Guessing to Prediction – A Conceptual Framework to Predict LNG Bunker Demand Profile in Australia

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Abstract Liquefied Natural Gas (LNG) is considered as one of the most appropriate alternative fuel to replace conventional marine fuels in near future. Major motivations for adopting LNG as a marine fuel are the recent international and regional regulations on ship emissions, increased awareness on improving air quality in strategic sea routes, demarcation of Emission Controlled Areas (ECAs) and the need for preserving marine environment including Particularly Sensitive Sea Areas (PSSAs) such as Great Barrier Reef, Coral Sea and Torres Strait in Australia. In recent years, European Union and few other individual countries such as Norway have been in the forefront in adopting LNG as a marine fuel and have invested heavily on research and development as well as in infrastructure development for LNG bunkering. The U.S. and Asian countries such as Singapore, South Korea and Japan have also followed the suit with similar interests in LNG adoption. Nevertheless, the lack of adequate LNG bunkering infrastructure along major sea routes and the early stages of the current developments found to be the main deterrent among several barriers for the adoption of LNG as a marine fuel.

Australia is well placed to become the leading LNG producer in the world by 2018 [1]. It is expected that Australia, as the world’s leading LNG supplier, could gain enormous economic benefits and preserve its invaluable ecosystems by actively adopting LNG as a marine fuel. Nevertheless, compared to the aforementioned leading countries, Australia has not taken strong initiatives so far to promote LNG as a marine fuel, build up necessary bunkering infrastructure and conduct relevant research and development work. Besides, a comprehensive scientific research to predict the future LNG demand in Australia has not been conducted so far. This leads to guessing rather than accurate prediction in taking important decisions related to the LNG future in Australia. In order to fill this knowledge gap, authors are developing an LNG bunker demand prediction method for Australia. This paper presents the conceptual framework of the prediction method. The projection could be used as a strategic decision support tool for Australian Government/authorities for development of LNG bunkering infrastructure in Australia, especially to identify the most important regions for bunkering.

Keywords: Emission Control Areas, Emission Regulations, LNG Bunkering, Liquefied Natural Gas, Marine Environment and Prediction tool.

1. Ship Emissions and Control Measures

Human civilisation has been intricately bound to its dependency on carbonaceous fuels for many millennia. The carefree and widespread use of such fuels has taken its toll causing far-reaching damages to the interdependent ecosystems we share. For the marine sector, Heavy Fuel Oil (HFO) and Marine Diesel/Marine Gas Oil (MDO/MGO) have been fuels of the choice for many ship operators due to obvious economic reasons. Key emission components from these fuels are Carbon Dioxide (CO₂), Nitrogen Oxides (NOₓ), Sulphur Oxides (SOₓ), Volatile Organic Compounds (VOC), Black Carbon or soot (BC) and/or particulate organic matter POM/PM. It has been reported that even the emissions occur at sea, they affect coastal areas and reach further inland polluting atmosphere, land and water [2; 3; 4; 5]. Out of these emissions NOₓ and SOₓ cause acidification of ecosystems. In additions, excessive Nitrogen input causes eutrophication in freshwater habitats, which threatens biodiversity [6] and contributes to increase of ground level ozone and thereby many respiratory issues. Having assessed the effects of emission factors on human health, the World Health Organisation (WHO) classified diesel exhaust as a human carcinogen [7]. Therefore, not only the economic and environmental factors but also human health related issues force to look for alternative fuels.
1.1 International treaties, regional and national regulations

Intergovernmental agreements such as Kyoto/Paris agreements aim to control Green House Gas (GHG) emissions and address the issues of global warming in the context of climate change phenomena. The international maritime organisation (IMO), through its Marine Pollution prevention treaties (MARPOL) regulates the pollutions and emissions by ships. MARPOL Annex VI (Prevention of Air Pollution from Ships) establishes control measures against SOx and NOx emissions as well as global fuel quality requirements. Following IMO regulations, U.S. and European Union (EU) have incorporated the emission control regulation in their national legislature and declared regional ECAs. To limit the CO2, IMO has introduced Energy Efficiency Design Index (EEDI) and Ships Energy Efficiency Management Plan (SEEMP) through advancements in engine efficiency. However, studies have shown that CO2 reduction achieved by EEDI/SEEMP is on the borderline and is not absolute [8]. In view of Paris Convention 2016 and global consensus against GHG emissions and climate change, mounting pressure is envisaged on IMO from various environmental lobbies demanding more stringent approach in near future to limit CO2 and PM output from ships by 2030 [9]. However, it remains to be seen if the industry sets out long-term solutions to reduce these substances or they would just be fleeting counter measures.

