LHP Engineering
St Louis Metro Bus
Predictive Maintenance
Executive Summary

LHP Engineering St Louis Metro Bus Predictive Maintenance Success Story

Quick Facts

Situation Analysis

- Metro St Louis used to invest money just to replace parts and keep the buses running
- Their buses operated at industry average performance levels
  - 4000 miles between failure
  - Average lifecycle of 12 years
- Primarily operated in a reactionary mode
- In 2002, Metro St. Louis developed a new maintenance program that they called the "K Plan." The new program was a great improvement over the traditional inspection but there was room for improvement

8x

Improvement in miles between failures achievable for metro buses

Innovation Strategy

- By partnering with Hortonworks and LHP Telematics, Metro St. Louis is able to gather data from over 2/3rd of its fleet of buses and analyze that data to successfully predict failure of parts
- Some processing of the data includes taking snapshots of the 330 different data points every 10 seconds
- Able to run algorithms, such as pattern recognition, to monitor usage rates and fault codes.
  - Patterns match up to the events where a part actually broke down
  - Predict where a part failure would happen

2x to 3x

Additional performance increase

Business Impact

- Metro STL reduced parts and labor cost by 50%
- The average Mean Time Between Failures (MTBF) of buses was 4,000 miles. Today with the K Plan, the MTBF has been improved to 21,000 miles and Metro STL estimates that with the LHPT and Hortonworks solution on the Smart Bus, the MTBF can be further extended to 30,000-35,000 miles
- The life cycle of a bus expanded from industry average of 12 years to 15 years and from 500,000 miles to 800,000 miles

30%

Increase in life cycle of a bus

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Needed to look at a proactive approach for improved fleet maintenance

Leverage data and analytics to measure everything

Similar to 99% of the industry, the City of St Louis performed regular maintenance on the buses. They used to invest money just to replace parts and keep the buses running. Every 12 years, they would buy a brand new fleet and replace the old one – all at the same time.

In 2002, Metro St. Louis developed a new maintenance program that they called the "K Plan." The "K Plan," or as the industry refers to it, "Reliable Centered Maintenance" (RCM), means that components are replaced prior to failure based on set intervals driven by mileage. Although it was a brute-force approach to maintenance, this new program was a great improvement over the traditional inspection. Part problems have not always been identifiable in traditional inspections. However, some components were being changed and discarded even though they had additional life left in order to prevent failures.

Even though it was better than traditional inspections, Metro STL knew this program had some inefficiencies. Not all buses operate on the exact same route, operate at the same average speeds, and are not all driven by the same operator. In addition, understanding emissions controls and the changing emissions standards year after year for each component was turning into a challenge to manage. In 2007, emissions standards were introduced with stringent specifications, and the result was an increased cost per mile, as high as 92 cents/mile. Subsequent emission standards for 2010 and 2012 proved to be increasingly strict. Metro STL needed a way to control the increased costs associated with staying compliant with the emissions standards.

"…we always operated in a reactionary mode"

Darren Curry
Chief Mechanical Officer

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Looking at failures before they take place

Smart analytics enabling Metro St Louis to make the best business decisions possible

Around 2010, Metro STL determined that there was a need to improve and enhance their maintenance program. After several failed attempts, Metro STL decided **to partner with LHP Telematics and Hortonworks** to implement a **Smart Bus Program** to complement the K-Plan. Since 2010, Metro has been gathering data from all systems that possess logic such as Allison, Cummins, Thermo-King, MGM e-stroke, and DinexI/O Controls on over 200 buses. This data is being stored on the buses and downloaded nightly by LHPT. Currently, Metro has the capability to review and manually analyze this data. In addition, LHPT has utilized machine learning algorithms against bus data to predict Cummins VGT (Variable Geometry Turbo Actuator) faults, which accurately predicted 5 out of 6 actuator failures.

The LHP Telematics system can connect with 4 separate CAN busses and communicate with every single component. Some processing of the data includes taking snapshots of the 330 different data points every 10 seconds along with measuring bus utilization. Data is compressed and the buses dump all of the data to the backend servers where it is stored on the **Hortonworks HDP Platform**. Utilizing the HDP platform, LHP Telematics data science team has been able to run algorithms, such as pattern recognition to find patterns that match up to the events where a part actually broke down. Metro STL maintenance department is then able to match up the events to the type of bus and predict where the failures were going to happen.

The next step is to pick the really important events on the bus and start using machine-learning algorithms for identifying specific higher value events.

