National Defence Défense nationale

Canadian Forces College

Collège des Forces Canadiennes

ENABLING FORESIGHT: THE TRANSITION TO A PREDICTIVE MAINTENANCE SYSTEM

Major Ronald R. Balkaran

JCSP 47

Service Paper

Disclaimer

PCEMI 47

Étude militaire

Avertissement

Canada

CANADIAN FORCES COLLEGE - COLLÈGE DES FORCES CANADIENNES

JCSP 47 - PCEMI 47
2020 - 2021

SERVICE PAPER – ÉTUDE MILITAIRE

ENABLING FORESIGHT: THE TRANSITION TO A PREDICTIVE MAINTENANCE SYSTEM

By Major Ronald R. Balkaran

ENABLING FORESIGHT:
THE TRANSITION TO A PREDICTIVE MAINTENANCE SYSTEM

AIM

1. The aim of this service paper is to recommend that a predictive maintenance approach be adopted for Canadian Army (CA) vehicles. It will illustrate the limitations of the current maintenance approach and how it affects serviceability rates and equipment availability. The use of emerging technologies for predictive maintenance will be highlighted including benefits to the CA through optimized maintenance and improved equipment serviceability. Lastly, success stories of predictive maintenance and related pilot projects in the US Army will be discussed to reinforce the benefits.

INTRODUCTION

2. The ability to maintain high equipment serviceability rates continues to be a challenge and a concern for the CA. The CA has tried to renew an equipment culture through the CA Equipment Readiness Program (CAERP) with a focus on its Force Posture and Readiness (FP&R) targets. Unfortunately, it is proving challenging to achieve these targets for several reasons (even prior to the COVID-19 pandemic). Firstly, CA maintenance organizations must support mixed fleets of vehicles from new, high-technology vehicles to aging and unreliable fleets. Secondly, maintenance organizations have remained largely the same in structure and personnel despite these changes. Finally, the corrective maintenance approach when a vehicle fails could require long and extensive diagnostics and face additional delays due to shortage of repair parts. As a result, a vehicle sits unserviceable until the part is received which could be longer than the actual repair time.

3. As the CA looks at the means and ways to align with the concept of Adaptive Dispersed Operations (ADO), the availability and serviceability of equipment will be essential. Integral maintenance organizations will be stretched to be able to support dispersed operations and must seek opportunities to improve the Land Equipment Management System (LEMS). The current approach of preventive and corrective maintenance, compounded by the mixed fleet and organizational challenges outlined above, will not be able to sustain the equipment availability on which ADO will rely. From this perspective, the LEMS should consider how a performance management framework using big data analytics and artificial intelligence (AI) applications could be harnessed to predict maintenance requirements.

DISCUSSION

4. <u>Preventive Maintenance</u>. The maintenance of equipment and vehicles includes both preventive maintenance and corrective maintenance which has served the CA well however, there are limitations with each approach. The main aspect of preventive maintenance is the equipment inspection which is “a detailed technical inspection of an equipment to determine if it is functioning in the manner and to the standard to which it

was designed, or which is required in a given set of circumstances."[1] Equipment inspections are condition-based maintenance and are scheduled by time intervals. Combat vehicles (A-vehicles) undergo an inspection "at least once every six months."[2] Similarly, inspections for support vehicles and trailers (B-vehicles) are scheduled "at least once every 12-month period."[3] While a more frequent inspection cycle may be directed by an Equipment Management Team (EMT) due to specific fleet concerns, the prescribed frequency described above is usually the standard. This standard has been described as sometimes too often or too little depending on the organization and the equipment involved. This highlights the fact that this standard is a "one size fits all" approach and does not factor the age of a specific fleet, the actual usage of equipment and the operating environment. In addition, equipment inspections are heavily reliant on visual inspections and are limited to both the technician's knowledge and experience. While preventive maintenance is important and necessary to reduce the occurrence of fault or failure, there are limitations which could be improved to better prevent equipment failure.

