parsed for track faults, and a Track Quality Index was produced. This was then compared and scored against a control turnout TQI and a track geometry score was assigned to each turnout.

The rail profile recordings were autonomously mined for wear data and wear values were compared against newly formed tolerances for steelwork wear on turnout components.



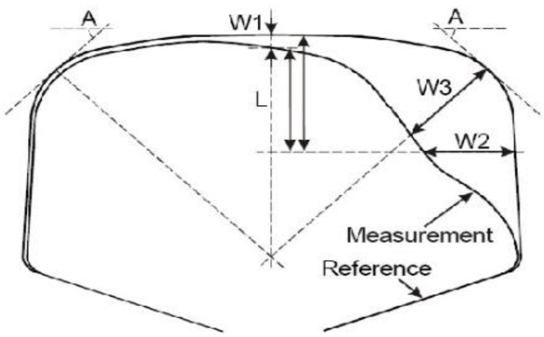
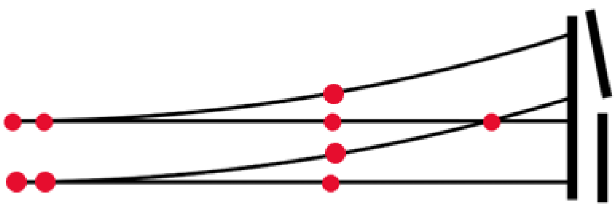


Figure 4 - Rail Profile Recording against Template (above)
Figure 5 – Miniprof Cross Section Locations (below)



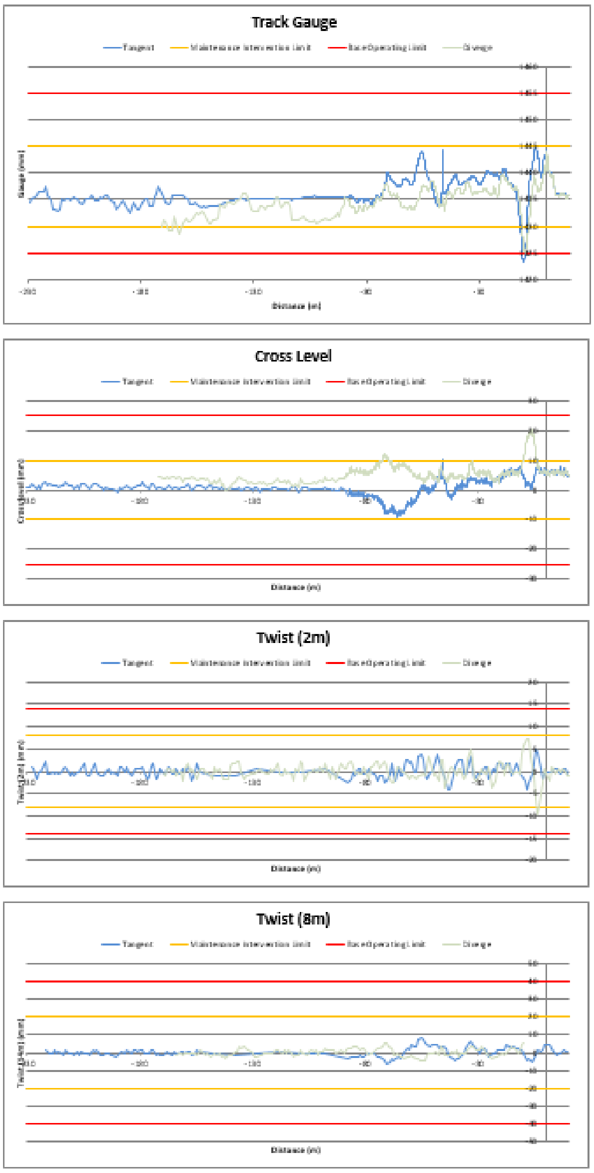


Figure 3 - Track Geometry Data - Graphed for Tangent and Diverge

The data from the asset database was then incorporated into a model to forecast turnout renewal works and classify turnouts into the following categories;

- Renewal of wear components (i.e. steelwork)
- Renewal of all components (i.e. steelwork and bearers)
- Renewal from track formation

Regular maintenance tasks such as rail grinding and tamping were not informed from this model as they are pre-planned maintenance activities with frequency driven by tonnage. However, the logic of the model did incorporate whether a turnout could be life-extended by regular maintenance activities or if it was more efficient to conduct a renewal.

