The Victorian Rail Infrastructure Survey

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Prior to undertaking a business development role at Geomatic Technologies (GT), David was the Senior Project Manager for many of the rail infrastructure projects undertaken by Geomatic Technologies since 2004; including the Victorian Rail Infrastructure project that was successfully completed at the end of 2006, and was awarded the Asia Pacific Award for Spatially enabling government.

Abstract

In 2007 the survey of all rail track infrastructure throughout Victoria, Australia was completed. Comprised of over 5,000 miles of electrified and non-electrified track the Victorian network is one of the largest in Australia.

The core project requirement was to map all track centerlines, track geometry and rail assets throughout Victoria’s urban and rural rail network. In addition to recording physical details (asset type, construction etc) about each asset critical to the performance of the public transport & freight systems, a coordinate for each asset was also captured and digital imagery at a frame interval of 2.5m was recorded over the entire rail network.

The Victorian Rail Infrastructure Survey has delivered network-wide asset data through a spatial application to an industry that was reliant on spreadsheets and archaic document management systems. The Department of Infrastructure (DOI) has developed an online spatial information website (PASS Assets) to publish the data and the take-up of PASS Assets user licenses (now 500+) is an endorsement of both the DOI’s initiative to conduct the asset survey and the need for accurate rail infrastructure data by engineers and public transport planners alike.

This paper will focus on the many technological and innovative techniques which were used to complete the project including the use of track-based digital imagery to map assets along the track corridor, and the use of GIS Applications that perform spatial validation on the data.
Introduction

Following a rail privatization process in the late 1990’s it was identified that the State had a requirement for a register of assets associated with Victoria’s Rail Infrastructure; estimated to be worth in excess of $6 billion. The Department Of Infrastructure (DOI) commissioned Geomatic Technologies (GT) to undertake a state-wide survey of all rail infrastructure through Metropolitan Melbourne and Rural Victoria.

Successful completion of the project required the application of geo-spatial technology throughout the planning, collection and processing phases of the project; including the innovative survey techniques employed by GT using photogrammetric drivers-view digital geo-referenced track imagery, 5cm resolution aerial photography and in-field data capture for this extensive data collection project.

Figure 1. PASS Assets - GIS Web Portal
The DOI has published the survey results using an internet-based GIS platform called PASS Assets developed and hosted by the DOI. PASS Assets provides the industry with access to accurate, field verified, comprehensive digital rail asset information through a single information portal.

The final data sets that were delivered to the DOI underwent a variety of geo-spatial applications to ensure the data was accurate and validated against both many business rules as well as legacy data sets of the network that existed mainly in paper form.

The results of the Rail Infrastructure survey throughout Victoria are now contained within a single source that not only provides accurate information about the infrastructure location and type, but is linked to quality imagery of the asset at the time of inventory.

From beginning to end the use of geo-spatial information, products and expertise was required at every step to ensure the data collected and displayed for the end user was both accurate and complete. This paper discusses how geo-spatial technology was used throughout the process as well as how the DOI is using the same technology to get the information to its user base.
Application of Geo-Spatial Technology

Project Extents

The Victorian rail network is defined by approximately 5,000 track miles of rail corridor, spread across the entire state. The corridor is defined by a lease which varies in width and encompasses the rails and ballast as well as all other infrastructure such as stations, buildings, bridges, signal equipment etc. The aim of the project was to coordinate, describe and photograph every asset contained within the rail lease. Due to the size and complexity of the network, traditional survey methods for collecting the information required by the DOI where not suitable or capable of delivering the entire project within any definition of a practical time frame.

Figure 2 Railway Map of Victoria, 2000
Data Collection Techniques

The Victorian Rail Survey had extensive specification (data dictionary) requirements, but could be conceived in the following four major project deliverables:

1. **Track Centerline & Geometry** – Including positional X,Y,Z at 1 meter intervals, Track straight, curve and transition information, vertical grade, and cant; track mileage.

2. **Drivers View Imagery** – Imagery of the rail corridor as witnessed by the rail driver.

3. **Asset Information** – Imagery, positional information and attribution of all assets within the rail corridor including ties, points, signals, signs, stations, utilities, bridges, road crossings etc (Over 40 major asset types, with a multitude of sub-asset types).

4. **High Resolution Aerial Imagery** – Imagery was required over stations and yards only due to the high asset density in those regions, and the requirement to map all assets within the fenced area of the yard or station.

Data collection using ground based digital imagery had been developed and deployed on several rail vehicles throughout Australia, and was considered to be the best technology and methodology for undertaking this project by the DOI. The ground based technology could achieve the collection for most of the requirements set forth in the specification for the majority of the rail corridor. This enabled the DOI to quickly and accurately collect the information they needed without performing traditional aerial or ground based survey methods along stretches of rail corridor which would have resulted in higher costs without much asset information.

The technology used involved the synchronization of high resolution digital still imagery, with survey positioning systems on board a rail vehicle (i.e. Geometry Car, Hi-Rail, etc). The rail vehicle traveled at normal operating speeds along every section of rail track in the network collecting both imagery and location data as it went. The location data collected in the field was processed using a robust Kalman Filter to generate a smoothed track.

