OPTIMIZING THE DESIGN USING MINIMIZING COST DURING THE LIFE CYCLE OF A DREDGE TOOL

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ABSTRACT

It can be said that when the civil construction market demands a tool to perform a specific dredge job, that then the main discussion to define the tool most often concentrates on defining the technical parameters.

It is stated that this approach often results in a design frame work defining a new dredge that is not optimum from an economic point of view.

Optimizing the return of investment has proven to require a more careful evaluation of the dredge's mission through life. Issues such as type of fuel, optimum power and other capacities can be evaluated in an early stage. It is not uncommon that in designs however, a significant number of criteria, including the ones just mentioned are defined based on experience or copied from other vessels already in operation.

Defining "How do we arrive near the maximum Return on Investment?" requires a more over all, in depth approach.

This paper will address a number of parameters addressed in the design of a dredge, applying it here to a Trailing Suction Hopper Dredge for the sake of a practical presentation. Cost per volume dredged (cubic meter/cubic yard) will be the vehicle used to evaluate the economic factors influencing efficiency from an economic point of view.

Keywords: Trailing Suction Hopper Dredge**,** Cutter Suction Dredge**,** dredge design, Mission Statement, Cost per unit dredged, Economy of scale, Economic modeling, Return on Investment

INTRODUCTION

When a new dredge is designed, its main parameters are defined during the very first phase of the design process. Some of these parameters are major factors for defining the dredge's cost and it's Return on Investment during the life of the vessel.

These early choices can result, from an economic point of view, in a less than optimum investment. For a maximum Return on Investment the mission profile of the dredge has to be properly defined and from that mission statement the dredge's design and performance parameters have to be carefully selected. Deriving such a complete balanced frame work of design and performance characteristics is not a simple task. Each parameter has to be tested for its impact on the desired efficiency.

> "The design of a dredge is for the major part defined by technical considerations, and as a consequence thereof the resulting vessel remains, from an economic point of view, often well below the achievable optimum."

The purpose of this paper is to document that this thesis is a valid and true statement. However we will also address what options are available to arrive still at an optimum solution.

The key question should be: "In what way can the maximum Return on Investment on a Trailing Suction Hopper Dredge be achieved?"

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This paper will explore the considerations which play a role in defining the design frame work for a trailing suction hopper dredge. In the considerations that eventually culminate in the design of this dredge the calculations of cost per unit dredged will be the means to optimize, from an economic point of view, the design to one with the highest Return on Investment.

It is well possible to verify in an early stage the impact on cost and production of selected type of fuel, dead weight, optimum power, etc. Some other parameters such as safety factors, material selection, level of redundancy etc. are quite often prescribed based on experience and company tradition. However on cost and efficiency that type of arbitrary selections can have a major influence. There are however today no practical methods available to qualify in a comparative framework quality differences and conclude what the optimum should be.

IHC is developing methods with which in the future it can analyze different executions in a qualitative comparison.

TRENDS OBSERVED DURING THE PAST DECADE

The considerations of a dredge contractor to invest in a new trailing suction hopper dredge are for a major part driven by the demand for capacity. That capacity demand can surface by the need to replace existing dredges or by the increase in the market of the volumes to be dredged. Also, special tasks, such as for instance dredging at large depths, can be a consideration for new investments to allow the contractor to participate in such jobs.

During the past decade the new investments have resulted in a lower cost per unit dredged material. The main cause for that was the addition to the world hopper fleet of very large vessels. This “Enlargement of Scale” resulted among others therein that dredge jobs that return from time to time, earlier done by a number of smaller dredges, are nowadays performed by a smaller number of larger dredges. As the volume to be dredged stabilizes, it is becoming increasingly more difficult to lower the cost per unit dredged even more, by continuing to invest in larger hopper dredges.

