

Paper 383-2012

## Leveraging Analytics in Transportation to Create Business Value

Vijitha Kaduwela, Kavi Associates, Barrington, IL, USA  
Rajesh Inbasekaran, Kavi Associates, Barrington, IL, USA

### ABSTRACT

In this paper, we discuss how Analytics is leveraged in the transportation industry to create business value. The real-life case studies presented in this paper cover Rail, Trucking and Airline. In each case study we discuss the business problems, the specific applications of Analytics to solve the business problems and the business value created in the process. We discuss the descriptive and predictive Analytics developed, and how they are used by the customers to gain a competitive advantage by optimizing capital expenditure, reducing operating costs, improving profitability, improving reliability, reducing risks and achieving compliance. We also discuss the specific SAS® solutions and the products used for solving these business problems. We are planning to invite several of our clients to join this presentation.

### CHALLENGES IN TRANSPORTATION INDUSTRY

Demand for freight transportation is projected to nearly double by 2035—from 19.3 billion tons in 2007 to 37.2 billion tons in 2035 (1). Additional capacity comes at a very high price, both financially and environmentally. This will put tremendous pressure on transportation providers to be more efficient in their operations while controlling costs as they scale. The Industry as a whole has to be creative and innovative in generating business value in terms of, reducing operating costs and improving reliability, making Analytics a necessity. Companies that leverage Analytics to compete in the market place will have a significant advantage over those who do not.

In the following sections, we discuss the challenges and offer real-life examples of how few companies are leading the way with Analytics, as they try to better manage their operating costs. The transportation modes considered in this paper include Rail, Trucking and Airline. We also limit the operating cost discussion to opportunities for reducing maintenance costs while improving reliability.

### FLEET MAINTENANCE COSTS

For many large companies overall annual maintenance spend runs into several hundred million dollars or more. For few large clients we have seen these costs exceed a billion dollars a year. The size and age of the fleet, complexity and cost of the assets, repair parts, labor, regulatory and safety requirements contribute to maintenance costs. It is illustrative to look at the per-asset annual maintenance costs for comparative purposes. Complex assets such as Aircrafts and Locomotives are very expensive to maintain, compared to a less complex asset such as a railcars and trucks. Application of Analytics can help reduce these costs significantly.

Maintenance Cost Per Asset (\$/year)	
Railcars	\$1 - \$3 K
Trucks	\$10 - \$15K
Locomotives	\$100 - \$200 K
Aircrafts including Engines	\$3 - \$ 6 M
<b>Source:</b> Internal Kavi Associates estimates, composite figures (2012)	

Leveraging Analytics in Transportation to Create Business Value, continued

**Table 1. Typical Annual Maintenance Spend per Transportation Asset**

### MAINTENANCE COST SAVINGS OPPORTUNITIES

For the discussion we have categorized fleet maintenance into three areas named Scheduled Maintenance, Unscheduled Maintenance and Predictive Maintenance. Primary maintenance cost drivers are parts costs, inventory costs, labor costs, warranty costs, facilities costs and supply chain costs associated with scheduling and routing assets for repairs. In the table 2 below we have summarized the cost drivers with the applicable analytical approaches that can be leveraged to deliver business value. Each of these cost drivers are described in details in the following sections with the real life examples.

<b>Cost Savings Opportunities</b>	<b>Characteristics</b>	<b>Analytical Approaches</b>	<b>Business Value</b>
Scheduled Maintenance	Preventive Maintenance. Fix it before it breaks Proactive in nature Mandatory checks and Overhauls	Determine optimal time intervals between scheduled maintenance events  Determine optimal repair scope for each scheduled maintenance event	Maximize component life  High reliability  Reduced overall repair spend  Avoid over-maintenance
Unscheduled Maintenance	Field failures Reactive in nature Fix only if it is broken	Root-cause analysis  Repair versus replace analysis  Quality of fix comparisons  Recurrent event models	Reduced field failures and repair spend  Minimize out-of-service time and improve asset utilization  Higher customer satisfaction
Predictive Maintenance	Condition monitoring Predictive in nature Fix if the evidence points to an impending failure	Real-time big data analysis  Failure signature detection  Rule-based AI Systems  Association and Sequence analysis	Prevents costly failures  Extends the life of components if they are in good condition  Reduced repair spend  Higher customer satisfaction
Parts Inventory Management	Higher inventory levels mean better service but higher costs.  Pooling across operators	Hierarchical part forecast by location  Multi-echelon inventory optimization across location with service level constraints	Free up unproductive capital  Reduce supply chain costs  Maintain optimal service levels
Warranty Analytics	Manufacturer to determine terms and conditions to minimize exposure  Owners and operators to identify opportunity to replace parts under warranty	Statistical techniques and data mining for early warning and detecting emerging issues	Minimize exposure for manufactures  Reduce warranty leakage for operators and owners