5. Corrective Maintenance. Corrective maintenance is the maintenance required after a vehicle or component fails. The time required for repair is also constrained by the supply system, availability of technicians and priority of repair. Corrective maintenance can be done immediately if all the factors are aligned – parts, priority and technician scheduling – or it can be deferred to when all conditions are in place. When a vehicle or a component fails, the process for ordering part(s) and scheduling the repair starts after the fault is diagnosed. While immediate repair is the ideal scenario to quickly return the vehicle to serviceable, in reality this is usually the exception and not the rule. Limited repair parts are held at integral units and if a required part is not readily available, the supply system tries to find it from the nearest location based on availability. Depending on the nearest location, which could be anywhere in Canada, there can be delays in reception of the required part(s). In addition, as technicians are often busy with other ongoing repairs, the work must now be prioritized and scheduled accordingly. Scheduling may not always coincide with the receipt of repair parts and, as a result, could also lead to additional delays. As a result, the actual repair time may only be a fraction of the overall total time a vehicle is rendered non-serviceable and remains out of operations. The emphasis must be to minimize the time when a vehicle is non-serviceable so that it can be quickly returned to operations. How do we better streamline scheduling and the supply process to optimize maintenance and minimize downtime?

6. ADO and LEMS. This challenge is relatively well-known and the Corps of Royal Canadian Electrical and Mechanical Engineers (RCEME) has started the discussion as the CA focuses its future on ADO. In issue 1 of the LEMS Journal April 2018, Colonel Robert Dundon proposed how LEMS would function in the future operating environment. He suggested ways in which current and future technology trends would be leveraged to better streamline maintenance and reduce the time where a vehicle is non-

---

[1] Department of National Defence, C-04-005-001/AG-C01 *Land Equipment Management System Inspection System* (DLEPS, 2020), 1-3.
[2] Department of National Defence, C-30-020-000/AG-002 *Preventive Maintenance Procedures Combat Vehicle (A Fleet)* (DLEPS 4, 2012), 1-5.
[3] Department of National Defence, C-30-020-000/AG-002 *Preventive Maintenance Procedures Tactical Support Vehicles (B Fleet)* (DLEPS, 2012), 6.

serviceable for corrective maintenance. Colonel Dundon illustrated where an advanced health usage and monitoring system (HUMS) would monitor all subsystems and, "as soon as a vehicle has a mechanical problem, breaks down, or is damaged, the HUMS performs a diagnostic and recommends repairs."[4] He also highlighted where and how AI can be used to select the right technicians based on tools and proximity (if deployed) and to initiate the supply process for the required parts.[5] This discussion accurately reflects a networked, agile and responsive LEMS in the future but it is still responsive to corrective maintenance after failure. Unfortunately, failure rarely occurs at a desirable time and place. The ability to choose when and where repairs are conducted (prior to failure) would ensure equipment serviceability and availability when required.

7. Predictive Maintenance. Current and emerging technology trends can be leveraged in order to operationalize maintenance and be able to predict failure. Informed predictions provide the opportunity to choose the right time and place for repairs prior to equipment failure. Predictive maintenance is a condition-based maintenance approach which uses sensors to monitor the equipment's condition in real-time in order to predict when the equipment will require maintenance and prevent failure. Commanders and technicians can better synchronize maintenance efforts to ensure the right equipment is available for operations with greater confidence in its reliability during the operation. This does not suggest that all failures can be predicted however, it can better streamline maintenance and synchronize efforts to improve equipment serviceability and availability. Although a new maintenance approach, the concept of predictive maintenance supports Foresight which is one of the six principles of LEMS.

