Estimating Capital Cost of Small Scale LNG Carrier

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Abstract: While the LNG industry has traditionally focused primarily on development of ever increasing plant capacities, the maturity of the technology has allowed development of technologies applicable for small volumes to be competitive and potentially economically attractive. The main challenge for small scale LNG applications is therefore not technical but economic. In Indonesia, the demand for small scale LNG transportation is entering a new phase of market trends, especially in East Indonesia. In East Indonesia region, there are a lot of planned location for new natural gas fuelled power plant. The demand for each location is relatively small, mostly around 1 to 10 mmscfd. However, such locations scattered around East Indonesia, creating new challenges for small scale LNG distribution solution. This paper provides an estimating method of capital cost for small scale LNG carrier around 7,500 – 30,000 m^3 cargo capacity. The estimating method verified by comparing two different approach; (i) regression method using market price data of new built LNG Carrier and (ii) estimating each cost for ship steel weight, outfitting weight, machinery weight and self-supporting LNG tank capacity. The result shows that the difference is below 10%.

1 INTRODUCTION

In Indonesia, according to National Gas Balance issued by Ministry of Energy and Mineral Resources, the demand of LNG as primary energy source is projected to be increase up to 8,000 to 9,000 mmscfd (General Directorate of Oil and Gas Resources Ministry of Energy and Mineral, 2016). The problem is, in most places in Indonesia, the demand locations are scattered and requires small scale LNG carrier to distribute the LNG. SSLNG or small scale LNG carriers are defined as vessels with a LNG storage capacity of less than 30,000 m^3 (Hekkenberg, 2014). The emerging market for LNG, especially new build power plants that going to be on-stream at the year of 2019 – 2021 are the main of market shift from conventional or big scale LNG shipment into small scale LNG shipment. The problem is, there are no previous similar supply chain model or cases, which can be taken as a benchmark example for small scale LNG market in Indonesia. On other hand, the stakeholders and especially the government itself and investors still in the problem to estimate and determine the most economic LNG supply chain model for east Indonesia. To accurately estimate the costs of LNG supply chain and logistic is the one of key factor that should be needed in order to estimate and determine the most economic LNG supply chain model for east Indonesia. However, until today there is common method to estimate small scale LNG infrastructure, except by looking at market price, quotation or looking at previously done project which is very rare in Indonesia. There is only one small scale LNG Terminal in Indonesia which is Benoa LNG Terminal, Bali. But, the information about the price and cost of those utilized units are limited as well.

In conventional LNG trading and LNG shipment, typical cargo capacity of 125,000 m^3 up to 145,000 m^3 is referred as standard of one cargo LNG shipment. In 1978, LNG several carriers with 125,000 m^3 cargo capacity start its service to deliver LNG from Indonesia to Japan. One of them, LNG Aquarius, is still in service to deliver LNG from Tangguh LNG to FSRU Nusantara Regas, one of the FSRU in Indonesia. In 1990s, Hyundai Heavy Industries in Korea, today is world's largest shipbuilding company, start to build LNG carrier with capacity up to 138,000 m^3 with 280 m in length, 43 m in width and 26 m in depth

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or height of the LNG ship. Those sizes of LNG carrier are historically used to transport large portion of LNG volumes under long-term and fixed destination contracts.

In recent years, there is new trend of LNG trading which is conducted in smaller scale and shorter contract. Over the past decade, a growing number of cargoes have been sold under shorter contracts or on the spot market. This "non long-term" LNG trade has been made possible by the proliferation of flexible-destination contracts and an emergence of portfolio players and traders. These market changes are the result of mainly two key factors: (i) The growth in LNG demands with destination flexibility, which has facilitated diversions to higher priced markets, (ii) The increase in the number of exporters and importers, which has amplified the complexity of the industry and introduced new permutations and linkages between buyers and sellers.

Such as in Indonesia, emerging and immature markets joining the global LNG market requires creative supply solution. Smaller and multi-destination characteristic of LNG market in Indonesia, creates such a challenging problems which has never been before. Small scale LNG supply therefore is need to be accurately and efficiently developed. There is very litter publicly available data about small scale LNG carrier moreover is information about new building cost.

