HARNESSING PUBLICLY AVAILABLE INFORMATION WITH DATA SCIENCE TO EXTRACT THE OPERATIONAL PROFILE OF A VESSEL

R. Bakker, B.T.W. Mestemaker and **J.T.M. Wijnands**, Royal IHC, the Netherlands

SUMMARY

The optimal design of an efficient and cost-effective vessel requires extensive knowledge about its intended operation. However, this information is not always available or accessible for a ship designer/yard. This often results in a vessel which is less well suited for the job than it should be. The vessel is over specified for the required task and as a result more expensive than it could be for the client to buy and operate.

A platform was developed which can extract the entire operational profile of a trailing suction hopper dredger with as little information as possible. The information used consists of publicly available data, such as that of the automatic identification system, weather information and sea charts. The platform uses machine learning algorithms to determine the vessel task, time spent in the task and the vessel uptime. Combining these results with additional knowledge of dredgers and their drive systems allows for an estimation of both the dredger production and the power and fuel consumption.

The paper discusses the methods used in the platform to extract the operational profile from the publicly available data and how this results in a power and fuel consumption estimation. The results of the platform will be validated with information available from two trailing suction hopper dredgers.

1. INTRODUCTION

It is vital for shipbuilders to know how their products perform in the field as this is the basis for among others product innovations and improvements. This information can also be used in sales process by comparing the equipment with competitors and/or it can be used to give advice to a customer for a more suitable solution. However, this information is not readily available for a ship yard as in many cases after the delivery (and the guarantee period) of the vessel, no performance data is shared by the operator with the yard.

This lack of performance data can possibly be covered by estimating it from the Automatic Identification System (AIS) data of the vessel. The AIS data of the vessel contains i.e.: the GPS coordinates, the heading and the velocity of the vessel. The AIS data can be analysed with the operational knowledge of dredging vessels in combination with the latest machine learning algorithms and technologies. In this paper, the results of the machine learning algorithm will be compared to the actual vessel telemetry to validate the approach and its applicability on trailing suction hopper dredgers.

Figure 1: Graphical representation of a dredge cycle

2. METHODS

2.1 DREDGE CYCLE

A trailing suction hopper dredger (TSHD) is a vessel that transports soil from one location to another. It essentially acts as a giant vacuum cleaner for the seafloor. It retrieves soil from the seafloor by means of a drag head connected to a suction tube. This drag head is lowered to the seabed (Figure 1, 2) after which a dredge pump is turned on and its hopper, a cargo hold usually positioned in the centre of the vessel, is filled up by a mixture of water and soil (Figure 1, 3). The TSHD will then sail to another location where it will offload the cargo (Figure 1, 4). The offloading process is usually one of three methods, namely: via the bottom doors located in the cargo hold (Figure 1, 5B), by pumping the mixture through a pipe to the shore (Shore pumping, figure 1, 5A) or by ejecting it through a nozzle at the front of the vessel (Rainbowing, figure 1, 5C).

Most TSHDs have bottom doors as this allows them to sail with a reduced freeboard [1] and thus they can carry more cargo. The bottom doors can be opened by an actuator after which several large holes will open up in the bottom of the hold and the cargo flows out. In general, this is the fastest method of offloading. Offloading by means of the either shore pumping or rainbowing takes more time.

