New York City Transit Authority
Automated Transit Infrastructure Maintenance Demonstration

Final Report

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NOTICE

Abstract and Key Words

This project was an implementation of a pilot system produced by Bentley Systems, Inc. (Bentley) on behalf of the New York City Transit Authority (NYCT) and sponsored by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYDOT).

The objective of this pilot project was to demonstrate that the safety and reliability of the New York City Transit transportation system can be improved by automating the correlation and analysis of disparate track related data. Through the use of the supplied technology NYCT is able to use synthesize traditionally disparate data sets into focused and actionable information. Bentley's Corridor Infrastructure Management (CIM) system was used to fuse multiple types of track related data into a single system and enabled the visualization of information with track charts and geographic maps. Furthermore, the CIM enables the identification of existing and anticipated problems along with indications of cause and effect relationships.

Through continuing usage of the pilot system, NYCT has concluded the capabilities of the pilot system enable NYCT to visualize the actual track network. This includes knowing the type of track (Type I, Type II, Type IIM, etc. (e.g., ballasted, guarded curve)) as well as the environmental conditions in the tunnel (Dry vs. Wet). Most importantly NYCT can see for the first time the combined data from multiple inspections by displaying the defects from these inspections on the map or track chart. Clusters and areas prone to certain types of wear are immediately apparent. Planning maintenance work with this type of tool promotes more efficiency.

A maintenance manager can sort the defects within a stretch of track, identify his work gang and material needs and schedule the work between point A and point B, with all this information on display and at their fingertips. In the past she or he would have to compile the information from the database by hand and mentally plan the job without the visual display. When doing the work by hand, a manager or supervisor would not look at more data then was minimally necessary. They would not see the whole line or even an extra mile or so down the track to take into account the bigger picture or a more effective solution. Multiply this with the fact that many work gangs receive assignments daily and the task of planning work effectively and efficiently suffers.

As the New York Metropolitan Area has grown, the MTA Agencies (NYCT Subways and Buses, LIRR, NJ Transit, Metro North RR) have become an indispensable asset. Additionally, with energy issues coming to a critical juncture, maintaining a safe, reliable transit system in New York will continue to gain importance.

For over 100 years the NYCT Subway Maintenance division has been performing inspections and maintenance in much the same fashion as it always has. Track inspectors walk the tracks on a bi-weekly basis and track geometry cars ride the rails and measure their condition and location. Switches, signals, infrastructure and a variety of other assets along the rail corridor are all inspected individually. Due to the volume of asset data captured in a variety of formats and from so many distinct sources, the agency's ability to identify maintenance trends is extremely difficult. Inspection information about track conditions exists, but there are difficulties in accessing and sharing within the organization and thus difficulties in prioritizing repairs. When maintenance is performed on an emergency basis the window of opportunity for repair is limited as it requires unscheduled shut downs of lines and negatively impacts the traveling public.

The Bentley Optram System (Optram) is the cornerstone of an automated Corridor Infrastructure Management (CIM) information system. It enables railroads to visualize, link and share railway corridor work conditions quickly and efficiently to all levels of the organization, eliminating waste and redundancy. Optram delivers accurate, up-to-the-minute integrated information that can be used for cost- effective work prioritization decisions and effective long-term maintenance planning.

The project centered on six miles of the Concourse Line between 155th and 205th Streets and involved the import of data from business units within NYCT, primarily the Tracks, Signal, Power and Infrastructure. Over 25 types of data, 120 individual data files and over 10 gigabytes of data were included in the pilot project.

Key Words: Transit Infrastructure, Track Charts, Track Schematics, Track Geometry, Geospatial Data Analysis, Temporal Data Analysis, Track Safety, Corridor Infrastructure Management, CIM, Optram

Acknowledgements

Bentley would like to acknowledge the work of Michael Iovino, Antonio Cabrera, Rene Corcino and Dr. Sam Rumala for their efforts during the course of this project. Without their leadership, sponsorship and efforts this project would not have be possible.

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1 EXECUTIVE SUMMARY

The comfort and efficiency of moving many people together on a transit railway makes it a practical and energy efficient mode of transportation. Using a national average ridership (person per vehicle) means Transit railway's energy per mile is 26% more efficient then cars and 52% more than busses. However in New York City, trains are consistently at maximum capacity compared to the national average. In this scenario, Transit railways are 250 to 550% more efficient than bus and car transport respectively. While transit railway is very energy efficient, its density of moving so many in a small corridor creates a unique burden in sustaining the infrastructure supporting this efficient and valued mode of rail transit[1].

Bentley and the NYCT worked together on a joint NYSERDA and NYDOT project with the objective of implementing a pilot system to demonstrate the benefits of linking engineering, maintenance and operations data together in an effort to improve the system reliability, efficiency and safety. The overall goal of this project was to evaluate the system's effectiveness in planning maintenance, reducing energy use, and improving ridership service. A fundamental premise is that NYCT can improve its maintenance decision process with the system, and thereby improve the operational capacity, safety and reliability of the NYCT subway system - one of the most efficient modes of transportation.

Bentley and NYCT have worked on the pilot project since April 2007. NYSERDA and NYDOT provided the project funding and the stakeholders contributed both time and funds in this cost sharing project.

The pilot system was delivered to NYCT in June 2008 and has been in use since that time. The objectives of the project were to:

- Link track, signal, power and infrastructure data into one system
- Provide a unified view of the integrated data with
    - Visualization tools using Optram Corridor Infrastructure Management for track schematic views and Bentley Map for geospatial views

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[1] TRANSPORTATION ENERGY DATA BOOK: EDITION 27–2008, Table 2.12, Passenger Travel and Energy Use, pg 2-14. Calculation was made with the US Department of Energy's assumption national average of 1.57 persons/vehicle for Cars, 8.8 for bus, and 22.5 for transit rail and full vehicle of 4 persons/vehicle for Cars, 50 for Bus, and 300 for Transit.

    - Analytical capabilities for all supplied data sets using linear data analysis techniques available in Optram and geospatial queries available in Bentley Map
    - Tabular and graphical reports using the Optram Report server
- Identify real world issues impacting NYCT stakeholders and devise queries to identify potentially problematic areas for field research

The pilot project included:

- A six mile portion of the Concourse Line
- Integrating 26 types of data and over 120 individual data files
    - Track network, track markers, various types of wayside assets,
    - Visual inspection
    - Survey records, geographical and linear extent data,
    - Video files (front of cab)
    - Raster imagery (aerial photos and infrared hot-spot detection)

The pilot system was configured on a laptop machine so it could be a standalone system and be highly portable for demonstration purposes. This machine was purchased with funding supplied by NYSERDA. The laptop was configured with Optram, Bentley Map, LDMx, an Oracle database and a Crystal Report application. The machine was delivered to NYCT stakeholders at the handoff meeting on June 25th, 2008.

During this meeting the system was demonstrated for the NYCT stakeholders, as well as representatives from NYSERDA and NYDOT. The predefined queries developed for NYCT were used to illustrate the analytical power of the system.

Through continuing usage of the pilot system, NYCT has concluded the capabilities of the pilot system enable NYCT to visualize the actual track network. This includes knowing the type of track (Type I, Type II, Type IIM, etc.) as well as the environmental conditions in the tunnel (Dry vs. Wet). Most importantly NYCT can see for the first time the combined data from multiple inspections by displaying the defects from these inspections on the map or straight line drawing. Clusters and areas prone to certain types of wear are immediately apparent. Planning maintenance work with this type of tool promotes more efficiency. A maintenance manager can sort the defects within a stretch of track, identify his work gang and material needs and schedule the work between point A and point B, with all this information on display and at his fingertips. In the past they would have to compile the information from the database by hand and mentally plan the job without the visual display. In this case a manager or supervisor would typically not look at more data then was necessary. He would not routinely see the whole line or even an extra mile or so down the track to take into account the bigger picture or a more effective solution.

Multiply this by many work gang assignments daily and the task of planning work effectively and efficiency suffers.

NYCT believes there is value in including the pilot technology within any future automated maintenance management system. Users would able to access data in linear track chart, transit map, geographic map, and tabular visual forms. The system would also provide a unifying and simple web page with pre-configured list of information targeted to the user's needs a secured through password protection. The system would include Track assets, Traction Power (3rd Rail) assets, and Elevated Structure and have the option to expand to Signaling assets. It would incorporate handheld/tablet computer system for collection and verification of visual track inspection and the ability to record the location and type of work performed. The system would store or link to the same data types evaluated in the pilot but with live links, simple editing tools, and automated import tools to load and keep data current with little or no human effort.

2 INTRODUCTION

2.1 TRANSPORTATION AND ITS SIGNIFICANCE TO NEW YORK STATE

As the New York Metropolitan Area has grown, the MTA Agencies (NYCT Subways and Buses, LIRR, NJ Transit, Metro North RR) have become an indispensable asset. Additionally, with energy issues coming to a critical juncture, maintaining a safe, reliable transit system in New York will continue to gain in importance.

The New York subway system serves over 5 million riders on an average weekday and over 1.5 billion annually (2007)[2]. The system is the 4th largest by annual ridership and has 468 stations – the largest number of public transit subway stations for any system in the world[3]. It has approximately 660 track miles in passenger service and approximately 840 track miles when counting track used for non-revenue purposes (e.g., in subway yards). Substations receive as much as 27,000 volts from power plants and convert it for use in the subway. The third (contact) rail uses 625 volts to operate trains. Alternating current (AC) power is use to operate signals, station and tunnel lighting, ventilation, and miscellaneous line equipment. Direct current (DC) power is used to operate the trains and auxiliary equipment, such as water pumps and emergency lighting. The NYC Transit subway system uses enough power annually to light the city of Buffalo for a year.[4]

2.2 USER ECONOMICS

NYCT's economic motivation in implementing a system is to focus time and energy on the proper maintenance activities at the correct time. With budgets in jeopardy and energy and resources becoming more costly, the methods of the past hundred years are no longer adequate.

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[2] MTA Web Site http://www.mta.info/nyct/facts/ridership/index.htm, March 2009.

[3] MTA Web Site http://www.mta.info/nyct/facts/ffsubway.htm#stations, March 2009

[4] MTA Web Site http://www.mta.info/nyct/facts/ffsubway.htm#stations, March 2009

2.2.1 KEY POLICY OBJECTIVES ADDRESSED

This project supports some of the Statewide Transportation Master Plan. A summary follows:

Seamless transportation, responsive to customer needs, customer-driven

Railways operate in an environment of increased vehicle weights, operating at higher speeds, and with greater frequency of trains over a diminishing number of tracks. Railway capital, operating budgets and manpower are not increasing at the rate to support this growing utilization. The pressure to perform maintenance and renewals while minimizing traffic interruptions increases. As a result, railways must take actions like increasing the work performed in the same or smaller work window and performing multiple tasks when the track is out of service. Work is performed when the track time is available, not when the manpower or equipment and materials are available. Optram will provide the NYCT with an automated track chart imaging solution, enabling railroads to share track-related conditions and maintenance information quickly and efficiently to all levels of the organization, eliminating waste and redundancy. Optram's centralized data system delivers accurate, up-to-the-minute information that can be used for cost- effective work prioritization decisions and effective long-term maintenance planning. The end result is that customers are not inconvenienced by last-minute emergency repairs during rush hour.

Allows operators to prioritize investments

With an automated system, operators are able to plan and prioritize maintenance activities, expenditures and upgrades, and will have a centralized record of decisions. The system provides the maintenance decision makers the ability to scrutinize all available information to make the most informed decisions.

Alleviates the burden on NY State's existing mature transportation system

Any system that facilitates the use of and improvement of rail, as Optram does, helps to alleviate this burden. Additionally, maintenance cost savings that can result from the implementation of Optram can result in a surplus that can be funneled to performing work on those portions of the system most in need.

