Toward improving the Cost Competitive Position (CCP) for shipbuilding yards – part II: Case study

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Among the elements affecting shipyard's productivity, low production technology level may be considered the main reason for declining the productivity and hence the competitiveness of the shipyard, especially those from developing world. In part I of this research the impact of technology change on shipyard Cost Competitive Position (CCP) has been studied. Based on that study, it is concluded that, for low productivity and low manhour-cost shipyards the cost competitiveness improvement due to technology change is expected to be slight. The purpose of this paper is to examine the impact of technology change through a case study. Whereas technology change takes many forms, increasing crane lifting capacity in the shipyard is selected as an example for investigating its effect on CCP. This investigation is done through three steps. Firstly, the saving in man-hours required for building a ship, $\Delta Mhr/CGT$, due to increasing the lifting capacity, is estimated. Secondly, increasing in shipyard's manhour-cost, $\Delta\$/Mhr$, due to increasing the lifting capacity is calculated. Finally, CCP-improvement, $\Delta\$/CGT$, for hypothetical nine shipyards with different productivity, manhour-cost, and CCPs is assessed.

مستوى التكنولوجيا المستخدم في ترسانات بناء السفن يعتبر من بين العوامل التى تؤثر فى إنتاجيتها. لذلك يُعتقد أن انخفاض مستوى تكنولوجيا الانتاج المستخدمة هو السبب الرئيسى لتدنى الانتاجية ومن ثم تدنى القدرة التنافسية خاصة للترسانات منخفضة الإنتاجية وتكلفة ساعة العمل. فى الجزء الأول من هذا البحث تم دراسة تاثير رفع مستوى تكنولوجيا الإنتاج المستخدمة في الترسانة على وضع التكلفة التنافسية لها وذلك بطريقة تحليلية نظرية. وقد تبين انه بالنسبة للترسانات منخفضة الإنتاجية وتكلفة ساعة العمل فان التحسن فى وضع التكلفة التنافسية للترسانة من خلال رفع مستوى تكنولوجيا الإنتاج المستخدمة بها فقط يُتوقع أن يكون طفيف ان وُجد. الغرض من هذا الجزء من البحث هو بيان تأثير رفع مستوى تكنولوجيا الإنتاج المستخدمة في الترسانة على وضع التكلفة التنافسية لها. وحيث أن التغيرات التكنولوجية تأخذ صور متعددة وتتم فى نواحى و مجالات مختلفة فقد تم أختيار زيادة قدرة الرفع فى ترسانة بناء السفن كمثال لبحث تأثيرها على وضع التكلفة التنافسية للترسانة. هذا وقد تمت الدراسة خلال ثلاثة خطوات. أولاً: تقدير الوفر فى ساعات العمل المُقدرة لبناء سفينة معينة نتيجة زيادة قدرة الرفع. ثانياً: حساب الزيادة فى تكلفة ساعة العمل نتيجة زيادة قدرة الرفع فى الترسانة. أخيراً: تقدير التحسن فى وضع التكلفة التنافسية لتسع ترسانات افتراضية ذات انتاجية وتكلفة ساعة عمل ومواضع تكلفة تنافسية مختلفة.

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

1. Introduction

In part I of this study [1] the impact of technology changes on shipyard Cost Competitive Position (CCP) has been theoretically investigated. It was concluded that, for low-productive and low manhour-cost shipyards, the role of technology change in improving the CCP is not as effective as required.

The purpose of the current paper is to investigate and emphasize this impact through a case study. In this study, increasing the lifting capacity of erection's cranes in the shipyard, as one of manifold potential technology changes, is selected for investigating its effect on CCP. In this paper the need for increasing the crane lifting capacity in the shipyard is explained. Afterwards the change in CCP due to increasing the crane capacity is assessed through three steps. Firstly, the saving in man-hours required for building a selected ship, $\Delta Mhr/CGT$, due to increasing the lifting capacity of erection's crane, is estimated. Secondly, the increase in shipyard manhour-cost, $\Delta\$/Mhr$, due to increasing the erection crane(s) lifting capacity is calculated. Finally, CCP improvement, $\Delta\$/CGT$, for hypothetical nine shipyards with different productivity, manhour-cost, and CCPs is assessed.

2. Increase of lifting capacity of erection's crane

Reducing the number of hull units, during erection stage of ship building, can decrease the building cost [2, 3]. This saving in the building cost is due to completing larger percentage of fabrication, assembly and outfitting works in the workshops in lieu of doing these works on erection berth. Completion of works in workshops requires man-hours less than completion of the same works on erection berth.