![Figure 3. Screen grab of the curve fitting software](image)
centerline. This centerline was then processed again using curve fitting software that applied geometric curves, transitions and straights to the smoothed centerline.

The result was an accurate track alignment that was connected in discrete geometric track segments. This accurate track alignment would provide a framework for referencing all other data, including the high resolution digital still imagery, and high resolution aerial photography.

Individual image frames collected by the cameras on board the rail vehicle were referenced to the track centerline and the imaging cameras were calibrated to support accurate mapping using photogrammetric techniques.

Figure 4. Screen grab of asset collection using track based imagery

These sequenced image frames served two purposes. The first was to provide an operator coordinated rail imagery linked to a common map base for visual inspection of the track. The second enabled the operator to accurately map and attribute point, line and polygon features that could be identified within the imagery. There existed over 40 major asset types from the specification that were to be mapped using the drivers’ view imagery. Once all assets within the imagery had been collected, there were many QA/QC steps which were followed as a defined process to ensure that all the data was complete and accurate.

High resolution (5cm) aerial photography was flown over all station grounds and yards due to the wider corridor boundaries and high asset densities found in these locations. This enabled the operator to continue mapping other assets that could not be seen in the drivers view imagery. It also assisted in QA/QC of the mapped assets via the track based imagery. Once all the available information had been collected via these two sources, the final phase was to send field teams equipped with tablet PC’s and
DGPS receivers to map, image, verify and validate sections of the network that had been identified as missing information based on many of the Geo-spatial reporting and analysis. By combining the track based imagery with the high-resolution aerial imagery and following that up with discrete targeted field visits, the complete and accurate collection of all asset information that met the project specifications was achieved.

**Field Planning and Reporting**

Prior to undertaking such an extensive mapping project required a host of pre-planning operations due to the enormity of the geographical area to be surveyed.

Ensuring the rail centerlines were surveyed accurately by the track vehicle meant performing precise surveying techniques across the entire state of Victoria; a huge logistical task in itself. Statewide overlays of track centerlines, from legacy datasets along with Base station locations from the Victorian GPS Network was required to determine where GPS “dead” zones might exist and need to be supplemented with additional control. The utilization of the States GPS network enabled the field data to be post processed using dual-frequency GPS data, which is capable of deriving far greater accuracies than that delivered by stand alone differential GPS units.

The collection of mainline track “drivers’ view” imagery was a core requirement; therefore consideration for the direction of the track being mapped in relation to sun angles and time of year had to be factored in to ensure the imagery collected was of suitable quality.

![Figure 5 Forward and Reverse Train Based Imagery](image-url)
Mapping vehicles were scheduled so that the bulk of a particular track could be imaged with the sun high in the sky and preferably behind the mapping camera.

High level aerial photography was required for over 450 rural stations, and so flight plans had to be generated over a central point for where the station was believed to be. Data sets of rural townships were integrated along with the legacy mapping of the railways and a point was defined as being the center of the station. Flight plans were generated to collect the station and surrounding yards based on this information. While over 95% of stations were collected successfully via this method, several stations were still missed due to the inaccuracy of the legacy data in placing the station correctly. For these stations a re-fly was required to ensure the whole station was covered by the high resolution photography.

All road / rail crossings had to be visited and imaged by field personal, therefore correct road names at level crossings had to be identified. Victoria has several road datasets from both public and private sectors which contain road names, however these datasets can both vary between each other as well as what’s on the ground. A hierarchical approach was mandated to the field crews so that they could adopt a consistent road name where more than one existed, however additional names were included as alias to support emergency management and local access uses.

As different parts of the network had many different stages of field collection, i.e. track based imagery & position, aerial photography, field crews, and office processing, it was difficult to manage the network to ensure that no sections were missed. Using a network map as a report mechanism provided all project personnel with a clear view of the entire project schedule.
Geo-Spatial Queries and Analytics

The amount of checks and QA/QC built into this project was extensive. The government had access to huge amounts of legacy data, however much of it was not maintained, of dubious nature or not in a form or format that was useful for incorporating into a geo-spatial dataset. This information did however provide valuable links to systems and business rules which could be applied into the data collection and attribution process to ensure that the data collected was as accurate as it could get.

Many of the systems and software needed to undertake this type of rail inventory project were not commercially available. To solve this, in-house software which was used on previous rail mapping projects was enhanced, modified, produced and applied based on the geo-spatial expertise and project knowledge gained from previous mapping campaigns.

Office personnel used the in-house mapping software and configured it to suit the Victorian rail specification. Many business rules were built into both the field and office software components so that
operators could run specific processes or checks over the collected data throughout the project. These “checks” would be reported in a database format which was linked geographically to the rail network.

The rail track was the framework for the entire project and was the key to linking the entire network together. Network topology (to support rolling stock permissible movements) was an outcome of the project’s high spatial accuracy and requirement to capture all turnout, points and crossings assets. Some fundamental checks involved reviewing the nodal topology of the track centerline to ensure it had consistent X,Y,Z values, and that no gaps or overlaps existed in the track network.