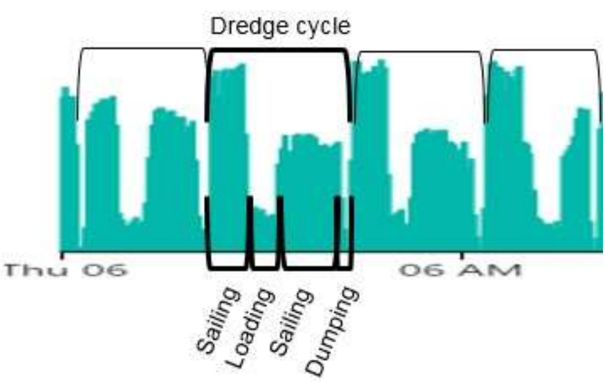

Figure 2: Expected speed over time track of a Trailing Suction Hopper Dredger

Dredging operations are cyclic, they have fixed order of activities which are always in the same order and repeat. The large amounts of soil that need to be transported, require multiple trips from the loading to the offloading location. Depending on the nature of the operation the soil is either desired, when creating new land, or undesired, when maintaining the depth of a port. The dredging cycle consists of four activities, namely: free sailing empty, loading, free sailing full and offloading. These activities can be estimated based on the velocity profile of a trailing suction hopper dredger. In this profile (Figure 2), periods of high ship velocities are expected, and these indicate free sailing of the vessel either empty or full, a period with a low ship speed indicating the loading process and depending on the chosen offloading method (in this case dumping), a short period of low speed. This pattern is repetitive, but depending on the sailing distance, velocity restrictions and chosen discharge method, the shape of the pattern can vary.

2.2 AUTOMATIC IDENTIFICATION SYSTEM (AIS)

The Automatic Identification System (AIS) is a collaborative and self-reporting system that allows the efficient exchange of navigational data between ships and shore stations. It is intended primarily for surveillance and safety of navigation purposes in ship to ship use, ship reporting and vessel traffic services [2]. AIS integrates a standardized VHF transceiver with a position system such as a GPS receiver in combination with other available electronic navigation sensors such as a gyrocompass or rate of turn indicator [3]. A unique identifier number is also broadcast with the information. These signals can be picked up either via a satellite (satellite-AIS) or a shore station (terrestrial-AIS). The data quality is very dependent on the network that is being used to pick up these signals. Terrestrial stations generally have a range of several kilometres, thus in order to get global coverage, an extensive network combining both systems is required.
An important limitation of the AIS is, that not all vessels are required to be equipped with a transceiver. Only ocean-going vessels above 300 gross tonnage and all passenger ships regardless of size are required to have the system. Ships can also turn-off their transponders for a number of reasons.

2.3 VESSEL SPECIFICATIONS

The AIS signal only transmits a unique identifier, an MMSI number. No details on the specifications of these vessels are broadcast. However, to be able to analyse the performance of a vessel this information is required. Therefore, an internal IHC database containing the specifications of all known dredging vessels is combined with the AIS data. These specifications include information, such as: dimensions, dredging equipment installed, hopper size, owner, name, history, etc.

2.4 VESSEL TELEMETRY

The telemetry from a vessel can come in many forms, from direct sensor input to daily, handwritten, production reports or manual input in a system. On the vessel used in the case study, the telemetry is being logged by sensors and made available in a database. In some cases the crew is required to do a manual adjustment to the data. For example, delays in any form should be updated manually. E.g. if a vessel breaks down during operations or when a vessel is forced to reduce speed due to traffic. However, this manual input is often omitted and influences the analysis results.

2.5 FUEL CONSUMPTION

The fuel consumption of a vessel can be estimated based on the estimated operational profile and total power consumption of the vessel. The power consumption of the propulsion system during the different steps of the dredging cycle can be determined based on the vessel sailing speed. While the power consumption of the dredging system can be estimated from the dredging time, the dredging location, the hopper content of the vessel and limitations of the dredging system.

3. RESULTS

An 8,000m^3 TSHD operating in the Port of Mumbai in January 2019 has been used for the validation of the analysis method. The TSHD was working on a port maintenance project in the vicinity of the Bharat Mumbai Container terminal (Figure 3). The aim of the project was to maintain and improve the depth of the berthing location. This enables large vessels, such as container vessels to enter the port and offload their cargo. The discharge location of the dredged material was west of Mumbai and the offloading method was dumping.

The machine learning algorithm applied at this moment requires one manual step to function properly. The complete automation of the analysis process is the next step in the development process of the tool, but due to the nature of the work a significant amount of domain knowledge is required, and it will take more time to teach the algorithm. The loading and unloading locations of the vessel can easily be confused by an algorithm as both the time required and the sailing speed for both operations is in a similar range. The time required for loading generally can be anywhere from 30 minutes to 2 hours depending on the soil loaded. For offloading anything from 15 minutes to multiple hours depending on the offloading method used is possible. The location of the vessel is not useable for an algorithm as in some cases the soil needs to be used near or on shore and in other cases the soil needs to be transported away from a certain location. For these reasons, the applied algorithm needs to be told where, approximately, the loading and offloading locations are.