Provides for mobility and safety needs and vigilant protection of the transportation system

An automated system which documents rail conditions, one that allows data sharing between agencies, is a significant improvement over the existing manual system in terms of minimizing response time for safety-related issues.

Promotes improved policy and programmatic coordination between agencies

The front end track chart in use will be available to the New York City Geographic Information Systems (GIS) efforts, such as the NYCMAP, a coordination of mapping data from many city and state agencies.

Optram also allows regulatory agencies a means of auditing what the fault points were in post assessment of incidents and fatalities. It is in effect a “black box” for post incident information.

Will allow the NYCT to build an integrated customer responsive system utilizing the latest technologies

Optram will directly benefit NYCT in this area. By automating rail conditions, travel information will be up to the minute; repairs can be anticipated and scheduled for non-peak customer use hours; and data on rail conditions can be shared to the customers through many avenues.

Recommendations to Governor Pataki for Reducing NY State Greenhouse Gas Emissions

Adding capacity to highways has not had the desired effect of easing congestion. One of the transportation-related issues addressed is railway transportation, and Optram is critical to managing the safety and reliability of the tracks.

This project supports some of the 2005 State Energy Plan.

Policy Objective 4: Promoting and achieving a cleaner and healthier environment

By improving and facilitating the use of rail travel as a means of safe and secure transportation, Optram is an important part of NYCT’s ability to achieve a cleaner and healthier environment by encouraging rail transit.

Relevance to any metropolitan transportation plan or regulation

The use of Optram will enable NYCT to be compliant with the New York Safety Board (NSTB) regulations regarding rail service; the state Public Safety Transportation Board (PSTB) which investigates safety incidents and defects; and the National Transportation Safety Board (NTSB), which requires that a system be in place.

2.3 PROCESS BACKGROUND

For over 100 years the New York City Transit (NYCT) Subway Maintenance division has been performing inspections and maintenance in much the same fashion as it always has. Track inspectors walk the tracks on a bi-weekly basis to perform field based inspections. Switches, signals, infrastructure and a variety of other assets along the rail corridor are all inspected individually. Information from all of the varied business processes is stored in standalone systems, local spreadsheets or databases, or in some cases, paper based systems. More recently, track geometry cars ride the rails and measure their condition and location and paper strip charts are used.

Due to the volume of asset data captured in a variety of formats and from so many distinct sources, the agency's ability to correlate data to predict maintenance issues is extremely difficult. The information about track conditions exists in standalone systems and is actionable for those individuals having access. However, it is difficult to share this information and to visualize it in the context of the entire organization, so coordination of corrective actions is difficult. When maintenance is performed on an emergency basis the window of opportunity for repair is limited as it requires unscheduled shut downs of lines and negatively impacts the traveling public.

3 SYSTEM OVERVIEW

The Bentley Optram System (Optram) is an automated Corridor Infrastructure Management (CIM) information system enabling railroads to visualize, link and share railway corridor work conditions quickly and efficiently to all levels of the organization, eliminating waste and redundancy. Optram delivers accurate, up-to-the-minute integrated information that can be used for cost- effective work prioritization decisions and effective long-term maintenance planning.

Optram was developed initially for Amtrak on the Northeast Corridor and is in use in transits and freights around the world. Rail systems use Optram to:

- Save up to 10-23% on annual maintenance costs (based on actual data)
- Target maintenance operations *where and when* they are needed
- Provide operating personnel with an easy-to-understand “unified view” of track condition and maintenance
- Improve safety and reliability

- Identify areas of high costs or repeated repairs and apply cost-efficient, long-term solutions
- Improve overall efficiency by increasing asset life without spending additional capital
- Transition maintenance practices from a "run-to-fail" approach to a highly targeted, proactive maintenance planning model
- Evaluate maintenance needs and create work orders in an efficient, integrated process

Figure 1 below provides an illustration of the Optram system.

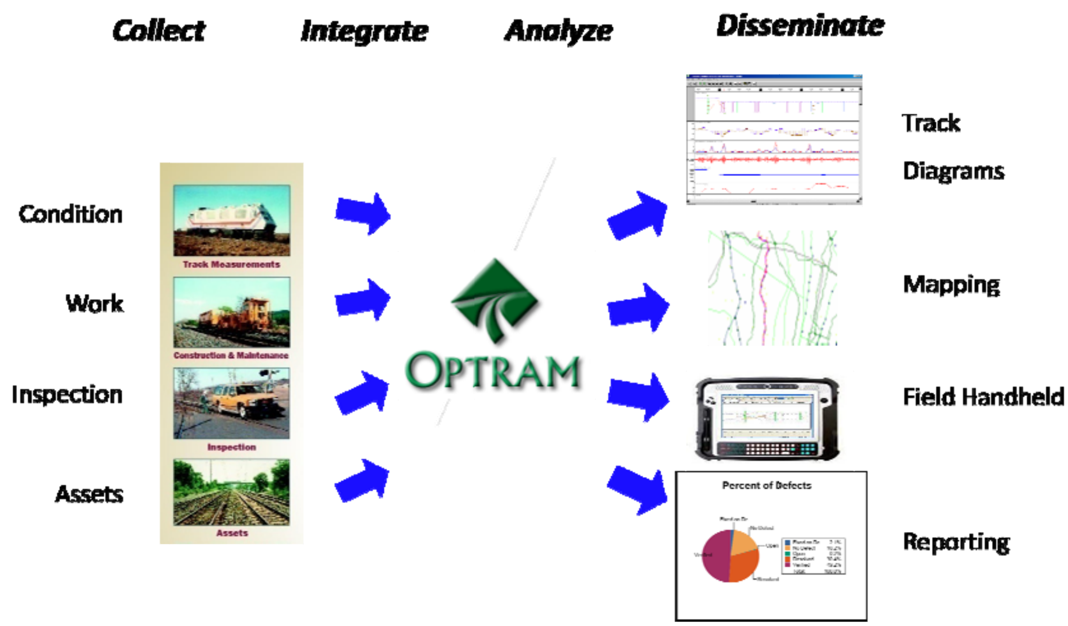

Figure 1 - Optram System Diagram

3.1 LINEAR VISUALIZATION OVERVIEW

The Optram Linear Visualization synchronizes any combination of asset, condition, and defect data within a single view, which allows the users to pin point where problems may exist. Informed with this information, educated users may now take proactive measures to investigate and take corrective actions. The following examples are used to demonstrate the functionality of this unified viewer.

Figure 2 on page 9 is basic configuration of a typical Optram Workbench viewer. The top bracketed section represents the linear asset network, a configuration of the track, track assets and marker views. This view may contain any number of assets the user will load into the Optram system and can be configured to be drawn per user specification. The marker views provide information regarding where along the particular line the information occurs.

The views below the linear asset network are a combination of plot views and extent views, essentially linearly referenced data that correspond in location to the above referenced rail network. Figure 2 outlines Cuts & Fills, Left Profile Roughness, Left Profile, Work Input and Crosslevel.

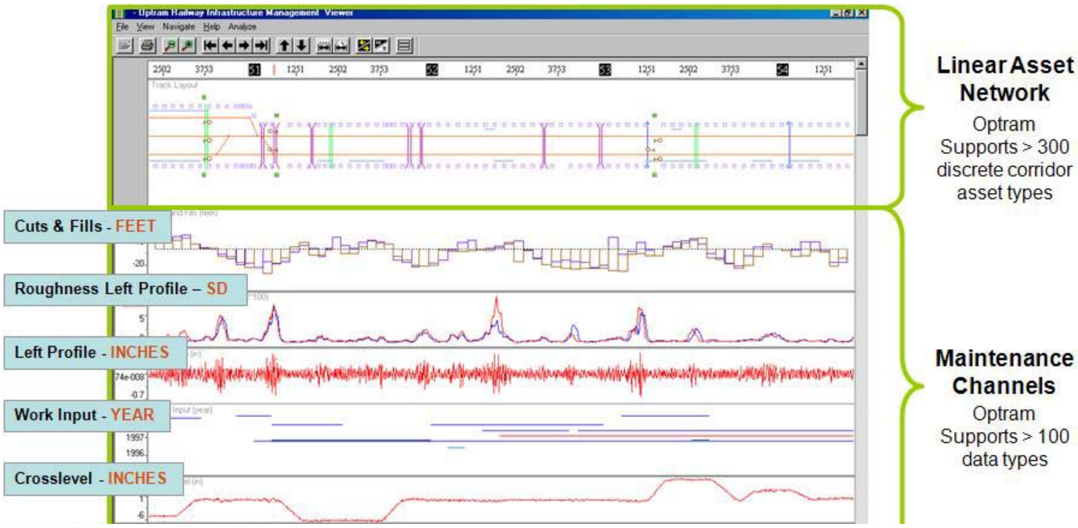

Figure 2 - Optram Overview

Figure 3 on page 10 illustrates the basic layout of the Optram Viewer as it has been configured for NYCT. In this example, only two basic views are illustrated, the Marker and Track Layout. The Marker view shows the milepost markers which are the monuments for the linear locations of the assets. The Track Layout view presents the track network and associated assets. It also includes a pop-up property window showing the attributes of the selected asset.

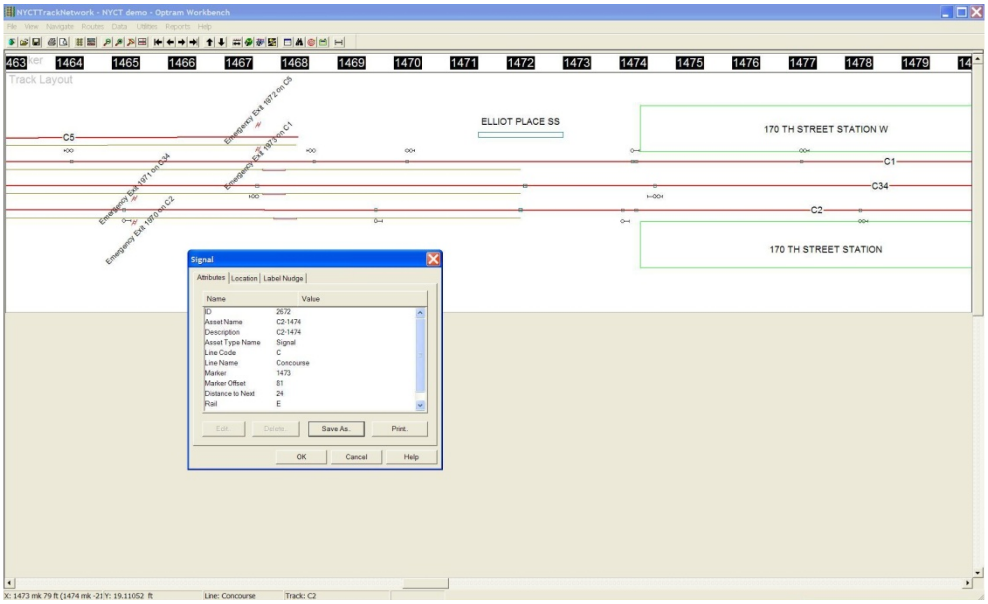

Figure 3 - Optram Workbench

Figure 4 below illustrates how additional content can be linked into the Optram system. It adds an additional view of thermal defects images. Aligning with the track layout, you can identify where the defects occurred and what assets and what environmental conditions occur in the defect vicinity. The left edge of Figure 4 shows the attributes for the selected defect via its property window, as well as the defect image which is invoked by clicking the hyperlink in the property window.