Leveraging Analytics in Transportation to Create Business Value, continued

<b>Cost Savings Opportunities</b>	<b>Characteristics</b>	<b>Analytical Approaches</b>	<b>Business Value</b>
Labor Planning	Identify labor needs Consider sourcing options Allocate available resources optimally	Hierarchical forecast of labor needs Optimization considering overtime and outsourcing	Higher degree of labor utilization Improved repair quality Ability to identify training needs Ability to generate resource plans
Repair Capacity Planning	Plan for the location, capacity and capabilities based on the planned repair needs	Statistical analysis of historical repair data	Minimize supply chain costs Consolidate repair volumes and negotiate favorable pricing
Repair Scheduling and Routing	Determine the potential repair scope Match the scope with shop capability reducing the need for shop transfers Check the availability of capacity Optimize supply chain costs	Operational analytics to forecast predictive repair scope Optimization to minimize supply chain costs and delays	Minimize supply chain costs Reduce cycle times Reduce out of service delays and associated costs Reduce costs due to shop transfers Take advantage of the lower labor rates outside US for aircraft maintenance
Reliability Analytics	Study component life in terms of time to failure or with respect to other usage parameters such as miles, take-offs, hours operated, etc.	Weibull analysis or fitting statistical distributions for non-repairable systems Parametric and non-parametric approaches for repairable systems - Wayne Nelson's Mean Cumulative Function - Homogeneous Poisson Process (HPP) and Non-Homogeneous Poisson Process (NHPP)	Extend component life by determining optimal replacement strategies Ability to improve design of the components Ability source from manufactures with higher reliability scores

Table 2. Maintenance Cost Savings Opportunities

## SCHEDULED MAINTENANCE

### Benefits

Scheduled maintenance involves routine repairs, inspections and overhauls that may require disassembly, cleaning and repair of major sub-systems. It is a labor intensive task. It is expected that scheduled maintenance increase the reliability and hence the life of an asset. Therefore, the cost of unscheduled maintenance is expected to drop following the scheduled maintenance. This may not be necessarily the case in practice. Analytics can help determine the optimal scheduled maintenance intervals and repair scopes during each visit based on analysis of historical repair events and their effectiveness.

### Analytical Approaches

The analytical approaches to scheduled maintenance involve optimizing the time between these visits and the scope of work during each visit. Due to operational constraints the scheduled maintenance activities are not always carried out on time. From the field data perspective this presents a great opportunity to analyze the effectiveness of the scheduled maintenance with respect to the time between scheduled maintenance events.

The idea is that if the longer time intervals do not result in statistically significant increase in field failures or unscheduled maintenance then there is an opportunity to increase the time between the scheduled maintenance events and the other way around. This approach also provide for improvements in the repair scope. For example if a failure rate of a given component increase as you increase the interval, then you can mandate an inspection for that component during the scheduled maintenance event and replace that part if necessary. Analytics techniques such as recurrent event models are very useful in determining expected field failures. Also, many of the data mining techniques including decision trees are useful in identifying the factors that contribute to field failures.

### Real Life Examples

Many of the Rail car leasing companies and railroads generally do not spend a significant amount of their maintenance budget on the scheduled maintenance. The industry as a whole prefers the break-fix model. A railcar is not a complex asset, it does not have a power source or an engine and this mode of operations seem work. However, there are opportunities to save by implementing a scheduled maintenance program for expensive components such as wheels. This requires collecting the trip information to know the usage, historical failures and application of Analytics to determine wheel life. Break-fix is expensive for wheels especially if the owner does not have the control of the repair in the field where a 3<sup>rd</sup> party may attend to the repair and charge back to the owner.

However, this is not the case with Locomotives. Locomotives are complex assets and field failures may result in significant disruption of service and potential safety violations with larger consequences, such as a derailment while carrying hazardous materials. Therefore the locomotives follow a rigorous scheduled maintenance program based on the model and the age etc. Trucks follow a similar scheduled maintenance and inspection program for the same reasons as locomotives.