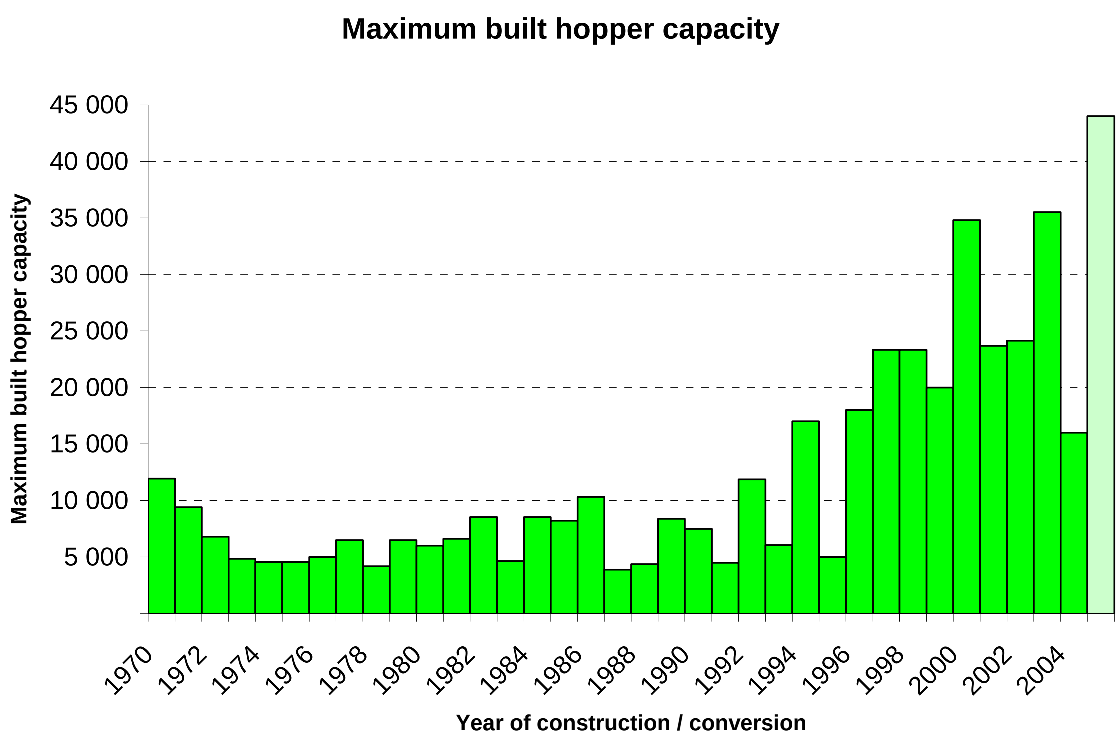

Figure 1. Maximum built hopper capacity

A second trend that resulted in a lowering of cost was an increasing trend to specialize dredges for one specific segment of the dredge market. This trend was obvious with the larger dredges, which design prioritized the winning of sand, as well as with the smaller hoppers, where designs targeted special methods such as the underwater sand nourishment to replenish beaches. That type of specialization entails however, also larger risks, as these vessels are then limited to participate economically in other types of dredge tasks.

A third trend which can lead to lowering the cost per unit dredged is by investing in specific items that will lower the operational cost during its life. Examples are installations that are suitable for heavy oil or invest in automation that reduces the crew or increases production.

COST PER UNIT DREDGED IN RELATION TO THE MAGNITUDE OF THE INVESTMENT

In order to determine in an acceptable fashion the influence of the size of the investment on the cost per unit dredged, a number of factors have to be closely monitored.

It is obvious that the operational cost per unit dredged will decrease if the annual cost increases at a slower pace than the annual production. Because of the "Economy of Scale", it is a given fact that with investing in a larger vessel, the production increases more than the cost. Specifically cost of crew, fuel and maintenance increase less than the production, when the size of the vessel is increased.

In general that rule is also valid for investments in power, automation of the dredge equipment and so also these investments result in a lower cost per unit dredged.

The graph below confirms this statement. This graph depicts of a large number of Trailing Suction Hopper Dredges built, the cost per unit dredged versus the real cost (i.e. excluding profit or loss and for specific countries: their subsidies, etc.).

