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EFFICIENCY APPRAISAL OF INDIAN SHIPYARDS USING DATA ENVELOPMENT ANALYSIS

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Abstract

The shipbuilding industry demonstrates dual nature: the global industry; as well as an industry with a great extent of state intervention. Various factors influence shipbuilding, ship repair and demolition activities and therefore, these activities are found to be concentrated in selected geographical regions from time to time. India has also identified an opportunity to develop its shipbuilding, ship repair and demolition industry. Indian shipbuilding industry was dominated by public sector shipyards till last decade, but presently private shipyards have also emerged as significant players in shipbuilding ship repair and demolition activities. Given this background, it necessitates reviewing the efficiency of Indian shipyards so as to identify the efficient and inefficient shipyards and ascertain the sources of inefficiency. In this context, the paper attempts to estimate the efficiency scores for the 19 major shipyards of India using input oriented Data Envelopment Analysis model to identify relatively efficient and inefficient shipyards and determines the sources of inefficiency for selected Indian major shipyards.

Keywords:Indian Shipyards;Effeciency Analysis;Data Envelopment Analysis;Indian Shipbuilding Industry;Sources of Ineffeciency.

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1. Introduction

The shipbuilding industry demonstrates dual nature: the global industry; as well as an industry with a great extent of state intervention. Paradoxically, the industry is highly globalised in terms of sales, but simultaneously it has been highly nationalized in terms of the organization of production with fairly high levels of state intervention. Due to the dynamic nature of maritime sector, the shipbuilding industry is highly influenced by the shipping (freight) markets, second hand sale and purchase market and demolition market. Although there are various other factors influencing the shipbuilding industry, the global shipbuilding activities are found to be highly concentrated in selected geographical regions from time to time. The leadership in global shipbuilding activities have gradually shifted from Europe to Japan and South Korea. Recently China has emerged as a major player in global shipbuilding activities. The shipbuilding output (Gross Tonnage) share of China had been 37.09% followed by Korea 35.30% and Japan 18.97% in the world economy during the year 2015 (UNCTAD, 2015).

In this context, India has also identified an opportunity to develop its shipbuilding industry. The share of India's shipbuilding production in world shipbuilding output is 0.04% and is ranked 22nd amongst all the 44 shipbuilding economies in the world for the year 2015, while the share of India's ship scrapping output in world shipbuilding output is 21.11% and is ranked 2nd amongst all the 23 ship scrapping economies in the world for the year 2015 (UNCTAD, 2015). As India have about 12 major ports and approximately 205 notified non-major ports on its vast coastline of 7517 kilometres, the shipyards along with ports are being developed with an integrated approach to create the maritime clusters. Till last decade, the Indian shipbuilding industry was dominated by public sector shipyards, but recently the Government of India invited private sector participation in shipbuilding activities to make Indian shipyards globally competitive.

In line with the ongoing developments in shipbuilding sector of India, it becomes essential to conduct the appraisal of the performance of Indian shipyards, as the appraisal would provide the feedback regarding the operations at Indian shipyards and help identifying the sources of inefficiency. In this context, the paper applies Data Envelopment Analysis (DEA) for efficiency appraisal of Indian Shipyards. The DEA method provides relative efficiency estimates for Indian Shipyards and also identifies sources of inefficiency at relatively inefficient Indian Shipyards.

The paper is structured in 4 sections. Section 1 deals with Introduction comprising of literature review, global shipbuilding industry and Indian shipyards. The Research Method including efficiency appraisal of Indian shipyards using Data Envelopment Analysis (DEA) model is discussed in Section 2. The empirical analysis and results of efficiency analysis are presented in Section 3. Lastly, the Section 4 summarises the conclusion of efficiency analysis of Indian shipyards.

1.1Literature Review

Among all the maritime activities, shipbuilding activity received least attention till 1980's. In last two decades due to the volatility in shipbuilding market and dramatic changes in shipbuilding activities attracted attention of researchers to analyse its dynamics. Str (1986) investigated the redundancy and solidarity aspects of contraction of the West European shipbuilding industry, while the changing leadership pattern in global shipbuilding industry was examined by Cho and Porter (1986). Todd (1991) analysed the industrial dislocation aspect of shipbuilding activities. The detailed analysis of nature and operations of global shipbuilding industry in maritime sector was provided by Stopford (1997). Klink and Langen (2001) studied effects of the cyclical pattern on the shipbuilding industry for northern Netherlands, while Eich-Born and Hassink (2005) examined aspects of shipbuilding competition between Germany and South Korea. Hassink and Shin (2005) reviewed the development of shipbuilding cluster in South Korea, while Ludwig and Tholen (2006) analysed the impact of development of Chinese shipbuilding industry on European shipbuilding industry.