8. Most recent CA vehicles already employ a series of sensors with onboard diagnostic systems. This is similar to commercial vehicles where oil change or tire pressure warnings are provided to the driver in advance of any failure. The data from existing monitoring sensors can be harnessed and analyzed along with other data from the fleet and other similar vehicles from allies, where possible. To enable this effort, a cloud-based solution will be necessary for data storage with an AI application to enable data analysis. Big data analysis would compare real-time operating information with "normal" operating information and be able to identify changes to the system. Feedback from this automated analysis could identify problem areas and the severity of the fault which can then be used for prioritizing and scheduling. This also reduces ambiguity, can identify the problem area and the replacement parts required. If integrated for greater efficiency, the system can also interface with the Defence Resource Management Information System (DRMIS) to ensure repair parts are available at the right time. The process would relay the problem area and initiate ordering of parts even before a technician looks at the vehicle and, in most cases, before failure. This outlines an obviously simplified explanation of the process for predictive maintenance. In general, the employment of

[4] Colonel Robert Dundon, "Adapting to Dispersed Operations: LEMS in the Future Operating Environment." Land Equipment Management System Journal (Issue 1, Spring 2018): 3.
[5] Ibid., 5.

sensor monitoring, cloud computing and AI through an automated performance management system provides the building blocks for predictive maintenance.[6]

9. Data Culture and Automation. The HUMS is already being used in the Tactical Patrol Armoured Vehicle (TAPV) fleet but there are ongoing challenges due to reporting issues. Data collection is focused on forecasted and actual usage in order to support and inform the performance-based in-service support (ISS) contract for the fleet. While the extent of its use in predictive maintenance is unknown, it has been suggested that this "data is not being used to support optimized maintenance decision-making."[7] Another key challenge is data reporting itself as the HUMS information must be manually transferred to DRMIS by maintenance staff. The importance of data should not be underestimated and it must be embraced in our organizational culture and disciplined to achieve maximum effect. As the data required for predictive maintenance is vast, automation is essential to provide more agile, real-time analysis. In addition, it removes the time-consuming requirement for manual input and chance of error where a technician could otherwise be gainfully employed. The employment of a fully networked and integrated predictive maintenance system will enable the effective and efficient use of HUMS data to optimize maintenance and operational decision-making.

10. Current Applications. Information such as usage, work orders and repairs parts already used in DRMIS and the HUMS in the TAPV fleet suggest the importance of data and data analysis in LEMS. It presents a start state and while an oversimplified description of predictive maintenance was provided earlier, it is no doubt a complex system. However, innovation in private industry has already implemented such systems and can be leveraged to facilitate the transition to predictive maintenance in the CA. The US Army started using predictive maintenance on a portion of its Stryker combat vehicles in 2016 as part of a pilot project with IBM. Its Watson AI platform was used and "sensors were installed on 350 Stryker vehicles, and Watson ingested and analyzed maintenance manuals and work orders to create a comprehensive maintenance picture."[8] Using this analysis, the system is able to flag anomalies and predict when components are likely to fail. A similar system was also introduced in the US Army's Bradley fleet in 2019 using industrial AI Company, Uptake. The application is being used to "predict component failures, decrease the frequency of unscheduled maintenance and improve the productivity of repair operations."[9] The actual benefits of these implementations are yet to be quantified however, the benefits of predictive maintenance were demonstrated by Italian train operator, Trenitalia. After its transition to predictive maintenance, Trenitalia "was able to decrease downtime by 5-8 percent and reduce its annual maintenance spend

---

[6] Schmidt, Bernard and Lihui Wang. "Cloud-Enhanced Predictive Maintenance." *International Journal of Advanced Manufacturing Technology* 99, no. 1-4 (2018): 5-13, 7.

[7] Roby Ayres, "Data and Information Management in LEMS." Land Equipment Management System Journal (Issue 3, Fall 2019): 12.

[8] Sara Friedman, "AI helps Army with Stryker maintenance," Defense Systems, 08 August, 2017. AI helps Army with Stryker maintenance -- Defense Systems

[9] "U.S. Army to Use Uptake's Artificial Intelligence Software to Increase Bradley Fighting Vehicle Readiness," U.S. Army to Use Uptake's Artificial Intelligence Software… | Uptake

by an estimated 8-10 percent, saving about $100 million per year."[10] The benefits of predictive maintenance to meet the challenges of LEMS and equipment serviceability are clear but there are other considerations to overcome.