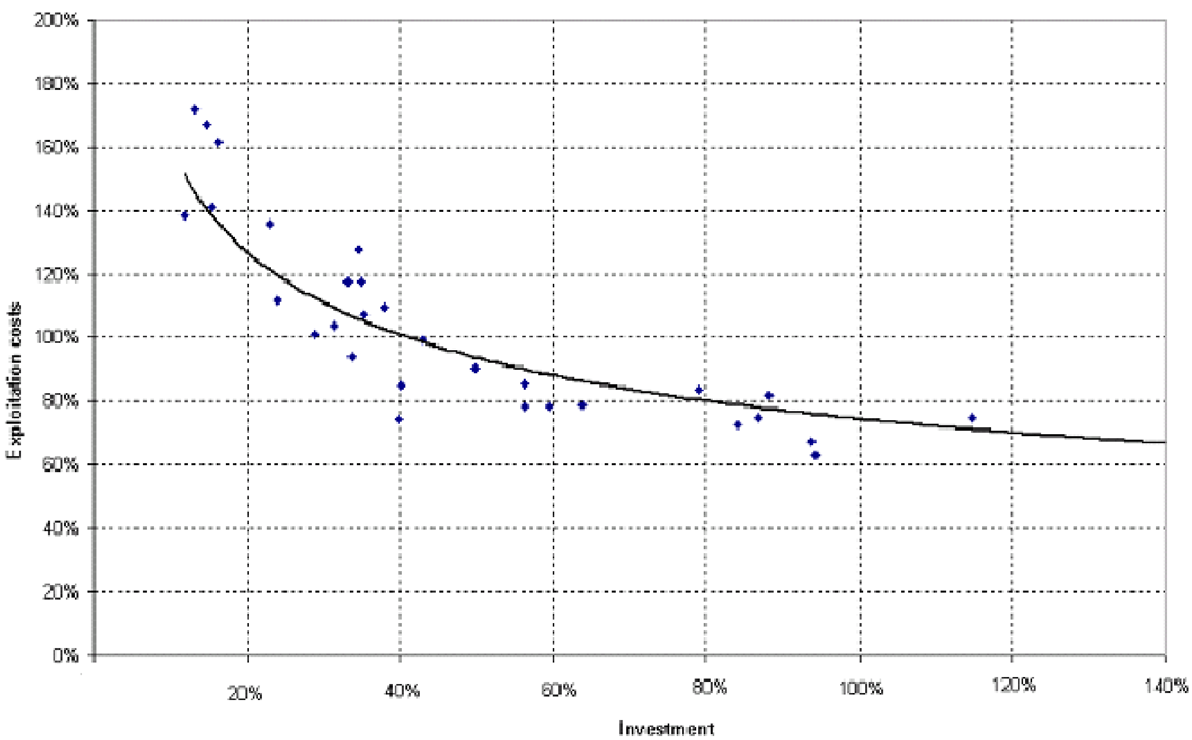

Figure 2. Exploitation costs versus investment

Assuming that an extra investment will always target a lower cost per unit dredged, than optimizing that specific design or its comparison with alternative designs, should always assume the same budget level as the basis to get a clear comparison.

If that principle is not adhered to, there is a large possibility that erroneous conclusions are drawn and wrong choices made. It is possible that that selection results in a lower cost per unit dredged, but that extra budget allotted could have resulted through applying it to another option, to even lower cost. As an illustration: transport capacity can be increased with a higher sailing speed by installing more power. But with that extra budget the target can also be achieved by increasing the transport capacity through lengthening the vessel and increasing dead weight, which comparison should be evaluated.

For certain investments it can sometimes be difficult to prove that they will result in a lower cost per unit dredged during the life of the vessel. To that category belong, for instance, the investments in the durability of the vessel, such as more expensive but more durable paint systems. Because it is difficult to prove that such types of investments result in lower cost per unit dredged; in stead often investments are selected that can be quantified such as a Heavy Fuel Oil installation. For such extra investments remains also valid that for the different alternatives always the same level of investment has to be applied in comparative calculations.

The following paragraphs will address the possibilities to estimate yet the impact on cost per unit dredged of investments that increase the durability of the dredge.

FLEXIBILITY OR SPECIALTY

A, or better the, principal selection when defining the mission profile of a trailing suction hopper dredge, is defining and delineating of the market where the vessel is targeted to deploy itself profitably. The more specific the market segment is delineated (so, is defined with a limited number of specific tasks), the more the definition of a “Special Purpose Dredge” will be applicable. If it is a versatile vessel and it is intended to be applied economically in many market segments, it can receive the label of a “flexible design”.