Moreover, OECD (2006) published research papers and policy documents of shipbuilding in leading shipbuilding nations like Korea, Japan, China, European Union and emerging shipbuilding nations to review and formulate appropriate strategies for developments in shipbuilding market. Since 1998, the Commission of European Communities published seven reports on the situation in world shipbuilding that incorporated aspects like shipbuilding market analysis, trends in prices and detailed cost investigations. Review of Maritime Transport published by UNCTAD covers the yearly developments in global shipbuilding activities like structure and growth of the world fleet by type of vessels, age distribution of the world merchant fleet, shipbuilding tonnage on order, delivery of new buildings, price trends of new buildings and prices of second hand ships etc.

Pires et al. (2009) applied Data Envelopment Analysis (DEA) with Analytic Hierarchy Process (AHP) method in comparing the efficiency of 12 shipyards in Japan, South Korea, China and Europe; while Chudasama (2010) analysed efficiency of major shipyards of India using DEA; whereas, Zhang and Xu (2010) evaluated management efficiency of shipbuilding enterprises based on the DEA and Moon (2011) analysed the effect of hedging on the exchange rate and the volatility of exchange rate on the shipbuilding industry. Commander and Navaneetha (2012) proposed considering Compensated Gross Tonnage (CGT) of ships along with the shipbuilding effort using Work Breakdown Structure (WBS) for efficiency estimation of shipbuilding productivity using DEA; while Jiang et al. (2013) develop a model to identify competitiveness factors and their relative importance and determined that Chinese competitiveness arises from shipbuilding costs, whereas for Japan and South Korea the contract price deviations has been the major driver of shipbuilding.

Lee (2014) discussed the uses of various robots in the shipbuilding process with an emphasis on newer developments and applications and proposed technologies for overcoming structural complexities in closed blocks as well as future directions of robot automation in the shipbuilding industry; while Rabar (2015) applied DEA method to measure relative efficiencies of 5 Croatian shipyards using Window Analysis to determine shipyard efficiency and observe possible changes in shipyard efficiency over time, whereas Parc and Normand (2016) critically reviewed industrial policies to suggest enhancing the competitiveness of the European Shipbuilding Industry. Following the pivotal research on shipbuilding sector worldwide, the present paper appraise the efficiency of Indian shipyards and identifies the efficient shipyards, inefficient shipyards and the sources of inefficiency at shipyards using Data Envelopment Analysis approach.

1.2. Global Shipbuilding Industry

The shipbuilding industry is dynamic in nature as it operates in response to the freight markets, sales and purchase market, and demolition market. The freight market consists of ship owners, charterers and brokers. The decisions about acquiring ships, either from the second hand market or from shipyards are influenced by prevailing freight rates and perceptions about their future behaviour. Sale and purchase market includes the selling / buying of the existing ship to / from other ship owners. The prices are determined by perception about the future freight markets and ability of the buyer to operate the second-hand vessel profitably. The demolition market comprise of ship breakers. As a vessel gets aged and the earning margins decreases from the vessel due to high repair and operating costs, the vessels are demolished. Moreover lower freight rates and regulatory pressures also influence the demolition / scrap market.

The fall in freight rates tends to increase sales of ships in second hand market or in the demolition market and decreases the new building orders, while the rise in freight rates tends to increase purchase of second hand ships, decreases the scrapping and increases the new building orders. Therefore, at given freight rates the new buildings and demolitions moves in opposite direction. During the period of favourable freight market, ship owners prefer to have second hand ships as second hand ships are available without waiting longer and at low initial cost. The rising demand for second hand ships leads to increase in its prices to such an extent that it competes with the new building prices.