Figure 1 illustrates the progression of emission regulations from the declaration of sulphur controlled areas (SECA) in Europe, NOx restrictions through tiered limiting approach and towards subsequent 0.5% global sulphur caps expected in 2020. It is anticipated that the scheduled review in 2018 would defer this deadline to 2025. Climate change phenomena linked to current unprecedented levels of CO2 in the atmosphere and increasing pressure from public and green Non-Governmental Organisations are potential driving forces for future regulations curbing CO2 and GHG emissions.

Figure 1 Progression of emission regulations [19; 24]

2. Compliance options

It is perceived that initial compliance is likely to be achieved by MGO and Ultra low sulphur HFO until viable and economical alternatives are available and/or fuel switching systems are accessible. One of the existing technologies for emission reduction is scrubbers. Although wet scrubbers eliminate sulphur from the exhaust gasses, they will eventually increase acidity of sensitive sea areas. Dry Scrubbers are considered a better solution for this issue, but the technology is still under development.

It is possible that NOx emission could be limited with Selective Catalytic Reactors (SCR). However, it was found that this technology is less effective at partial loads and absolutely ineffective before the
system reaches operational temperature hence limits the application [10; 11; 12]. Even for the full compliance, this necessitates the use of low sulphur fuel during start-ups. In addition, a network for supply of Urea-catalyst and disposal of residue from SCR and scrubbers are needed at a global scale.

Methanol is an alternative to be considered in fuel switching, which is easily transportable. However, due to its higher GHG potential, additional safety precautions in the fuel system and higher Free On Board (FOB) price thwart its adoption. Nevertheless, there are cleaner options [13] such as: biofuels, hydrogen, wind power and nuclear energy, which could be strong contenders as future ship fuels. In a very conservative and capital intensive industry such as shipping, new technologies are adopted cautiously, often after assessing their merits in other industries. Therefore, new alternatives are unlikely to be adopted in the immediate future due to various technical, economical, and safety challenges. In this context, LNG is considered as the most promising alternative marine fuel capable of meeting present emission regulations along with its availability/abundance and low cost compared to HFO/MGO.

3. LNG and its advantages

LNG produces 100% less SO\textsubscript{X}, about 25-30% less CO\textsubscript{2} and 95-100% less PM while reduction of NO\textsubscript{X} is 40-90% depending on the combustion cycle [14; 15; 16; 17; 18; 19; 8]. According to Ashworth 2016 [9], proven vast resources of gas are estimated to be sufficient for next 200 years’ worth of demand. The net calorific value of LNG is 18-20% higher than HFO/MGO [20] and is cost competitive, [21] with HFO/MGO through 2035. With vast known reserves and higher energy output, LNG commands respect as an economical and viable alternative compared to conventional fuel oils for many years to come.

3.1 Challenges for LNG adoption

Deal 2013[22] claimed that cost of LNG conversions for new-builds is going to be high by additional 15-20% of capital requirement. In addition, experiences from Norwegian LNG ferries and related studies [11; 23; 16] confirm that, the volume required to store LNG can be up to three times higher than HFO/MGO. Reduction in cargo volume and/or passenger carrying capacity and increased capital expenditure are main deterrents of LNG adoption.

IMO 2016 [24] calls for a reliable network of LNG bunker distribution essential for LNG adoption. Many relate this issue to chicken-egg paradox. While ship owners complain the lack of bunkering infrastructure for LNG adoption, bunker suppliers blame the lack of demand for LNG bunkers as a deterrent against investing on infrastructure. Many ship-owners and bunker suppliers are therefore likely to follow wait-and-see approach in LNG adoption.

Lack of unified regulation and standards [18; 25] are identified as an obvious issue for the widespread use of LNG as a ship fuel and therefore, IMO adopted International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code) in June 2015 to address this concern. Reviewing the safety records of gas carriers, it is expected that a similar safety culture could be developed upon careful training and enforcement of safety regimes. However, critics [26] argue that IGF Code applies only to receiving vessel and not the LNG supplier. This regulatory gap is expected to be fulfilled through International Standard Organisations’ (ISO) LNG bunkering guidelines including standardisation of bunkering equipment.