Most rigorous scheduled maintenance visits apply to aircrafts for obvious reasons. In general aircrafts go through four types of maintenance checks named as types A, B C, and Heavy Maintenance Visit (HMV). Type A check is generally conducted every 3 months and may take only few hours and can be performed at an airport hangar. Type B checks are performed between 3 to 18 months apart and generally performed overnight. Type C checks are performed every 18 months or so and can take about 3 days to perform. Every 5 years or so, the aircraft undergoes what is called as a "Heavy Maintenance Visit" (HMV). This is a very elaborate maintenance activity and is mandatory. For various constraints related with resources, the HVM may sometime get conducted before 5 year period. This leads to a Maintenance Scheduling Optimization problem, which in airline parlance, is called as "Green Time Burn Optimization" problem.

Locomotive, Truck and Aircraft engine need to go through the overhauls. Engine removal and maintenance is a time consuming activity. Therefore, repair providers generally need to keep a pool of spare engines to replace the removed engine. This may apply to other large components such as traction motors and wheel sets on locomotives.

In the field, optimal scheduled maintenance programs can significantly deviate from the ones recommended by the OEMs. In our experience, significant financial benefits can be associated with optimizing schedule maintenance intervals between visits and the repair scope during each visit for all three industries considered.

## UNSCHEDULED MAINTENANCE

### Benefits

Unscheduled maintenance is reactive in nature and is carried out after the failure. Lower incidences of unscheduled maintenance are a reflection of product reliability and effectiveness of planned maintenance. This also implies that there is a tradeoff between the scheduled and unscheduled maintenance. Analytics helps drive the right balance in this regard. Reduction in field failures saves costs while reducing down time associated with unscheduled maintenance. Proper management of unscheduled maintenance helps improve customer satisfaction.

### Analytical Approaches

Since failures experienced by a system depend upon many variables such as design, reliability, operating condition, age of the asset, unscheduled maintenance events are stochastic in nature, along with associated repair scope and costs. Therefore, there are many opportunities to apply Analytics in the area of unscheduled maintenance. Analytics techniques such as recurrent event models are very useful in determining expected field failures. Also, many of the data mining techniques including decision trees are useful in identifying the factors that contribute to field failures. Please also see the reliability section for other Analytics approaches that are used to determine failure rates of components and optimal replacement intervals.

Analytics can help determine best course of actions given an unscheduled maintenance event. Analytics can help understand the repair lifecycle for a given asset model and age, or a maintenance profile by model and age. Given that information one can estimate the probabilities of collateral repairs given a field failure, there by arriving at a predicted repair scope for the event.

Also, the logistics from the location of the field failure to the repair shop where it can be attended to can play a major role in the total costs, especially if there are multiple repair providers with different cost structures. The transportation costs need to be factored into this decision as well.

### Real Life Examples

Unscheduled maintenance in rail industry is referred to as bad-orders. When a railcar is bad-ordered the owner is responsible for providing instructions as to where the railcar should be routed for repairs. There are many factors to consider in this case: such as what is the reported failure, what other collateral repairs need to be performed, are there any scheduled maintenance events planned for the asset in the near futures that should be attended to during the same visit, which shops can handle the type of the railcar with the commodity it is carrying, what are the transportation costs etc. The repair costs may also vary by the provider. It is not as simple as send it to the closest shop that has the capacity to take it.

Many of the large truck owners have their own repair shops, shops at customer facilities and network of other repair shops where they may or may not have negotiated rates. Attending to a repair at a 3<sup>rd</sup> party repair shop compared to one's own shop may result in significant additional costs. There are other trade-offs such as attending to a repair at a shop on urgent basis by paying overtime to technicians vs. sending the repair to a 3<sup>rd</sup> party vs. delaying the repair taking into account the loss of in-service revenue.

In the airline industry an unscheduled maintenance event may or may not be attended immediately depending on the criticality of the failure considering safety and the passenger impact. For example a broken coffee maker or a broken lavatory door may be considered a critical failure due to the passenger impact when there is no apparent safety implication. Critical failures that need to be attended prior to the next takeoff can severely disrupt the schedule and have a significant down line impact in terms of pilots, crew and the ground resources. In such cases, Analytics are also used to determine the best way to recover the schedule with minimal impact to passengers and staff.