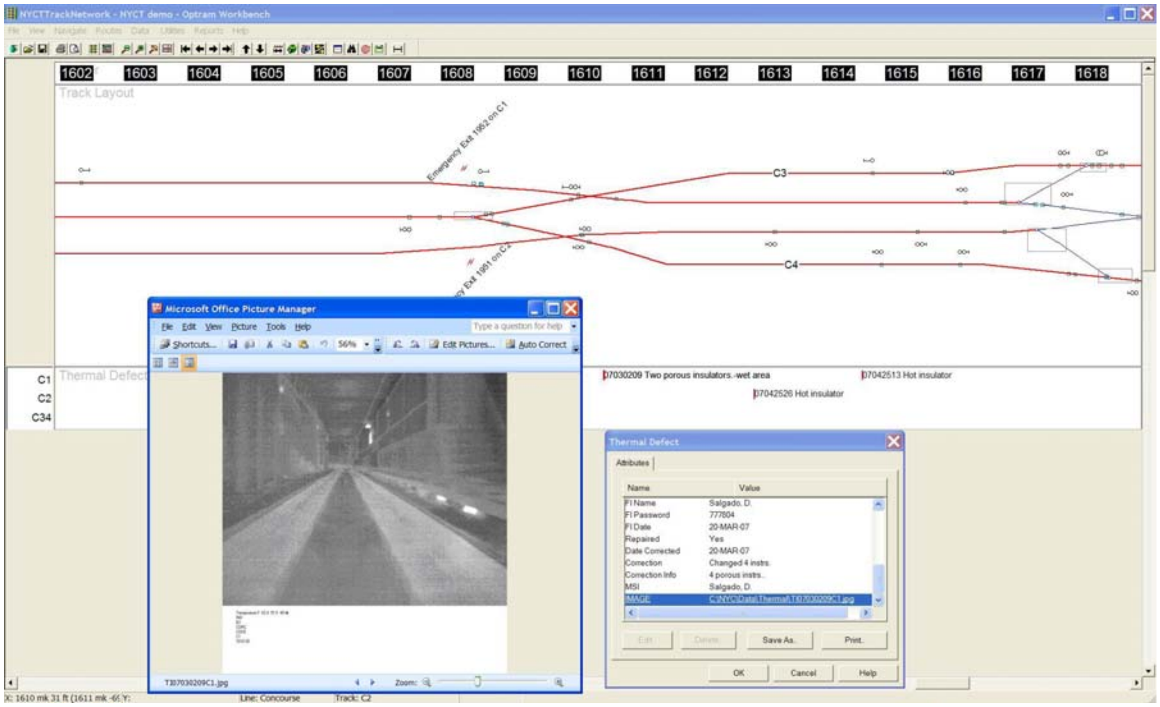

Figure 4 - Thermal Defect Images

Figure 5 presents the built-in search function. The users may define their search filter, such as line and asset type, the search criteria and then clicks the search button. This will list all the assets meeting the search criteria. If the user highlights an item found and click the Locate Item button, the cursor will move to the item. Or the user can choose “View Attributes” which will display the asset property window showing the asset attributes.

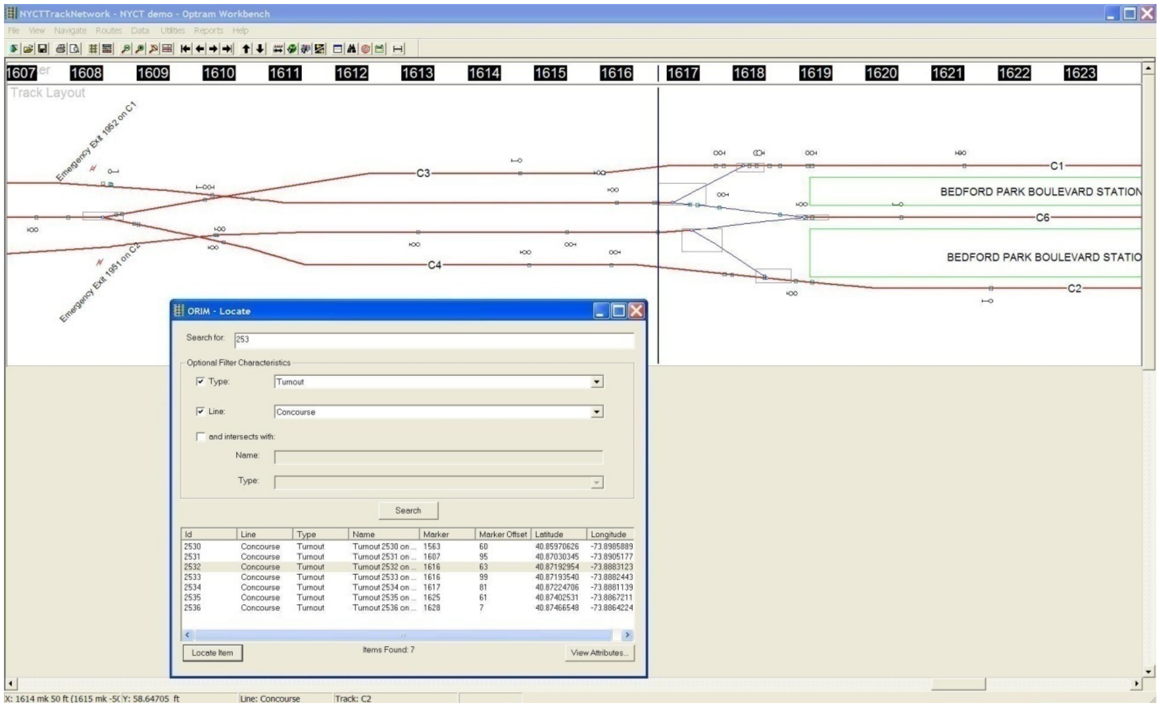

Figure 5 - Workbench Locate Function

Figure 6 demonstrates how a user may use the Workbench system to identify real world issues in the NCYT subway system. Based on the data loaded, rail wear defects have been found and logged. To find out why these happened, the view aligns up the device types, geometry survey results, rail wear defects, environmental conditions, track date, high rail plate condition, and video images. Once these data elements are aligned in the viewer, the user can analyze the available data, look at the associated images and make conclusive decisions regarding the appropriate level of maintenance and / or field response.

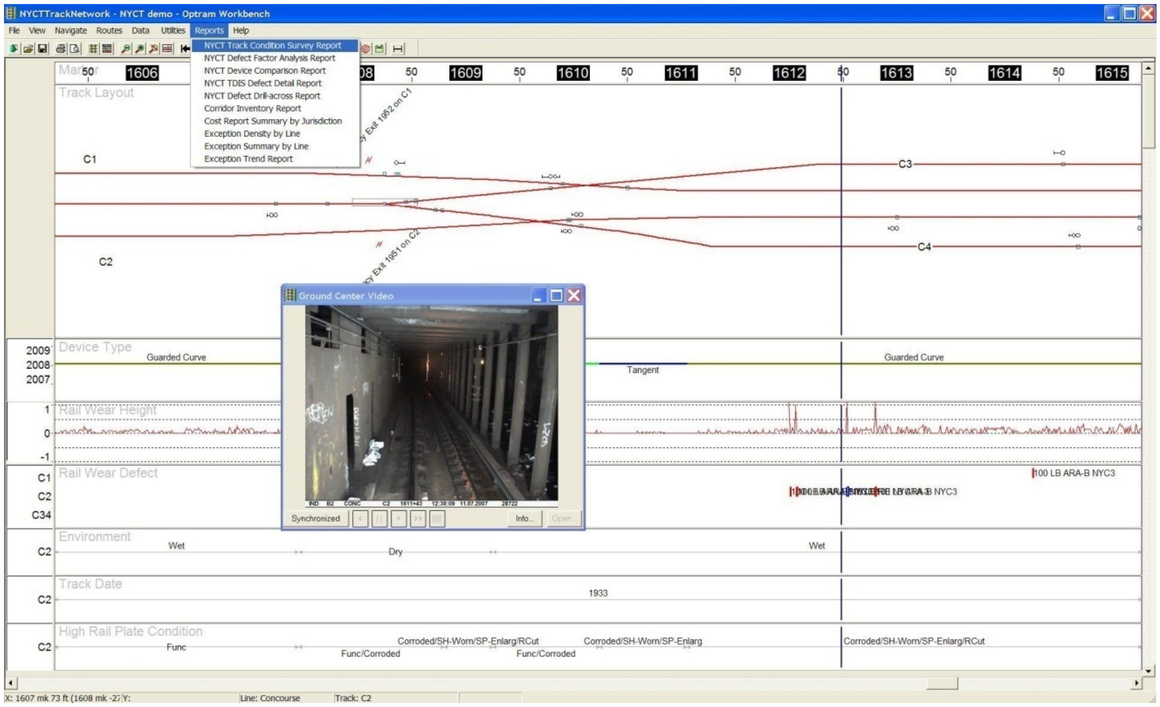

Figure 6 - Track Video

Figure 7 illustrates how the viewer is used for track geometry monitoring and analysis. It illustrates two consecutive track geometry surveys (one blue and other red). Comparing them identifies where the track quality has been improved or degraded. The view also includes the track condition survey for the device types aligned with the measured curve resulted from the track geometry survey.

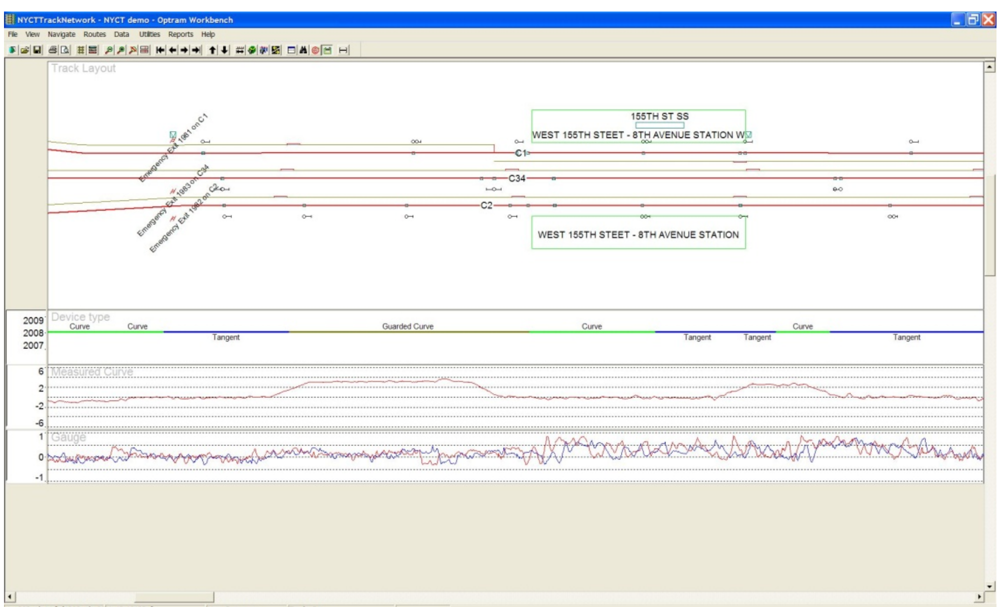

Figure 7 - Successive Geometry Measurements

Figure 8 illustrates how Workbench aligns the work performed and track geometry surveys to see if the work performed were effective maintenance measures. In the example, the blue line represents the survey conducted in 3/2006 and the red line represents the survey conducted on 7/2007. As seen, between the surveys, some tamping, renewing as well as repairing was carried out. As a result by the successive track geometry measurements, the track quality was improved for this section.

