Vehicle Health and Performance Monitoring for Fleet Transportation Systems

Background

Fleet logistics—the process of monitoring and managing field-deployed assets and support processes—has long been a cornerstone of fleet operations management. From Navy ships to school buses, the ability to understand the status of deployed resources and manage their use allocation according to dynamic needs remains a critical component of operational efficiency today. In environments where asset uptime is critically important, considering the details of fleet maintenance issues as an intrinsic component fleet logistics is key to sustaining these successes in operational efficiency.

Conventional maintenance systems are typically reactive; that is, maintenance need is generally identified and addressed only after an operational failure. This lack of anticipatory capability then creates logistics that must also be reactive, where repair resources are ordered after the maintenance need is identified and supporting fleet assets are reallocated only after service has already been disrupted. In any modern context, such a reactive system can have significant impacts on the underlying fleet objectives: from in-service mission failures to broader disruption of systems-level operations. In response to these risks, the importance of preserving and ensuring system functionality gave rise to development of a concept called reliability-centered maintenance (RCM). RCM is a philosophy that focuses on identifying specific failure modes in relation to unique operating contexts, prioritizing them based on the severity of their impacts, and addressing them proactively. To support this philosophy, a methodology called condition-based maintenance (CBM) was developed in which advanced monitoring technologies gather system performance data to assess asset health, and relate changes in that data to the emergence of maintenance needs. Analyzing trends in this data not only allows managers to anticipate maintenance and plan resource management ahead of time, but also enables them to connect maintenance issues to specific use contexts, creating insight that helps prevent similar failures in the future.

Collectively, these strategies led to the emergence of predictive maintenance as a transformative framework through which performance anomalies may be pre-emptively recognized and proactively addressed. This prevents unplanned failures, as well as reduces the impact and severity of failures that do occur, resulting in improved overall maintenance effectiveness. However, integrating predictive maintenance into a systems-level logistics planning capability remains a significant area of opportunity.

Initial Development and Deployment

The U.S. Military—operator of perhaps the single largest and most complex vehicle fleet in the world—also recognized the great opportunity to improve the operational and sustainment efficiency of their fleet systems. In military applications, especially, these strategies can be used to support efficient and continuous operations in environments where material and technical resources are scarce. To this end, the U.S. Office of Naval Research (ONR) sought to develop new capabilities by which it could monitor the condition of deployed vehicle assets, using real-time data to optimize maintenance and logistics response in order to minimize mission disruptions. Leveraging its expertise in both complex system monitoring as well as transportation technologies, the Systems Modernization and Sustainment (SMS) Center at Rochester Institute of Technology (RIT) was awarded an ONR grant that supported collaborative research towards this objective.

The SMS program at RIT focused on three fundamental technology challenges. First, a vehicle-level data monitoring system was developed to support advanced asset health monitoring for an existing legacy vehicle fleet. Second, an advanced information architecture was developed to support data collection, communication, and analysis for an entire fleet of vehicles in a shared data environment. Finally, decision support and planning tools were developed to demonstrate multiple user interaction, allowing several layers of command to interpret and respond to fleet data efficiently. Together, these technologies enabled a complete solution that was leveraged in support of a U.S. Marine Corps (USMC) program called Sense and Respond Logistics (S&RL).[1] Supported by the ONR research, the SMS team developed a strategic relationship with the USMC through which S&RL technologies were deployed to Active Duty fleet systems—including the widely-used Light Armored Vehicle (LAV)—to test and provide feedback on system capability. Ultimately, these S&RL technologies became the core of a larger USMC effort to integrate and deploy a comprehensive embedded platform logistics system (EPLS) across several fleet systems.[2] While Lockheed Martin managed this program, deploying the capability to over 7,000 USMC vehicle assets, RIT retained the rights to the fundamental software framework, aiming to develop the concept into a marketable product for commercial transportation markets.[3,4,5] In effort to both continue support for the USMC deployment effort beyond RIT's own involvement, and simultaneously pursue the potential for commercial opportunities, stakeholders in RIT's original research established an independent company called Vnomics that continued to develop and refine a streamlined product.