## PREDICTIVE MAINTENANCE

### Benefits

Many transportation assets come with sophisticated and automated systems that can transmit information from onboard computers and variety of other sensors. This has led to the new areas of research and analysis, referred to as Asset Health Monitoring. There are locomotives and aircraft avionics capable of transmitting several thousands of different sensory readings and diagnostics, almost on a continual basis. Many failures can now be prevented well before they can cause any serious damage. Predictive maintenance is a highly desirable approach for reducing the amount of unplanned maintenance and extending the life of components.

Leveraging Analytics in Transportation to Create Business Value, continued

Many of the intelligent transportation assets are also equipped with the sensors to monitor the abuse by the operators such as excessive speeding, acceleration, hard breaking, idling etc. With appropriate analytics one can improve the metrics such as asset life and fuel usage.

### **Analytical Approaches**

The condition monitoring data is big in volume because of sheer number of sensors present in an asset as well as because of frequency of measurements. Analyzing condition monitoring data from several assets, to build a predictive failure model is therefore a challenge. Condition monitoring readings are also prone to a high error rate due to the extreme operating environment. Hence, data validation and correction also plays an important role. Statistical methods of dimension reduction are used prior to building a predictive model.

Advanced data mining techniques such as Association and Sequence analysis can be used to identify failures which take place together as well as failure patterns where one failure is followed by other. The underlying theme is to look for “failure signatures” and to immediately take corrective action once they are detected. For building predictive models, advanced data mining techniques such as decision trees and neural networks are employed.

### **Real Life Examples**

One of the challenges in using the sensor information in trucking is the standardization. A large fleet owner may have assets sourced from multiple manufactures resulting in a need for standardizing the outputs from the sensors across the manufacturers prior to using for Analytics. Many trucks are now mounted with the telematics devices that transmit on-board diagnostics, location information and driver behavior information, including speed, duration at a stop, hard breaking, acceleration, fuel usage etc. Analytics built using this information help improve the operational efficiency and reduce maintenance costs.

Some railcars have telematics devices mounted on them for determining the exact location. There is a recent regulation that mandates these telematics devices on all tank cars carrying hazardous materials. Other than telematics railcars generally do not have complex onboard sensors. Location of the railcars also can be identified approximately using the Car Location Messages (CLMs), that are collected by the wayside CLM readers that identify the RFID tags on the railcars as they pass by.

Rail industry has an Equipment Health Management System (EHMS) that monitors the condition of the asset and alert the owners when wheel repairs are needed. The sensors are not attached to the assets in this case; the system takes readings of the railcars that go by using the wayside detectors. They are four types of detectors currently deployed in the North American rail infrastructure. They are Wheel Impact Load Detectors (WILD), Truck Hunting Detectors (THD), Acoustic Bearing Detectors (ABD), and Truck Performance (TP). Asset owners are slow to take advantage of this information during opportunistic level (giving them chance to schedule repairs before they start causing damage) to drive predictive maintenance. However, repair providers are actively using this information containing condemnable levels (telling shops that wheels need to be replaced) to actively attract business to their facilities.

Sensor data indicating aircraft operating conditions/health of critical components/systems is called AHM (Aircraft Health Management). Usually AHM data is closely tied with unscheduled/preventive repair planning, where AHM data is monitored and any abnormalities leads to proactive scheduling of parts and repair on arrival. Various parameters are also monitored and analyzed to determine the health of engine. These include Engine Oil Analysis to determine the metal contents in the oil, Exit Gas Temperature analysis, where higher temperature of exiting gases indicates lower fuel efficiency of engines. This analysis is conducted to schedule engine washes that give a temporary improvement in performance, or fine-tune the repair work-scope when the engine is sent to the shop. The use of health/operating parameters data is more prevalent for engine maintenance as compared with the aircraft maintenance.

## **PARTS INVENTORY MANAGEMENT**

### **Benefits**

Organizations maintain spare parts inventory across service shops and warehouses to provide for the material consumption during the planned and unplanned maintenance. The cost of capital tied to inventory levels is one of the key drivers of maintenance costs. Higher inventory level can provide better service level, but at a higher cost. Optimum quantity of spare parts across the service supply chain frees unproductive capital locked in inventory, while maintaining the required optimal service levels.

Leveraging Analytics in Transportation to Create Business Value, continued

### **Analytical Approaches**

Advanced analytical techniques are used for spare part consumption forecasting and subsequent optimization, across the supply chain. Time series and hierarchical forecasting techniques are used for determining the demand for spare parts. The forecasts are made at a shop level and then aggregated to arrive at warehouse level forecasts. The multi-echelon inventory optimization model takes into account the forecasting results and supply chain cost parameters to determine the optimum stocking levels at each location.