The data flow is as follows;

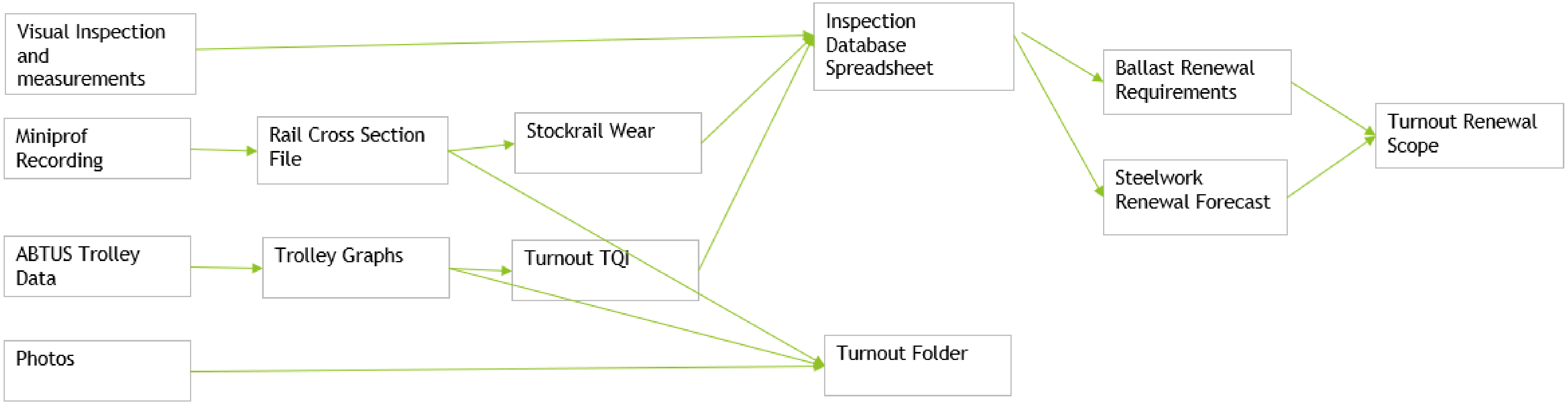


Figure 5 - Turnout Assessment Model Data Flow

Outcomes

The project was able to generate a turnout renewal and maintenance programme compliant with the standards of the network.

The programme logic used steelwork wear rate and current condition to predict the steelwork renewal requirements. Each turnout was assigned a score for further renewal based on the condition of the asset.

The weighting of each inspection outcomes is automatically calculated by the model and can be adjusted to target specific configuration changes or maintenance needs of the network.
The model and methodology are customisable to suit individual clients and turnout asset configurations, and trending can be carried out over multiple inspection cycles to continuously improve the model inputs.