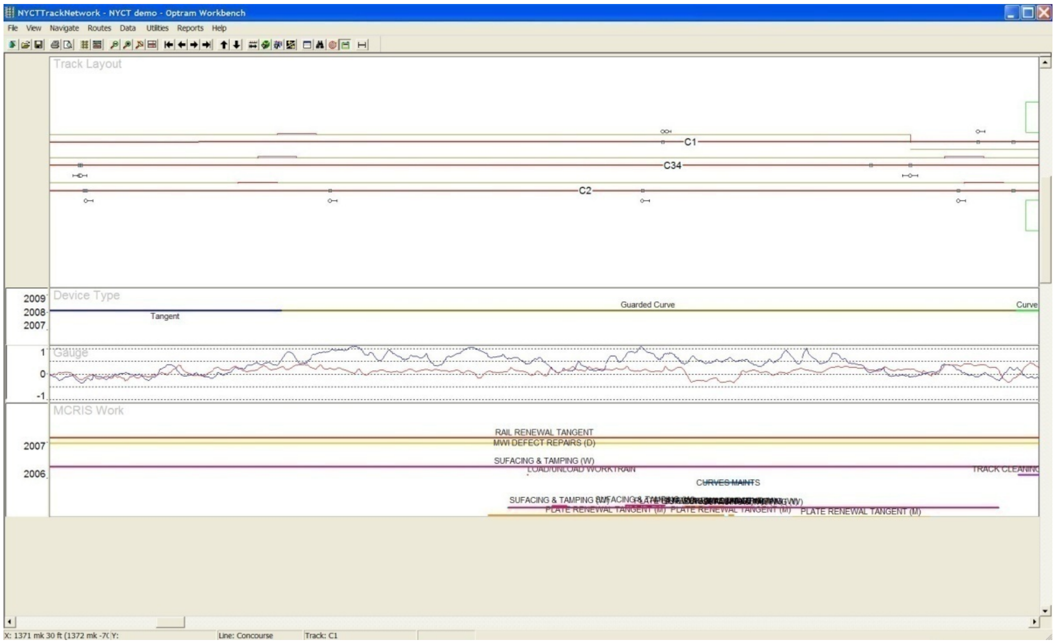

Figure 8 - Work Compared With Geometry

3.2 MAPPING OVERVIEW

During the course of the project NYCT expressed an interest in visualizing their data in a geospatial context. The original scope of the project included only the track schematic views as provided by the Optram Workbench product. However, the Bentley portfolio of software includes the Bentley Map product which is a powerful Geographical Information System (GIS) software package.

To enable the integration between the Optram Workbench and the Bentley Map products, a third Bentley product was used – Location Data Manager (LDMx). The LDMx product provides a method to synchronize linear and geospatial data objects, and also provides a GIS service known as dynamic segmentation. The linear network file created to support the Optram Workbench schematics is stored in an Oracle Spatial database. This network contains all the linear information needed for the schematic rendering, and it also contains all geographic information necessary to display data in a geospatial context. All assets and extents that are displayed in Optram have the requisite information to place the data along the linear asset. The process to turn these objects into assets that can be displayed in the Bentley Map product is known as dynamic segmentation.

Bentley Map uses the preserved and generated spatial layers mentioned previously. And also it uses the raster imagery files provided by New York State's Information Technology Department as backdrop. In total there are 16 raster images files provided covering both Manhattan and Bronx areas and 3 of them are used, which are associated with the Concourse Line.

Figure 9 below provides a screen capture from the Bentley Map system delivered to NYCT. The pane on the left hand side of the image provides an overview of the raster imagery, track network and associated stations. The raster images are aerial orthophotographs that were provided by the New State Department of Information technology. The lines in red are the track centerline representation and the green boxes are symbols representing the stations. The pane on the left hand side is the "Map Manager" which provides the end user the ability to interact with all available spatial data layers and derived queries.

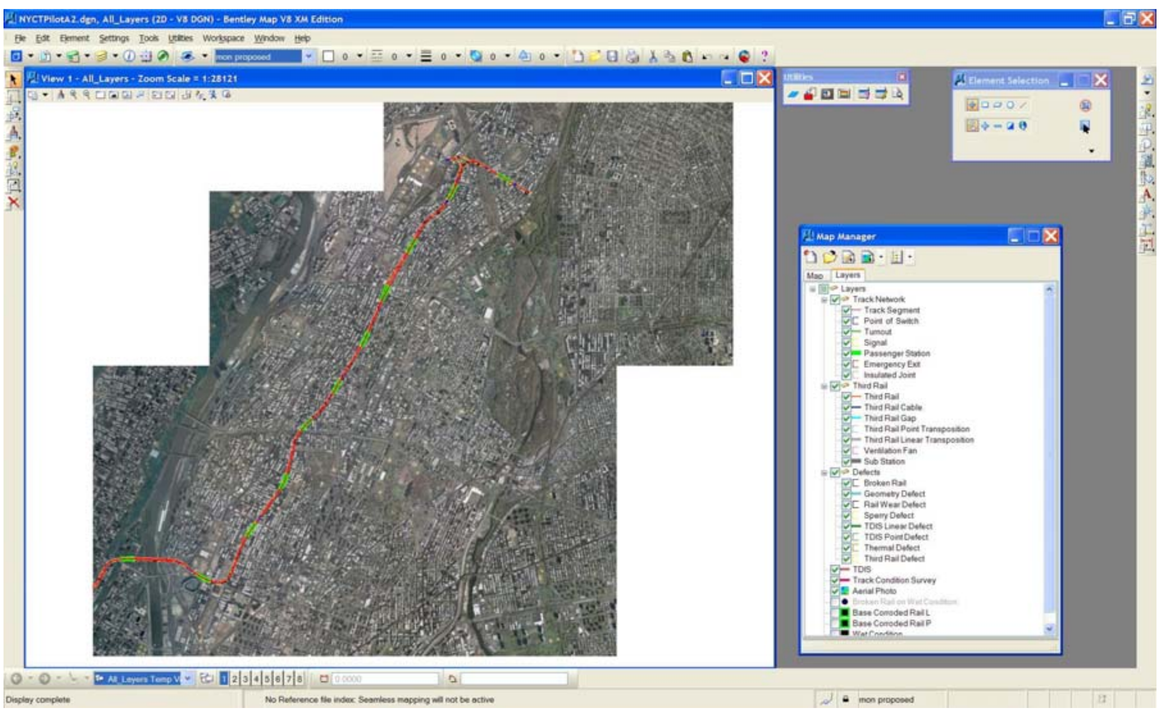

Figure 9 - Bentley Map Overview

Figure 10 below provides a close up overview of the section of the Concourse line near Yankee Stadium. As before, the left pane is the map window presenting orthophotography, the track centerline in red and various assets represented by the appropriate symbols.   The window on the right details the properties for a particular asset. In this scenario, the user has selected a signal record and its associated properties are provided in the dialog box.

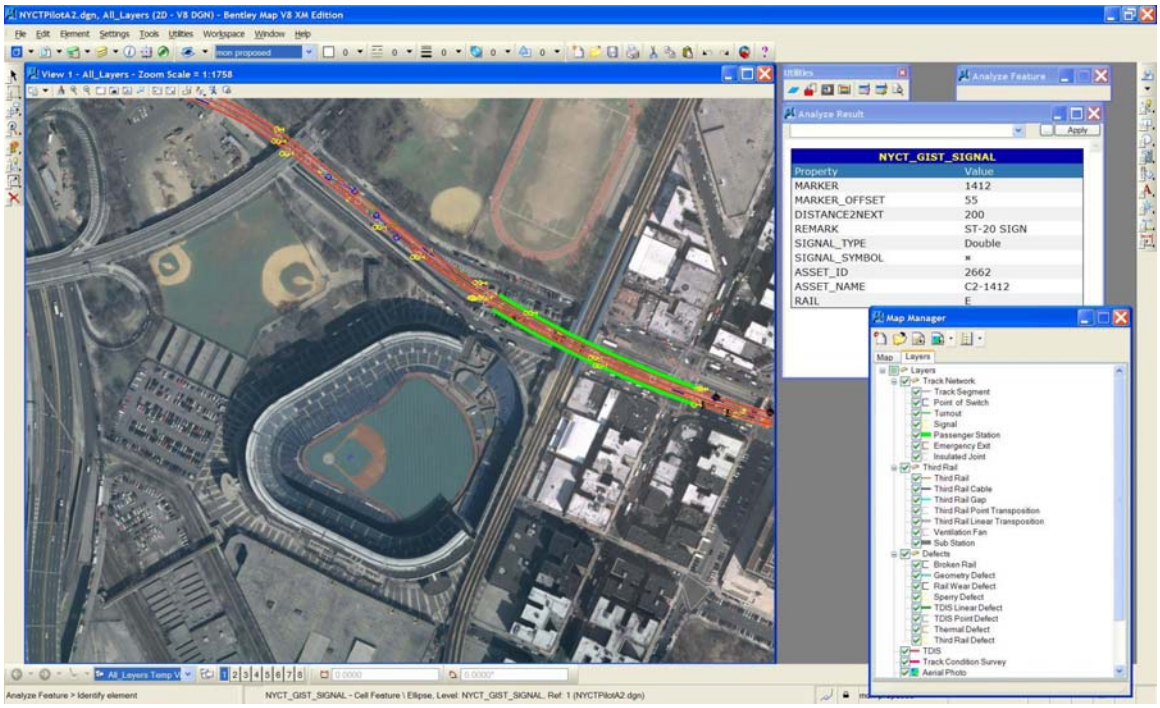

Figure 10 - Bentley Map Close-up

3.3 SYSTEM DATA OVERVIEW

The pilot project included data loaded for a six mile portion of the Concourse Line and included integrating 26 types of data and over 120 individual data files. The system data included data about track network, track markers, various types of assets, inspection and survey records, geographical and linear extent data, video files and raster imagery.

A summary of the loaded data is shown below.

- Track Schematics
  - Track Network
  - Markers
- Features and Extent Data
  - Generic Data Attributes
  - Emergency Exit
  - Signals

- Third Rail
- Switches
- Insulated Joints
- Stations & Platforms
- Turnouts

Extent Data

- Line Survey
- Switch Condition Survey
- Track Walker Inspection
- MCRIS Work

Defect Data

- Broken Rail
- Ultrasonic Defects
- Track Walker Identified Defects
- Track Geometry Car Defects
- Third Rail Defects
- Rail Wear Defects
- Thermal Imaging Defects

Data Plot Information

- Track Geometry
- Third Rail Geometry
- Rail Wear Geometry

3.4 SYSTEM INFORMATION REPORTING

The system delivered to NYCT included producing reports summarizing the integrated information using the Optram Report module. The module enables the creation of tabular and graphical reports based upon the information collected and collated during the course of the pilot. Table 2 outlines the capabilities of the reports configured for the NYCT Pilot effort. The appendix shows samples of the reports.