2 INVESTMENT ANALYSIS

A SSLNG carrier's investment cost is higher per ton LNG compared to large scale LNG vessels. For example, the investment cost (CAPEX) for a 215,000 m^3 LNG carrier is approximately USD 250 million, a 135,000 m^3 LNG carrier is approximately USD 170 million, and a 28,000 m^3 LNG carrier is approximately USD 80 million. This relates to a capital expenditure for SSLNG ships to be typically in the range of 5 – 15 thousand USD/ton, while large conventional shipping is 2 – 5 thousand USD/ton (Hekkenberg, 2014). Another rough cost estimation for a SSLNG carrier about 6,000 m^3 is USD 45-55 million (International Gas Union, 2015), about 12,000 m^3 is USD 50 million and about 30,000 m^3 is USD 105 million (Kanfer Shipping, 2014). Keppel Shipyard which is located in Singapore, acquired new build order of two 7,500 m^3 LNG ships with each cost about USD 37 million (Regan, 2017). Based on current ongoing project run by the author, estimated new build cost of 22,500 m^3 LNG carrier is USD 80 million..

3 MARKET ANALYSIS

In this paper, new build cost estimation of small scale LNG carrier is done by considering various parameter such as weight of steel, volume of cargo tank, capacity of the particular equipment and also principal particular of the ship itself such as length, width and height of the ship. This study will estimate three size types of the ship which are 7,500 m^3; 22,500 m^3; and 30,000 m^3 based on the data availability. As mentioned before, the estimation method requires specific technical information of the LNG carrier.

Therefore, the study is limited according to data availability. The methodology is using empirical equation to estimate the overall ship construction cost. The ship structural weight, outfitting weight, diesel engine weight and remainder weight. After that, the cost of the ship construction is estimated using weight based estimation. The cargo tank cost is estimated using volume based estimation. The cargo pump is estimated using six-tenths rule (Tractebel Engineering S.A, 2015). The cargo piping is estimated using per meter per inch based estimation.

The main propulsion system and power generation system on-board, are estimated using per kW or per kVA based estimation. The bilge and ballast system, which contributing in a lot of piping construction, the cost is estimated using per meter of ship length basis. The cost of mooring gear is estimated as per m^3 basis of LBT of the ship. The total estimation of construction cost is then compared by actual price of similar scale of LNG ship, obtained from market information.

4 WEIGHT ESTIMATION OF LNGC SHIP

4.1 Structural Weight

Lloyd Equipment Number is a dimensionless parameter used to determine the size and number of anchors and chain cables for a new ship. The Lloyd's equipment numeral (E) of 1962 is no longer in use for the determination of ship's anchors and cables, hawsers and warps; it was replaced in 1965 by a new numeral, which is now common to all classification societies having been agreed to be a more rational measure of the wind, wave and current forces which act on a vessel at anchor. The new numeral, however good it is for its primary purpose, is not a suitable parameter against which to plot steel-weights, but the reasons given for the use of the old numeral still stand, the use of Lloyd's equipment numeral of 1962 was advocated

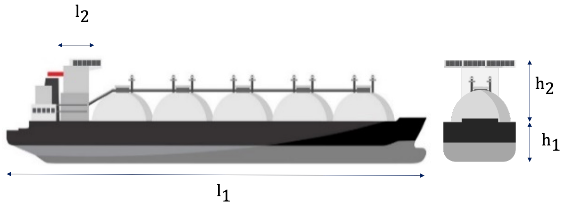

Figure 1: Definition of l_1; h_1; l_2, and h_2 (source: private document).

as a basis for estimating steel-weight in preference to the numerals $L \times B \times D$ or $L(B+D)$ which were in common use at that time.

$$E = L(B+T) + 0.85L(D-T) + 0.85(I_1 h_1) + 0.75(I_2 h_2) \tag{1}$$

where l_1 and h_1 = length and height of full width erection; l_2 and h_2 = length and height of houses. Figure 1 gives a visual illustration of the parameter in the Equation 1. The ship steel weight can be estimated using following formula (Turton et al., 2012).

$$W_{st} = KE^{1.36}[1 + (C_b - 0.70)] \tag{2}$$

4.2 Outfitting Weight

To estimate the outfitting weight for a new merchant ship was by proportioning the outfit weight of a similar ship on the basis of the relative “square numbers”, i.e., LxB, B, and then making corrections for any known differences in the specifications of the “basis” and “new” ships (Turton et al., 2012) . For typical tanker, the value for outfitting weight is estimated by following empirical equation.

