Institution: Newcastle University

Unit of Assessment:12

Title of case study: Fuel, Performance and Energy Management for Global Shipping

Period when the underpinning research was undertaken: 2010-present

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:**
Kayvan Pazouki	Senior Lecturer	2007 – present
Alan J Murphy	Reader in Maritime Engineering	2007 – present

Period when the claimed impact occurred: 2013-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Advances in non-physical measurements and data analytics for fuel, performance and energy management systems have led to a sustained and profitable relationship with Royston Diesel Power. Our research outputs have been incorporated into the 'state of the art' modularised Fuel, Performance and Energy Management product: engine*i*.

The development of engine*i* has generated sales of £6m and led to a reduction in fuel consumption of 3-10% over 12 months without affecting vessels operations. Embedding an innovative design capability within Royston Diesel Power has enabled a step change in the business moving the company capabilities' from repair and maintenance to 'intelligence selling'.

2. Underpinning research (indicative maximum 500 words)

Work undertaken by Pazouki on virtual sensing to inferentially measure non-measurable quality parameters using primary physical parameters in the period (2007-2012) led to a step change in the approach to fuel monitoring and energy management measurements [R1]. Before Newcastle University involvement, Royston's engine*i* products relied on primary physical measurements by using only hardware, which were suboptimal due to limited data storage, lack of ability to perform statistical analysis and lack of telemetry. Pazouki's work on non-physical measurements enabled shifting from an all hardware system to a combined hardware/software system to include performance indicators such as fuel consumption for a given work done and distance travelled. The novelty is on software development allowing required hardware interfaces to be routinely configured within the system (plug and play concept), which brings on board data storage, data transfer and processing capability for data analysis. This collaborative research received certificate of "Excellence" from the Technology Strategy Board [E3].

In parallel Dr Murphy's previous work with Svitzer provided an ideal conduit for testing the first engine*i mark* II product. Applying data analytics on the engine*i* output during sea trial of a Svitzer tugboat, the optimum engine-propeller operating point was identified. This was not included in the original design of engine operating system. The optimum engine operating point could potentially save up to 30% of fuel consumption during transit operation [R2].

The resulting improvements in engine*i* product are:

- Development of modularised features such as Automatic Mode Detection System (Auto-Mode) and Economic Speed (Eco-Speed). Currently 11 Auto-Mode and 3 Eco-Speed products have been installed on the commercial vessels.
- Development of common hub system for the unification of data collection, storage and analysis.
- Development of algorithm for energy mapping and distribution on board the ship for energy management and reduction of fuel consumption.

Bespoke data analytics gained through the development of this system have enabled researchers to develop Automatic Mode Detection System [R3]. The published work has drawn the attention of a research institute (Monohakobi Technology Institute) part of the Japanese shipping company 'NYK Line' and this has led to a commercial research contract (£30K) as a pilot study with a potential of a further to 2 years of research collaboration [E9].

The software- based analysis and KTP projects led to the Innovate UK project on Whole vessel energy management- remote monitoring of energy use, which led into development of algorithm for energy mapping and distribution on board the ship for energy management and reduction of fuel consumption [R4].

The data analytics that were produced from this refined system then fed into further research on ship performance monitoring dedicated to biofouling analysis and a novel detection approach for the detection of hull and propeller fouling [R5].

The analytical research on big data carried out in UK funded project, "Whole vessel Energy Management", in collaboration with Royston and EU funded project, "CLINSH" [E6], enhanced the research strength and portfolio of Newcastle University team thereby they joined by invitation to an EU consortium and secured H2020 project, SUSTUNTECH [E10].

3. References to the research (indicative maximum of six references)

R1 - Kayvan Pazouki PhD Thesis; "Inferential Measurement and Control of Ballast Water Treatment System", 2012, Newcastle University

http://theses-test.ncl.ac.uk:8080/jspui/handle/10443.1/1433

R2 - Murphy AJ, Weston SJ, Young RJ. Reducing Fuel Usage and CO_2 emissions from Tug Boat Fleets: Sea Trial and Theoretical Modelling. International journal of Maritime Engineering 2012, 154, A31-A41. doi.org/10.1016/j.trd.2016.10.026

R3 - Zaman I, Pazouki K, Norman R, Younessi S, Coleman S. Development of automatic mode detection system by implementing the statistical analysis of ship data to monitor the performance. International Journal of Maritime Engineering 2017, 159(Part A3), A225-A235. doi:10.3940/rina.ijme.2017.a3.411

R4 - Lim S, Pazouki K, Murphy AJ, Zhang B. Capturing and analysing real-time data from TUGS. In: 37th International Conference on Ocean, Offshore and Arctic Engineering - OMAE. 2018, Madrid, Spain: American Society of Mechanical Engineers (ASME). https://doi.org/10.1115/OMAE2018-78003

R5 - Coraddu A, Lim S, Oneto L, Pazouki K, Norman R, Murphy AJ. A novelty detection approach to diagnosing hull and propeller fouling. Ocean Engineering 2019, 176, 65-73. doi.org/10.1016/j.oceaneng.2019.01.054

R6 - Gibson M, Murphy AJ, Pazouki K. Evaluation of environmental performance indices for ships. Transportation Research Part D: Transport and Environment 2019, 73, 152-161. doi.org/10.1016/j.trd.2019.07.002