Report Name	Description	Input Parameter
Corridor Inventory Report	The Corridor Inventory Report will provide an inventory of asset types including track segments. The report includes a count of different asset types found on the rail corridor and also includes the length in feet of the selected linear asset and track segments. The hyper link to the selected asset type will provide the detail information of the assets. A sample screen shot (Figure 11 - Corridor Inventory Report) is provided below after Table 2	Line, Track and Asset Type
Defect Trend Report	The Defect Trend Report will provide a graphical representation of defects over time in the form of a histogram.	Line, Track, Defect Category, Defect

Report Name	Description	Input Parameter
	Users will have the ability to control the defects which are included in the report based upon the entry of parameters which includes a date range, time interval for grouping, defect type, defect category, track and line.	Type, Survey Date Range, and Grouping Interval
Defect Summary by Line Report	The Optram Defect Summary by Line Report will provide a count of the number of defects by line, track, defect category, and defect type based on the entry of a date range by the user. The report will be presented in summary form only.	Line, Track, and Survey Date Range
Defect Density by Line Report	The Defect Density by Line Report will provide a count of defects per distance by line, track, track segment, defect category, and defect type based on the entry of a date range by the user. The report will also include a calculation of the density of defects in the form of a calculated field. Density will be calculated based on the number of defects per track mile using a statute mile measurement of 5280 feet. The report will be presented in summary form only.	Line, Track, Defect Category, and Survey Start Date
Cost Summary Report	Optram Cost Summary Report will provide a summary of cost of work performed within a jurisdiction over a given date range.	Line, Track, Section, Job Number and Work Conducted Date Range
Track Condition Survey Detail Report	NYCT Track Condition Survey Detail Report will provide the detail information for the specified survey type entered by the report user. Users will have the ability to control the representation of the survey results by specifying Line, Track and Survey Type. A sample of this report is included below as Figure 12 - Condition Survey Detail.	Line, Track and Survey Type
Defect Factor Analysis Report	NYCT Defect Factor Analysis Report will provide a graphical representation of defect dominant factors in the form of a pie chart. Users will have the ability to control the representation of the analysis by specifying Line, Track, Defect Category and Survey Date Range. A sample of this report is included below as Figure 13 - Defect Factor Analysis.	Line, Track, Defect Category and Survey Date Range
Device Comparison Report	NYCT Device Comparison Report will compare the device type information obtained by Track Condition Survey and the same set of information maintained in TDIS. The report users have the ability to specify the comparison for certain track and/or line based upon the entry of parameters: Line and/or Track. A sample of this report is included below as Figure 14 - Survey	Line and Track

Report Name	Description	Input Parameter
	Comparison.	
TDIS Defect Detail Report	TDIS Defect Detail Report will provide the detail defect information based on the multiple selection criteria specified by the user via the input parameters.	Line, Track, Start and End Station, Survey Date Range, Component Code, Defect Code and Status
Defect Drill-across Report	Defect Drill-across Report will correlate the defect detail for all the specified defect categories occurred at the same location.	Line, Track, Start and End Station, Defect Category, and Survey Start Date

Table 1- Optram Report Module

4 SYSTEM SUMMARY

With all of the data imported into the Pilot system, an amazing wealth of analytical capability is now available for NYCT stakeholders. The centralized information store of all the data by itself was a major achievement for the project. The NYCT stakeholders have the unprecedented ability to simply see all of their data together in one place. Whereas this data was typically housed in standalone systems or “stovepipes”, the pilot has brought it all together in one place.

One of the major advancements available with the pilot system was NYCT’s ability to visualize the Quadrennial Survey information correlated to the Track Walker Inspection Database. Both of these systems are integral to the management and inventory reporting systems within NYCT, but the two systems have never been synchronized. Using the data loaded in the Optram Workbench, both sets of data that map similar information sets can be analyzed side by side. Previously attempts to analyze this information required time consuming and inefficient manual collation processes.

NYCT is now also capable of analyzing track geometry data alongside other critical information. Prior to the pilot, the process of analyzing the track geometry data required painstaking manual processes to print and manually sequence the data. To analyze this data against other information sets required the manual alignment of other data against the hard copy print outs of the track geometry data. The Workbench system provides the capability to visualize this data immediately alongside all data loaded into the pilot system.

Using the inherent capabilities of Bentley Map, the project delivered several highly focused queries to help NYCT stakeholders identify real world maintenance issues. A maintenance problem impacting the NYCT stakeholders is the prevalence of base corroded rails in the subway system. Given the subterranean nature of the subway environment within a brackish water table, and the ambient moisture coupled with the close proximity of the electrified third rail, the conditions for corrosion are exacerbated.

Having a wealth of information in the same place is terrific in itself. But the ability to sort it into subsets and display it side by side allows for endless possibilities. With the use of the Bentley Map users can zoom in and out of areas of the system of interest to align queries with subsets of assets and conditions to pinpoint specific trends. The best news is that a given analysis can be so quick and easy (a few mouse clicks) that a supervisor or manager can generate many scenarios and can allow one question to lead to another (a "what if" analysis). This can lead to a more in-depth study and hopefully more thorough and complete solutions. Better solutions should lead to more cost effective and reliable service both for the asset and the Transit System.

In an article entitled "Rail base corrosion problem for North American transit system" (Hernandez, Plascencia, & Koch, 2008) the authors postulate that "Under extreme circumstances a few grams of lost rail in the right location, with the right geometry and orientation can be responsible for its removal or failure shortening rail's life to less than a year and can compromise safety."[5]

Using the analytical capabilities of the pilot solution, NYCT stakeholders are able to isolate areas that necessitate careful field inspection. Using Bentley Map, queries were developed that enable the users to:

1. Pin point all locations that are prone to environmental dampness
2. Identify where these damp areas also contain specific types of fasteners
3. Intersect this superset of data with those locations prone to third rail defects, and consequently possible electricity leakages.

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[5] Hernandez, F. R., Plascencia, G., & Koch, K. (2008, June 10). *Science Direct - Engineering Failure Analysis.* Retrieved March 17, 2009, from Science Direct: http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V2X-4SPYKM6-2-R&_cdi=5714&_user=10&_orig=browse&_coverDate=01%2F31%2F2009&_sk=999839998&view=c&wchp=dGLbVzb-zSkzV&md5=efcc07b0c52449eb75f9ad75455325a3&ie=/sdarticle.pdf

Through the use of the pilot's technology, the NYCT stakeholders believe this type of system, when applied to the entire transit network, will improve maintenance planning. By using the system to identify performance and maintenance trends, the future design of the system can be improved. Ultimately this can lead to improving the service reliability and system safety for the riders of the NYCT transit system.

5 SYSTEM CONFIGURATION

The following sections provide an overview of the hardware and software that were delivered as part of the pilot program.

5.1 HARDWARE ENVIRONMENT

Bentley purchased a Dell laptop to meets the specifications of NYCT. It was a Dell Precision M90 with the following specifications:

- Intel Core 2 Duo Processor T7600 running at 2.33 GHZ / 667 MHz
- Windows XP Service Pack 2
- Onboard 17" Monitor
- 4 gigabytes of DDR2-667 SDRAM in 2 DIMMs
- External Dell 20" Flat panel Monitor with DVI
- External docking station
- nVidia Quadro FX 2500M Video Card with 512MB
- 160 GB hard drive running at 7200 RPM with NTFS
- Intel 3945 802.11 a/g Wireless Network Card

The laptop and peripherals were purchased as opposed to a server to enable it to run in a standalone environment. NYCT stakeholders were more interested in having a portable system so it could be taken to meetings and to ensure it did not require network connectivity.

5.2 SOFTWARE ENVIRONMENT

Bentley delivered version 7.9 of the Optram Workbench software. This software works in a 2 tier mode with direct ODBC requests made into the underlying Oracle database. The ODBC drivers are configured on the laptop machine to connect directly the Oracle database. The Oracle database is also installed on the same machine.

To configure the pilot system for NYCT, Bentley utilized the following software products: Optram Workbench, Optram Video Module, Optram Track Condition Module, Bentley Map, LDMx and Optram Report Server. The Video Module enables the playback of video files that have been synchronized to the linear referencing system. The Track Condition Module enables the importing of track condition data that is collected from track measurement vehicles.

In order to support the Oracle Spatial features, version 10g release 10.2.0.1.0 of Oracle was deployed. The software licenses for the database were supplied by NYCT. In addition, a version of the Crystal Reports was delivered on the laptop machine to enable the Optram reporting module. This utilized Crystal Report XI Developer Edition version 11.0.1282.

To support the geospatial data viewing, Bentley Map XM Version 8.09.04.78 was configured and delivered on the laptop machine.

Information about these systems is available at www.bentley.com and www.bentley.com/optram.

5.3 DESCRIPTION OF IMPORTED DATA LAYERS

All data layers imported into the configured pilot system are described in the following sections. These outline the contents of the files themselves, the work required to prepare them for bulk loading, and any additional steps needed to ensure they would load properly into the system.

5.3.1 TRACK SCHEMATICS

Track schematics are built from representations of the railway's running rails and the physical markers, often referred to as "mile markers" or simply "markers".

5.3.1.1 TRACK NETWORK

The data source for the track network was a Microstation DGN files. These were converted into the Optram file format using Feature Manipulation Engine (FME). FME is a product from Safe Software, an industry leader in the field of geospatial transformation, extraction and data loading tools. Extensive data cleansing was necessary to ensure the file was topologically accurate. These steps included:

1. Reorientation of linestrings to ensure they are digitized in the direction of the ascending linear referencing system
2. Closure of gaps to ensure linestrings are edge matched at points of switch
3. Removal of loopbacks, overlaps or other deviations in the digitized linestrings
4. Splitting of linestrings that were not broken at points of switch
5. Assignment of y-offset values for linestrings that are not the Optram reference track
6. Assignment of attribution to the linestrings to denote the relevant track section details such as line code, track code, beginning and ending linear location.
7. Reorientation of the file to a recognizable cartographic projection and datum.
8. The thinning of vertices for linestrings that had too many. In some cases tangent tracks had thousands of vertices were only two are needed to properly draw the track either cartographically or linearly.

For display in Optram the NYCT track network data was manipulated and displayed in a straight line diagram. The data in the horizontal (x) dimension was displayed to scale. The data in the vertical (Y) dimension was stored to scale (if the data was provided to Bentley) and was not be displayed to scale in order to facilitate the proper look and feel of the system.

5.3.1.2 MARKERS

To calibrate the Optram track network, markers were created in the Optram database at one hundred foot intervals. The first marker loaded into Optram for the pilot area occurs at mile 25 along the Concourse line. This equates to a line offset of 132,000 feet.

The Optram software dynamically displays markers and offsets in the marker toolbar which is normally displayed along the top of the Workbench software window. In addition, the Workbench has a status bar in the lower left which can continuously update the marker + offset location as the cursor moves through the track schematic view.

With markers at every one hundred feet, the data presentation for linear locations conforms to a “marker + offset” convention. When the offset value reaches a value of 100, the marker values increment to the next marker value.

In order to create the markers, the DGN files were utilized. The end of the Concourse line was utilized and measurements were counted backwards. The bumper blocks at the end of the Concourse line are listed as being at a station and offset of 1667 + 55.365. Therefore, a measurement of 55.365’ was calculated backwards from the end of the line and a marker placed at marker 1667. From that point, markers were calculated every 100’ thereafter and conformed to the geometric centerline measurements of the DGN file.

5.4 FEATURES AND EXTENT DATA

Features are graphical representations of assets in the field that appear in the Optram Track Schematic view and in the Bentley Map geospatial windows. The assets are interactive objects from which users may interrogate or query, or use as part of a track chart diagram.

Extent data are representations of homogeneous sections of linear data. An extent view will typically be used to record and present information for a section of track where individual asset records are not feasible. An example being: from location 145+10 to location 146+25 a section of track is supported by wooden ties. In this example, each individual wooden tie is not an individual asset in the system. A single record in the database records a beginning and ending location of the extent type as opposed to storing individual asset records.

5.4.1 GENERIC DATA ATTRIBUTES

All features and extents loaded into the pilot system share a common set of attributes that do not need to be individually replicated in the sections that follow. All of the layers populated into the system contain the following list of attributes. The data type column expresses the types of data stored in Oracle formats. These are:

Attribute Name	Data Type	Description

Attribute Name	Data Type	Description
ID	Number(10)	The primary key for the record
Line Name	Varchar2(255)	The name of the line that the asset is associated
Linecode	Varchar2(10)	An abbreviation of the line name.
Track ID	Number(10)	A foreign key from the track segment table
Track Name	Varchar2(255)	The Name of the associated track, in the context of the pilot C1, C2, etc.
Track Type	Varchar2(50)	A description of the track type.
Start Marker	Number(10)	The marker associated with the beginning location of the asset
Start Marker Offset	Number(10)	The offset from the start marker associated with the beginning location of the asset
End Marker	Number(10)	The marker associated with the ending location of the asset
End Marker Offset	Number(10)	The offset from the end maker associated with the ending location of the asset

5.4.2 EMERGENCY EXITS

NYCT delivered a PDF file that contained 36 records of emergency exits along with a 9 columns of attributes. This document was entitled "CONCOURSE Line Emergency Exits.pdf". These files were manually migrated into a suitable format for bulk loading.

