Toward improving the cost competitive position for shipbuilding yards– part I: impact of technology changes

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Increasing shipyard productivity is an important factor which improves its Cost Competitive Position (*CCP*). There are many factors affecting shipyard's productivity such as shipyard management competence, level of applied technology, and worker's efficiency. For low-productive and low manhour-cost shipyards it may be conceived that technological change is the best way to increase productivity and hence *CCP*. This is due to the simplicity of observing the low level of technology applied in such shipyards. This paper presents the impact of technology development on the *CCP* of shipyards. The effect of technology change on the shipyard productivity is studied at first so as to evaluate the change in productivity due to any technology changes. Afterwards, economics of technological change is investigated. In addition, factors affecting the increase in manhour-cost of the shipyard, due to technological changes, such as initial cost, life time, salvage value, number of workers, and interest rate are investigated. Finally, the impact of technology change on *CCP* improvement is studied.

رفع إنتاجية ترسانات بناء السفن من العوامل التي تؤدى إلى تحسين وضع التكلفة التنافسية لها. بالرغم من أن هناك عوامل كثيرة تؤثر في إنتاجية الترسانات مثل كفاءة الإدارة ومستوى تكنولوجيا الإنتاج المستخدمة في الترسانة وكفاءة العامل إلا أنه بالنسبة للترسانات منخفضة الإنتاجية وتكلفة ساعة العمل قد يرى البعض أن رفع مستوى تكنولوجيا الإنتاج المستخدمة هو الحل الأمثل لزيادة الإنتاجية وذلك لسهولة ملاحظة أن مستوى تكنولوجيا الإنتاج في هذه الترسانات منخفض. هذا البحث يبين تأثير رفع مستوى تكنولوجيا الإنتاج المستخدمة في الترسانة على وضع التكلفة التنافسية لها وذلك من خلال دراسة تأثير أي تغير تكنولوجي على إنتاجية الترسانة أولا. بعد ذلك تم دراسة تأثير رفع مستوى تكنولوجيا الإنتاج المستخدمة في الترسانة على تكلفة ساعة العمل بالإضافة إلى دراسة العوامل المؤثرة في مقدار الزيادة في تكلفة ساعة العمل نتيجة التغيير التكنولوجي. ثم بعد ذلك تم دراسة تأثير رفع مستوى تكنولوجيا الإنتاج المستخدمة علي وضع التكلفة التنافسية للترسانة.

Keywords: Cost competitive position, Productivity, Manhour cost, Technology change, Compensated gross tonnage

1. Introduction

Shipbuilding is an industry with true global competition, at least as far as the building of commercial ships is considered [1, 2]. The competition in shipbuilding market is very difficult because there is no balance between supply and demand; supply is more than demand. In such shipbuilding market there is no place for any shipyard unable to compete internationally. Generally, few shipyards, called world class shipyards or shipbuilding market leaders, dominate a large percent of shipbuilding market [2, 3]. On the other side, many shipyards cannot entirely compete and often have a blank order book. These shipyards are characterized by low productivity and/or high manhour cost [4].

In order to increase competitiveness, shipyards have to consider the factors affecting competitiveness. Although, competitiveness is affected by many factors such as price, delivery time, quality, productivity, performance rates, promotion, marketing, confidence of ship-owner, and other factors [5-12], ship acquisition price, measured in terms of Dollar per Compensated Gross Tonnage, $\$/(CGT)$, is considered the most important factor especially in view of ship-owners [10]. Ideally, this price is defined as the total ship building cost plus suitable profit determined by the shipyard. As competition among shipyards is considered, the cost of direct materials attributed to specific contracts should be excluded from the costs and concentrate on the added value, i.e. the total manhour costs for the company [13]. The

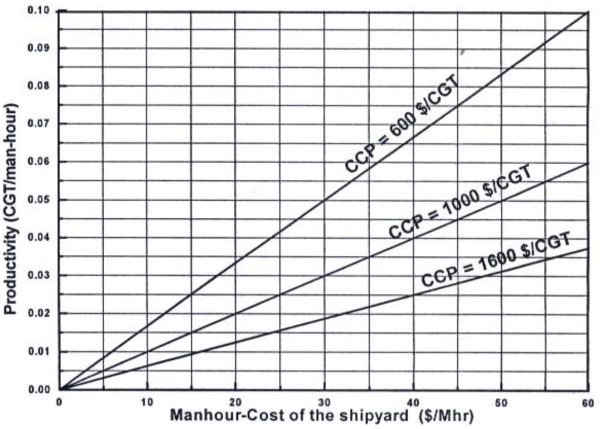

Fig. 1. Constant cost lines.