[G1] EU funded project, “CLINSH: CLean INland Shipping” (BH152170)

[G2] EPSRC IAA funded project, “Whole journey ship analysis” (BH183529)

[G3] Joint EPSRC and Lloyd’s Register PhD Scholarship, “A novel approach to Environmental assessment of ships”

[G4] Commercial Research funded by Monohakobi Technology Institute, “Ship Operation Profiling”, (NU-000522)

[G5] EU funded project, “Sustainable Tuna Fisheries Through Advanced Earth Observation Tools (SUSTUNTECH)” (NU-000167)

4. Details of the impact (indicative maximum 750 words)

Advances in non-physical measurements for fuel and energy management systems have led to the development of a hybrid hardware-software monitoring product to measure key performance indicators. The novelty of this product is in the software development allowing for ‘plug and play’ of the hardware interface with the system. This concept brought additional ability for on board data storage, transfer, analytical processing and manipulation.

The development of multi-featured engine*i* mark II has generated sales of £6m and is installed on 250 ships globally. The incorporation of this multi-featured product has led to a 3 to 10% reduction in fuel consumption and consequential reduction in harmful emissions over 12 months of operations. The research has allowed Royston to develop the engine*i* R&D department within the company to secure jobs as well as creating culture for further product development.

Economic Impact:

The route to market is based upon the existing enginei system which has grown from £2m sales in 2017; and now represents £6m export sales at year end February 2019 (27% of the business); and generates a gross margin of 40%. This growth has incorporated the setup of an international distributor base together with increased telemarketing and directly employed international sales support [E1].

The company relied on testing of engine*i* built products from an outside source prior to the Newcastle University collaboration. It now undertakes all build and test in-house, which provided savings of £30k by reducing dependency on outside expertise and the advancement of the engine*i* mark II product enabled more time-efficient operations, saving £5k in 2014 [E1].

Business structure overhaul:

As a result of the Knowledge Transfer Partnership commitment to engine*i*, the Group has evolved the engine*i* product specifically and is to focus in its current 5-year plan on the development of new products/services [E1]. This represents a step change in the business whereby it’s past, reactive service-oriented approach will change to a customer focussed solutions base of product and service offerings from a “suite” of functional approaches to a problem. The solutions orientated business approach will give Royston the opportunity to bid for higher value work as it becomes known for its technical approach to market issues.

Newcastle University research gave the necessary technological support to enable new export markets to be developed including Auto-Mode, Eco-Speed and Energy Mapping [E1].

Product and Knowledge development:

The improved data analytics have made it possible to address several research questions such as reduction of fuel consumption and carbon footprint for a given task and understanding the influence of external factors such as tide and wind on the fuel consumption for a ferry operating in the UK waters. This has led to a successful EPSRC Impact Acceleration Account [E7] to assess the impact of wind on a ferry operation.

User impact

The engine*i* system is in operation in 250 ships globally. The incorporation of this novel energy management system enables accurate fuel and emission monitoring. The system is installed on the fleets of tugs, Offshore Supply Vessels (OSV), ferries and tankers operating in an increasingly challenging economic environment and ever-tightening emissions regulations and has led to a reduction on fuel consumption of 3 to 10% and consequential reduction in harmful emissions over 12 months without affecting vessel operations. [E1, E5]

The incorporation of engine*i* solutions on 10 major passenger vessels operating in the sensitive maritime environment led to a significant improvement on the client's carbon footprint and bottom-line financial performance with an anticipated annual fuel savings of more than £450K and a reduction in CO_2 emissions of 1,800 tonnes [E5].

For example, Svitzer, has seen a 15% reduction in energy bills over the 7 years it has been utilising the system [E2]. That is, the system allowed the identification of the most fuel-efficient mode of engine & vessel operation for vessel transit which subsequently led to Svitzer installing permanent engine operating settings they dub “Eco-Speed” to make these fuel savings in the longer term [E2].

Environmental Policy Impact:

The data generated from this research and associated data analytics approach has led to the production of policy recommendations for the EU Commission [E4].

Furthermore, greater expansion of engine*i* on a modular basis enables flexibility to respond to environmental legislation in the Marine Industry or a customer’s needs. Specifically, data generated form the modularised engine*i* product on RV Princess Royal and associated analytical research on the generated data has led to the development of “A novel approach to Environmental assessment of ships”, which is used in the EU funded project “CLINSH” [E6, E8 & R6].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[E1] Testimonial from Lawrence Brown, Chairman, Royston

[E2] Testimonial from Richard Young, Fleet Manager & Operations BPO, Svitzer Europe

[E3] Knowledge Transfer Partnerships, ‘Certificate of Excellence’ and confirmation of ‘outstanding grading’ award letter

[E4] Clean North Sea Shipping (CNSS) Policy recommendations document

[E5] Royston engine*i* website (https://www.enginei.co.uk)

Research grants are included here as evidence to demonstrate the continued support for application of Newcastle research. Both through expanding commercialisation opportunities and application within other research projects (e.g. environmental and sustainability analysis).

[E6] EU funded project, “CLINSH: CLean INland Shipping” (BH152170)

[E7] EPSRC IAA funded project, “Whole journey ship analysis” (BH183529)

[E8] Joint EPSRC and Lloyd’s Register PhD Scholarship, “A novel approach to Environmental assessment of ships”

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