The success of a trailing suction hopper dredge is defined by the relation between utilization and performance on the one side and the related cost on the other side.

If the dredge can be applied for a variety of tasks, the utilization degree will likely be higher. The possibility to deploy the vessel effectively is determined by its technical features, such as dredging depth, draft, ability for shore discharge or rain-bowing, pre-emptying doors, size and maneuverability, etc. The more complete the vessel, the more flexible the vessel can be deployed. A higher degree of flexibility results however in a heavier ship at a higher cost, caused by outfitting the dredge with more equipment. If the utilization is not higher than the utilization of a less flexible vessel operating in that same market, the cost per unit dredged will of course be higher.

The strategy that is selected is for a major part dependent on the way the contractor conducts his operations, but is most often defined by the market which the contractor plans the dredge to be assigned to and operate in.

The large Dutch and Belgium Contractors require in general that their vessels can be deployed worldwide. That results in a very broad market definition, resulting in a demand for vessels with a high level of flexibility.

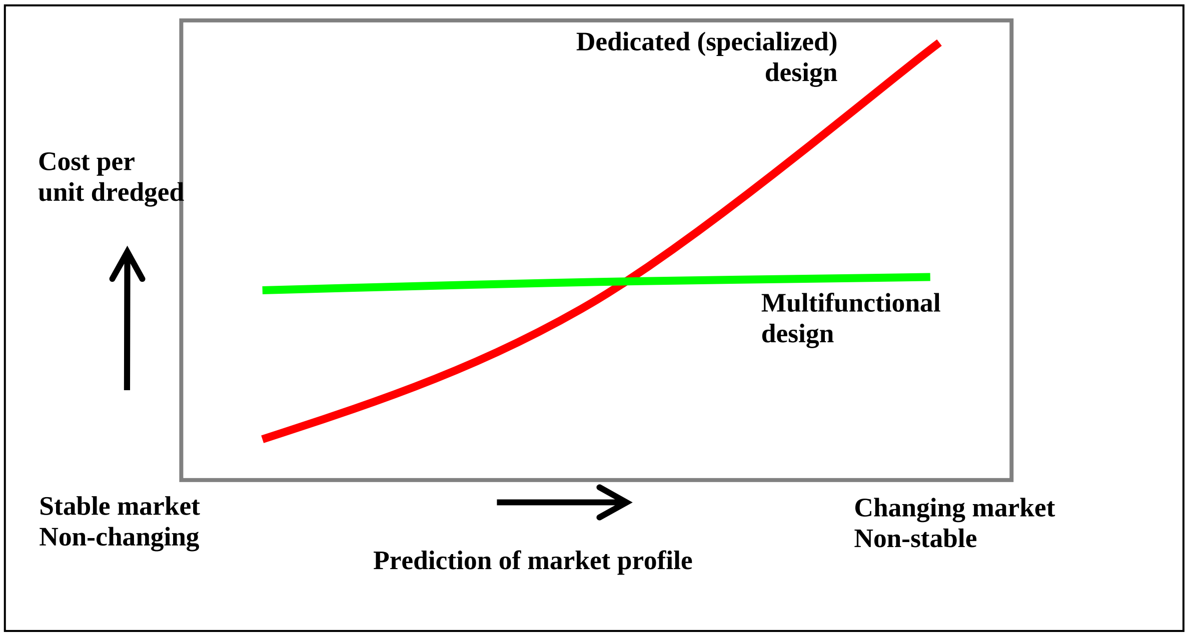

Figure 3. Prediction of market profile of a special purpose and a multi functional design

Dredge contractors limiting themselves to operating in the domestic market or its proximity, can often concentrate on a special target, because in a local market parameters such as soil, type of work and site circumstances, are not subject to large variations.

If the market is exposed to large changes than a special purpose design can quickly become a disadvantage, especially with larger vessels. This can result in reduced utilization or high additional investments needed to adapt the vessel to execute other tasks economically. A possible solution to alleviate such "surprises" is to include in the original special purpose design, provisions for possible later additions. Also for such provisions there is a price tag however.