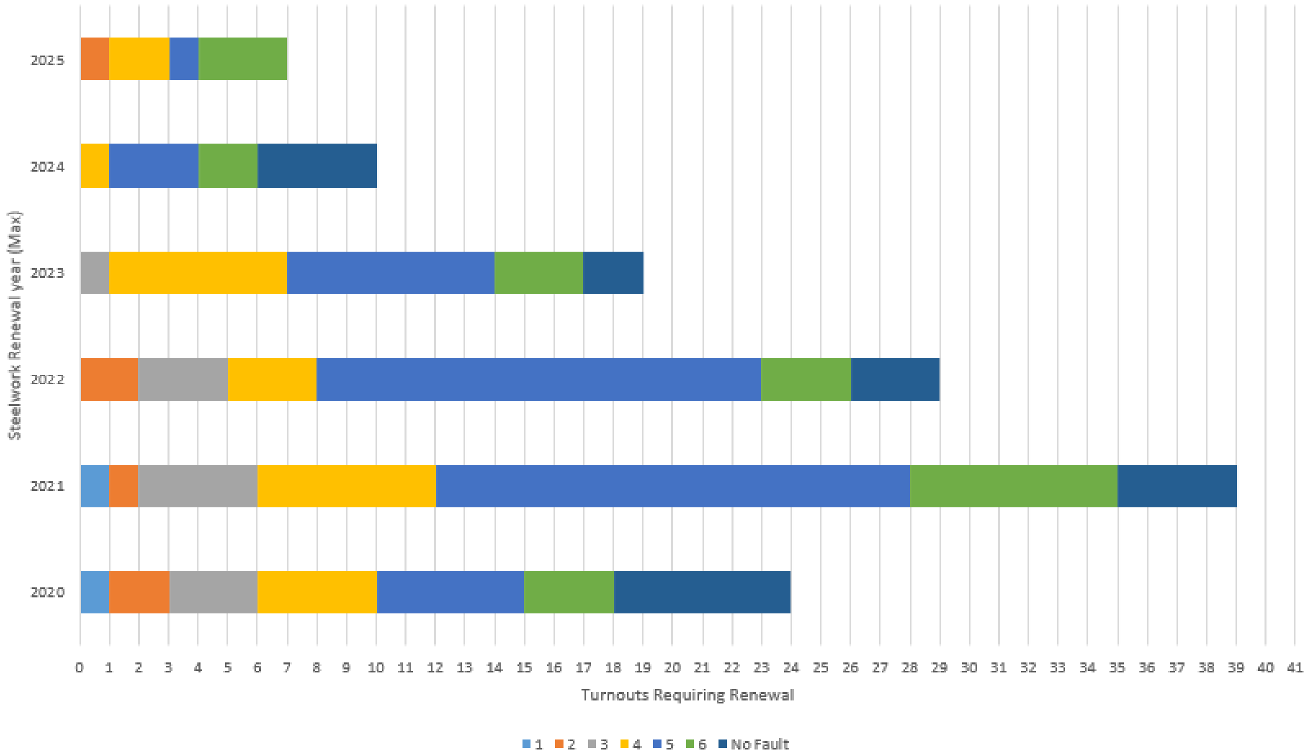


Figure 6 - Forecast Turnout Renewals by Year and Fault Category

Conclusion and Further Work

The model was designed to become more accurate with further use. It is expected that each turnout would have a trackable condition score that would deteriorate over time. The rate of degradation can then be fed back into the model to increase the accuracy over the long-term use of the asset.

Plateway is currently working on incorporating drone aerial imagery into the inspection method. This can be completed outside of a track possession, and can be used to compare the current asset against the design general arrangement drawings and as-built surveys to monitor the track geometry.

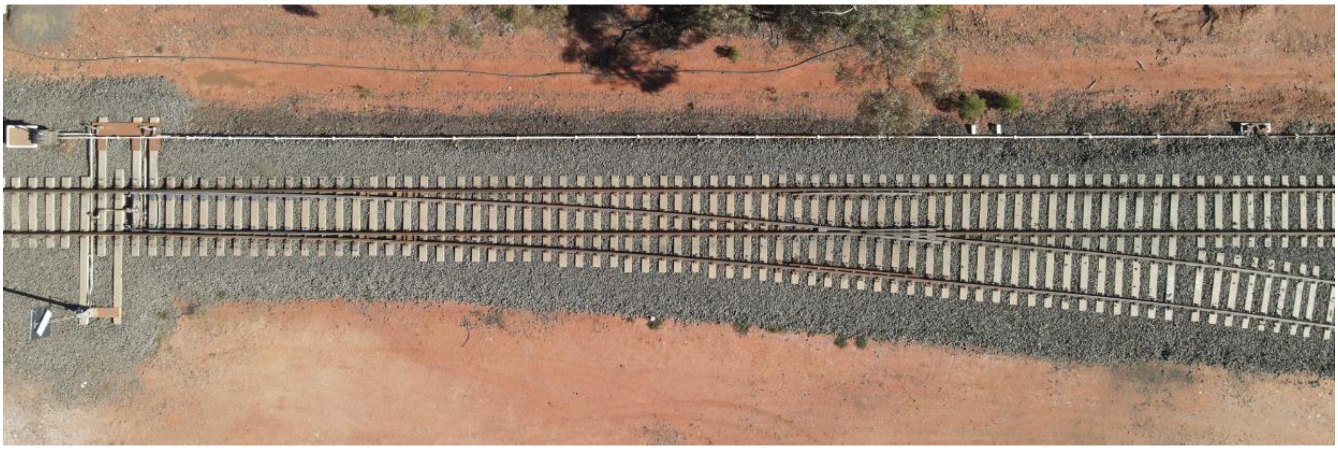


Figure 7 – Turnout Aerial

The asset model was designed to be modular, and able to be modified to suit inspection of other assets such as plain track, bridges, level crossings and culverts.