LNG as a bunker fuel is still a novel concept for the world and there are many LNG-specific hazards [14] which may result in casualties and damage to property during delivery and storage. Emphasise are given on safety and security [27; 28] of transporting LNG through populated areas and development of filling stations in strategic areas. That highlights the importance of risk analysis in development of LNG bunkering infrastructure, which requires thorough risk assessments, control measures and mitigation procedures. Any catastrophe involving LNG can create a public outcry against its adoption and
discourage potential initiatives from governments and private sector. Even minor seepages could make LNG a worse alternative [11] considering its GHG potential, which is 25 times that of CO₂ if released accidentally.

4. Future of LNG in Australia

Australia is a signatory to both MARPOL and Paris Convention [29] and the commonwealth has pledged to reduce country-wide emissions of 2005 baseline by 26-28 per cent by 2030. The record warming of atmosphere and recent unprecedented bleaching phenomena of the Great Barrier Reef have prompted public support for stricter environmental regulations at state and federal level. According to EPA NSW 2015 [30], government of New South Wales has urged the commonwealth to address shipping emissions when developing The National Clean Air Agreement, which is due for completion in 2016. In addition to strict limits for SOₓ and NOₓ as in ECAs, CO₂ and PM/BC emissions shall probably be given precedence in these regulations. Enforcement of relative regulations would encourage adoption of cleaner fuels; this is more evident in North European ECA where LNG’s prominence as a marine fuel is on the rise. A similar effect is anticipated assuming Australia would declare emission controlled areas in its waters in near future.

Australia is en-route to become the leading LNG producer in the world by 2018 [1] owing to its various LNG projects nearing completion. Meanwhile in the milieu of widespread regulatory push for stricter emission controls, Australia is in a unique position as a nation which attracts significant international/domestic maritime traffic. These opportunities present the strong possibility of using LNG as a transient fuel for a future energy by breaking away from dependency from fuel-oil. Australia should seize this opportunity and learn from leading countries in LNG adoption and thereby, secure enormous environmental and economic benefits for the society and the generations to come.

4.1 Challenges to be met

Ongoing LNG projects in Australia have run into cost overruns and delays due to their remote locations, high labour costs and interference of powerful trade unions [1]. The repercussions of these eventualities would cause higher LNG prices and reluctance of investors to launch new projects, limiting future supplies as well as damage to Australia’s reputation as a LNG supplier.

Natural gas in Australia was first utilised for domestic power generation. As a result, some state governments declared gas reservation policies to secure supplies for domestic use in view of LNG projects targeting export market. However, as noted by EnergyQuest 2009[31], reservation policies have not prevented domestic price sensitivity in relation to global gas demands. Therefore, domestic consumers demand subsidies and/or nationwide reservation policies to be in place. If Australia is to supply LNG as bunker fuel, it would add another dimension to the current issues surrounding reservation policies. If security of LNG supply as a bunker fuel to be ensured, it would probably warrant intervention of the commonwealth to declare an across board gas distribution policy addressing all stakeholders.

It is now apparent that existing regulatory framework for LNG fuelled shipping in Australia is inadequate [17]. However, adoption of IMO’s gas and low-flash point fuels code (IGF Code) and ISO standards for LNG bunkering could well supplement these gaps. Once the regulations and standards are in place, it is expected that public support can be earned if all stakeholders collaborate [27].

The initial capital requirements for establishing LNG bunkering facilities could be overwhelming for many investors considering the current economic outlook and price dynamics in worldwide energy markets. Therefore, government intervention in the form of subsidies/tax rebate schemes and co-sharing the initial risk by various stakeholders would encourage first movers and expedite early adoption of LNG as a ship fuel.
Given the political landscape in Australia, all these factors would demand concerted efforts of states, the commonwealth, port authorities and individual investors if they are to influence LNG adoption positively.