An example of a specialization is a "shallow draught requirement". If a vessel is designed to operate at a limited draft, then that ship can operate at lower cost compared to others in that specific limited draft requirement, caused, of course, by the fact that a ship designed for limited draft can carry more hopper load than other vessels designed without that limitation or those that with the same capacity require a lower investment. If that shallow draft is a limited time assignment, then the standard design vessel with larger maximum draft will have the advantage.

The graph below compares two dredges with a hopper capacity of about 2000 cubic yard (1500 m³). The investment in both vessels is equal.

The dotted line identifies a dredge with a maximum draft of 13¾ft (4.20 m.). For that draft the dead weight of this ship is 2750 short tons (2475 metric tons). At a draft of about 12ft 2in (3.70 m.) the dead weight is 2140 short tons (1925 metric tons). The solid line reflects a dredge with a maximum draft of 12ft 2in (3.70 m.) and a maximum dead weight at this draft of 2335 short tons (2100 metric tons). The free sailing speed of both vessels is comparable.

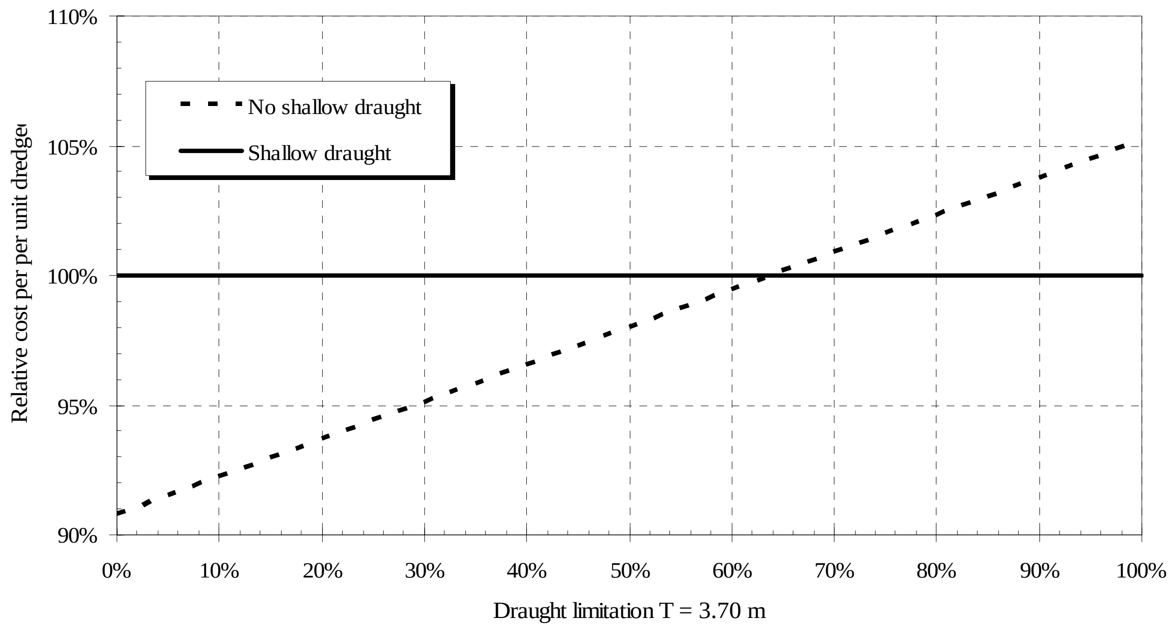

Figure 4. Shallow draught versus no shallow draught – Relative costs per unit dredged

If the work to be executed in the future will always impose a draft limitation of 12ft 2in (3.70 m), the cost per unit dredged by the shallow draft ship will be an ample 5% lower than the vessel with larger draft.

If, in the future no draft limitation will be imposed, then the vessel with larger draft will show in its cost per unit dredged a 10% lower cost.

The transition point is at 60%: if more than 60% of the jobs has the draft limitation of less than $12^1/_8$ft (3.70 m.) then the shallow draft design has the advantage.