$$\frac{W_o}{LB} = 0.23 \tag{3}$$

4.3 Diesel Engine Weight

The base parameter used is the maximum torque rating of the engines as represented by MCR or RPM, it was commented that most of the current engines conformed remarkably closely to a mean line represented by following formula(Turton et al., 2012).

$$W_d = 12\left[\frac{MCR(kW)}{RPM}\right]^{0.84} \tag{4}$$

4.4 Remainder Weight

Remainder things are such installations of engine room required such as piping, floor plates, ladders, gratings, vent trunks, etc. The base parameter used is also engine MCR represented by following formula (Turton et al., 2012).

Figure 2: A Type C tank being installed.

$$W_r = 0.72MC^{0.7} \tag{5}$$

5 COST ESTIMATION OF LNGC SHIP

5.1 Cargo Tank

One distinctive difference between small and large scale LNG carriers is the allowable pressure in the ship. There are two main types of LNG cargo storage tanks: (i) membrane tank and (ii) self-supporting tank. As a general rule, the main selection criterion to choose one or the other is the volume of LNG to be stored. For larger LNG volumes, membrane tank is the optimum solution, due mainly to their great volume efficiency characteristic. Figure 2 shows the process of installing the pre-fabricated IMO type C LNG tank on the hull of LNG ship.

For small volumes the IMO type C insulated tanks are the best option for several reasons : short delivery time, can be built in the workshop (maximum volume of per unit of 1,000 m^3), simpler and less expensive foundation system, allows modular and sequential construction and lower boil-off gas generation from heat ingress.

The small scale ships often have IMO type C tanks (pressure vessels). So far, recent small LNG carriers are all designed with type C tanks. The advantage of type C tanks is that there is limited or no need for boil-off gas management within specified duration. For example, the BOG will be contained within the tank resulting in rise of pressure and temperature until it reaches the designed relieving pressure of the tank. Disadvantages of Type C pressure tanks are reduced volumetric efficiency, limited tank size and increased weight compared with atmospheric tanks. Cost of LNG Storage is roughly 1,600 to 2,000 USD/m^3 for volume 1,000 m^3 to 15,000 m^3 and 1,000 to 1,300 USD/m^3 for volume 15,000 m^3 to 30,000 m^3 (Watson, 1998).

5.2 Cargo Pump and Piping

For cargo pump, the most common simple relationship between the purchased cost and an attribute of the equipment related to units of capacity is given by following relation.

$$\frac{C_a}{C_b} = \left(\frac{A_a}{A_b}\right)^n \tag{6}$$

where A = equipment cost attribute, C = purchased cost and n = cost exponent. The equipment cost attribute is the equipment parameter that is used to correlate capital costs. The equipment cost attribute is most often related to the unit capacity, and the term capacity is commonly used to describe and identify this attributes. Some typical values of cost exponents are given by reference (Tractebel Engineering S.A, 2015). The value of cost exponent, n, used varies depend on the class and type of the equipment. However, if such a value is not known, the value of n for different items of equipment is often around 0.6 provides the relationship referred to as the six-tenths rule (Tractebel Engineering S.A, 2015). Some cost data of LNG cargo system and its technical specification is available as private documentation from previous projects. For cargo piping system and the available data from previous projects, typical insulated cryogenic piping cost is around 1,000 USD/meter/inch.

Table 1: Results of Cost Estimation

LNGC (m^3)	Market Price	Estimated Price	Dev.
7,500	\$ 37,000,000	\$ 36,011,533	2.7%
22,500	\$ 80,000,000	\$ 75,649,529	5.4%
30,000	\$ 105,000,000,	\$ 97,737,663	6.9%

5.3 Others Approximate Cost Data

Hull Cost: The cost estimate of cost of the ship's hull can be estimated in various ways. Commonly accepted values are in the range of 2.5 to 3 EUR/kg. The second main aspect of the cost of the hull, being the cost of the purchased materials, is directly related to the amount of steel that is used to build the hull structure. Multiplying this weight with the steel price per ton will result in an acceptable first estimate of the material cost of the hull.