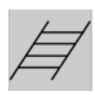
Bentley mapped the columns as follows:

NYCT Column Name	Optram Column Name
Station and / or EME Exit No and (Borough)	Station Exit Number
Stand Pipe	Stand Pipe
Location – DIST & DIR FM NEAREST STATION STANDPIPE ST CONNECTION LOC	Location
TYPE AREA	Area Type

NYCT Column Name	Optram Column Name
LINEAR DIST FM STREET	Street Distance
LINE NAME & LETTER RTO LINE(s)	Generic Attribute
TRACK OPEN ONTO ACC TO	Generic Attribute
EME COLUMN NO	Generic Attribute
PHONE ALARM	PHONE ALARM

NYCT requested the following symbol be used to represent the emergency exits. They are drawn in red and are displayed 7’ to the right of the associated track in the direction of travel.

The symbol used to draw the emergency exits looks like:



5.4.3 SIGNALS

Multiple sources of signal related data were investigated during the course of the pilot effort. Each of these data sources were evaluated for system loading before the final approach was determined. In the end, there was no single data file delivered to provide signal information. NYCT provided a series of files produced from the Track Geometry car. In general, these files contained the Track Name, the Month & Year of the geometry car run, the acronym TGC and then “events”. A typical example is “C1 trk – March 2005 TGC events.txt”. There were a total of 29 files with track geometry events provided from NYCT.

In order to process these files and produce a distinct listing of signals, the following procedure was used:

- All 29 files were loaded into Oracle staging tables and filtered for Signal events
- Removed all duplicates by identifying records with identical tracks and linear locations
- Filtered out all signals that are out of range of the pilot project area. Example, those not on the Concourse line or outside the 6 mile pilot area.
- Signals that were within + / - ten feet of each other were combined into single records.
- By default, all signals will be loaded 6’ right of the centerline in the direction of travel.

Using this logic, a total of 802 signal records are produced for the pilot area. In order to validate this data, another source of data from NYCT was identified. NYCT provided two PDF files that were scanned images entitled "General Signal Arrangements". In total, the PDF files were 16 pages that show the location and type of signals. Validating the data via the drawings took approximately 3 days.

An additional data source was identified for assisting in the processing of Signal Data. NYCT personnel provided a series of nine spreadsheets associated with an insulated joint inspection. These files contained a discreet listing of all signals in the pilot area. After discussion with the NYCT stakeholders, it was determined to use these files for creating the file suitable for bulk loading into Optram. The nine spreadsheets were loaded into staging tables and then processed into Optram accordingly. To process into Optram, Track Stationing column shall be parsed to separate the marker and offset values. The records with no "Location Number" column will be removed.

5.4.4 THIRD RAIL

NYCT provided three TIF image files that illustrate the layout of the third rail. These files were:

1. Contact Rail Layout – MW – 201-102 - X.tif. This file is dated May 19, 1967 and according to the title bar of the drawing it encompasses Elliot Place to 205th Street.
2. Contact Rail Layout – MW – 201 -103 – BB.tif. This file is dated May 9, 1967 and according to the title bar of the drawing it encompasses 141st Street to Elliot Place.
3. Contact Rail Layout – MW – 201 – 106 - X.tif. This file is dated March 20, 1967 and according to the title bar it encompasses 199th Street to 153rd Street.

These three diagrams contained more information than just the third rail layout. They provided information regarding the gaps, cables, transpositions, ventilation fans, and associated substations.

To utilize this data, the location, offset, and name of the assets marked on the diagrams were manually entered into a spreadsheet. This is then loaded into an Optram staging table which in turn is loaded into an Optram database. This process was done for approximately 2 miles of the third rail layout starting at the beginning of the pilot section and ending at 147,275.

5.4.5 SWITCHES

The points of switch for the track schematic were created from the track network DGN files. Within the Optram and Bentley networks, these points of switch are treated as network nodes. The nodes define connectivity between track segments. To augment the data Bentley used two additional Excel spreadsheets entitled:

1. Concourse Line Switch Condition Survey.xls
2. Concourse Line Track Condition Survey.xls

To create the attributes of the switch assets, the first file was utilized. This file contained the "static" properties of the switch asset. These are the attributes of the asset that do not change over time and equate to the first 15 columns of the spreadsheet.

The remaining columns of the first spreadsheet and the 2nd spreadsheet will be utilized to create an extent view that will be displayed below the track schematic. These are discussed in more detail in Section 4.2.1.

The switch assets in the track schematic are displayed as blue circles and correspond to the points of the switch from the track network DGN files. The extended properties for the switch assets parsed from the first spreadsheet include:

- Switch Number
- Switch Type
- Location
- Point Type
- Hand
- Point Switch Length

5.4.6 INSULATED JOINTS

NYCT personnel provided a series of Excel spreadsheet files that can be combined for a listing of all insulated joints along the pilot area. There were nine files in total provided, they are:

- Insulated Joints - concourse_c1_list_05-27-05.xls
- Insulated Joints - concourse_c2_list_05-27-05.xls
- Insulated Joints - concourse_c3-4_list_05-27-05.xls
- Insulated Joints - concourse_c3_list_06-21-04.xls
- Insulated Joints - concourse_c4_list_07-11-05.xls
- Insulated Joints - concourse_c5_list_04-04-05.xls
- Insulated Joints - concourse_c5a_list_06-21-04.xls
- Insulated Joints - concourse_c6_list_04-04-05.xls
- Insulated Joints -concourse_c7_list_06-21-04.xls

To load the data for insulated joints, all of these nine files were processed to remove irrelevant data and to normalize the formatting. These were loaded into individual staging tables and then combined into a single file for loading into the Optram database. In order to populate the appropriate track for each record, it was necessary to use the name of the individual file being loaded.

The properties for the insulated joints presented in Optram are:

- Number
- Location Number
- Track Stationing
- Distance to Next Location
- Rail
- Signal Type
- Remarks

The insulated joints were drawn as small squares directly on top of the track segments.

5.4.7 STATIONS & PLATFORMS

The data for loading stations and platforms came from the track network DGN File. During the contract pre-award period the DGN file were utilized and manually measured to calculate the beginning, ending and cross sectional positions. The names were copied from the labels on the DGN and also loaded into the system. Using this method, there were 11 stations and 21 platforms loaded from the DGN files.

A subsequent DGN file was provided that contained 12 stations, which included sections of track outside the pilot area. For the purpose of the pilot project, a decision was made to only load the original track network and corresponding 11 stations.

The stations are drawn as compound polygon objects. There is one rectangle drawn for every platform associated with a station. The 11 stations loaded are:

1. 161TH STREET - RIVER AVENUE STATION
2. 167TH STREET STATION
3. 170 TH STREET STATION
4. 174TH - 175TH STREET STATION
5. 182ND - 183RD STREET STATION
6. 205 TH STRT STATION
7. BEDFORD PARK BOULEVARD STATION
8. EAST KINGSBRIDGE ROAD STATION
9. FORDHAM ROAD STATION
10. TREMONT AVENUE STATION
11. WEST 155TH STEET - 8TH AVENUE STATION

The extended properties of the stations that will be displayed in Optram are:

- Name
- Description

5.4.8 TURNOUTS

The data for loading turnouts came from a combination of the track network DGN files and the 29 track geometry event, third rail event & rail wear event files (collectively referred to as event files). The point of switch was derived from the DGN files and the length of the turnouts was derived from the 29 events files. The beginning and ending of the turnouts were accumulated and averaged from the 29 event files. In the case there are no corresponding turnouts in the event files for a DGN derived point of switch, a default length of 60’ was used; 30’ feet in front of the point of switch and 30’ after.

The turnouts were drawn in the Optram workbench as a gray rectangular object that encompasses the point of switch and will drawn 10’ wide. The only properties displayed for turnouts were the default from table in Section 4.1.

5.5 EXTENT DATA

Extent data is a method for displaying linear data associated to a particular track. It is typically displayed below the track schematic, but this is dependent upon the user configuration. It may also be configured to display data for all tracks at a particular location, a single track at a particular location, or a single track at a particular location across a configurable range of time.

5.5.1 LINE SURVEY

NYCT provided a file entitled “Concourse Line Track Condition Survey.xls”. From this file, many individual extent data sets have been created. These include:

- Geometry Type
- Ballast Type
- Ballast Condition
- Ballast Life
- Tie Condition
- Tie Date
- Tie Life
- High Rail Date
- High Rail Joint
- High Rail Life
- High Rail Plate Condition
- High Rail Plate Life
- High Rail Plate Spike
- High Rail Plate Type
- Track Date
- Track Life
- Track Type
- High Rail Type
- High Rail Weight
- Low Rail Date
- Low Rail Joint
- Low Rail Life
- Low Rail Plate Condition
- Low Rail Plate Life
- Low Rail Plate Spike
- Low Rail Plate Type
- Low Rail Type
- Low Rail Weight
- Guard Rail Condition
- Guard Rail Date
- Guard Rail Life
- Guard Rail Type
- Geometry Condition
- Environment

Each of the Line Survey Extent views will have an individual ID, the Line Code, Start Marker, Start Marker Offset, End Marker, End Marker Offset, Track Name and Device Type columns. Each extent view will also have its individualized "Code" property which contains the relevant business data for the particular extent.

In all cases, the data has been processed to remove redundant records that are created from the process of loading a large flat file that is comprised of homogenous sections.

5.5.2 SWITCH CONDITION SURVEY

The switch assets described in section 4.1.6 have an extent data set created for them that came from the merging of the following two files:

1. Concourse Line Switch Condition Survey.xls
2. Concourse Line Track Condition Survey.xls

The 2nd file was utilized to provide the linear location data for the switch area. It described the beginning linear offset and ending offset and was combined with the first file using an outer join. The combination of the two files creates an extent data set that describes the condition of the switch at a particular point in time. The two files were merged using the Switch # column as the key to join them. The attributes for this extent data are:

- Length
- Line Offset
- Code (Dbl X-Over, Sgl X-Over, Turnout, Unknown)
- Track Name
- Track Type
- Label
- Marker
- Platform
- Location
- Point Type
- Hand
- Switch Design
- Switch Point Length
- Ballast Life
- Head Panel Ties Date
- Head Panel Ties Life
- Switch Ties Date
- Switch Ties Life
- Closure Timbers Date
- Closure Timbers Life
- Frog Type
- Frog Design
- Frog Size
- Frog Life
- Environment
- Geometry
- Switch Date
- Switch Life

The initial join of the two files achieved approximately an 80% match rate. NYCT determined it was okay to remove the unmatched files for the purpose of the pilot project. This means there will be certain switch assets in the track schematic that will not have corresponding extent data.

5.5.3 TRACK WALKER INSPECTION

NYCT provided a spreadsheet entitled “ta_c_trk_dev_div_rpt2.xls” that was used to load an additional source of track information. The file was loaded into the staging area and parsed appropriate to create separate columns for the line and marker information. The “Dev Type” column was translated into textual code descriptions based on direction from NYCT:

- Curve – translated from 300M
- Guarded Curve – translated from 200M
- Switch – translated from 400M
- Tangent – translated from 100M

In addition to the basic location information, the following properties were migrated into the Optram database:

- Switch Number
- Switch Direction
- Distance to Next
- Zone
- Section
- Sequence Number
- Nearest Platform

5.5.4 MCRIS WORK

NYCT provided a Microsoft Access database to provide some historic information regarding the location and type of work performed along the MOW. The database was entitled Concourse.mdb and contained 12 tables. Two of these tables were loaded into the Optram staging tables; the remaining tables were not used. Those loaded were:

1. Finished
2. Material

The finished table was used to provide the location of the work records, as well as the following list of properties:

- Selection Code
- Code
- Job Number
- Location
- Defect Number
- Weather Condition
- Supervisor Name
- Remark
- Input Date

In addition, the records were populated with a value for "Total Cost". This field was derived based on a database join of the finished and material tables, and an aggregation of the cost fields in the Material table.