### **Real Life Examples**

For a large airline cost of parts in the inventory may exceed a billion dollars. They store the critical parts such as engines at strategic locations such as hubs from where they can transport them to where they are needed quickly. They also may have agreements for pooling such parts with other airlines at a given location.

A large repair facility for locomotives may be shared by multiple parties, generally there are tracks dedicated to each party. Each party maintains their own parts inventory. However, there may be agreements similar to airline that allow them to borrow parts in case of an inventory stock-out

Parts inventory management does not get as much focus in the railcar and trucking compared to airline and locomotive due to the fact that the assets are less expensive and generally have other assets available to take the place of failed asset to maintain the service levels.

## **WARRANTY ANALYTICS**

### **Benefits**

The manufacturer is obligated under warranty contract, to repair or replace the asset without charging the customer. Hence any opportunity to reduce the amount of field failures or complaints when asset is still under warranty has the ability to decrease the liability and increase profitability. Manufactures can also use Analytics to determine warranty terms and conditions to minimize their exposure.

The transportation owners and operator on the other hand, saves maintenance costs if component failure is detected and a claim is made when a component is still under warranty. When condition monitoring capabilities exist, accurate information on health of the part is possible to be obtained in real-time. This helps timely replacement of the part while it is still under warranty.

### **Analytical Approaches**

Higher warranty costs are reflection of poor product quality and Analytics can help identify the reasons for poor product quality by analyzing claims data. The actionable insights obtained by Analytics translate into corrective action, thereby eliminating the root cause of the poor quality.

From a warranty provider's perspective, the analytical techniques fall under two broad categories – early warning system for detecting serious field reliability issues as early as possible and subsequent root cause analysis techniques. The early warning systems are generally based on advanced statistical techniques which are sensitive to detect the trends indicating serious reliability problems. Once existence of a problem is evident, analytical techniques based on statistical quality control techniques, data/text mining and reliability analysis are used to perform a root cause analysis and obtain actionable insights from the data.

### **Real Life Examples**

In all transportation segments Analytics can be effectively used to manage the exposure for the manufactures and improve the recovery by the owners and operators. One of the problems in terms of data is that many components are not tracked at the serial number level, especially the low cost consumable parts.

In the rail industry there is recent regulation that mandate components such as wheels are tracked at the component level to manage the cost and reduce repair fraud.

Generally, it is easier to track the first time failures since the asset is put in to service brand new. Even for the high cost components such as engines that are tracked by the serial numbers complications arise when it comes to warranties. For example an engine consist of lower level subsystems such as fuel system, exhaust system etc. Some of these systems are not tracked by the serial numbers. There for one has to keep track of the subsequent replacement of subsystems by Analytical means considering parts used for the historical repairs. We have encountered similar practical problems in all modes of transportation and provided analytically based data management approaches to cope with the situation.



## LABOR PLANNING

### Benefits

Scheduled, unscheduled and predictive maintenance needs drive the demand for labor. Similar to the availability of parts, the availability of the labor, at the location where they are needed and when they are needed with the right skill sets is a necessary requirement for timely completion of maintenance activities, while ensuring quality of repairs. In this regards, applying analytics for labor planning can result in large productivity savings and quality improvements.

The split of parts vs. labor contributing to the total maintenance cost vary by industry. For highly complex assets such as aircraft and locomotives overall parts cost is bigger than the labor cost as a percentage of overall maintenance cost. For less complex assets such as trucks and railcars, labor cost is bigger compared to parts cost as a percentage of the overall maintenance cost. In both cases however labor cost is a very significant component of overall maintenance cost.

### Analytical Approaches

Analytics applied to labor planning has two primary components. First one has to estimate the repair needs at a granular level by repair facility by asset type etc. considering the scheduled, unscheduled and predictive maintenance needs. Hierarchical forecasts that take advantage of the historical repair volumes from the time-series perspective and combine that with the other macro economic factors that drive the asset utilization and repair needs serves this need. The next component is the optimization of the available labor resources given the forecast considering the overtime and possibility of sending the repairs to multiple providers with different cost structures.

Labor productivity and repair quality across repair facilities can be benchmarked to determine the factors leading to higher productivity and better repair quality. Training needs can also be identified using data mining techniques to analyze repair records and develop training plans.

