MS-E2177 Seminar on Case Studies in Operations Research, 2018

ABB Marine: Models of vessel hull and propeller fouling

Interim Report

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Project status

The main objectives of the research project were divided into three sections; progress of the objectives with different tasks are presented in Appendix 1. This research project has progressed according to our milestones but the complexity of the project and lack of appropriate data have caused challenges. Therefore, we have prioritised some objectives and tasks in order to ensure the most important objectives are addressed.

The first objective is to the estimate the overall level of fouling with the quantified impact on propulsion power demand. We approached the problem by assuming that the fouling of the hull and the fouling of the propeller are non-distinguishable from each other, an approach taken by many in the literature. We have accomplished many of the tasks for this objective, however, a small number of tasks are still in progress. Next, the most important tasks of the first objective will be reviewed.

Transforming the raw data into an understandable format was a major computational effort as there were over 30 files (with observations every minute) in each quartile and different stages of preprocessing were involved, such as cleaning and filtering. First, the data were merged to create datasets of variables spanning all quartiles. Next, the variables were filtered based on wind speed and ground speed of the vessel. Maximum limit for the wind speed was set to the 97.5 percentile which corresponds to the speed of 44.2 knots. Minimum and maximum limits for the ground speed were decided based on a detailed conversation with our ABB contact, and they were set to 4 and 20 knots. Time stamps which included data outside of these limits were filtered out, as well as time stamps with missing information about any of the needed variables.

In order to achieve the first objective, fuel consumption is used as a proxy variable for the level of fouling once the external conditions (wind, waves, draft, etc.) have been corrected for. Therefore, as the data did not include a fuel consumption variable, it was calculated using total propeller power and average consumption per kilowatt hour. The achieved fuel consumption rates were validated by our ABB contact and the Meng et al., paper. This consumption rate is used as the ‘y’ value in our regression model.

This research relies on real shipping log data that need to be examined. Thus, correlation analysis of variables which are related to the vessel's fuel efficiency was conducted. Spearman's rank correlation coefficient test was adopted due to the nonlinear relationship between different variables. Spearman's rank test was used to identify correlation levels between the most critical variables, which create a foundation to calculate the overall level of fouling. Thirty-six variables were observed and as result of the test, 666 pairs of correlations were achieved. The most critical variables, such speed of vessel and wind will be compared to the paper of Meng et al., (2016) to validate our results, and then will be used in the model.

Regression techniques are currently being implemented to investigate the impact and co-interactions of various variables on the rate of fouling, with estimates of fuel consumption for given periods before-and-after cleaning used as a way of calculating the level of fouling. As showed above, most of the focus has been placed on the first objective because it presents the majority of the workload and it will enable us to be able to solve the third objective.

The second objective is the individual impact of hull and propeller fouling of the cruise ship, unfortunately, at the moment, this objective is neglected due to lack of appropriate data, excessive workload and prioritisation of objectives. This was noted as a high-risk objective in the project plan.

The third objective is to develop a method that enables one to optimise the scheduling of hull and propeller cleaning, with the minimisation of operational costs. The tasks for this objective have not yet begun, though they will be prioritised in the coming weeks once we have validated the regression model and fouling level it produces.

Schedule

The Gantt chart shown in Figure 4 (Appendix 2) displays our project schedule progress, with the light green bars representing completed tasks and the light blue bars representing remaining tasks, with deliverables in darker shades. The chart is regularly updated to ensure that we stay on schedule, any tasks that are prolonged (planned or not) are displayed in red. For instance, we extended the literature review task in order to achieve the objectives 1 and 3. However, we have not missed any planned start weeks yet but at the moment it seems that final report write up activity will be postponed couple of weeks.

Preliminary results

The preprocessing of the data has been completed, time series plots and histograms of the data were created to enable study of the graphical representation of the data instead of the data itself, a widely used technique. The most obvious result from the plots was the amount of null/or missing observations, Figure 1 illustrates this. In addition to the plots, basic statistics (percentiles, mean, and variance) were calculated in order to filter out anomalies and possible errors from the variables.