Adaptation

Although these technologies were first developed and deployed for military applications, both the fundamental need and the potential benefits are equally applicable to commercial transportation markets. Indeed, industry and government data suggest there are over 30 million registered commercial trucks and nearly 900,000 public and commercial buses registered on U.S. roads.[6,7] With such large transportation fleets, the opportunity to improve economic and environmental impacts of commercial fleet operations through technologies developed for S&RL was apparent. Initial discussions with commercial fleet operators showed an interest in predictive maintenance technologies; however, the business case was difficult to prove *a priori*, as existing maintenance systems were already well-situated. In contrast, early RIT analysis of commercial fleet deployments instead highlighted significant opportunities to improve fleet fuel efficiency (and thus reduce both costs and environmental impacts of fleet industries) through identification of sub-optimal vehicle conditions and changes to driver behavior. Recognizing this, Vnomics refined the software technology originally developed for the USMC application and launched a telematics system for the commercial trucking industry that focused primarily on fuel consumption monitoring, with early deployments yielding fuel savings of 5-20% across an entire fleet. After eight years of business operation, over 25,000 trucks monitored, and millions of miles driven, Vnomics recently launched a streamlined and lower-cost system that can be installed across a fleet in just minutes per vehicle. Like the initial complete telematics solution, this system—called TrueFuel™—records fuel consumption data and analyzes use patterns in relation to specific driver behavior characteristics. And like the original EPLS system, TrueFuel™ provides feedback both to vehicle operators and to fleet

[1] U.S. Office of Naval Research. *Sense and Respond Logistics*.
[2] Morin, E.L. (2008). *Marine Corps Autonomic Logistics*. Presentation at 2008 DoD Maintenance Symposium.
[3] EurekAlert (2009). "RIT and Lockheed Marin enhance sustainable mobility and economic growth," Public Release, 8 Jan 2009.
[4] RIT (2007). "Work in progress at the new Golisano Institute for Sustainability," *The University Magazine*, Winter 2007.
[5] RIT (2007). *Final Report: Defense Systems Modernization & Sustainment Initiative*. Report for U.S. Office of Naval Research. Award No. N00014-06-01-0998
[6] American Trucking Associations (2016). "Industry Data," *Reports, Trends, & Statistics*.
[7] U.S. FHWA (2017). "Bus Registrations—2015," Table MV-10 in *Highway Statistics* *2015*. U.S. Department of Transportation.

managers, revealing patterns between driver activity and fuel efficiency—a direct relationship between *how* the vehicle is driven and the economic and environmental costs of operation.

Results

As Vnomics deployed systems over thousands of vehicles across the U.S., average realized savings in the field inherently narrowed, due largely to variations in vehicles, environments, and other fuel-saving strategies independently leveraged by customers. However, with current observed fleet savings between three and 10%, the new system can still dramatically improve fuel efficiency, thus inherently reducing both fuel costs and environmental impacts.[3] While early deployments saw some resistance from drivers concerned that individual data would influence performance evaluations, both Vnomics and their customers have worked to ensure that the TrueFuel™ system is used as a constructive tool. Today, the system allows recognition of experienced drivers for their abilities, and with driver shortages across the industry, less experienced drivers can be trained to drive efficiently much more quickly, reducing the costs incurred in early learning curves. In over 1.5 billion miles traveled with Vnomics technology on-board, these performance monitoring and driver training systems have now helped companies save over seven million gallons of fuel and nearly $23.5 million in operating costs.[8,9] As an ultimate result, trucking companies are able to provide better service more consistently and at lower cost, sending economic ripples throughout the industries they serve.

Beyond economic impacts, the system can also identify fuel efficiency performance degradations related to the trucks themselves, informing maintenance need recognition and decision making, and thus prolonging the life of vehicle assets. In addition, fleet fuel savings also create environmental benefits by reducing greenhouse gas emissions that affect both local and global environmental conditions. Beyond reducing the generation of particulate matter and nitrogen oxides responsible for urban smog, the seven million gallons of avoided fuel use outlined previously correspond to over 150 million pounds of avoided carbon dioxide emissions—the major contributor to global climate change.[10] According to the Environmental Protection Agency, this level of reduction would offset the annual emissions produced by approximately 15,000 modern passenger vehicles.[11]

In whole, the combined benefits of vehicle operations monitoring and predictive maintenance are significant. Minimizing vehicle damage and degradation through condition-driven maintenance mitigates the costs and broader impacts of downtime, service disruption, and possible loss of perishable loads. Likewise, proactive management of transportation fleet fuel use allows for a reduction in operating costs that improve the bottom line while simultaneously mitigating the associated environmental impacts of operation. Together, these technologies, deployed in both military and commercial applications, continue to move the U.S. towards more sustainable transportation systems.

[8] Vnomics Corporation (2016). *TrueFuel: Optimizing Driver Performance*.
[9] Based on U.S. average diesel price of $3.35 from 2010-2017; U.S. Energy Information Administration (2017). *Gasoline and Diesel Fuel Update*
[10] Based on 22.38 pounds of CO2 per gallon of diesel fuel; U.S. Energy Information Administration (2016). "How much carbon dioxide is produced by burning gasoline and diesel fuel?" *Frequently Asked Questions.*
[11] U.S. Environmental Protection Agency (2016). *Greenhouse Gas Equivalencies Calculator*.