OPERATIONAL COST DURING THE LIFE OF THE VESSEL

Ultimately, the contractor will pursue the lowest cost per unit dredged during the full life of the vessel.

Roughly speaking, the total cost can be divided in finance cost, fuel cost, cost for maintenance and repair, crew cost and cost for over head, insurance, etc. For an arbitrary selected dredge, a relative relation between the cost elements is shown in the pie chart below.

In some projects it can make sense to compare designs solely on variable cost, so without the capital cost, overhead or the like. That may apply if a vessel has been written off, when the contractor has to know his absolute bottom cost price.

For optimizing a design the capital cost must be included. An extra calculation without capital cost can provide a comparison with market prices of that moment.

Cost not influenced by the design, such as overhead or cost resulting from different methods of financing, are excluded in optimizing cycles for the design.

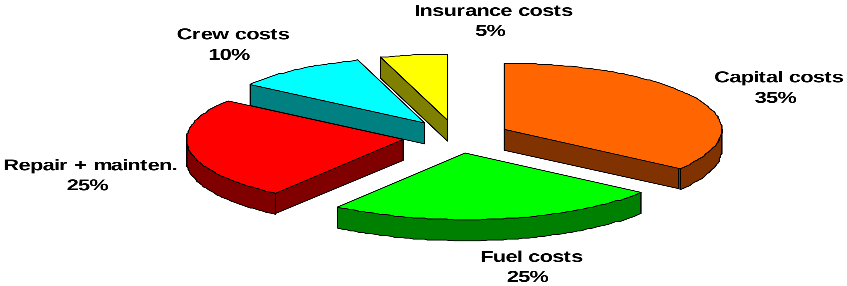

Figure 5. Operational cost of an arbitrary hopper dredge

The capital cost to compare two designs, can be determined quite accurately when the required investment and interest percentages are known. Also, fuel cost can be determined accurately when a well defined operational framework is known, as well as the specific fuel consumption of the engines.

The cost of crew is less dependent of the design. Aspects such as automation and complexity do influence cost, however, this effect has proven to be difficult to qualify. The Contractor's way of operating the ship and the origin and background of the crew have proven more often to cause a larger impact on these costs.

Maintenance and repair cost - and derived from that: reliability (not scheduled down time) - of the different systems are, contrary to other operational cost, much more difficult to qualify. In the analyses of operational cost, often the maintenance and repair cost are defined as a percentage of the investment, corrected for type of material, utilization and type of work. (The Dutch Contractors Association VGBouw provides standards for these costs).

As a matter of principle this standard is considered to be incorrect, because with this way of estimating maintenance and repair, an investment in better quality of execution leads the formula to predict a higher cost of maintenance and repair. With quality or execution, one should think of material selections, safety factors and redundancy. A few examples of such executions are: applying higher allowable stresses, roller bearings in stead of friction bearings and applying wear resistant materials in slurry pipelines.

LEVEL OF EXECUTION, MAINTENANCE AND RELIABILITY

The differences in the level of execution can significantly influence the maintenance cost and the reliability of the dredge. In a design phase it is difficult to estimate what the effect on operational cost will be caused by the level of execution and redundancy. The philosophies of the different contractors differ greatly on these specific issues. Many of the investment decisions in this area are done in an early phase of the design and often based on intuition or personal preference.

The extra cost for extra redundancy and executions fitted with additional facilities, that differ greatly from the "standard execution" can vary greatly. The differences in investments required for vessels with the same capacity but with different levels of execution can be very large.

Figure 6. An example of a down-time cause and an option to invest in reliability

COMPARISON OF SIMPLE DESIGN WITH A MORE COMPLEX DESIGN

In the following example two designs are compared. For both designs accurate data are known. Both designs resulted in about the same cost, but have different levels of execution and different capacities. With exploitation calculations both designs have been compared with each other.

As may be anticipated, the calculation results in a lower operational cost per unit dredged for the simpler design with more standard features and a higher capacity. It may, however, also be anticipated that the cost for maintenance and repair (M&R) will not be the same for both vessels. For the more complex design the cost for M&R has been decreased. The M&R cost have to be reduced to 80-90% for the more complex design to arrive at the same cost per unit dredged.