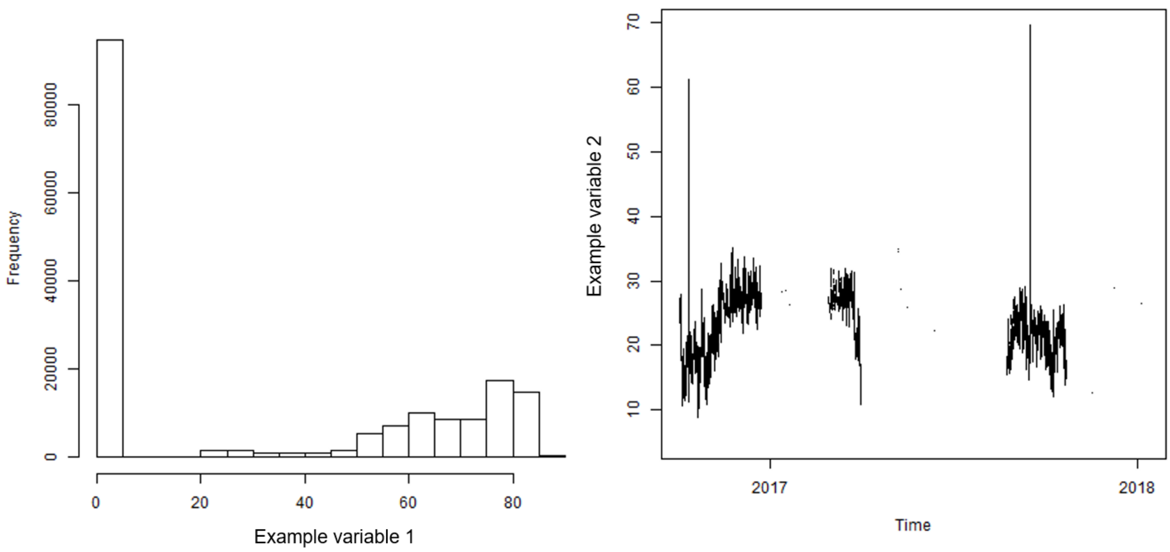

Figure 1 Preprocessed data plots

Once the data had been cleaned the fuel consumption rate was calculated. Fuel consumption is in metric ton per day (MT/day), and is based on the total propulsion power (the summation of power from both propellers) and estimated fuel consumptions per kilowatt hour (~200g/kwh). Figure 2 and Figure 3 illustrate the uncorrected fuel consumption rate, note the two further anomalies Figure 2 exposed, as well as the highlighted cleaning events in Figure 3. This data is being used in the regression model to correct for external conditions in order to estimate the overall effect of fouling, regrettably we do not yet have any viable results.