### Real Life Examples

Labor planning is very critical for an owner, operator or a repair provider if they have a large labor force deployed across many locations. We have clients with hundreds of repair facilities and thousands of labor resources. In these cases proper data management for forecasting and optimization is critical. Also, the modeling activities have to follow a hierarchical approach rolling labor needs at individual locations to higher levels of geographies such as states and countries. In order to be actionable labor plans need to be constructed across multiple time horizons: starting from annual plans all the way down to monthly, weekly, daily and shift level.

Many owners and operators have their own repair shops and outsource some repairs to other providers. Most often they have negotiated rates with the external providers. At a large locomotive repair shop a manufacture may use the contract labor provided by the customer or the repair facility owner. In such cases a manufacture may not get involved with labor planning activities.

In the rail industry the labor rates and the amount of labor that can be applied to a given repair task is specified by American Association of Railroads (AAR) in their repair manual. However, there are other complications in controlling costs in the field as it is difficult to contain the repair scope. In these scenarios Analytics can be very effectively used to detect anomalies and repair fraud.

## REPAIR CAPACITY PLANNING

### Benefits

Determining location for a new repair facility by performing a cost benefit analysis which includes fixed asset costs, forecasted facility utilization and estimated increase in asset uptime, leads to cost savings in long run. Primary drivers for facilities location is where the repairs originate and the availability and cost of labor. Repair capabilities at each location depend on the types of assets that would be maintained at that location and the types of repairs performed.

### Analytical Approaches

Statistical analysis of historical data provides insights regarding the asset downtime attributable to travel to the repair shop as well as waiting time for repairs. When alternatives are available to choose a location, analytical techniques are used for determining the right repair shop location. The analysis takes into account the cost of building a new shop, its future utilization and savings that can be achieved by increased asset utilization.



Leveraging Analytics in Transportation to Create Business Value, continued

### Real Life Examples

There are hundreds of repair facilities for repairing railcars in North America. Owners and operators can use Analytics with historical repair events to determine who the strategic suppliers are in terms of their location and shop capabilities. This helps consolidate repair volumes and negotiate favorable pricing contracts.

Analytics using historical repair events is the key to determining repair facility locations and capabilities at each location for all transportation segments considered.

## REPAIRS SCHEDULING AND ROUTING

### Benefits

Time spent in movement of asset to a repair shop and waiting time before the repairs can actually commence, has a direct bearing on asset uptime. Strategically located repair shops based on the asset attributes and volume, significantly increase asset availability by reducing unproductive movement and waiting time. Correct repair scheduling and routing, when multiple routing options are available with different cost structures can contribute to supply chain cost savings.

### Analytical Approaches

Operational analytics are deployed for routing an asset to a to the right repair facility. The optimal location is selected in real time, taking into account the current asset location, potential scope of work, shop capability and availability of capacity to attend to the repair in a timely manner.

Ideally the repair needs in terms of potential scope of work needs to be matched with the capabilities of the repair facility to avoid the need for transferring the asset to another repair facility to perform a portion of the repair scope.

### Real Life Examples

In railcar maintenance it is common for owners and operators to transfer the railcars to multiple facilities to complete needed repairs increasing the supply chain costs and out of service delays. This happens because at the time of the break-down appropriate analytics are not available to determine the potential scope of repairs. Analytics can help minimize the need for shop transfers.

Many large airlines own their repair facilities. Several US commercial carriers own or contract with facilities outside US. It is very common for a large airline to fly an aircraft out of US to a facility usually in Asia to take advantage of the lower labor rates there. Analytics are used to determine the cost/benefit considering the out of service time, fuel costs etc. in these scenarios. The solution usually involves allocating aircraft to routes that are closer to the repair station.

## RELIABILITY ANALYTICS

### Benefits

Getting reliability metrics right has a direct impact on customer satisfaction. With the right amount of spend, the overall fleet reliability can be increased to meet corporate objectives. This can result in optimal fleet sizes and parts inventory that help reducing number of spare and under-utilized vehicles, and having the right amount of spare parts inventory where they are needed.

Analytically identifying chronic failure patterns means that the corporation can run “replacement campaigns” proactively, instead of reacting to field failures, maximizing the useful part life results in direct savings in deferred part-replacement costs. By going back to the part manufacturers while under warranty, the company can save costs by identifying instances of failures where the part does not live up to the stated specifications.

### Analytical Approaches

Analyzing part failure-codes is the place to start root-cause analysis. Increasingly, text mining (based on shop-floor mechanic's notations) is leveraged to gain insights into root-causes. Rework (instances of the same failure in quick succession) can point to latent failure causes. Chronic problems and part recalls of similar components are analyzed to do preventive replacements.