5.6 DEFECT DATA

Defect data is a specific subset of extent data types displayed as a stack view or date range view, typically below the track schematic objects. This defect data was generated from a number of sources, some were automated condition monitoring tools and others are based on field observations.

5.6.1 BROKEN RAIL

This was a data file provided by NYCT that included 81 records with 21 columns entitled "Concourse Line Broken Rails.xls". This file contained a single location marker and offset value and is represented in Optram as points in the data extent window.

In addition to the basic location information fields, the following properties were imported into Optram for these records:

- Location Description
- Date Found

- CWR or Bolted
- Geometry
- Track Type
- Break Type
- Rail Date
- Track Condition
- Plate
- Status
- Reason

5.6.2 ULTRASONIC DEFECTS

These are defects generated by the ultrasonic data collection process. The data file provided included 64 records and 20 columns. NYCT provided a file entitled "Concourse Line Sperry Defects 2004-2006.xls" which was used as the source file for the data load. In addition to the standard location information, the following properties were associated with each record:

- Code
- Defect Size
- Location Description
- Geometry
- Track Type
- Plate
- Status
- Test Date
- Verified Date
- Installed Date
- Rail Length
- Rail Date

5.6.3 TRACK WALKER IDENTIFIED DEFECTS

One excel data file was provided that contain defects found by the walking track inspectors. The file contained 1006 records. In addition to the standard location information, the following properties were associated with each record:

- Component Code
- Reference Number
- Defect Number
- Section
- Sequence Number
- Division
- Rail
- Switch Number
- Status
- Inspection Severity
- Defect Description
- Inspection Date
- Verified Date
- Supervisor Severity
- Resolved Date

5.6.4 TRACK GEOMETRY CAR DEFECTS

Six text files were provided that contain defects identified by the geometry survey car for different surveys and processed by the track engineering department to give the clear location information for the field personnel. Some of the files were comma delineated and others are tab delineated. In total, there were 122 records in the files. The locations of the defects were determined by the nearby signals so only 76 of the defects have been allocated. In addition to the standard location information, the following properties were associated with each record:

- Defect Code
- Defect ID
- Device Type
- Sub Division
- Nearby Station
- Peak Location
- Date Detected
- Dates Checked
- Dates Checked

5.6.5 THIRD RAIL DEFECTS

The third rail defects were stored in an access database (Concourse Line Third Rail Defect Data.mdb) and in total 356 records were loaded into the Optram database. In addition to the standard location information, the following properties were associated with each record:

- Defect Code
- Year
- Sector
- Zone
- Division
- Station
- Station Number
- Device Code
- Priority Code
- Defect Description
- Date Reported
- Date Corrected
- Week Corrected
- Supervisor
- Program
- Job Number
- Date Entered
- Defect ID

5.6.6 RAIL WEAR DEFECTS

The rail wear defects were stored in 3 text files, 07110709 C1 Head rail wear.txt, 07110708 C2 head rail wear.txt, and 08290712 C4 head rail wear.txt. In total 50 records were loaded into the Optram database based on the text files. In addition to the standard location information, the following properties were associated with each record:

- Defect Code
- Length
- Parameter
- Maximum Value
- Location

5.6.7 THERMAL IMAGING DEFECTS

The thermal defects were stored in an access database (TGC3 Concourse Line Third Rail defects 2007.mdb) and there were 40 records. Each of the records has one JPEG file for the image of the defect. The image files were parsed out from the database and the records were filtered for the defects on

Concourse Line. As the results, 34 defects were loaded into the Optram database. In addition to the standard location information, the following properties were associated with each record:

- Defect Code
- Division
- Date Run
- Camera Location
- Train Heading
- Image ID
- Station
- Image Code
- FI Name
- FI Password
- FI Date
- Repaired
- Date Corrected
- Correction
- Correction Info
- MSI
- H_IMAGE

5.7 DATA PLOT INFORMATION

Data plot information is typically data capture from continuous field measurement tools. As described in **Error! Reference source not found.**, the roughness band shows a typical data plot view. NYCT provided numerous types of information to be modeled as data plots and the following sections outline the structure and content of this data.

There were three kinds of Geometry Car survey data provided by NYCT in text file format. They are the survey results for Track Geometry, Third Rail Geometry, and Rail Wear Geometry respectively. The survey results are recorded at each foot for pre-configured channels.

5.7.1 TRACK GEOMETRY

The track geometry survey was comprised of seven channels of data. These included: Average Grade, Gauge, East Alignment, East Profile, West Alignment, West Profile, and X-Level. The raw data was provided in the following text files. The files were processed to synchronize with the linear location system in the Optram and loaded by using Optram Geometry Import tool.

- C1 track - August 2006 TGC Data.txt
- C1 track - December 2006 TGC Data.txt

- C1 track - March 2004 TGC Data.txt
- C1 track - March 2005 TGC Data.txt
- C1 track - March 2006 TGC Data.txt
- C1 track - May 2006 TGC Data.txt
- C1 track - November 2005 TGC Data.txt
- C2 track - August 2006 TGC Data.txt
- C2 track - December 2006 TGC Data.txt
- C2 track - March 2005 TGC Data.txt
- C2 track - March 2006 TGC Data.txt
- C2 track - May 2006 TGC Data.txt
- C2 track - November 2005 TGC Data.txt
- C3-4 trk - August 2006 TGC Data.txt
- C3-4 trk - December 2006 TGC Data.txt
- C3-4 trk - March 2004 TGC Data.txt
- C3-4 trk - March 2005 TGC Data.txt
- C3-4 trk - March 2006 TGC Data.txt
- C3-4 trk - May 2006 TGC Data.txt
- C3-4 trk - November 2005 TGC Data.txt

The following table lists the Survey Names for the imported track geometry surveys:

Survey Name	Description
G:20050301:C:1360I	Survey for C1 in 03/05
G:20050303:C:1360I	Survey for C34 in 03/05
G:20050302:C:1358I	Survey for C2 in 03/05
G:20051101:C:1360I	Survey for C1 in 11/05
G:20051102:C:1358I	Survey for C2 in 11/05
G:20051103:C:1360I	Survey for C34 in 11/05
G:20060301:C:1360I	Survey for C1 in 03/06
G:20060302:C:1358I	Survey for C2 in 03/06
G:20060303:C:1360I	Survey for C34 in 03/06
G:20060501:C:1360I	Survey for C1 in 05/06
G:20060503:C:1360I	Survey for C34 in 05/06
G:20060502:C:1358I	Survey for C2 in 05/06
G:20060801:C:1360I	Survey for C1 in 08/06
G:20060803:C:1360I	Survey for C34 08/06
G:20060802:C:1358I	Survey for C2 08/06
G:20061201:C:1360I	Survey for C1 in 12/06
G:20061202:C:1358I	Survey for C2 in 12/06
G:20061203:C:1360I	Survey for C34 in 12/06

Survey Name	Description
G:20070301:C:1360I	Survey for C1 in 03/07
G:20070302:C:1358I	Survey for C2 in 03/07
G:20070403:C:1360I	Survey for C34 in 04/07
G:20070701:C:1360I	Survey for C1 07/07
G:20070702:C:1358I	Survey for C2 in 07/07

5.7.2 THIRD RAIL GEOMETRY

The third rail geometry survey was comprised of six channels of data. These included: Left Gauge, Right Gauge, Left Height, Right Height, Left Gap, and Right Gap. The survey results were provided in the following text files. The files were processed to synchronize with the linear location system in the Optram and loaded by using Optram Geometry Import tool.

- 08060708 3rd rail & gap report C1 final.txt
- 04250708 3rd rail & gap report C2 final.txt
- 08060704 3rd rail & gap report C4 final.txt

The following table lists the Survey Names for the imported third rail geometry surveys:

Survey Name	Description
G:20070422:C:1360I	Survey for C2 in 04/07
G:20070821:C:1360I	Survey for C1 in 08/07
G:20070822:C:1618I	Survey for C2 in 08/07
G:20070823:C:1360I	Survey for C34 in 08/07

5.7.2.1 RAIL WEAR GEOMETRY

The rail wear geometry survey was comprised of six channels of data. These included: Left Height Wear, Right Height Wear, Left Width Wear, Right Width Wear, Left Gauge Wear, and Right Gauge Wear. The survey results were provided in the following text files. The files were processed to synchronize with the linear location system in the Optram and loaded by using Optram Geometry Import tool.

- 07110709 C1 rail wear report final.txt
- 07110708 C2 rail wear report final.txt
- 08290712 C4 rail wear report final.txt

The following table lists the Survey Names for the imported rail wear geometry surveys:

Survey Name	Description
G:20070812:C:1358I	Survey for C2 in 08/07
G:20070813:C:1360I	Survey for C34 in 08/07
G:20070911:C:1360I	Survey for C1 in 09/07
G:20070912:C:1659I	Survey for C2 in 09/07
G:20071213:C:1360I	Survey for C34 in 12/07

6 SYSTEM REPORTING

The system delivered to NYCT included a version of Crystal Reports to enable the usage of the Optram Report module. The module enables the creation of tabular and graphical reports based upon the information collected and collated during the course of the pilot. Table 2 outlines the capabilities of the reports configured for the NYCT Pilot effort.

The reports are accessed from within the Optram Workbench Product from the “Report” menu item. This invokes the Crystal Report application. Depending on the report selected, the user will be requested to fill in one or more of the possible input parameters as detailed in Table 2 below.

Report Name	Description	Input Parameter
Corridor Inventory Report	The Corridor Inventory Report will provide an inventory of asset types including track segments. The report includes a count of different asset types found on the rail corridor and also includes the length in feet of the selected linear asset	Line, Track and Asset Type

Report Name	Description	Input Parameter
	and track segments. The hyper link to the selected asset type will provide the detail information of the assets. A sample screen shot (Figure 11 - Corridor Inventory Report) is provided below after Table 2	
Defect Trend Report	The Defect Trend Report will provide a graphical representation of defects over time in the form of a histogram. Users will have the ability to control the defects which are included in the report based upon the entry of parameters which includes a date range, time interval for grouping, defect type, defect category, track and line.	Line, Track, Defect Category, Defect Type, Survey Date Range, and Grouping Interval
Defect Summary by Line Report	The Optram Defect Summary by Line Report will provide a count of the number of defects by line, track, defect category, and defect type based on the entry of a date range by the user. The report will be presented in summary form only.	Line, Track, and Survey Date Range
Defect Density by Line Report	The Defect Density by Line Report will provide a count of defects per distance by line, track, track segment, defect category, and defect type based on the entry of a date range by the user. The report will also include a calculation of the density of defects in the form of a calculated field. Density will be calculated based on the number of defects per track mile using a statute mile measurement of 5280 feet. The report will be presented in summary form only.	Line, Track, Defect Category, and Survey Start Date
Cost Summary Report	Optram Cost Summary Report will provide a summary of cost of work performed within a jurisdiction over a given date range.	Line, Track, Section, Job Number and Work Conducted Date Range
Track Condition Survey Detail Report	NYCT Track Condition Survey Detail Report will provide the detail information for the specified survey type entered by the report user. Users will have the ability to control the representation of the survey results by specifying Line, Track and Survey Type. A sample of this report is included below as Figure 12 - Condition Survey Detail.	Line, Track and Survey Type
Defect Factor Analysis Report	NYCT Defect Factor Analysis Report will provide a graphical representation of defect dominant factors in the form of a pie chart. Users will have the ability to control the representation of the analysis by specifying Line, Track, Defect Category and Survey Date Range. A sample of this report is included below as Figure 13 - Defect Factor Analysis.	Line, Track, Defect Category and Survey Date Range