5. LNG Bunkers in Australian ports; Guessing to Prediction

Investing on new technologies carry great risks and therefore an erroneous decision based on wrong predictions may have irreparable consequences for an organisation [32]. Yet, predictions have to be made to carry out decision making for future direction of institutions, nations and society as a whole. It is expected that an LNG demand prediction tool brings forth consistent and accurate projections based on available data and trends that were consistent within the last 15-20 years. The tool is commanding in terms of its ability to produce projections for each port or cluster of ports as well as demand of fuel by each ship type. By analysing future LNG demand profiles for each region, the most important ports or cluster of ports are identified for initial development and coordination of LNG bunkering solutions. This enable the Australian Maritime Industry to make sound judgements and set out for its future endeavours with regard to formulating business strategies and policy decisions in LNG Bunkering Infrastructure.

5.1 Conceptual framework, Assumptions and Limitations

Figure 2 shows the conceptual framework of the LNG demand prediction methodology for Australian ports through 2050. A time line of 30 years, starting from 2020 to 2050 is chosen to provide a reasonable scope for this study. It is anticipated that LNG projects which are under development at present shall be fully operational by 2020 and they would continue to deliver LNG steadily through 2050.
5.2.1 Baseline of fuel oil bunker demand

In this conceptual framework, the present Fuel Oil (HFO/MDO/MGO) bunker demand in Australia is considered to be business as usual (BAU). This represents the annual aggregate bunker quantities received by domestic ships and deep-sea-going vessels in Australia.

By anticipating stringent air emission regulations in near future, there is a strong possibility that all vessels shall be obliged to consume ECA compliant fuels in Australian territorial waters. In addition, there is a great potential that fuel burnt in Australian waters will be bunkered in Australia provided that fuel pricing is attractive compared to international markets.

These two baselines of demand profiles set a foundation for future prediction paths of BAU bunker demands as well as potential bunker demands.

Analysis of annual ship traffic data determines the time spent by ships in Australian waters and thereby, the fuel consumption in Australian waters is calculated.

5.2.2 Factors affecting FO bunker demands

Trade volumes and/or GDP have strong correlation to shipping traffic trends [33; 34]. Considering the present global economic downturn and grim state of offshore/mining sectors, there is a high probability of a decline in shipping activity in Australia along with its GDP and trade-volumes. However, a thorough analysis of historical data related to fuel consumptions and trade-volume/GDP can be carried out to establish whether similar correlation exists in Australia. Another fact that affects future of fuel consumption is the trend in engine and hull form efficiency improvements. O’Malley et al. 2015 [16] suggested that the operating efficiency of ships is expected to increase at an average of 1% annually. The regulatory push from EEDI and SEEMP as well as competitive research and development efforts by engine makers are expected to improve this trend further. Therefore, efficiency improvement rates shall be factored in bunker demand projections. Thus, annual fuel oil (FO) bunker demands for both BAU and potential case scenarios are projected through 2050 in relation to mentioned two governing factors.

5.2.3 Annual bunker demands for ship type

It was identified [20] that offshore support vessels, tug segments, new-build cruise and new-build container feeder segments are the potential early adopters of LNG in Wider Caribbean, whilst another study [17] found that tug and offshore segments could trigger early LNG adoption in Australia. As experienced in Norway and EU, it is widely expected that initial bunkering of LNG will cater the small vessels followed by larger ferries and cargo ships. Considering diverse operations in Australian waters, the offshore sector and commodity export market, tugs, offshore support vessels, container feeders, bulk carriers, ferries, and tankers should all be included as ship types for future prediction.

Analysis of ship traffic data is a reliable source to identify present distribution of each ship type in Australia. It is assumed that growth rate of each ship type is generally dependent on future trends in trade-volume/GDP growth projections in Australia. In addition, key trends in demand for different shipping services in Australia shall be identified so that ship-type-specific trends could also be factored for projections in growth trend of ship types through 2050. Annual FO Bunker demand is then projected for dual scenarios by combining annual projected FO demands with growth trend for each ship type through 2050.