term cost competitiveness is determined by dividing the manhour-cost of the shipyard measured in terms of dollar per man-hours, *$/Mhr*, on the Since shipyards have a little control on manhour-cost, *$/Mhr*, then the only available way to improve *CCP* is to increase the productivity for the same manhour-cost. Therefore, shipyards have to give considerable attention for factors which lead to increase in productivity. Special consideration should be given to those factors which can be controlled by the shipyard and have rapid and considerable impact on productivity and hence *CCP*.

For the difficult shipbuilding market it should be noted that it is not sufficient for shipyards to increase their productivity and thereby improve their competitiveness. This increase must also take place faster than that of their competitors and more rapidly than the fall in prices [1]. Therefore, shipyards have to prioritize the means by which they can increase the productivity according to their priorities. This priority is evaluated based on the percentage that the mean can contribute to increase productivity and hence *CCP*.

There are many factors affecting shipyard's productivity, but for low-productive and low manhour-cost shipyards, due to simplicity of observing and assessing the level of applied technology, it may be conceived that technological modernization/change is the best way to increase productivity and hence *CCP*.

Although technological change is one of the industry's rubrics, but in such shipbuilding market conditions it may have an adverse effect on the shipyard's *CCP*, especially if it has high investment costs. The priority of the technological changes for shipyards must be evaluated through investigating the impact of technological modernization/change on the *CCP* of shipyards.

Technological change has two opposite effects on a shipyard. The first effect is positive where it leads to decreasing the man hours required to build a ship [14]. This saving in required man hours, *ΔMhr/ship*, can be evaluated in terms of man hours per Compensated Gross Tonnage, *ΔMhr/CGT*. The second effect is negative where, it leads to increasing the manhour-cost of the shipyard in terms of *$* per man-hour, *$/Mhr*, [13]. Therefore, the shipyard has to perform a techno-economical study to insure that the proposed technological change is effective, i.e., the cost in terms of *$/CGT* will reduce, which means improving the *CCP* of the shipyard.

This research discusses the impact of technology development on the *CCP* of shipyards. At first, the effect of technology change on shipyard productivity is discussed. Afterwards, economics of technological modernization/change is investigated. In addition, factors affecting the increase in manhour-cost of the shipyard, due to technological changes, such as initial cost, life time, salvage value, number of workers, and interest rate are investigated. Finally, the impact of technology change on *CCP* improvement is studied.

2. Effect of technology changes on productivity

To investigate the effect of technology changes on shipyard's productivity, one should calculate the change in productivity, *ΔP*, due to any technological change. To calculate the change in productivity, in terms of *CGT/Mhr*, one must first calculate the reduction in man-hours required to build a ship. This saving in man-hours required to build any specified ship type(s), *ΔMhr*/ship, can be estimated through providing work content database with the new performance rates of the new technology. For a considered specified ship type(s) the equivalent *CGT*,

CGT/ship, can be calculated consequently, *ΔMhr/CGT* can be estimated as follows:

$$\Delta Mhr/CGT = (\Delta Mhr/ship)\ /\ (CGT/ship). \qquad (1)$$

Saving in man-hours per compensated gross tonnage, *ΔMhr/CG*, is only a function in the performance rates of existing and proposed technologies. Then, it may be assumed that *ΔMhr/CGT* is constant for the same proposed technological changes and ship type. However, even if the proposed technological change may lead to the same reduction in required *Mhr/CGT* in different shipyards, it leads to different productivity change, *ΔP*, in different shipyards according to their initial productivity. The change in productivity, *ΔP*, due to the technological change is greatly influenced by the initial productivity, P_1, which can be drawn from the following equation:

$$\Delta P = P_2 - P_1 = \frac{1}{\left(\frac{MHr}{CGT}\right)_2} - \frac{1}{\left(\frac{MHr}{CGT}\right)_1} = -\frac{\left[\left(\frac{MHr}{CGT}\right)_2 - \left(\frac{MHr}{CGT}\right)_1\right]}{\left(\frac{MHr}{CGT}\right)_2 \cdot \left(\frac{MHr}{CGT}\right)_1}$$

$$\therefore\ \Delta P = -(\Delta Mhr/CGT).\ P_1\ .\ P_2\ , \qquad (2)$$

where,

P_1 is the initial productivity before technology change, and

P_2 is the final productivity after technology change.