Although, the ship owners prefer new ships compared to second hand ships, when the prices of second hand ships are more than the prices of new ships, but the favourable freight rates during that particular period and delays in delivery of new ships, stimulates ship owners to buy second hand ships to earn from the market. This indicates that second hand ship prices significantly influence the new shipbuilding. Moreover, other factors like shipbuilding demand and corresponding capacity, shipyard cost of production and corporate goals, national and international policies, currency fluctuations, broker’s aspirations and etc significantly influence the shipbuilding market.

In total, the world fleet grew by 42 million Gross Tonnage in 2014, resulting from new buildings of almost 64 million Gross Tonnage minus reported demolitions of about 22 million Gross Tonnage. Almost 91.3% of Gross Tonnage delivered in 2014 was built in just 3 countries: China (35.9%); Korea (34.4%); and Japan (21.0%), with China mostly building dry bulk carriers, followed by container ships and tankers; while the Korea building mostly container ships and oil tankers; whereas Japan specializing fundamentally in bulk carriers. Nearly 90.35% of Gross Tonnage demolished in 2014 was scrapped in just 4 countries: India (31.10%); China (21.76%); Bangladesh (19.06%) and Pakistan (18.42%), with India mostly demolishing container ships; while China and Bangladesh mostly demolishing bulk carriers; whereas Pakistan mostly demolishing oil tankers (UNCTAD, 2015).

The world new orders of ships that stood at 88,000,000 Gross Tonnage in 2008 decreased to 82,400,000 Gross Tonnage in 2010 and further declined to 34,400,000 Gross Tonnage in 2012 and increased to 82,582,000 Gross Tonnage in 2014. The share of Japan, Korea and China in world new orders was 16.7%, 39.4% and 33.1% respectively in 2008 changed to 23.4%, 29.8% and 38.8% for Japan, Korea and China in 2014 respectively. However, the new orders of ships at India stood at 955,000 Gross Tonnage in 2008 that declined to 178,000 Gross Tonnage in 2010, which further declined to 145,000 Gross Tonnage in 2012 and 4,000 in 2014 and the share of India in world new orders of ships had been 1.1% in 2008, 0.2% in 2010, 0.4% in 2012 and 0.004% in 2014 (SAJ, 2015).

The world completions of orders of ships that stood at 67,690,000 Gross Tonnage in 2008 increased to 96,433,000 Gross Tonnage in 2010, which declined to 95,575,000 Gross Tonnage in 2012 and further decreased to 64,442,000 Gross Tonnage in 2014. The share of Japan, Korea and China in world completions of orders of ships was 27.6%, 39.0% and 20.06% respectively in 2008 changed to 20.8%, 34.8% and 35.2% for Japan, Korea and China in 2014 respectively. However, the completions of orders of ships at India stood at 84,000 Gross Tonnage in 2008 that increased to 109,000 Gross Tonnage in 2010, which further increased to 216,000 Gross Tonnage in 2012 and declined to 96,000 in 2014 and the share of India in world completions of orders of ships had been 0.12% in 2008, 0.11% in 2010, 0.22% in 2012 and 0.15% in 2014 (SAJ, 2015).

1.3. Indian Shipyards

Shipbuilding industry in India is regulated by the Ministry of Shipping, Road Transport and Highways, Government of India. At the time of independence, there were about a dozen shipyards around Kolkata and Mumbai, which rose to around 45 shipyards in the late seventies. At present, there are 23 shipyards, out of which 8 shipyards are in the public sector and the rest are in the private sector. The Indian Ship-Building Industry can broadly be categorized into following categories: (1) Large ocean-going vessels catering to overseas as well as coastal trade; (2) Medium size specialized vessels like Port Crafts, Fishing, Trawlers, Offshore vessels, Inland and other smaller crafts and; (3) Defence /Naval crafts and Coast Guard Vessels.

Major Shipyards and R&D Facilities in Public Sector:

(1) Cochin Shipyard Limited, Kochi (Under Ministry of Shipping), (2) Hooghly Dock and Port Engineers Limited, Kolkata (Under Ministry of Shipping), (3) Hindustan Shipyard Limited, Visakhapatnam (Under Ministry of Defence), (4) Mazagon Dock Limited, Mumbai (Under Ministry of Defence), (5) Garden Reach Ship-builders and Engineers Limited, Kolkata (Under Ministry of Defence), (6) Goa Shipyard Limited, Goa (Under Ministry of Defence), (7) Alcock Ashdown Co. Limited, Gujarat (Under the State Government), (8) Shalimar Works Limited, Kolkata, West Bengal (Under the State Government).