5.2.4 Factors affecting future LNG adoption

As per report DNV-GL 2014 [19], 100 LNG fuelled new-builds are on order as of end 2015 and would increase to 1000 by 2020. The global drivers affecting adoption of LNG fuelled ships are regulatory push, attractive pricing, public consensus and push for cleaner fuels and possible economic incentive
schemes. Australian-specific elements for LNG adoption are security of gas supply for bunkering, outlook of ongoing and future LNG projects, and future trends in potential regulatory changes at federal level. Whilst these are common factors which affect all ship types, present order books for new-builds reveal that different ship types have different rates of LNG adoption, which is referred to as LNG adoption rate in figure 2. Therefore, in addition to common factors, ship-type-specific factors should be considered and factored in determining future LNG adoption forecasts. The combination of common factors and ship-type-specific sub-factors shall be used to forecast LNG fuelled portion of each ship type through 2050. Consequently, by comparing the projected growth trend (through 2050) of a certain ship type and its projected portion of LNG adoption through 2050, the number of LNG fuelled ships for a particular ship type could be determined.

5.2.5 Predicting LNG bunker demands

The annual bunker demand forecast for ship types in both scenarios are compared against annual predicted number of LNG fuelled vessels to determine the annual LNG demand through 2050. To derive at predicted LNG bunker figures, simply an energy equivalent conversion factor in relation to HFO/MGO is introduced.

5.3 Data Collection and Analysis

Data of past Bunker quantities can be sourced from publications of Australian Petroleum Statistics to project future growth rates for BAU scenarios. As Bunker delivery quantities are categorised for each state, Analysis of ship traffic data is necessary to recognise concentration of ship traffic and various ship types in different ports so that approximate individual bunker delivery could be assigned to each port/port-cluster. Nevertheless, ship traffic data could be obtained from Automatic ship Identification Systems’ (AIS) or AMSA’s vessel traffic data.

GDP and trade-volume growth rate forecasts required for LNG prediction could be retrieved from publicly available reports of Reserve Bank of Australia and World Monetary Fund. Annual growth rate of Ship efficiency is assumed to be 1%; however, relevant literature shall be continuously scrutinised for further developments in engine and ship design enhancements, which effect fuel consumption profiles.

According to Verbeek 2012 [35], prediction techniques and Econometric conceptualising could be categorised as follows, depending on their objectives and utilization of data:

a) Models that appraise interactions between descriptive and dependent variables over periods of time, which normally lack inclusion of causal economic dynamics;
b) Techniques that represent interactions between the historical and contemporary parameters, and estimate forthcoming events based on historical outcomes with addition of causal economic dynamics;
c) Models that describe relationships between several variables at a point in time for diverse entities; and

d) Methods that study interactions between different variables for different entities over a long period of time involving panel data.

Nature of this framework suggests utilising time-series data such as fuel consumptions, GDP growth, cross sectional data such as ship traffic data and multistep projections over time with many variables or factors, which could potentially evolve over the timeframe. This complexity demands a model that could carry out individual projections for various entities separately over a period of time and show how their final projections interact with each other to present final dual scenario predictions. Considering multiple variables involved and the type of data to be utilised, the third prediction model mentioned above is appropriate for developing the projection tool. Review of literature suggests that combining regression methods and stochastic forecasting is adequate to tackle the complexity of the demand prediction methodology. For projecting LNG adoption rates, different weights are allocated in addition to the common factors affecting LNG adoption for all ship types. Ship-specific weightages
would be allotted for each ship type concerning their suitability for early LNG adoption. However, the workable model is to be verified and validated accordingly.

6. Conclusion

There are clear and obvious benefits of adopting LNG as a ship fuel, especially in Australia as stated in section 4. However, there remains a number of challenges which should be overcome by cooperation of various stakeholders in the private and public sectors. The conceptual framework set forth in this paper aims to develop a decision support tool which would assist the decision makers to formulate sound strategies with regard to developing bunkering infrastructure in Australian ports. The demand prediction methodology is based on dual scenario approach; addressing BAU and Potential future bunker demand in Australia. Such methodology widens potential gains as it increases scope of exploring prospective growth paths of LNG bunkering in view of future trends in energy markets and environmental regulations. As various ship types show different growth trends as well as differing LNG adoption rates, both variables are projected separately in order to derive the number of LNG fuelled ships for each ship type and finally, LNG bunker demands through the timeline. Whilst the data collection is deemed simple, the data analysis part, especially that of ship traffic data and FO bunker consumptions, would be a complex task entailing cautious approach to determine distribution of vessel types and their individual bunker intakes. The ultimate product can be customisable so that it could be applied to a specific port or port-cluster based on baseline bunker demand and ship traffic data specific to that region.

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