The relationship between the productivity change, *ΔP*, and the initial productivity, P_1, based on eq. (2), is shown in fig. 2 for different values of *ΔMhr/CGT*.

It is obvious from fig. 2 that the higher the initial productivity, P_1, the higher the productivity increment that shipyard can achieve through technological change with considerable saving in *Mhr/CGT*. On the contrary, for low initial productivity, P_1, the productivity increment is fairly small. Thus, for shipyards with low productivity, the increasing in the productivity due to technological change is expected to be small. On the other hand, increasing the initial

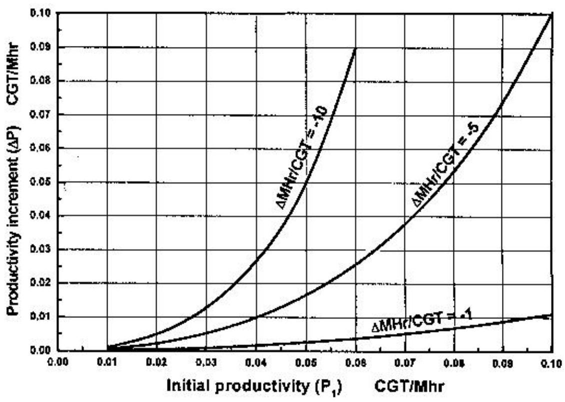

Fig. 2. Effect of initial productivity P_1, on productivity increment *ΔP*.

productivity of shipyard will in turn increase the productivity increment, *ΔP*, due to technological change. Thus, in order to improve CCP of low-productive shipyards, they should first extremely utilize their full capacity of existing production technology before performing any technological changes, that is, increase P_1.

3. Influence of technology changes on manhour-cost

Technology change at any shipyard needs discharging new investment. This new investment will lead to increasing the manhour-cost of the shipyard in terms of *$/Mhr*. The increase in the manhour-cost, *Δ$/Mhr*, can be calculated, as given in the Appendix, from the following equation:

$$\Delta\$\ /\ Mhr = C_A/Mhr_{year}\ \ \$/Mhr, \qquad (3)$$

where,

C_A is the annual cost of the new equipment, $/year, and

Mhr_{year} is the average man-hours per year, *Mhr*/year.

The magnitude of C_A depends on the values of the initial cost, expected life time, annual operating and maintenance costs, salvage value of the new equipment and interest rate. Also Mhr_{year} depends on the number of employees and the average working hours per year.

The increase in manhour-cost, *Δ$/Mhr*, due to the technology change is affected by many factors such as:

- Interest rate, i.
- Average man-hours per year, Mhr_{year}, which basically depends on number Worker, WN, and average working hours per year, Whr_{year}.
- New equipment factors.
  - Expected life time, N, in years.
  - Initial cost, C_I, in $ (difference between initial cost of new equipment and salvage value of old equipment)
  - Annual maintenance cost, C_{AM}, in $.
  - Annual operating cost, C_{AO}, in $.
  - Salvage Value (SV), in $.

The effect of each above factor on the increase in manhour-cost, $\Delta\$/Mhr$, can be explained through giving the above factors some different assumed, hypothetical, values as shown in table 1. C_{AO} is assumed to be constant where they slightly vary. Although Whr_{year} is variable, ranging from 1550 to 2600 working hours per year [1], only a mean value of 1880 Hour/year is considered here whereas the effect of Whr_{year} is the same as the effect of WN. The values of $\Delta\$/Mhr$ corresponding to the values given in table 1 are shown in figs. 3 and 4. From these figures, it can be shown that, as the annual cost of the new equipment increase the manhour-cost increment, $\Delta\$/Mhr$, increases and vice versa. Also one can see that the labor intensive shipyards have less cost increment, $\Delta\$/Mhr$, than of low worker number shipyards for constant annual cost C_A. The same result is true regarding Mhr_{year} whereas, $\Delta\$/Mhr$ in case of high Mhr_{year} shipyards will be less than of low Mhr_{year} ones and vice versa. Thus, technology change with low annual cost, C_A, and great saving in Mhr/CGT is most suitable for shipyards of high Mhr_{year}.