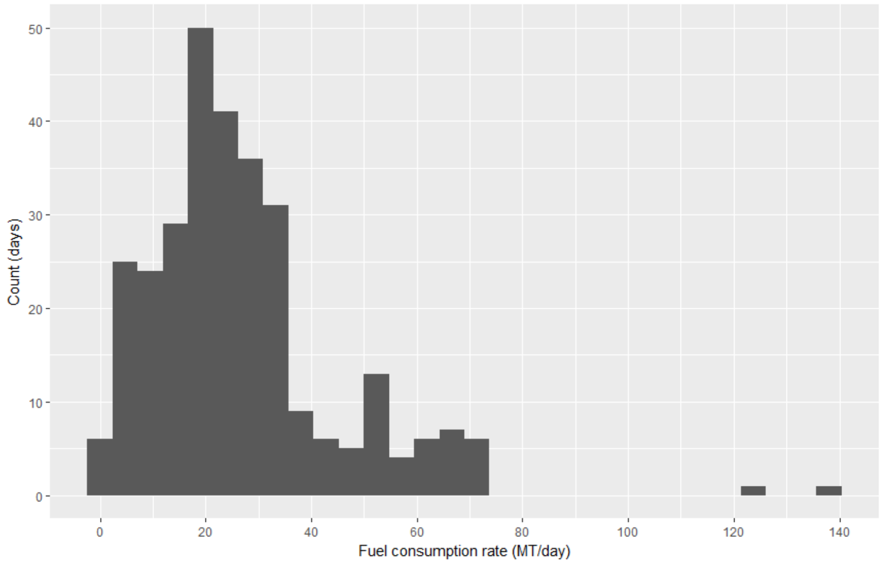

Figure 2 Fuel consumption histogram

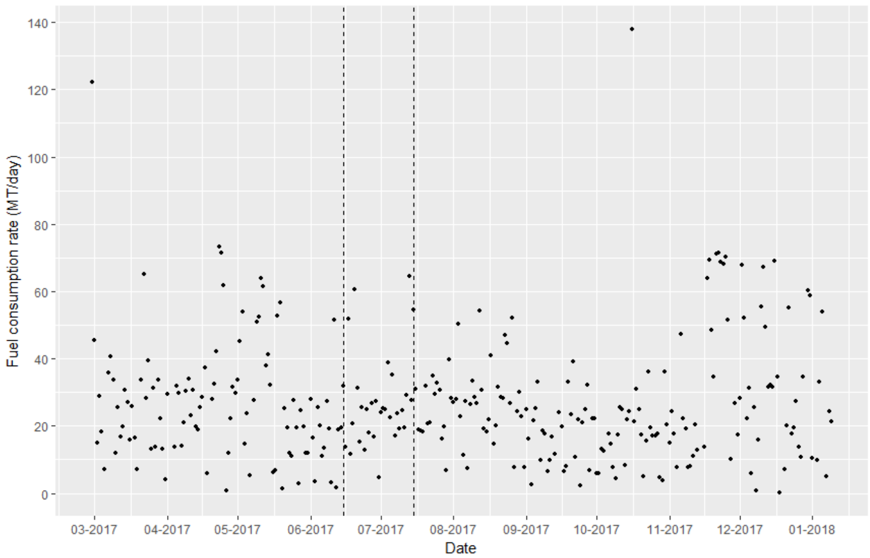

Figure 3 Fuel consumption scatter plot (with cleaning events)

Updated risks

Table 1 displays the identified risks from the project plan that could affect the final project outcome, with new assessments on the likelihood, the current status, and the mitigation measures in place for each risk factor.

Table 1 Updated project risk factors

Risk factor	**Likelihood (project plan assessment)**	**Current status**	**Mitigation measures**
Member absence	*Complete absence is extremely low, short absence is moderate (low, high)*	*One team member was absent for two weeks, however this was known in advance and planned for*	*As in project plan*
Excessive workload	*Moderate – high (Moderate – high)*	*The workload is high yet manageable*	*As in project plan*
Distinguishing hull and propeller fouling	*Certain (High)*	*We have decided not to perform objective 2*	*There are no mitigation measures, as it will not be completed*
Quality of data	*None (Moderate – high)*	*We scheduled plenty of time for preprocessing, hence the quality was not a major issue*	*This task is completed*
Optimisation model not implemented	*Moderate (Low – moderate)*	*Objective 3 has not begun as of yet*	*As in project plan*
Overly simplified model assumptions	*Low - moderate (Moderate)*	*The project manager is in contact with ABB to ensure assumptions are reasonable*	*As in project plan*

References

Meng, Q., Du, Y., and Wang, Y. 2016. "Shipping log data based container ship fuel efficiency modeling." *Transportation research Part B: Methodological* 88: 207-229.

Schultz, M.P., Bendick, J.A., Holm, E.R. and Hertel, W.M. 2011. "Economic impact of biofouling on a naval surface ship." *Bioufouling* 27 (1): 87-98.

Appendices

Appendix 1

Table 2 Project objectives with tasks, status and comments

Objective	Tasks	Current status	Comments
1. Estimate the overall level of fouling	*Data preprocessing*	*Completed*	*Transforming raw data into an understandable format took major effort due to the quality*
	Calculate fuel consumption rate (MT/day)	*Completed*	*Calculated the total propulsion power and then converted it to consumption rate in MT/day. Comparing results to* Meng et al., (2016) *paper*
	Spearman's rank correlation coefficient	*Completed*	*Correlations of 36 variables were calculated, and results compared to* Meng et al., (2016) *paper*
	Estimate the overall level of fouling	*In progress*	
	Develop regression model	*In progress*	
	Validating results	*Not started*	
2. Calculate the individual impacts of hull and propeller fouling	*Same tasks as objective 1*	*Not started*	*Due to lack of appropriate data and excessive workload, this objective will not be achieved*
3. Develop a method to optimise the scheduling of hull and propeller maintenance	*Selecting articles that can be used as a template*	*Completed*	*Schultz et al., (2011) examined costs associated with hull fouling*
	Collection of additional information/data	*In progress*	*Additional information on cleaning and maintenance costs, bunker fuel price, and fuel consumption needed*
	Developed a mathematical optimisation model	*Not started*	
	Assessing the sensitivity of the optimisation model	*Not started*	

Appendix 2

Task	Week start	Duration
Project planning	*1*	*2*
Literature review	*2*	*3*
Project plan report	*3*	*5*
Data preprocessing	*8*	*4*
Model construction	*10*	*6*
Interim report	*12*	*3*
Validation and verification	*16*	*3*
Final report	*15*	*6*

Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	12-Jan	*19-Jan*	*26-Jan*	*2-Feb*	*9-Feb*	*16-Feb*	*23-Feb*	*2-Mar*	*9-Mar*	*16-Mar*	*23-Mar*	*30-Mar*	*6-Apr*	*13-Apr*	*20-Apr*	*27-Apr*	*4-May*	*11-May*	*18-May*

Figure 4 Updated Schedule ABB Team