Life distributions are plotted and studied to determine how much value is there in the remaining life of the parts and to analyze the failure modes. The Weibull analysis or fitting statistical distributions, to failure data is most appropriate

Leveraging Analytics in Transportation to Create Business Value, continued

when one is analyzing non-repairable systems. There are parametric as well as Non-parametric methods for analyzing recurrent failure events of the repairable systems. Wayne Nelson's Mean Cumulative Function (MCF) is popular non-parametric method. Under parametric methods, Homogeneous Poisson Process (HPP) and Non-Homogeneous Poisson Process (NHPP) are two commonly used methods. NHPP allows an analyst to model deteriorating systems. Under HPP, the failure rate of the system does not change as the system ages. CROW – AMSAA model is one implementation of the NHPP.

Analysis of manufacturer warranties against actual field failures can point out the components that are under-performing their stated reliability metrics.

### **Real Life Examples**

At an airline we worked with, analyzing delay code associated with aircraft reliability and followed by investigation of the failure codes led to identifying several root-causes and cost saving opportunities.

Maintenance programs for aircraft and engines is driven primarily through reliability analysis and estimating the likelihood for failure. This helps the engineers determine the number of redundant systems that need to be in place to ensure overall aircraft requirements to service the schedule. Reliability analysis also help engineers set limits on how long a part can be used before it needs to be either inspected, or removed and re-furbished. Reliability analysis is also used to increase the FAA mandated maintenance intervals for heavy repairs, which delivers cost savings over the life of the aircraft.

Trucking companies and railcar owners are constantly analyzing part-recalls, and create campaigns or programs to fix assets before they break when they come to the shop for other reasons. We used data about chronic failures to drive part replacement decisions. In our experience, in these scenarios Analytics can be used to generate significant cost savings.

Many asset owners also routinely compare asset reliability metrics across different manufacturers to select manufactures with higher reliability scores for future purchases.

### **CHALLENGES WITH THE DATA**

Data needed to implement Analytics reside in verity of operational systems. These systems are generally ERP systems or home grown systems that house repair data with the information related to cost drivers such as parts, labor, warranty, facilities and supply chain costs information associated with scheduling and routing for repairs.

The first issue is that IT systems are designed to collect information to support financial and operational needs such as billing, inventory management and payroll. These systems may not necessarily collect the critical information for Analytics, such as the condition of the replaced parts, probable root cause of the failure or the data may not be stored at the required level of granularity. A very common problem is that the systems track usages at a product group level, which meets finance & accounting needs, but the critical part-number & part serial-number level information that is important for accurate analysis is lost. These types of systems gaps may require enhancements to the existing IT systems or acquiring new systems while improving the operational procedures for collecting required details.

The second major challenge is the data quality. Many operational systems do not have the appropriate error checking capabilities and validation processes to prevent data quality issues at the source. These gaps require implementation of an elaborate data validation and issue resolution processes for making the data usable for Analytics. Also, when the data is integrated from multiple operational systems they may not necessarily match and be in sync, which requires master data management and maintaining of referential integrity to reconcile data across multiple operational systems. In this regard a robust data quality reporting framework is necessary for driving data quality improvements upstream in the source systems.

Sometimes data quality issues are not easy to detect and resolve, especially when they are logical in nature. For example the usage of an asset measured by mileage, engine hours, idle hours etc. may contain values that may look accurate, but they are not. In such cases the validation and resolutions algorithms based on Analytics need to be developed.

The third major challenge is the big data. Many of the assets today have intelligence built in to them in the forms of on-board diagnostics, telematics and various other sensors that continuously monitor the health these assets. These continuous streams of data need to be properly modeled and warehoused so that they can be used for Analytics, especially in terms of proactively identifying emerging issues and implementing corrective actions. These streams of data also can be mined to recognize failure signatures that can be used to identify and prevent field failures.

## CONCLUSION

Across transportation modes the application of Analytics to solve maintenance related problems are very similar. Asset owners and their customers have to find ways to source high quality assets that cost less to acquire and maintain, they have to ensure the reliability and the safety of operations and comply with regulatory requirements, and they have to streamline the processes for maintaining assets to reduce costs and repair cycle times to ensure the optimal utilization of assets and return on their investments. Maintenance providers have to maintain an appropriate inventory of parts at the right locations, they need to understand the asset and parts reliability characteristics, and they have to track the part usage to recover the warranty costs.