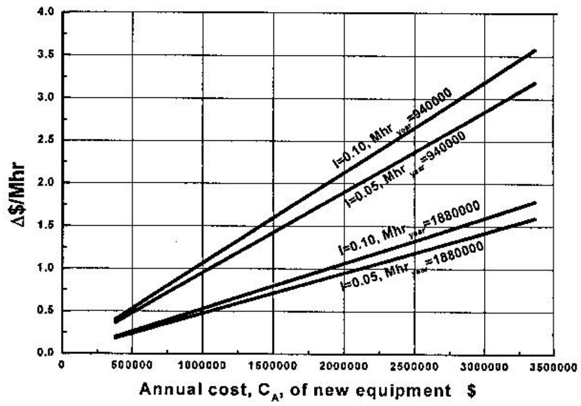

Fig. 3. $\Delta\$/.Mhr$ for different values of C_A, i, and Mhr_{year} (N=5).

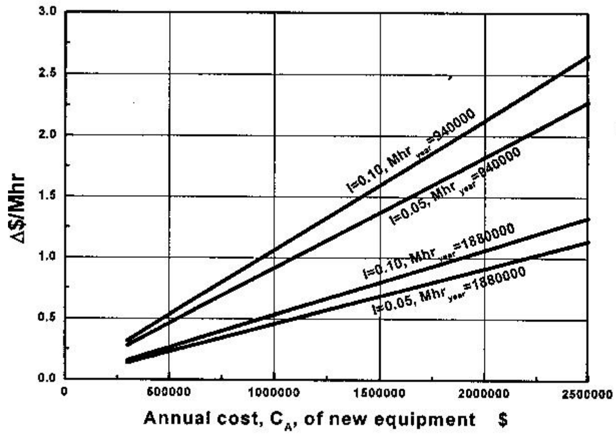

Fig. 4. $\Delta\$/.Mhr$ for different values of C_A, i, and Mhr_{year} (N = 10).

Table 1
Assumed values of the factors affecting manhour-cost increment, $\Delta\$/Mhr$

Factor	Status	Assumed values
Initial cost (C_I)	Variable	1M$, 5M$, and 10M$
Life time (N)	Constant	5 year and 10 year
Annual maintenance cost (C_{AM})	Variable	10% of C_I
Annual operating cost (c_{ao})	Slightly varies	50,000 $
Salvage Value (SV)	Variable	20% of C_I
Interest rate (i)	Variable	0.05 and 0.10
Worker Number (WN)	Variable	500 and 1000
Average working hours per year (Whr_{year})	Variable	1880 *Hr/year*

4. Impact of technology changes on shipyard's *CCP*

The cost competitive position of a shipyard, measured in $\$/CGT$, as seen before is a division of manhour-cost of a shipyard, $\$/Mhr$, by the shipyard productivity, *CGT/Mhr*. Technology change has two opposite effects on the shipyard's *CCP*. The first is the increase in productivity which can be expressed by the productivity ratio P_2/P_1. The second is the increase in manhour-cost of the shipyard which can be represented by the manhour-cost ratio C_2/C_1, where C_1 and C_2 refer to the manhour-cost, $\$/Mhr$, before and after performing the proposed technology change, respectively.

In order for the proposed technological change to be constructive, ΔCCP must be less than zero then,

$$\Delta CCP < 0.0. \tag{4}$$

To explain the influence of the technology change on *CCP* of shipyards those have different initial productivity and manhour-cost, ΔCCP can be expressed as follows:

$$\Delta CCP = CCP_2 - CCP_1 = (C_2/P_2) - (C_1/P_1). \tag{5}$$

Where, CCP_1 and CCP_2 refer to the *CCP* before and after performing the proposed technology change, respectively.

