Institution:
Glasgow Caledonian University

Unit of Assessment:
12: Engineering

Title of case study:
Sustainable Railway Rolling Stock Maintenance Optimisation Strategy

Period when the underpinning research was undertaken:
2014 - 2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Babakalli Alkali	HoD of Dep. Mechanical Engineering	2008 - present

Period when the claimed impact occurred:
2014 - 2016

Is this case study continued from a case study submitted in 2014?
No

1. Summary of the impact

ScotRail collaborated with Glasgow Caledonian University between 2014-2016 through a joint Knowledge Transfer Partnership (KTP) to undertake a study to review maintenance practices and conditioning monitoring of railway rolling stock. GCU research led by Professor Babakalli Alkali and his team on the concept of maintenance modelling of railway rolling stock incorporates a data analytic approach on safety critical systems. The research has led to the optimised maintenance intervals from 7k miles to 10k miles. The overall result impact has resulted in a 95% performance improvement of service operations across the fleet, and hence increased customer satisfaction of 95 million passenger journeys across Scotland.

2. Underpinning research

The Railway Industry in Great Britain Value for Money is around £1.9 billion per annum, and the Rolling Stock maintenance cost account for 15% of total rail industry costs per annum. In 2014 a GCU research team led by Babakalli Alkali studied the rolling stock fleet predictive maintenance data analytics to improve availability, performance, reliability and maintenance management towards ensuring smooth service operations, and hence customer experience and satisfaction [R1]. A joint two-year Knowledge Transfer Partnership (KTP) funding of £126,000 was obtained from Innovate UK between GCU and First ScotRail to support the project [C3]. Babakalli worked together with First ScotRail maintenance supervisors and conducted Condition Monitoring (CM) trials at Edinburgh Waverley station depot using the Class 170 Diesel Multiple Unit (DMU) feet for the trial. The team in particular investigated condition monitoring technology to support improvement of fleet performance [R2]. This involved harnessing and integrating the relevance of dynamic stochastic process methodology, statistical analysis and expert opinion to detect the precursor of failure and anomalies in order to extend the lifetime of the train fleet systems [R1]. A major part of the rolling stock project led by Babakalli focused on the door system design operation and specifically in relation to improving the reliability of door systems through enhanced monitoring and maintenance. In using the Failure Mode and Effect Criticality Analysis approach, the door system was identified as one of the worst performing systems, and multiple work streams were undertaken to improve operational efficiency such as risk incident identification and fault rectification [R3, R4].

The research key stages include; (i) Reliability Centred Maintenance (RCM) Cost Analysis and (ii) Condition Monitoring (CM) solutions implementation within the door system [R2]. The research work had significant impact on the maintenance and reliability of rolling stock door systems [R5]. The trial provided the following results:

- Records information status of the Door Interlock Switch (DIS) and Door Control System (DKS) operations in-service.
- Tracks poor performing slow to close doors.
- Identify intermittent electrical failures through signal alerts.
- Identifies potential Wrong Side Door Failures.
- Schedule maintenance cost and reliability savings of £116,000 per year.

The maintenance and reliability challenges of rolling stock Diesel Multiple Units (DMU) using the new tools have delivered the solutions to the door maintenance challenges. This has been incorporated into First ScotRail's current Condition Based Maintenance (CBM) strategy in 2015.

The overall portfolio of solutions from Babakalli's research findings has delivered a greater impact across all areas of maintenance (proactive, preventative, predictive planned and unplanned) to improve reliability and performance of safety critical systems [R2]. The findings were disseminated to key stake holders during performance review meetings in 2015 to recommend new maintenance practices, design enhancements and condition monitoring solutions. These results have been implemented into ScotRail's continuous improvement programme to achieve maximum availability, reliability of trains and reduction in delays and cancellation of services due to door incidents [R5]. The implementation across the Scottish railway maintenance depot demonstrates the application of new technology in engineering practice, from theory through to actual site application [R4].

3. References to the research

- [R1] Alkali, B.M., (2018). Railway rolling stock fleet predictive maintenance data analytics. Fourth International Conference on Railway Technology: Research, Development and Maintenance, 3-7 September 2018, Sitges, Barcelona, Spain.

- [R2] Alkali B., Dinmohammadi F., and Ramani A., (2017). Towards Implementing Condition Based Maintenance Policy For Rolling Stock Critical System. IMechE The Stephenson Conference: Research for Railway. 25-27 April 2017, One Birdcage Walk London UK.

- [R3] Dinmohammadi F., Alkali B., Shafiee M., Bérenguer C., and Labib A., (2016). Risk Evaluation of Railway Rolling Stock Failures Using FMECA Technique: A Case Study of Passenger Door System. Urban Rail Transit December 2016, 2(3), pp 128-145. (IF: 1.54).