Report Name	Description	Input Parameter
Device Comparison Report	NYCT Device Comparison Report will compare the device type information obtained by Track Condition Survey and the same set of information maintained in TDIS. The report users have the ability to specify the comparison for certain track and/or line based upon the entry of parameters: Line and/or Track. A sample of this report is included below as Figure 14 - Survey Comparison.	Line and Track
TDIS Defect Detail Report	TDIS Defect Detail Report will provide the detail defect information based on the multiple selection criteria specified by the user via the input parameters.	Line, Track, Start and End Station, Survey Date Range, Component Code, Defect Code and Status
Defect Drill-across Report	Defect Drill-across Report will correlate the defect detail for all the specified defect categories occurred at the same location.	Line, Track, Start and End Station, Defect Category, and Survey Start Date

Table 2- Optram Report Module

New York City Tansit Authority
Optram Corridor Inventory Report

New York City Transit

Line:Concourse   Track: ALL   Asset: ALL

4/3/2008

Line	Track	Asset Type	# of Asset	Total Length (in feet)	
Concourse	17_18_S213	Track Segment	1	175.72	Asset Detail
Concourse	19_20_S213	Track Segment	1	249.15	Asset Detail
Concourse	9_10_S210	Track Segment	1	57.61	Asset Detail
Concourse	C1	Cable	11	459.02	Asset Detail
Concourse	C1	Emergency Exit	11	0.00	Asset Detail
Concourse	C1	Gap	14	617.03	Asset Detail
Concourse	C1	Insulation Joint	156	0.00	Asset Detail
Concourse	C1	Signal	86	0.00	Asset Detail
Concourse	C1	Station	11	7,469.85	Asset Detail
Concourse	C1	Substation	2	300.00	Asset Detail
Concourse	C1	ThirdRail	17	10,504.99	Asset Detail
Concourse	C1	Track Segment	15	30,678.35	Asset Detail
Concourse	C1	Transposition	5	256.00	Asset Detail
Concourse	C1	Turnout	14	891.17	Asset Detail
Concourse	C1	VentilationFan	4	0.00	Asset Detail
Concourse	C105A_C105B_S219	ThirdRail	1	16.90	Asset Detail
Concourse	C105A_C105B_S219	Track Segment	1	67.72	Asset Detail
Concourse	C107B_C107A_S219	ThirdRail	1	16.99	Asset Detail
Concourse	C107B_C107A_S219	Track Segment	1	67.36	Asset Detail
Concourse	C2	Cable	11	440.03	Asset Detail
Concourse	C2	Emergency Exit	13	0.00	Asset Detail
Concourse	C2	Gap	14	617.06	Asset Detail
Concourse	C2	Insulation Joint	153	0.00	Asset Detail
Concourse	C2	Signal	84	0.00	Asset Detail
Concourse	C2	Station	10	6,771.69	Asset Detail
Concourse	C2	Substation	2	300.00	Asset Detail
Concourse	C2	ThirdRail	17	10,719.95	Asset Detail
Concourse	C2	Track Segment	13	30,892.85	Asset Detail
Concourse	C2	Transposition	6	155.45	Asset Detail
Concourse	C2	Turnout	12	745.64	Asset Detail
Concourse	C211B_C211A_N218	ThirdRail	1	17.85	Asset Detail
Concourse	C211B_C211A_N218	Track Segment	1	71.33	Asset Detail
Concourse	C215A_C215B_N218	Track Segment	1	116.83	Asset Detail
Concourse	C217B_C217A_N218	Track Segment	1	44.06	Asset Detail

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Figure 11 - Corridor Inventory Report

New York City Transit Authority
Track Condition Survey Detail Report

New York City Transit

Line: Concourse Track: ALL
Survey Type: Environment

4/3/2008

Track Name	Start Marker	Start Marker Offset	End Marker	End Marker Offset	Code	
C1	1339	25.00	1342	19.00	Dry	CheckDefect
C1	1343	39.99	1347	37.99	Wet	CheckDefect
C1	1350	2.99	1356	14.99	Wet	CheckDefect
C1	1356	14.99	1357	41.99	Dry	CheckDefect
C1	1357	41.99	1360	45.01	Wet	CheckDefect
C1	1360	45.01	1361	98.00	Dry	CheckDefect
C1	1361	98.00	1365	19.00	Wet	CheckDefect
C1	1365	19.00	1370	69.00	Dripping	CheckDefect
C1	1370	69.00	1384	75.00	Dry	CheckDefect
C1	1384	75.00	1398	89.99	Wet	CheckDefect
C1	1397	54.99	1408	75.98	Wet	CheckDefect
C1	1397	54.99	1398	89.99	Dry	CheckDefect
C1	1408	75.98	1409	47.01	Dry	CheckDefect
C1	1410	31.99	1411	54.00	Dry	CheckDefect
C1	1411	54.00	1414	56.99	Wet	CheckDefect
C1	1414	56.99	1420	44.00	Dripping	CheckDefect
C1	1420	44.00	1421	45.01	Dry	CheckDefect
C1	1421	45.01	1433	20.01	Dripping	CheckDefect
C1	1433	20.01	1445	50.00	Wet	CheckDefect
C1	1445	50.00	1448	0.00	Dry	CheckDefect
C1	1448	0.00	1452	96.00	Wet	CheckDefect
C1	1452	96.00	1455	62.99	Dry	CheckDefect
C1	1455	62.99	1457	0.98	Wet	CheckDefect
C1	1457	0.98	1458	4.99	Dry	CheckDefect
C1	1460	48.00	1480	64.99	Dry	CheckDefect
C1	1480	64.99	1491	54.00	Wet	CheckDefect
C1	1491	54.00	1506	60.01	Dry	CheckDefect
C1	1506	60.01	1510	83.01	Dripping	CheckDefect
C1	1510	83.01	1518	19.00	Dry	CheckDefect
C1	1521	12.01	1528	0.00	Wet	CheckDefect
C1	1528	0.00	1532	14.99	Dripping	CheckDefect
C1	1532	14.99	1549	85.01	Wet	CheckDefect
C1	1549	85.01	1551	89.99	Dry	CheckDefect
C1	1551	89.99	1562	60.01	Wet	CheckDefect

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Figure 12 - Condition Survey Detail

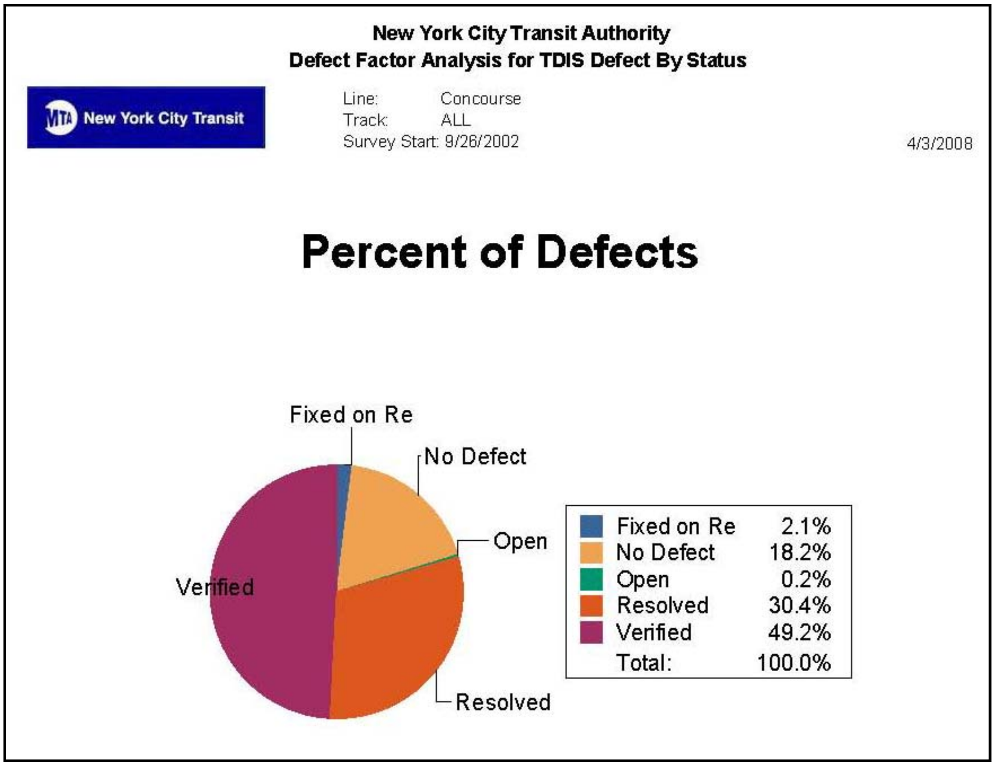

Figure 13 - Defect Factor Analysis

New York City Transit Authority
TDIS and Track Condition Survey Comparison Report

New York City Transit

Line: Concourse Track: ALL

Line	Track	Start Station	End Station	Device Type
Concourse	C1	136,047.00	136,139.00	
Concourse	C1	136,045.01	136,198.00	Tangent
Concourse	C1	136,120.08	136,204.07	Switch
Concourse	C1	136,139.00	136,666.00	
Concourse	C1	136,045.01	136,198.00	Tangent
Concourse	C1	136,120.08	136,204.07	Switch
Concourse	C1	136,198.00	136,519.00	Curve
Concourse	C1	136,519.00	136,681.99	Curve
Concourse	C1	136,666.00	137,087.00	
Concourse	C1	136,519.00	136,681.99	Curve
Concourse	C1	136,681.99	137,069.00	Tangent
Concourse	C1	137,069.00	137,816.99	Guarded Curve
Concourse	C1	137,087.00	137,816.00	
Concourse	C1	137,069.00	137,816.99	Guarded Curve
Concourse	C1	137,816.00	138,236.00	
Concourse	C1	137,069.00	137,816.99	Guarded Curve
Concourse	C1	137,816.99	138,212.01	Curve
Concourse	C1	138,212.01	138,475.00	Tangent
Concourse	C1	138,236.00	138,490.00	
Concourse	C1	138,212.01	138,475.00	Tangent
Concourse	C1	138,475.00	138,583.99	Tangent
Concourse	C1	138,490.00	138,612.00	
Concourse	C1	138,475.00	138,583.99	Tangent
Concourse	C1	138,583.99	138,754.99	Curve
Concourse	C1	138,612.00	138,783.00	
Concourse	C1	138,583.99	138,754.99	Curve
Concourse	C1	138,754.99	139,535.99	Tangent
Concourse	C1	138,783.00	139,747.00	
Concourse	C1	138,754.99	139,535.99	Tangent
Concourse	C1	139,535.99	139,889.99	Tangent
Concourse	C1	139,747.00	140,881.00	
Concourse	C1	139,535.99	139,889.99	Tangent
Concourse	C1	139,754.99	139,889.99	Tangent
Concourse	C1	139,754.99	140,875.98	Guarded Curve
Concourse	C1	140,875.98	140,947.01	Tangent
Concourse	C1	140,881.00	140,943.00	
Concourse	C1	140,875.98	140,947.01	Tangent
Concourse	C1	140,943.00	141,030.00	
Concourse	C1	140,875.98	140,947.01	Tangent
Concourse	C1	140,947.01	141,031.99	Switch

Figure 14 - Survey Comparison