Then,

$$C_2/P_2 - C_1/P_1 < 0.0. \tag{6}$$

$$C_2/P_2 < C_1/P_1.$$

$$P_2/P_1 > C_2/C_1. \tag{7}$$

In order the technology change to be effective, the productivity ratio, P_2/P_1, must be much more than the manhour-cost ratio, C_2/C_1. On the other side, if P_2/P_1 is less than C_2/C_1 this means that the proposed technology change will have a negative effect on the *CCP*, i.e., cost per *CGT* will increase.

The relationship between productivity ratio, P_2/P_1, and initial productivity, P_1, is given in fig. 5. It can be shown from fig. 5 that as P_1 increases the productivity ratio, P_2/P_1, increases and vice versa. Also, the relationship between manhour-cost ratio, C_2/C_1, and initial manhour-cost, C_1, is illustrated in fig. 6 from which it can be seen that the increasing C_1 leads to a decrease in the manhour-cost ratio, C_2/C_1, and vice versa. One can easily see from figs. 5 and 6 that for low-productive and low manhour-cost shipyards, P_2/P_1 is small and C_2/C_1 is large, unnecessary $C_2/C_1 > P_2/P_1$. Thus, for low-productive and low manhour-cost shipyards the *CCP* improvement due to technology change is expected to be small if any.

In addition, values of the percentage change in *CCP*, $\Delta CCP\%$, for different values of $\Delta Mhr/CGT$ and $\Delta\$/Mhr$ are calculated for CCP_1 equal to 1000 $\$/CGT$ and 2000 $\$/CGT$ and presented in figs. 7 and 8, respectively. From these figures, one can see that for low-

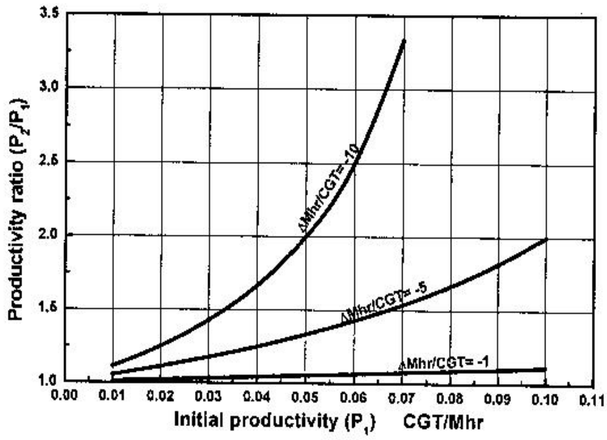

Fig. 5. Relationship between P_2/P_1 and initial productivity P_1 of different values of $\Delta Mhr/CGT$.

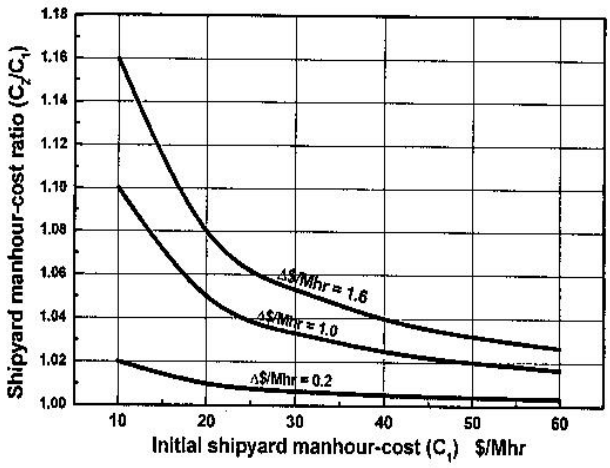

Fig. 6. Relationship between manhour-cost ratio, C_2/C_1 and initial manhour-cost, C_1 for different values of ΔMhr.