Propulsion: For the determination of the cost of the propulsion system several rules of thumb exist. According to previous projects done, typical value of main engine is about USD 350 per kW. For propellers, shafting and attached hydraulics (if any) is 55 EUR/kW for a fixed pitch propeller at 100 rpm and 65 EUR/kW for a fixed pitch propeller at 250 rpm. For the gear box, values are not quoted in terms of EUR/kW, but as 15-25 EUR/kg of gearbox weight. When a weight 2 kg/kW is assumed as a standard gearbox weight, this brings cost of the gearbox to roughly 40 EUR/kW.

Electrical System: The cost of electrical system is hard to estimate, especially since it interacts with virtually all other systems and is, therefore, very ship-specific. Generator sets are cost is estimated at 175 EUR/kW, while the cost of the total electrical system (including gensets) is estimated at 500 EUR/kVA.

Bilge and ballast systems: Bilge and ballast systems are related to vessel length and are estimated to cost EUR450 per meter of ship length.

Mooring gear: The cost of mooring gear is estimated at 13 EUR/m^3 of LBT, based on a quotation and the reasoning that L, B and T of the vessel all affect the forces on the anchors.

Outfitting: Outfitting cost, being generally recognized as one of the most difficult and design specific factors to calculate, is determined as a function of outfitting weight to the 2/3 power both by Watson (1998). Based on the reference, the cost of outfitting is estimated at EUR40000*$W^{2/3}$, with W, expressed in ton of outfitting weight, subdivided in The coefficient of 40000 is again provided by reference.

6 RESULTS AND DISCUSSIONS

In this paper, the study estimates three size types of the ship which are 7,500 m^3; 22,500 m^3; and 30,000 m^3 based on the data availability. As mentioned before, the estimation method requires specific technical information of the LNG carrier. Therefore, the study is limited according to data availability.

The results show that the estimated price deviation from the market price is about 2% - 7%. The discussion will talk about some factors in this study, which affect pricing of LNG carrier.

Risk Margin: The purpose of having a risk margin is to ensure the attainment of the specified deadweight even if there has been an underestimate of the lightweight or an overestimate of the load displacement. The size of the margin should reflect both the likelihood of this happening and the severity of the penalties which may be exacted for non-compliance.

When the design is well detailed and clearly specified and the light-weight has been calculated by detailed methods, the margin should in principle be reduced. When the ship type is novel or the design and/or the specification are lacking in precision, larger margins are appropriate.

The profit margins raise the question of how much a customer or shipyard is willing to pay for a certain probability of project success. In most ship construction contracts at least parts of the risks are transferred to the shipyard in order to give the right incentives by means of contract penalties for failure to meet all specifications. Given competitive pressures to bid with a small and therefore cheap ship design, the shipyard needs to balance construction cost against the risk of having to pay penalties. Lowering margins for example would lower construction cost because of the size reduction of the vessel but also increases the yard's exposure to the risk of potentially paying high penalties or even having the customer refuse the ship, which could put the shipyard into financial distress.

For the customer, the question is whether they are willing to accept higher bids from shipyards because of his stringent performance requirements even though missing those requirements by small amounts does not have a very significant impact on general required result.

Emerging small scale market: With the LNG product market expected to remain over supplied, low prices could motivate more small-scale LNG to-power projects. Power producers will get access to a potentially cheaper and cleaner fuel, while LNG suppliers will have new downstream markets to supply.

The development and maturation of LNG technology is seen as the key enabler to give more efficient and cost-effective small scale LNG supply chain processes altogether with other technologies are being developed and market for LNG as transport fuel is rapidly developing.

7 CONCLUSIONS AND RECOMMENDATIONS

In this paper, a method to estimate the building cost of small scale LNG carrier was presented. Furthermore, this method was used to derive easier-to-use rules of thumb for the cost of small scale LNG ship for which only cargo volume, engine power, length, width height and draught of the ship are known. The method has been validated for a three size of ships with particular main dimensions. There is however still significant room for improvement in the underlying data of the model and its validation. It is, therefore, recommended to continue to gather information on the building cost of small scale LNG ships in the future and to use this information for further fine-tuning and validation of the method.

The aim of this paper is to introduce a method of small scale LNG ship capital cost estimation which is still rare and not widely known. Especially in Indonesia which the LNG market is shifting into new pattern of supply chain, the method in this paper should be able to be used as an initial estimation of small scale LNG ship capital cost.

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