- [R4] Alkali, B.M., Orsi, V., and Ramani, A., (2016). Rolling Stock Door System Reliability Improvement using Maintenance Optimisation, in J. Pombo, (Editor), Proceedings of the Third International Conference on Railway Technology: Research, Development and Maintenance, Civil-Comp Press, Stirlingshire, UK, Paper 281, 2016. https://doi.org/10.4203/ccp.110.281

- [R5] Alkali, B.M., Brown, G., Tait, C., and Orsi, V., (2014). Reliability Analysis of Railway Rolling Stock Failure Patterns. Proceedings of the Second International Conference on Railway Technology: Research, Development and Maintenance, Civil-Comp Press, Stirlingshire, UK, Paper 177, 2014. https://doi.org/10.4203/ccp.104.177

4. Details of the impact

Babakalli's research in the area of maintenance and condition monitoring of rolling stock has had significant impact on maintenance planning and continuous improvement in Scotland.

Impact condition monitoring strategy

The analysis capabilities of the railway research led by Babakalli had offered insight on how to transform raw data into valuable information which enabled the review of historical failures, performance monitoring and condition monitoring data to identify poor performing systems [C1, R3]. This new knowledge allowed ScotRail to develop new enhanced maintenance procedures to improve maintenance effectiveness and reduce the amount of technical in-service failure [C4].

The techniques have been strategically important at the maintenance depots in Glasgow, Edinburgh and Inverness, to service the busiest route of train maintenance schedules. The key Maintenance Instructions have been updated and business processes have been modified to utilise the new information streams adapted that are now in use by ScotRail maintenance teams. The current railway franchise remains committed to the Remote Condition Monitoring and Condition Based Maintenance strategies and the research project findings by Babakalli and GCU team forms part of works being undertaken by ScotRail, in collaboration with other partners (Arrowvale Technologies, Chrome Angel Technologies, Nexala Trimble-C2M) to update On-line Train Monitoring Recorder (OTMR) with a new parameter channel to pick up signals and transfer data remotely to support decision making on maintenance regimes [C3].

The success of the research output is used as specification for acquiring new rolling stock assets. Abellio ScotRail has acquired 70 new Hitachi Electric Trains and High-Speed Trains (HST), which are fully introduced into service in the railway network in Scotland.

Impact on maintenance policy

This door system has historically been one of the worst performing systems on trains, and multiple work streams have previously been undertaken to improve the reliability through enhanced maintenance operations [C2]. The project has led directly to a change in ScotRail's Door maintenance strategy. The maintenance instructions have been revised accordingly based on the results of the Reliability Centred Maintenance simulation analysis [R5].

The GCU team were also able to collaborate with First ScotRail bringing valuable specialist skills and knowledge of mechanical and electrical systems, maintenance strategy and train operation, to create a tailored condition based maintenance approach to the door system. Overall, the KTP has delivered a multi-layered improvement across the business – upskilling 50 maintenance staff, providing depot management staff with tools to improve maintenance efficiency and effectiveness, and guiding the overall Engineering strategy towards an innovative Condition Monitoring based approach to maintenance [C1,C3].

The company invested close to £50,000 over and above the contribution of the Knowledge Transfer Partnership (KTP) project to explore and research new and innovative maintenance methodologies, technology and skills. The company has collaborated with multiple SME's to create a tailored approach to the performance issues being faced during the project. The company is committed and has the desire to extend the findings from the KTP project and the condition monitoring technology to a wider section of ScotRail's fleet. The trial was completed successfully in October 2015, and an investment decision was been made to roll out condition monitoring on the doors with £200,000 invested over two years. The specific business need of the franchise is to address reliability improvement and performance of the Diesel Multiple Unit (DMU).

5. Sources to corroborate the impact

- [C1] IMechE Railway Division Scottish Region Invited talk on the topic "Implementing Condition Monitoring on Railway Rolling Stock"– GCU Feb 2018. http://nearyou.imeche.org/docs/default-source/scottish-rd-centre---past-presentations/180215-glasgow-caledonian-university---class-158-door-reliability.pdf?sfvrsn=4

- [C2] Dinmohammadi, F., Alkali, B.M., Shafiee, M., Saati, S., and Labib, A., (2020). Simulation-based Multi-Criteria Evaluation of Cost-Risk-Effectiveness in Prognostic Maintenance Operations: A Case Study from Railway Industry. Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference, 1-5 Nov, Venice, Italy. ISBN:978-981-14-85930. https://www.rpsonline.com.sg/proceedings/esrel2020/html/4215.xml

- [C3] 2015 Rail Maintenance Success: Knowledge Transfer Partnership https://www.gcu.ac.uk/media/gcalwebv2/businessnew/ScotRail_KTP.pdf (Innovate UK KTP Grant (No. 9070); GCU in Partnership with ScotRail).

- [C4] 2020 ScotRail Testimonial on the Impact of implementation of condition monitoring tools and data analysis approach to improve maintenance and reliability of rolling stock.