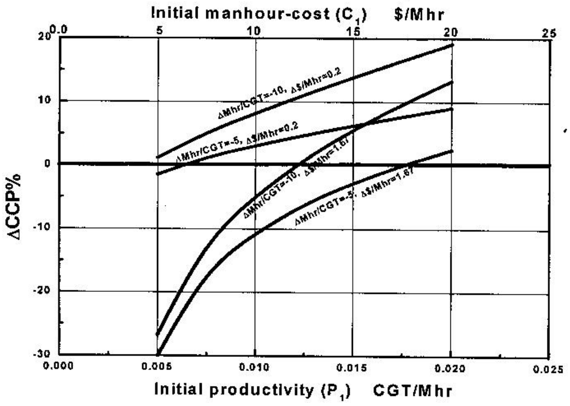

Fig. 7. $\Delta CCP\%$ for $CCP_1 = 1000$.

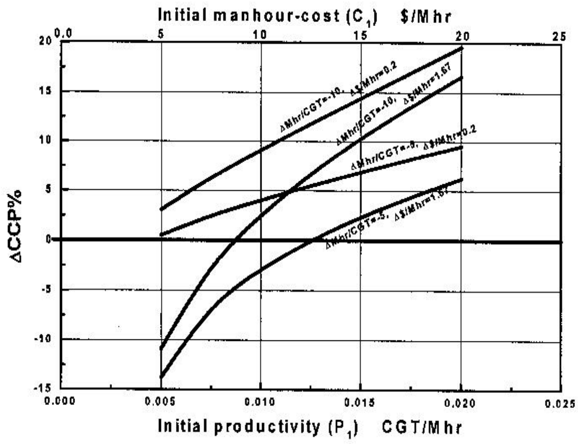

Fig. 8. $\Delta CCP\%$ for $CCP_1 = 2000$.

productive and low manhour-cost shipyards the percentage change in *CCP* is negative or small positive.

5. Conclusions

From this study it can be concluded that:

1) For shipyards with low productivity, the increase in the productivity due to technology change is expected to be small.
2) Increasing the initial productivity of a shipyard will in turn increase the productivity change due to technology change.
3) In order to improve *CCP* of low-productive shipyards, they have first to utilize their maximum capacities of existing production technology before performing any technology changes, that is, increase P_1.
4) Technology change with low annual cost, C_A, and great saving in *Mhr/CGT* is most suitable for shipyards of high Mhr_{year}.
5) For low-productive and low-manhour-cost shipyards the *CCP* improvement due to technological change is expected to be small if any.

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Appendix

The following are the procedures by which manhour-cost increment, *Δ$/Mhr*, can be estimated:

1. Determine initial cost C_I of the new equipment in *$*.
2. Estimate expected life time of the new equipment, *N*, in years.
3. Estimate annual maintenance cost, C_{AM}, in $ of the new equipment.
4. Estimate annual operating cost, C_{AO}, of the new equipment in *$*.
5. Estimate *SV*, of the new equipment in *$*.
6. Determine the interest rate, *i*.
7. Using the previous data, the annual cost, C_A of the new equipment can be determined in *$*/year as follows [16]:

$$C_A = C_I\,(A/P,\ i,\ N) + C_{AM} + C_{AO} - SV\,(A/F,\ i,\ N), \quad \text{(A1)}$$

where,

$(A/P,\ i,\ N)$ is the uniform series capital recovery factor = $\left[\dfrac{i(1+i)^N}{(1+i)^N - 1}\right]$

$(A/F,\ i,\ N)$ is the uniform series sinking fund factor = $\left[\dfrac{i}{(1+i)^N - 1}\right]$

8. Determine the average man-hours per Year, Mhr_{year}, in *Mhrs/year* as follows:

$$Mhr_{year} = WN \times Whr_{year} = Mhr/year, \quad \text{(A2)}$$

where:

WN is the number of workers (including direct and indirect workers and subcontractors and considering number of shifts), and

Whr_{year} is the average working hours per year which can be calculated as follows:

$$Whr_{year} = Whr_{day} \times WD_{year} \times (1 - APA). \qquad (A3)$$

where:

Whr_{day} is the number of hours per working day (including average number of hours overtime worked by an individual per day),

WD_{year} is the number of working days per year, and

APA is the average percentage of absenteeism in a year.

9. Calculate the increase in manhour-cost, $\Delta\$/Mhr$, due to the proposed technological change, which is:

$$\Delta\$/Mhr = C_A \;/\; Mhr_{year} \;\; \$/Mhr \,. \qquad (A4)$$

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