In the same fashion as the M&R cost, the utilization in weeks per year has been reduced for the simple design, so that both vessels arrived at the same cost per unit dredged.

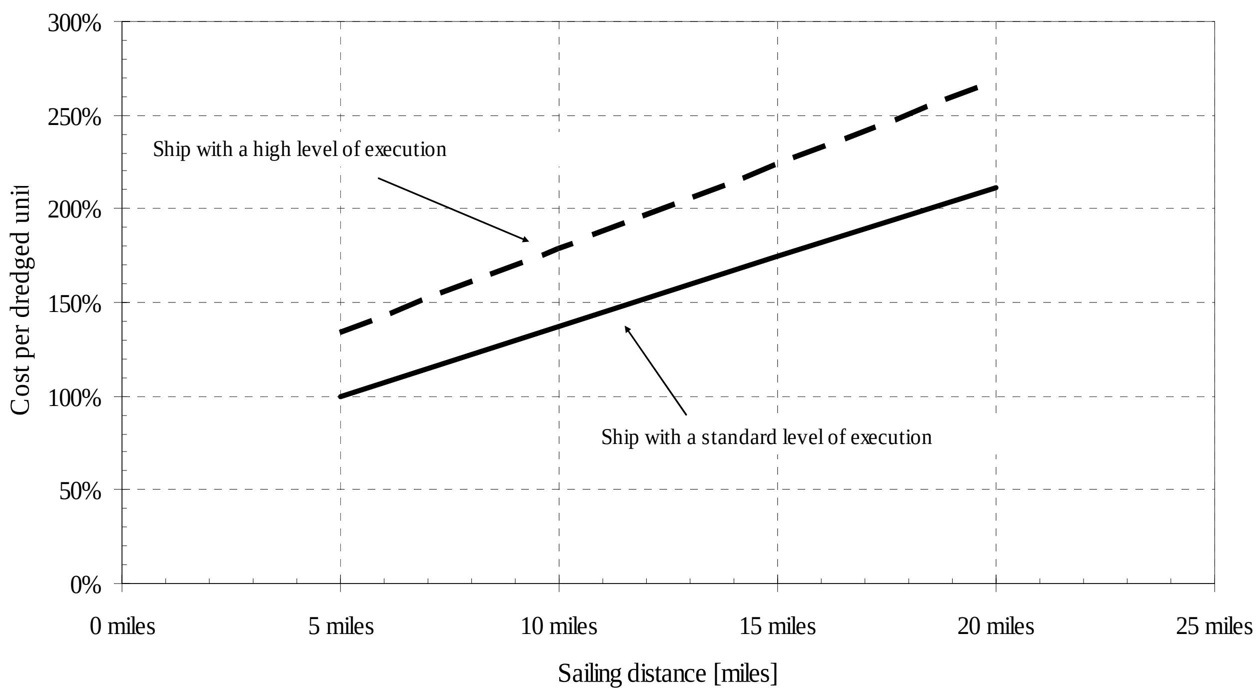

Figure 7. Comparison of a simple and a more complex design

It proved however, that the utilization of the simple design had to be reduced from 40 to 25 weeks, to keep the cost per unit for both designs identical. By halving the forecasted M&R (compared to the Dutch VGB industry standards), the utilization of the complex design had to be reduced from 40 to 33 weeks, again to arrive at the same cost per unit dredged.

From the above comparison one can conclude that the simpler design requires less utilization and can afford substantially higher cost for maintenance and repair, based on the same cost per unit dredged. The differences in cost per unit dredged of both designs require major manipulation and result in large differences in maintenance and repair and utilization to have both designs arrive at the same cost per unit dredged.

The differences are so large that the conclusion may be drawn that the simpler design will deliver lower cost per unit dredged.

PREDICTION MAINTENANCE COST AND RELIABILITY

To achieve a better insight into the cost versus savings of specific levels of execution, IHC has started a modeling system with which the impact can be estimated of cost of Maintenance and Repair- M&R -, based on choices made in the design and a profile of the user.