11. Other Considerations. One of the key considerations to the implementation of predictive maintenance technologies is the upfront cost and any recurring costs. This will include sensor development, implementation and management of the AI application and cloud computing via a contracted service. The return on investment for the CA may be difficult to gauge in terms of dollars however, it will enhance overall equipment serviceability and availability by reducing repairs and equipment downtime. If faults are predicted, vehicle maintenance can be done before failure and operational capability can be optimized. The second consideration is related to the data and the cyber domain. Data transmission, cloud storage and analysis would not be classified and potentially vulnerable to cyber threats regarding capability. That said, at least in Canada, DRMIS is used on the unclassified network and this risk has already been accepted. This could be different for deployed operations and will need further research.

CONCLUSION

12. Equipment serviceability rates within the CA remain a challenge to meet FP&R targets due to several factors including: (1) mixed fleets from new to old; (2) stretched maintenance resources; and (3) lengthy diagnosis and supply-related processes. As a corrective maintenance approach only starts the scheduling and supply processes after diagnosis of the equipment, actual repair time is sometimes only a fraction of the overall vehicle downtime. In addition, vehicle failure seldom occurs at a desirable time and place. Predictive maintenance uses sensor monitoring, historical fleet data and AI applications to predict failure, optimize maintenance, reduce downtime and ultimately enhance readiness. As emerging technologies are leveraged for predictive maintenance to improve equipment serviceability and availability, it presents an opportunity for the CA to meet the current and future challenges of LEMS in an ADO environment.

RECOMMENDATION

13. The transition to a predictive maintenance approach should be a deliberate process with sufficient research and planning. Data monitoring and historical data already available within CA systems could be considered a starting point to further explore options for predictive maintenance. As a result, the following steps are recommended:

a. Data discipline should be enforced to create a data culture as the information in DRMIS could be harnessed as historical data for analysis;

---

[10] Dennis Schultz, Joe Mariani, Isaac Jenkins, Frank Strickland, Lacey Raymond, "*Military readiness: How emerging technologies can transform defense capabilities*," Deloitte Center for Government Insights. DI_Military-readiness.pdf (deloitte.com)

b. A feasibility study should be conducted to determine potential applications, associated costs, other requirements and timelines to implement a predictive maintenance system;

c. A single fleet should be targeted for trial before further roll out. Using the HUMS system, the TAPV could be considered as the trial fleet (if possible); and

d. A predictive maintenance system should be considered in the capability development process for all future CA vehicles.

BIBLIOGRAPHY

"U.S. Army to Use Uptake's Artificial Intelligence Software to Increase Bradley Fighting Vehicle Readiness," https://www.uptake.com/newsroom/u-s-army-to-use-uptakes-artificial-intelligence-software-to-increase-bradley-fighting-vehicle-readiness

Ayres, Roby. "Data and Information Management in LEMS." Land Equipment Management System Journal (Issue 3, Fall 2019).

Dundon, Robert, Colonel. "Adapting to Dispersed Operations: LEMS in the Future Operating Environment." Land Equipment Management System Journal (Issue 1, Spring 2018).

Department of National Defence, C-04-005-001/AG-C01 *Land Equipment Management System Inspection System* (DLEPS, 2020).

Department of National Defence, C-30-020-000/AG-002 *Preventive Maintenance Procedures Combat Vehicle (A Fleet)* (DLEPS 4, 2012).

Department of National Defence, C-30-020-000/AG-002 *Preventive Maintenance Procedures Tactical Support Vehicles (B Fleet)* (DLEPS, 2012).

Friedman, Sara. "AI helps Army with Stryker maintenance," Defense Systems, 08 August, 2017. https://defensesystems.com/articles/2017/08/08/army-stryker.aspx

Schmidt, Bernard and Wang, Lihui. "Cloud-Enhanced Predictive Maintenance." *International Journal of Advanced Manufacturing Technology* 99, no. 1-4 (2018): 5-13.

Schultz, Dennis, Mariani, Joe, Jenkins, Isaac, Strickland, Frank, Raymond, Lacey. "*Military readiness: How emerging technologies can transform defense capabilities*," Deloitte Center for Government Insights. https://www2.deloitte.com/content/dam/insights/us/articles/4645_Military-readiness/DI_Military-readiness.pdf