Major Shipyards and R&D Facilities in Private Sector:

Dempo Shipbuilding & Engineering Pvt. Ltd., ABG Shipyard Ltd., Bharati Shipyard Ltd., Chowgule& Co. Ltd., Ferromar Shipyard Pvt. Ltd., Vedanta Ltd., A.C. Roy & Co. Ltd., Bristol Boats, Tebma Shipyard Ltd., Larsen & Toubro Ltd., N.N. Shipbuilders & Engineers Pvt. Ltd., Reliance Defence& Engineering Ltd. (formerly Pipavav Shipyard), Modest Infrastructure Pvt. Ltd., ChidambaranarShipcare Pvt. Ltd. and Sembmarine Kakinada Ltd.

As far as shipbuilding capacity is concerned, among all the shipyards of India, the public sector yards share 228750 Dead Weight Tonnage (DWT), i.e. 27.5% of the shipbuilding capacity, while the private sector yards share 602550 DWT (72.5%) of the shipbuilding capacity (MoS, 2015). Amongst public sector shipyards; Cochin Shipyard Ltd and Hindustan Shipyard Ltd with the shipbuilding capacity of 1,10,000 DWT and 80,000 DWT respectively, dominate the public sector shipyards. While, amongst the private sector shipyards Pipavav Shipyard with the shipbuilding capacity of 400,000 DWT dominate the private sector shipyards followed by Bharti Shipyard Ltd and Sembmarine Kakinada Ltd. with the shipbuilding capacity of 70,000 DWT and 50,000 DWT respectively.

In the order book for the year 2014-15, out of total 292 ships, 93 are with public sector yards and 199 are with private sector yards amounting to 122,000 DWT and 2,566,790 DWT respectively. In term of vessel types, bulk cargo vessels had largest contribution in the order book position in both public and private sector as compared to other vessel types. During the year 2014-15, among public sector companies, Garden Reach Ship-Builders & Engineers delivered highest tonnage with 85000 DWT consisting of 2 ships followed by Mazagon Dock Ltd at 10700 DWT (2 ships), and Cochin Shipyard Ltd. at 10600 DWT (7 ships). In the private sector, the highest tonnage was delivered by Pipavav Shipyard (76500 DWT with 3 ships) followed by Tebma Shipyard Ltd. (5560 DWT with 4 ships). Out of the total tonnage (204600 DWT) delivered during 2014-15, the public sector accounted for a share of (106910 DWT) 52.3 % and private sector accounted for a share of (97690 DWT) 47.7 % (MoS, 2015).

As far as ship repair capacity is concerned, amongst public sector companies, Cochin Shipyard Ltd had the highest capacity for ship repairing (125,000 DWT) followed by Hindustan Shipyard Ltd. (80,000 DWT) and Goa Shipyard Ltd (10,000 DWT) in 2014-15. In private sector category, Pipavav Shipyard had the highest capacity for ship repairing (400,000 DWT) followed by Sembmarine Kakinada Ltd. (54,000 DWT) and Larsen & Toubro Ltd. (30,000 DWT).

In 2014-15 total 482 ships were repaired by private (286 ships) and public (196 ships) sector shipyards. Amongst the public sector, Cochin Shipyard Ltd. had repaired the highest number of ships (158 ships) followed by Goa Shipyard Ltd. (19 ships). In the private sector, ChidambaranarShipcare Pvt. Ltd. had the highest number of ships repaired (155 ships) followed by Sembmarine Kakinada Ltd. (31 ships) and Larsen & Toubro Ltd. (31 ships) (MoS, 2015).

With this given background, it becomes essential to review the efficiency of Indian shipyards as the review would provide the feedback regarding the operations at Indian shipyards and help identifying the sources of inefficiency. In this context, the paper attempts to estimate the efficiency scores for the major shipyards of India using input oriented DEA model.

2. Research Method

2.1. Efficiency Appraisal of Indian Shipyards

India is emerging as a maritime nation with special emphasis on shipbuilding activities. India's share in world shipbuilding has been less than 1% in 2014 but the share in ship demolition and ship repair is noticeable. With this kind of growth performance in recent years and available opportunities, the Indian shipyards are poised with the challenge of continuous improvement in efficiency to cope with competitive global demand. In this context, the appraisal of efficiency of Indian shipyards using input oriented DEA model is carried out to assess the extent of optimal allocation of input resources to achieve the intended targets.