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Realizing dramatic savings through Smart Bus performance

Value Realized through real-time data analytics

The K Plan and Smart Bus program has been extremely successful to date, enabling the buses to communicate problems and predict when maintenance will be required. Before these programs, the average Mean Time Between Failures (MTBF) of buses was 4,000 miles. Today with the K Plan, the MTBF has been improved to 21,000 miles and Metro STL estimates that with the LHPT and Hortonworks solution on the Smart Bus, the MTBF can be further extended to 30,000 to 35,000 miles.

Originally Metro STL thought the K Plan would cost more money, but the reality has proven to be quite the opposite. Metro STL was able to cut its original costs by 50%. Metro STL estimates that another 20-30% in cost reduction is feasible with the newer solution from LHPT and Hortonworks on the Smart Bus. Operating costs have decreased from 92 cents/mile to 43 cents/mile. Metro STL expects another 2 to 3 times performance increase with Smart Bus.

With these results, Metro STL soon realized that they could run the buses for much longer, thereby increasing their return on investment in their fleet. Previously, buses were being retired after 35,000 miles per year at 12 years and currently Metro STL is able to continue using the buses up to 60,000 to 70,000 miles per year at 15 years – a 2x improvement on mileage and 30% increase in bus lifecycle.

The K Plan and Smart Bus have not only enhanced Metro STL's maintenance program, they have changed the way Metro STL does business.

"…we will be able to increase our performance with LHPT and HDP another 2-3 times on top of what we have achieved"

Darren Curry
Chief Mechanical Officer

LHP Engineering St Louis Metro Bus Predictive Maintenance Success Story

Meeting future objectives through innovations

Establishing strategic partnership with Hortonworks and LHP Telematics

In the near future, Metro STL and LHPT expect this Smart Bus system to reduce the need to manually analyze algorithm results. Their goal is to integrate with Metro's vehicle maintenance system (M5), giving the bus the ability to generate its own work requests, forecast maintenance functions, and order its own part. These parts include sensors, starter motors, alternators, door motors, air compressors, engine components, transmission components, A/C components, brake components, and other electric devises.

In addition, they want the bus to tell us when a major failure will occur and what the overall health of the bus is. The goal is never to go into catastrophic failure. Finally, they also want to look into real-time fleet utilization and determine the amount of idle time for their buses, and then proactively change their fueling procedures.

No longer will maintenance be driven by mileage, but rather by counts, cycles, time, and other measurements down to the individual component rather than by the overall bus. Eventually Metro STL would like to extend the Smart Bus program to other fleets for vehicles such as para-transport buses and service vehicles.

"…really excited about how we move forward from here, it will give us a lot of tools to analyze data and look at things differently than what we were doing before"

Darren Curry
Chief Mechanical Officer

CASE STUDIES

METRO BUS - Telematics

3501
2008 Gillig Low Floor

Phoenix Pentaband
633570

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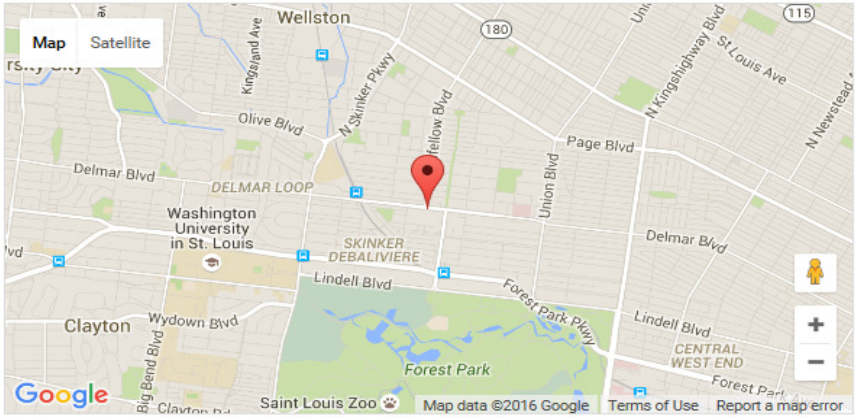
3/4/2015 - Present

Summary | Positions | Engine | Unit Data | Alerts | Maintenance | Faults !