More complex checks contained parent-child relationships and involved placing buffers around a particular asset type to ensure that other assets which were “related” to it existed within that buffer. This methodology enabled an automatic approach to look for incomplete data.

By performing these checks at various stages, operators could look for problems within the data and fix them prior to moving to the next level in the mapping process. For example, prior to sending a field team out, an operator could run checks over the data to look for signage that has not been completed or for an asset which is missing its discrete image attachment. Field crews could then target these assets without having to check the entire infrastructure within their work area.

Figure 7 Screen grab - Internal office processing checks
The provision of high resolution ortho-rectified aerial imagery to supplement major yards and stations was first for this type of conditional inventory project. It offered a complete and detailed snapshot that could be combined with a multitude of other information and imagery to give industry an overall picture of the infrastructure and its connectivity.

Once data had been collected from the track based imagery, the mapped assets could be overlaid with the high resolution photography of the station yards. The overlay would assist office personnel to review both previously mapped assets as well as assets which had not been collected. The imagery provided an accurate background layer for operators to continue mapping assets within the lease parcel to complete the inventory. Many assets positioned using the imagery still required a field visit in order to complete the attribution of that asset based on the project specification. In many cases signs and markers or signa types required field identification that could not be seen in the imagery.

Figure 8 Overview of major yard with project assets overlaid
A report was generated through the process office providing field crew a series of “work orders”. These work orders were linked to geographic locations that enabled the teams to drive directly to the points which required further investigation.

GT field teams were equipped with Tablet PCs, Digital Cameras and DGPS hardware running the same software that was used to map the assets in the office. The aerial photography was loaded onto the tablets as a background layer providing the field crews the ability to track their locations through the yards and stations. With the previously mapped assets overlaid on the imagery, field workers could then review a site to determine which assets may have been missed as well as validating the information that had been collected via the track based and office mapped processes.
Geo-Spatial Deliverables & Future Considerations

As the data collection for sections of track was completed, the information was delivered to the DOI for further QA/QC. Upon receipt of the data, a Geospatial Quality Assurance team appraised the asset information, digital photography and aerial photography for accuracy and completeness for a second time. This ensured a high level of quality for the information loaded into the PASS Assets GIS application. The PASS Assets application went into production at the DOI in December 2003 as a GIS Asset Register with an initial user base of 5 DOI engineers and containing textual, geospatial and imagery of all the Metropolitan Train and Tram infrastructure. It soon became apparent that the application had more potential than was originally envisaged and has now expanded to a total user base of 500+ including franchisees and sub-contractors as well as staff from different government DOIs.

With the Victorian Rail network infrastructure collection almost complete, the DOI is now concentrating on collecting additional information that will be overlaid on top of the infrastructure within the PASS Assets GIS application to enable users of the application to obtain a holistic view of Public Transport. For this reason, several projects have recently been completed including the collection of Structure Gauge Encroachment information using laser technology across the complete rail network and a Tram Ride Quality exercise by using accelerometers bolted onto a B class tram to measure vertical and horizontal acceleration along the tram network. This information along with High resolution (5cm) Aerial photography of the entire electrified, or Metropolitan network, has all been added to the PASS system to increase its usability throughout the organization.
Many other datasets and applications are being considered for inclusion within PASS Assets including:

- rail head profiles
- bus routes
- bus operators (safety audit purposes)
- safety incidents
- operational data
- market segmentation
- signaling topology
- ground penetrating radar ballast data
- grade and curve information
Other inclusions to the system are an interface between the Drawing Management System (DMS) and PASS Assets so that when drawings are created or modified, metadata describing the drawing is published by the DMS and transferred using XML over HTTP (SOAP) to a Web Service provided by PASS Assets. Once received, the data is validated to meet CAD standards and quality assured prior to being automatically loaded into the GIS. The user is able to locate the drawing spatially and select a polygon representing the footprint of the drawing before using a HTML link to access the drawing directly within the DMS.

![Figure 10 PASS Assets - Displaying Electrical Drawings and hyperlink to a DMS](image)

Interfaces are also planned with franchisees Asset Management Systems to allow the user of the GIS to locate annual works plans, work orders and inspections to be examined in detail in the AMS. Over time a history of work carried out on the network will be built up and this, with the addition of condition data, will allow the franchisees to better plan their renewal and maintenance activities to improve the transport network.
Conclusion

The Victorian Rail Infrastructure Survey and PASS Assets project has delivered network-wide asset data through a geo-spatial application to an industry that was reliant on spreadsheets and archaic document management systems. By undertaking a complete inventory of the network using a geo-spatial reference frame, the government can now begin linking all their other rail information and management systems through a common source.

A project of this size and complexity faces many challenges, and traditional methods of collecting this data would not have accomplished that goal. By applying geo-spatial technologies and techniques throughout, the project lifecycle delivered a comprehensive and accurate data set to the Victorian Government.

With the State Government planning to spend $10 Billion dollars on improving Public Transport over the next 10 years a decision was made to expand the function of the application with the long term aim of becoming a portal to relevant Public Transport Information. The collection of infrastructure data was the first very important step in this process.
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