Basic Data Envelopment Analysis (DEA) Model

DEA is a linear programming based non-parametric method to measure the relative efficiency of the decision making units (DMUs) that use similar multiple input(s) to produce similar multiple output(s). The DEA asserts that the efficiency of any DMU is demonstrated by its ability to convert inputs into outputs. According to this approach, the efficiency is always less than or equal to one due to some energy loss that occurs during the transformation process. In the nonparametric computation of DEA, the prior knowledge of weights for the inputs and outputs is not required. In DEA, a single 'virtual' output and single 'virtual' input is obtained without estimating the production function. The ratio of sum of weighted outputs to the sum of weighted inputs is used to measure the efficiency. The simple presentation of general DEA with the assumptions of constant returns to scale and an objective of minimising inputs (use) for a given/targeted level of output (an input-orientated version of DEA), proceeds by solving a sequence of linear programming problems as follows:

Minimise E_n with respect to $w_1, ..., w_N, E_n$

Subject $\sum N \quad w_j y_i - y_{in} \geq 0 \qquad i = 1,\ldots,I$

to : $_{j}$

$j = 1$

$$\sum_{j=1}^{N} w_j x_{kj} - En\, x_{kn} \leq 0 \qquad k = 1,\ldots,K$$

$$w_j \geq 0 \qquad j = 1,\ldots,N$$

The efficiency score ‘ En ’is being minimised because it represents the smallest proportion of existing inputs that organisation ‘ n ’ can use and still produce its existing output if it was using the best practice observed in the sample. In the above model, ‘ N ’ denotes the number of organisations in the sample. ‘ I ’ denotes the level of different outputs and the combination ‘ y in ’ denotes the observed amount of output ‘ i ’ for organisation ‘ n ’. Similarly, ‘ K ’ denotes the level of different inputs and the combination ‘ x kn ’ denotes the observed amount of input ‘ k ’ for organisation ‘ n ’.

The ‘ w j ’ are weights applied across the ‘ N ’ organisations. When the ‘ nth ’ linear program is solved, these weights allow the most efficient method of producing outputs for ‘ n ’ organization to be determined. The efficiency score for the ‘ nth ’ organisation, ‘ En* ’, is the smallest number ‘ En ’ which satisfies the three sets of constraints listed above. For a full set of efficiency scores, this problem has to be solved ‘ N ’ times (once for each organization in the sample).

The above formula indicates that the efficiency score for the ‘ nth ’ organization should be minimised subject to a number of constraints. The factors that can be varied to do this are the weights ‘ w j ’and the score ‘ En ’ itself. The constraints are that the weighted average of the other organisations must produce at least as much of each output, as does organisation ‘ n ’ (the first set of constraints), while not using any more of any input than does organisation ‘ n ’ (the second set of constraints). The third set of constraints simply limits the weights to be either zero or positive.

If the DMU obtains an efficiency score of less than one, the DMU is termed as relatively inefficient with respect to the other DMUs in analysis and no other combination of weights can possibly make it efficient. If the DMU obtains a score of one, it is termed as relatively efficient (the scope of improvement may exist), but the combination of weights makes it efficient. Similarly for each DMU, the linear program should be solved. This means that each DMU is allowed freedom in assigning the set of weights to its factor inputs, which will render the DMU as efficient as possible subject to the constraints. Solving the linear program using DEA helps identifying the relatively efficient and inefficient DMUs on the basis of derived efficiency scores.

The Input and Output Variables

As the shipyard operation is influenced by the efficient use of available resources, the main objective of shipyard is assumed to be the optimum allocation of resource (in other words: to minimise the input use for a given/targeted level of output). The Income Earned by Shipyard (in Lakh Rs.) has been considered as an output variable. The Shipyard Capacity (in Thousands Dead Weight Tonnes), the Ship Size Area Available (in Square Meters) and the Number of Total Employees has been considered as input variables as these variables contributes to operational activities of shipyards. The input and output variables are selected after a discussion with experts in the concerned field.