Engine Summary

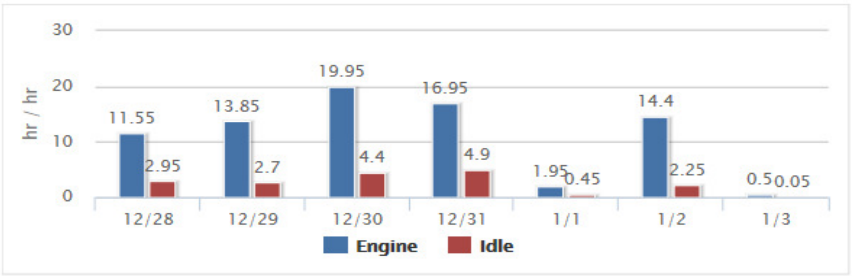
	Engine (hr)	Idle (hr)	Odometer (mi)
Lifetime	**29,371.55**	**2,802.05**	**366,742.23**
Today	-	-	-
Yesterday	-	-	-
This Week	-	-	-
This Month	30.60	4.15	380.74
This Year	30.60	4.15	380.74

Last Known Location

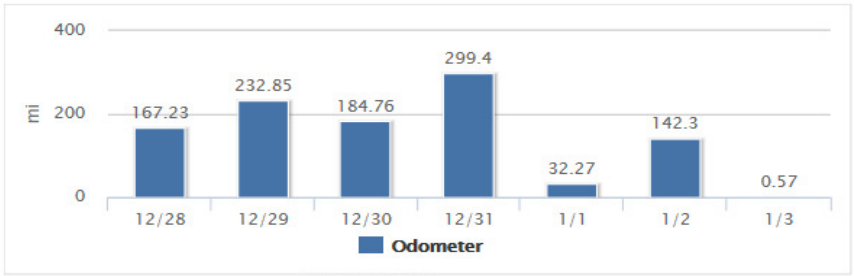


Position valid as of 26 days ago
38.653968, -90.286411

Engine



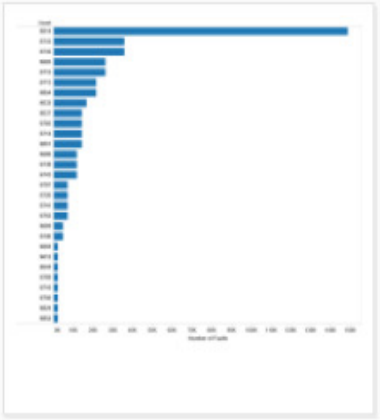
Distance Traveled



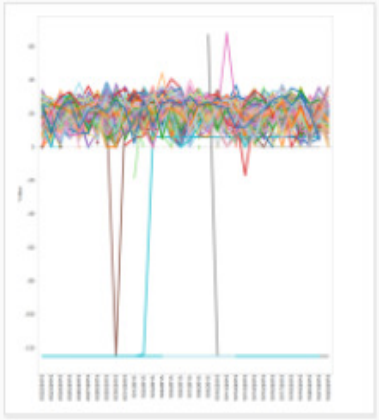
CASE STUDIES

METRO BUS - Advanced Analytics

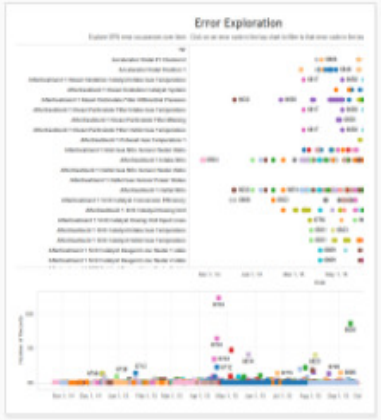
Pattern Analysis



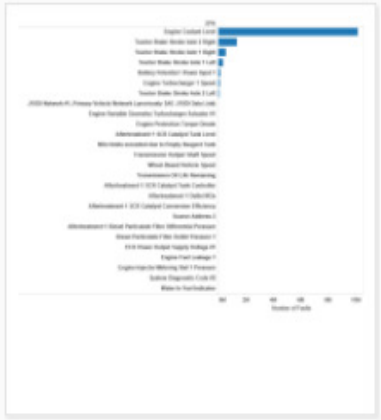
Failure Count Comparison



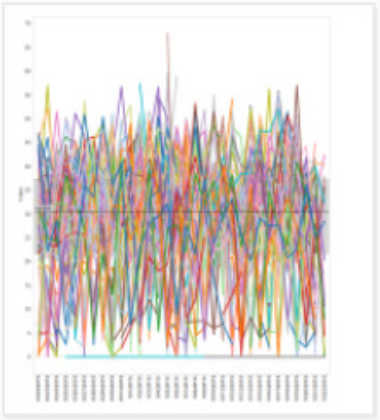
Attribute Comparison



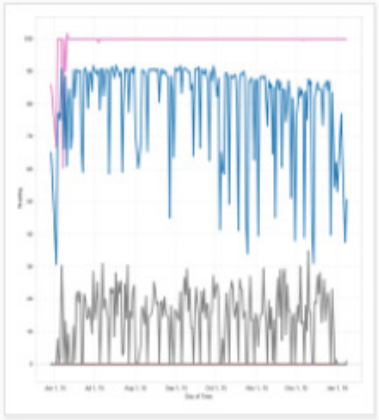
Error Exploration



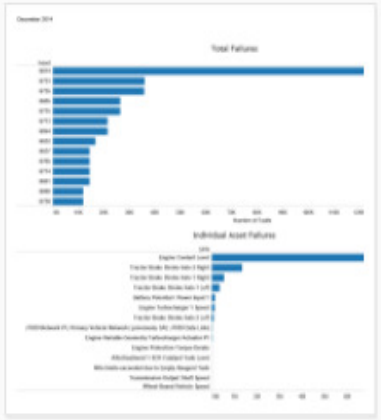
Failure Breakdown For Asset



Quantile Attribute Comparison



By Asset



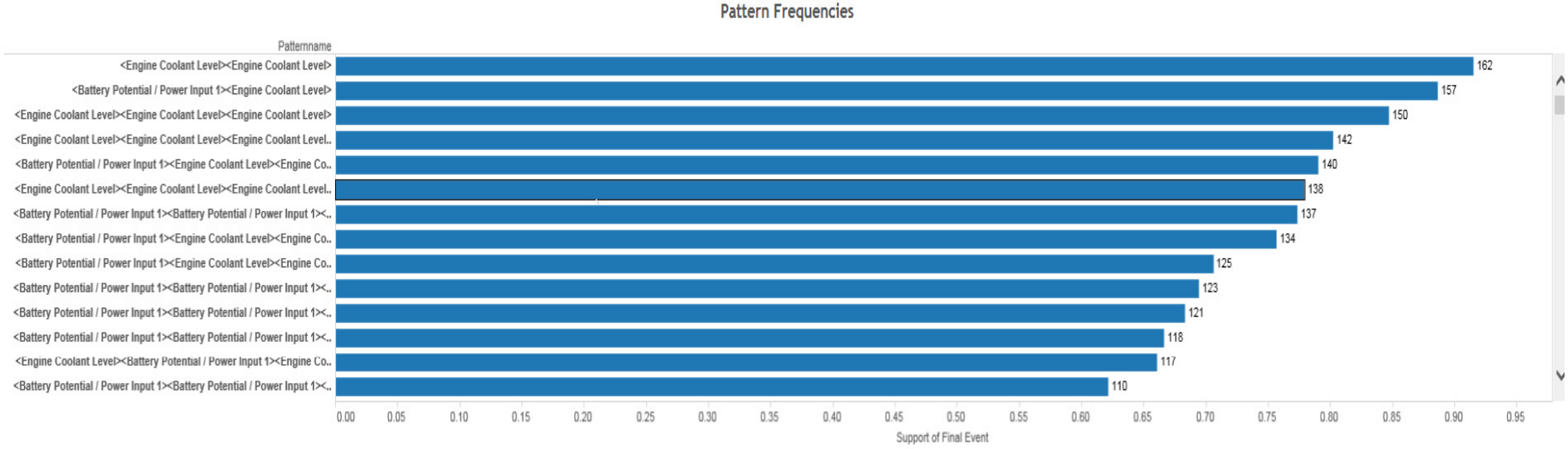
Asset Faults

CASE STUDIES

METRO BUS - Advanced Analytics

Initial Event: (All)

Final Event: Engine Coolant Level



Affected Machines

Machineid	Startdate	Enddate
3501	*	*
3502	*	*
3503	*	*
3505	*	*
3507	*	*
3508	*	*
3509	*	*

The "Pattern Frequencies" graph is showing the number of machines that experienced each pattern of faults. Clicking on a pattern will filter that event for the other charts.

The patterns are in the format of <code1><code3> code1 occurred and code3 occurred on a subsequent day.

The box and whisker "Time Span" plot shows the time span, in days, between the first fault and the final fault for each asset that exprienced the selected pattern. The box shows the middle half of the assets with the dividing line being the median.

The list at the bottom shows the machine ID of the assets that exprienced the selected pattern.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