Opportunities for applications of advanced analytics techniques to solve these problems are many. Inventory management requires the application of forecasting and optimization techniques. Managing the reliability require application of statistical techniques. Deeper understanding of parts and component failures require association and sequence analysis to see parts or assemblies that fail as a result of another failure. At times they have to analyze textual comments added by the repair technicians to understand the repair reasons and other critical information that may not be captured due to the systems limitations.

Data collection, data validation and issue resolution and data warehousing is very important in preparing the data to be used by Analytics effectively. In planning for implementing analytics initiatives it is also important to analyze the maintenance spend across listed dimensions in this paper and prioritize the areas with larger cost saving opportunities or where most improvement is needed.

In the past, benefits of the Analytics were accessible to chosen few who could afford it, such as commercial airlines. Now Analytics is becoming mainstream due to several contributing factors. Over the last several decades the processing speeds of the computers have been doubling every eighteen months or so according to Moor's law, while the costs have been coming down significantly. At the same time software tools used for data management and analytics have matured, making them more sophisticated and productive in terms of labor required to implement them. Today it is common to use a data warehousing appliances for the management of big data leveraging parallel computing capabilities while SAS is leading the way in Analytics.

## RELEVANT SAS SOLUTIONS

In our experience of working with various transportation companies, we have found three specific SAS solutions that solve the business problems in the asset maintenance and reliability areas to be particularly useful. They are SAS<sup>®</sup> Predictive Asset Maintenance (PAM), SAS<sup>®</sup> Service Parts Optimization (SPO) and SAS<sup>®</sup> Warranty Analysis (WA).

### SAS PREDICTIVE ASSET MAINTENANCE

SAS Predictive Asset Maintenance solution provides a framework where analytic power of SAS is leveraged to predict asset failures and reduce corrective maintenance. This leads to an increase in asset up-time. It integrates and analyzes data from different data sources. Using advanced predictive modeling techniques models can be built to predict impending failures in an asset. Solution also provides dashboards for KPI reporting and alert notification.

### SAS SERVICE PARTS OPTIMIZATION

SAS Service Parts Optimization solution is developed to address the needs to the service organizations. It provides ability to forecast demand of service parts and recommends optimum inventory level across the supply chain. It uses multi-echelon inventory optimization and advanced forecasting techniques to reduce inventory costs while achieving the customer service levels.

### SAS WARRANTY ANALYSIS

SAS Warranty Analysis solution allows early detection and resolution of field quality issues. Solution provides multiple analyses to detect emerging issues and perform root cause analysis. It employs advanced statistical and data/text mining techniques to enable user faster issue detection and resolution. Solution is flexible to integrate and analyze data from different data sources including the text data containing technician comments or the customer complaints.

Leveraging Analytics in Transportation to Create Business Value, continued

## REFERENCES

1. National Rail Freight Infrastructure Capacity & Investment Study, Cambridge Systematics, Inc., September 2007
2. SAS Predictive Asset Maintenance | SAS – [www.sas.com/solutions/sci/pam.html](http://www.sas.com/solutions/sci/pam.html)
3. SAS Service Parts Optimization | SAS - [www.sas.com/industry/mfg/spo/](http://www.sas.com/industry/mfg/spo/)
4. SAS Warranty Analysis | SAS - [www.sas.com/solutions/warranty](http://www.sas.com/solutions/warranty)

## CONTACT INFORMATION

Your comments and questions are valued and encouraged. Contact the authors at:

Name: Vijitha Kaduwela

Enterprise: Kavi Associates

Address: 1250 S Grove Ave, Suite 300

City, State ZIP: Barrington, IL 60010

Work Phone: 312-405-0345

Fax: 847-382-1427

E-mail: [vijitha@kaviglobal.com](mailto:vijitha@kaviglobal.com)

Web: [www.kaviglobal.com](http://www.kaviglobal.com)

Name: Rajesh Inbasekaran

Enterprise: Kavi Associates

Address: 1250 S Grove Ave, Suite 300

City, State ZIP: Barrington, IL 60010

Work Phone: 847-946-4857

Fax: 847-382-1427

E-mail: [rajesh@kaviglobal.com](mailto:rajesh@kaviglobal.com)

Web: [www.kaviglobal.com](http://www.kaviglobal.com)

SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc. in the USA and other countries. © indicates USA registration.

Other brand and product names are trademarks of their respective companies.