Lacking feed-back in such a new system, that model has not yet been tested for its suitability and accuracy to predict cost maintenance and repair in hard currency. It is possible, however, to determine trends, using input of suppliers OREDA (Offshore Reliability Data, statistical maintenance data issued by the Offshore Industry) figures and wear pattern modeling by IHC's R&D laboratory MTI Holland.

The method applies running hours, calendar time and volumes dredged.

The first parameter, running hours, allows defining maintenance cost for engines, motors, winches, auxiliaries, etc. The second parameter, maintenance costs which are calendar dependent, are determined by means of a cost price method. These costs are determined based on the cost of components or weights of parts, such as, for instance, the hull. For those items, qualifying factors have been determined based on replacement of parts and an estimated time interval after which parts need to be replaced or repaired.

With the last parameter, volumes slurry pumped, slurry velocities and type of material, an estimate can be made of wear of pump parts and different pipe parts. This method is coupled to MTI Holland's wear model. In addition to comparing alternatives, the wear model allows to estimate the impact of different soils. Also, the impact of different dredge methods, such as slurry velocities, can be easily verified once the ship has been designed.

It is foreseen that this method will be refined and adjusted, also using actual feed-back to make the model more reliable. IHC solicits for that cooperation of the contractors.

With the model as available, it is possible to forecast specific trends. These trends do allow comparison of different alternatives. The way the model is structured allows comparing both levels: total concept as well as detail design features.

Combining the above with other variables such as cost, capacities and performance, has shown to allow during the design phase already today to ability to search and find an economical optimum.

Trends combined with practical experience can provide a basis for a thorough evaluation allowing to make balanced decisions on investments. The latter requires of course a close cooperation and mutual understanding between yard and contractor during the design process.

IHC handles its model yet with care when optimizing the design and comparisons it with alternative designs. The accuracy and reliability have still to be proven. Yet it can be confirmed that it has already proven to provide valuable insights for the contractors involved and has proven to be an important tool for estimating the utilization of the vessels. In order to determine the value of this feature, an analysis has to be made of the likelihood of failure of different components and the results of the failure of such components on the performance of the vessel.

Repair cost increase with a higher level of execution. That higher level of execution manifests itself often in more complex products, which are more difficult to de-mount and mount, due to higher weights and more complex accessibility. This is an apparent symptom for more complex vessels.

CONCLUSIONS

The major determining factor for the design of a dredge is defining the profile of its mission. The sharper that is defined, the better the design can respond to the task set.

A specialized design results in a lower operational cost, however also in a higher risk of lower utilization.

By means of a systematic failure sequence analysis, it is possible to determine which design is considered to be most failure sensitive. After that, one can decide which adjustment can be made to increase the reliability or even add redundancy.

When designing a dredge, most of the information to perform such a reliability analysis is available. Testing the reliability if the model can be done when more knowledge is developed and feed-back received in the level of outfitting and reliability. Once more insight is gained in that field; extra investments can be mathematically evaluated on their economic merits.

An investment in larger redundancy or a higher level of execution, does not necessarily decrease the cost for maintenance and repair, contrary to the dredge being idle. Except for the higher cost for spare parts, a clear correlation between maintenance, repair and reliability and the level of outfitting of a vessel have yet to be proven.

IHC has made its first steps to define a model to estimate maintenance cost during the design phase. This model will need to be developed further and reliability analysis needs to be developed and applied, for which close cooperation with contractors is sought. .

Finally, it may be stated that during the last decade, when large sums were invested in large vessels, the stress on economy followed the “Enlargement of Scale”. The methods to create conceptual and actual contract designs have become more structured, applying more advanced economic modeling and forecasting during the design process. While the models are new and not fully tested, these “Return on Investment” calculations have already had a profound impact on the execution of different designs. It is foreseen this type of approach will govern future designs.

Note: In this paper the Trailing Suction Hopper Dredge was taken as a practical example. For a cutter suction dredge, a similar approach to the design is applicable. Of course in the cutter suction dredge design process this dredge’s own parameters will be addressed. For instance in stead of the special purpose application with shallow draft for a hopper dredge, an evaluation can be made if a cutter suction dredge should be designed for hard rock digging only with more cutter horse power and a smaller diameter discharge pipe or more general purpose execution.