The data pertaining to input and output variables of 19 Shipyards of India for the year 2015 are sourced from the Ministry of Shipping (MoS), Government of India. As per the requirement of DEA Model, the numbers of DMUs (shipyards) has to be more than (at least twice) the sum of inputs and outputs and therefore, three input variables and one output variable has been included in the analysis. Table 1 represents the output and input variables incorporated in the analysis.

Table 1: Output and Input Variables for Selected Shipyards of India (2015)

Shipyards	Output	Inputs

		Y1	X1	X2	X3
1	Alcock Ashdown (Gujarat) Ltd. (AAGL)	401.39	15	2600	109
2	Cochin Shipyard Ltd. (CSL)	195296.63	125	12150	2544
3	Garden Reach Ship-Builders & Engineers Ltd. (GRSEL)	167823.00	9	2040	2834
4	Goa Shipyard Ltd. (GSL)	68077.00	10	2750	1545
5	Hindustan Shipyard Ltd. (HSL)	32301.05	80	7410	2270
6	Hooghly Dock & Port Engineers Ltd. (HDPEL)	5226.75	12	1440	408
7	Shalimar Works Ltd. (SWL)	1322.81	1.2	780	179
8	Dempo Shipbuilding & Engineering Ltd. (DSEL)	3273.55	5.5	2000	240
9	ABG Shipyard Ltd. (ABGSL)	40167.00	20	3300	1020
10	Bharati Shipyard Ltd. (BSL)	4372.78	70	11250	1124
11	Chowgule& Co. Ltd. (CCL)	6683.02	8	1980	94
12	Ferromar Shipping Pvt. Ltd. (FSPL)	675.13	2	910	2
13	A. C. Roy & Co. Ltd. (ACRCL)	2638.00	2	960	58
14	Bristol Boats (BB)	112.17	0.05	100	12
15	Tebma Shipyard Ltd. (TSL)	15851.23	12	2750	725
16	Larsen & Toubro Ltd. (LTL)	59275.87	30	6000	4126

17	Reliance Defence& Engineering Ltd. (RDEL)	86207.91	400	22050	4930
18	Modest Infrastructure Pvt. Ltd. (MIPL)	5301.48	6	1782	352
19	Sembmarine Kakinada Ltd. (SKL)	6561.33	54	8000	95

Source: - Compiled from (1) Ministry of Shipping, GoI, (2015)

Note:- Y1: Income Earned (Lakh Rs.), X1: Shipyard Capacity ('000 DWT), X2: Ship Size Area Available (Sq. Mtrs.), X3: Total Employees (Nos.).

Mazagon Dock Ltd., Vedanta Ltd. (formerly Sesa Goa Ltd), N. N. Shipbuilders & Engineers Pvt Ltd., ChidambaranarShipcare Pvt. Ltd. have not been included in analysis due to unavailability of required data.

3. Analysis and Result

3.1. The Empirical Analysis

The DEA formula for the Alcock Ashdown (Gujarat) Ltd. in one output, three inputs model with the sample of 19 shipyards example (listed in Table 1) would be:

Minimise E_1 with respect to $w_1, w_2, \dots, w_{18}, w_{19}$ and E_1

Subject to:

$$401.39w_1 + 195296.63w_2 + \dots + 5301.48w_{18} + 6561.33w_{19} - 401.39 \geq 0$$

$$15w_1 + 125w_2 + \dots + 6w_{18} + 54w_{19} - 15E_1 \leq 0$$

$$2600w_1 + 12150w_2 + \dots + 1782w_{18} + 8000w_{19} - 2600E_1 \leq 0$$

$$109w_1 + 2544w_2 + \dots + 352w_{18} + 95w_{19} - 109E_1 \leq 0$$

$w_1 \geq 0 \quad , \quad w_2 \geq 0 \quad , \ldots, \quad W_{18} \geq 0 \quad , \quad w_{19} \geq 0$

The first constraint requires that the weighted average of the output (Income Earned, measured in Lakh Rs.) minus output of Alcock Ashdown (Gujarat) Ltd. (i.e. 401.39 Lakh Rs.), be greater than or equal to zero. This means that the hypothetical shipyard frontier for Alcock Ashdown (Gujarat) Ltd. has to achieve output of at least (401.39 Lakh Rs.). The second, third and fourth constraints require the hypothetical shipyard to not use any more than inputs of Alcock Ashdown (Gujarat) Ltd. (i.e. Shipyard Capacity of 15,000 DWT, 2600 Sq. Metres of Ship Size Area Available and 109 Employees respectively). Similarly, each linear program is constructed for each of the 19 shipyards under analysis and solved to obtain the relative efficiencies of shipyards.