The vessel speed in both the loading and offloading is low, generally below 4 knots. Therefore, all data points that have a higher speed between them are removed. What remains are the areas in which the vessel sails at a low speed. Figure 4 shows that two main clusters emerge. One near the berths and one out west. In the Searchlight tool used, these are classified as loading (2) and offloading (1). This classification is manually done based on the project characteristics, in this case port maintenance which means that the soil is generally not used and must be removed. There are cases where a low speed cluster is neither loading nor unloading. Perhaps it remained idle or had to reduce speed due to traffic, as seen here. In these cases, the cluster will be classified as an anomaly. This is a deviation from the expected dredging cycle which the algorithm cannot classify at the moment as one of the four dredging cycle steps.

After analysing the project, labelling the correct low speed clusters and running the algorithm, it shows that during the month of January, the vessel has completed 104 trips with an average completion time of roughly 7 hours. This is including time spend idle, classified as an anomaly. These anomalies account for roughly 37% of the entire month, this includes downtime such as bunkering, repairs, crew change etc. In total it has travelled roughly 4,350 miles for an average of 41.8 mile per trip.

Focussing on the first week, from January 3rd until January 9th and after time correction (AIS data is in GMT+1, the telemetry from the vessel in GMT+5:30) shows 37 completed cycles with an average cycle time of roughly 4 hours. During this time period there are many less anomalies in the data compared to the entire time period, resulting in shorter cycle times. The average

Figure 3: Operational activity of an 8,000m^3 TSHD in the port of Mumbai in January 2019

Figure 4: Low speed clusters

analysis is 247.8 minutes compared to 247.9 minutes for the average cycle time according to the vessel telemetry (Table 1). This difference is negligible as it is a difference of 0.1 minutes on an entire cycle or 0.02% of the total cycle time. A cycle by cycle analysis reveals a deviation ranging from a -1.7% to a +2.8 % in the cycle time between the telemetry and statistical analysis (Figure 5).

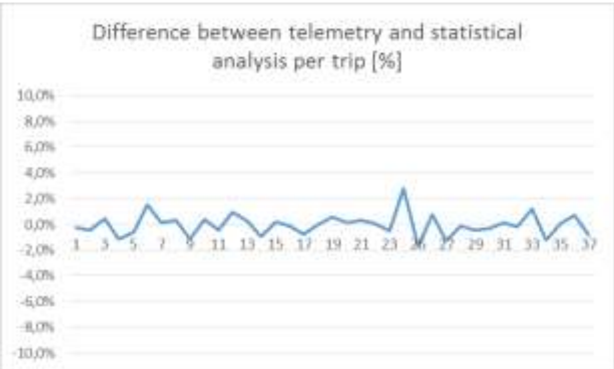

Figure 5: Difference per dredging trip between the statistical analysis and the vessels telemetry.

A more detailed analysis of the trips by analysing the time spend per state results in larger differences. This is mainly since in the telemetry received from the vessel no distinction has been made regarding anomalies and these anomalies can occur during every state. In the statistical analysis this distinction has been made. When observing the trip breakdown this can be seen (Figure 7). Especially on sailing empty the difference is large. This is large part due to trip #3 where the telemetry shows 510 minutes for sailing empty, but the statistical analysis only shows 91.9. It does identify 410 minutes as an anomaly. Reducing the difference on sailing empty to 8 minutes.

Figure 6: Speed of time track of trip #3.

A closer look as the speed over time (Figure 6) and the location figure (Figure 7) of this particular trip reveal that the statistical analysis appears to be correct. The vessel has no speed and remains in one location for a large portion of the cycle, laying idle (purple data points, Figure 7). This should have been manually updated by the vessels crew, however this has not been done skewing the telemetry data.

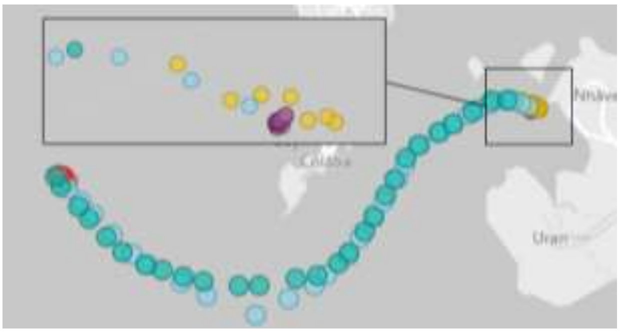

Figure 7: Map plot of trip #3.