For this purpose Efficiency Measurement System (EMS) Software, Version 1.3 (HolgerScheel, 2000) is employed to derive the efficiency estimates of 19 selected shipyards of India. DEA-CCR Model (for Constant Returns to Scales) provides information on relative technical efficiency of shipyards under analysis. On the basis of derived efficiency estimates using DEA-CCR model, the relatively efficient and relatively inefficient shipyards can be identified. Moreover, the sources of inefficiency can be acknowledged and appropriate utilisation of resources (inputs) can be recommended.

3.2. The Efficiency Results

The efficiency scores estimated with DEA reveals the extent of optimal allocation of available inputs. It is found that during the year 2015, out of the 19 shipyards of India, CSL, GRSEL and FSPL turned to be relatively efficient with the efficiency score 100% (although the scope of improvement may still exist), while all other shipyards turned out to be relatively inefficient with the efficiency scores less than 100%. The estimated efficiency scores also reveal the extent to which all inputs would need to be reduced in equal proportions to reach the optimal output level. In case of some shipyards, after all inputs have been reduced in equal proportions, one or more inputs could be still reduced further without reducing the output to become optimal. (These are referred as ‘Input Slacks’ in DEA). The peer group in DEA for each shipyard refers to the group of best practice shipyards with which, a relatively less efficient shipyard is compared and less efficient shipyard may use the peer group as a guide for improving its performance. The peer weights indicate the weighted average contribution of peer shipyard in making particular shipyard better as compared to other shipyards. Number of times a shipyard appears in a peer group of other shipyards (excluding itself) is indicated by peer count. On the basis of input slacks, peer group and peer weights, the sources of inefficiency of shipyards can be analysed. The efficiency scores and sources of inefficiency of shipyards are presented in Table 2.

Table 2: Efficiency and Sources of Inefficiency of Shipyards*

	Shipyard	**Efficiency Scores**	**Status of Shipyard**	**X1 Slack**	**X2 Slack**	**X3 Slack**	**Peer Group**	**Peer Weight**	**Peer Count**
1	AAGL	4.19%	Relatively Inefficient	0.22	0	0	CSL	(0.002)	0
							FSPL	(0.097)	
2	CSL	100.00%	Relatively Efficient	0	0	0	LTL		16
3	GRSEL	100.00%	Relatively Efficient	0	0	0	FSPL		12
4	GSL	72.86%	Relatively Inefficient	0	865.81	0	CSL	(0.032)	1
							GRSEL	(0.369)	
5	HSL	20.26%	Relatively Inefficient	1.49	0	0	CSL	(0.113)	0
							GRSEL	(0.060)	
6	HDPEL	18.50%	Relatively Inefficient	0	37.3	0	CSL	(0.017)	0
							GRSEL	(0.011)	
7	SWL	12.20%	Relatively Inefficient	0	72.65	0	CSL	(0.001)	0
							GRSEL	(0.007)	
8	DSEL	20.43%	Relatively Inefficient	0	287.91	0	CSL	(0.008)	0
							GRSEL	(0.010)	
9	ABGSL	60.13%	Relatively Inefficient	0	653.33	0	CSL	(0.086)	0
							GRSEL	(0.139)	
10	BSL	4.88%	Relatively Inefficient	0.11	0	0	CSL	(0.021)	0
							FSPL	(0.318)	

11	CCL	82.48%	Relatively Inefficient	0.12	0	0	CSL	(0.029)	0
							FSPL	(1.402)	
12	FSPL	100.00%	Relatively Efficient	0	0	0	GSL		5
13	ACRCL	63.91%	Relatively Inefficient	0	484.4	0	CSL	(0.010)	0
							GRSEL	(0.004)	
14	BB	15.68%	Relatively Inefficient	0	14.17	0	CSL	(0.000)	0
							GRSEL	(0.001)	
15	TSL	33.99%	Relatively Inefficient	0	466.43	0	CSL	(0.028)	0
							GRSEL	(0.062)	
16	LTL	23.64%	Relatively Inefficient	0	363.7	0	CSL	(0.034)	1
							GRSEL	(0.313)	
17	RDEL	23.17%	Relatively Inefficient	40.49	0	0	CSL	(0.416)	0
							GRSEL	(0.030)	
18	MIPL	23.35%	Relatively Inefficient	0	256.27	0	CSL	(0.010)	0
							GRSEL	(0.020)	
19	SKL	56.25%	Relatively Inefficient	18.79	0	0	CSL	(0.017)	0
							FSPL	(4.714)	

Note: * Derived using Efficiency Measurement System (EMS) Software, Version 1.3.

AAGL obtained an efficiency score of 4.19%. This indicates that AAGL can reduce (use of) its inputs (X1, X2 and X3) by 95.81% and still produce its output (Y1) to operate at observed best practice. This means that AAGL can reduce (use of) its X1=15 by 14.37 (95.81% of 15) to a new total of 0.63 (15−14.37); its X2=2600 by 2491.06 (95.81% of 2600) to a new total of 108.94 (2600−2491.06) and its X3=109 by 104.43 (95.81% of 109) to a new total of 4.56 (2600−2491.06) theoretically. The peer group and peer weights columns indicate that the best practice for AAGL is given by a weighted average of about 2.02% of CSL [(0.002*100)/(0.002+0.097)] and about 97.98% of FSPL [(0.097*100)/(0.002+0.097)]. However, as evident from the input slack columns, as well as reducing (use of) all its inputs (X1, X2 and X3) by 95.81%, AAGL has the additional inputs (i.e. about 0.22 of X1 input). That means to remove all the apparent waste and inefficiency relative to CSL and FSPL, AAGL has to reduce (use of) its X1=0.63 (i.e. 15−14.37) to a new total of about 0.41 (i.e. 0.63−0.22). Similarly the efficiency scores and sources of inefficiency can be interpreted for all other inefficient shipyards.

4. Conclusion

Given the background and analysis of selected 19 Indian shipyards to review its efficiency, the efficiency scores estimated with DEA reveals that during the year 2015, out of the 19 selected shipyards of India, Alcock Ashdown (Gujarat) Ltd., Goa Shipyard Ltd., Hindustan Shipyard Ltd., Hooghly Dock & Port Engineers Ltd., Shalimar Works Ltd., Dempo Shipbuilding & Engineering Ltd., ABG Shipyard Ltd., Bharati Shipyard Ltd., Chowgule& Co. Ltd., A. C. Roy & Co. Ltd., Bristol Boats, Tebma Shipyard Ltd., Larsen & Toubro Ltd., Reliance Defence& Engineering Ltd., Modest Infrastructure Pvt. Ltd. and Sembmarine Kakinada Ltd. turned to be relatively inefficient shipyards as compared to Cochin Shipyard Ltd., Garden Reach Ship-Builders & Engineers Ltd. andFerromar Shipping Pvt. Ltd.

Alcock Ashdown (Gujarat) Ltd., Hindustan Shipyard Ltd., Bharati Shipyard Ltd., Chowgule& Co. Ltd., Reliance Defence& Engineering Ltd., and Sembmarine Kakinada Ltd. turned out to be relatively inefficient due to underutilisation of shipyard capacity measured in ‘000 DWT (i.e. these shipyards can generate more output with its existing capacity or these shipyards can generate existing level of output even with less than existing capacity). Whereas, Goa Shipyard Ltd., Hooghly Dock & Port Engineers Ltd., Shalimar Works Ltd., Dempo Shipbuilding & Engineering Ltd., ABG Shipyard Ltd., A. C. Roy & Co. Ltd., Bristol Boats, Tebma Shipyard Ltd., Larsen & Toubro Ltd. and Modest Infrastructure Pvt. Ltd. turned out to be relatively inefficient due to underutilisation of ship size area availability (accommodation facility) measured in Sq. Mtrs. (i.e. these shipyards can generate more output with its existing ship size area availability (accommodation facility) or these shipyards can generate existing level of output with less than existing ship size area availability (accommodation facility). However, it was noticed that none of the inefficient shipyards underutilised the human resources (employees). Furthermore, the scope of improvement in efficiency and possibility of increase in output exists at all the selected shipyards and especially at relatively inefficient shipyards of India.

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