However, the anomalies do not cause all of the differences. When 21 different trips are selected in which the statistical analysis does not identify anomalies this becomes more evident. In table 2 it can be observed that the entire cycle time is estimated quite well with a difference of 0.2%. But that in the individual cycle sections, the deviations are significantly larger, namely: sailing times (full; 4.1min / 4.4%, empty: 3min, 3.3%), dumping time (3min / 17.7%) and trailing time (3.6min / 8.2%). However, the AIS signal is transmitted once every 3 minutes and it is expected that this is the cause of some of the deviations observed. There is a bandwith of 6 minutes (3 minutes at the start of a phase and 3 minutes at the end) possible even when the statistical analysis is completely accurate. Percentage wise this could be large number, especially when looking at the dumping time. Dumping is a relatively short process which makes this bandwidth more visible. The absolute difference is much more reasonable.

Table 1: Comparison between the telemetry and statistical analysis over 104 trips completed in January 2019

	Total Cycle Time [min]	**Time Trailing [min]**	**Time Sailing Full [min]**	**Time Sailing Empty [min]**	**Time Dumping [min]**	**Anomaly**
Telemetry	247,9	39,8	93,6	101,2	13,2	-
Statistical analysis	247,8	35,9	89,8	87,7	16,4	18,0

Table 2: Comparison between the telemetry and statistical analysis over 21 trips without anomalies completed in January 2019

	Total Cycle Time [min]	**Time Trailing [min]**	**Time Sailing Full [min]**	**Time Sailing Empty [min]**	**Time Dumping [min]**	**Anomaly**
Telemetry	240,2	40,0	94,8	91,7	13,8	-
Statistical analysis	239,8	43,6	90,7	88,7	16,8	0,0
Time difference	0,4	-3,6	4,0	2,9	-3,0	
Percentual difference	-0,2%	8,2%	-4,4%	-3,3%	17,7%	

4. CONCLUSIONS

The total cycle time the statistical analysis and telemetry are within 2% of each other. Based on the timing interval with which the AIS signal is received this is above expectation. A higher accuracy will be difficult to achieve with the current AIS data frequency and the results can be considered as accurate and representative. The same applies when considering the accuracy of the different parts of the dredging cycle. A deviation of on average 3 minutes is observed and this can also be a result of the AIS data frequency. However, it can also be caused by the operation and when the vessel telemetry logs its dredging cycle state.

The statistical analysis determines the state of the vessel based on location, clustering and speed of the vessel. The telemetry can use a signal from equipment. For example, the starting point of the loading process. The suction tube rests on deck when not in use. Before it is lowered in the water, it has to be put over board and winches have to lower the suction tube. This could be done at a higher vessel speed before arriving at the loading location. This could be the starting point for the telemetry to say this vessel is loading while the statistical analysis uses the vessel speed and does not known when the suction tube is lowered overboard.

The anomalous operation detection is difficult to validate. Based on the analysis performed of trip #3 it appears to function properly. However, because the telemetry did not specify cause of the anomalous behaviour in the free sailing cycle, the cause of this cannot be confirmed. Further research needs to be done in this regard. The algorithm has been validated for one vessel and one type of project, but in order to breed more confidence other vessels with a different operation should be analysed as well.

5. REFERENCES

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6. AUTHORS BIOGRAPHY

Rolf Bakker holds the current position of marketer at Royal IHC. He is responsible for the development of IHC Searchlight, IHC's digital market intelligence platform and the implementation and improvement of marketing within IHC. His previous experience includes market intelligence and product marketing.

Benny Mestemaker is a researcher at IHC MTI, the knowledge development centre of Royal IHC. He has been involved in several project regarding the integration of new prime movers in drive systems of highly transient loaded applications. These projects include the application of among others LNG and hydrogen in engines and fuel cells and hybridisation of drive systems with energy storage systems.

Jasper Wijnands holds the current position of dredging consultant at IHC MTI. As a dredging consultant he is responsible for advice towards clients on dredging related topics and projects. Based on the outcome of Searchlight and interpretation of the results by him, different costumers on the African continent have been provided with knowledge, in order to improve their dredging cycles.