The main problem associated with reducing the number of units during the erection stage, which make the shipyard unable to apply this concept, is that there is no adequate lifting capacity to handle heavy units. Increasing the lifting capacity of erection's crane, as any technology change, has two opposite effects on the shipyard. The first effect is positive where, it will lead to decrease in the man-hours required to construct the ship in terms of man-hours per Compensated Gross Tonnage, Mhr/CGT, [4]. The second effect is negative where, it will lead to increasing the shipyard's manhour-cost in terms of dollar per man-hour, $\$/Mhr$, [5]. Therefore, the shipyard has to perform a techno-economical study to ensure whether the application of the proposed new technology is positive, i.e., the cost of ship building in terms of $\$/CGT$ will decrease, which means improving the CCP of the shipyard.

3. Saving in man-hours

To calculate the change in man-hours required for building a ship, $\Delta Mhr/CGT$, due to any variable, there must be an approach to estimate the work-content required for constructing a ship in terms of man-hours. This approach has to correlate, directly or indirectly, between the work-content and the variable (s) that require investigating its effect on the ship building cost and hence on the shipyard's CCP. In the current study the variable is the lifting capacity of the crane(s) used during erection stage. In this case the relationship is indirect where the work-content is related to the number and size of hull units which depend on the lifting capacity. Such approach is presented by Hills et al. [2]. However, the approach considers only the man-hours required for fabricating and erecting steel works only for parallel middle body of RO/RO ship during design stage.

For the purpose of current study the data presented by Hills [2] is used. These data are the work-content, man-hours, required for fabricating, assembling, and erecting parallel middle body of a 7500 tonne deadweight two-deck RO/RO ship. The main dimensions of this RO/RO ship are as follows:

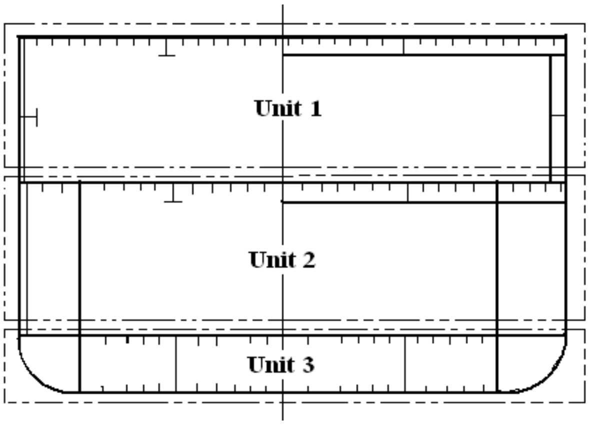
Length BP	= 136.0 m
Breadth molded	= 23.0 m
Depth molded to upper deck	= 16.4 m
Depth molded to main deck	= 9.0 m
Design draft	= 6.9 m
Block coefficient	= 0.622

Fabrication/assembly and erection man-hours are estimated considering three different cases of hull breakdown [2]. Those are: 3-units, 6-units, and 9-units as shown in fig. 1, a, b, and c, respectively.

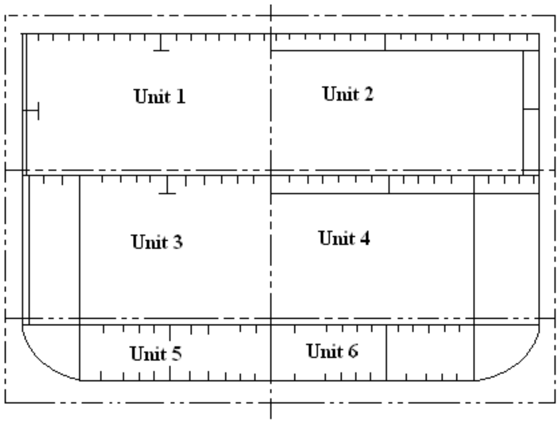
Tables 1, 2, and 3 show actual fabrication and erection work content as will as the weight of each individual unit and for the grand block in the three cases of hull breakdown (3-units, 6-units, and 9-units) respectively. Table 4 shows a summary of total man-hours required to fabricate and erect a complete mid-ship section grand block, about 11 m long, in each case of breakdown. It is clear from table 4 that applying 3-units breakdown case will require man-hours less than the two other cases, where it saves about 11% over 9-units case and about 9% over 6-unit case.

From table 4, it is easy to predict the problem, or restriction, which may face some shipyards if they want to apply 3-units breakdown. This restriction is the higher of the minimum required crane lifting capacity, approximately 120 tones.

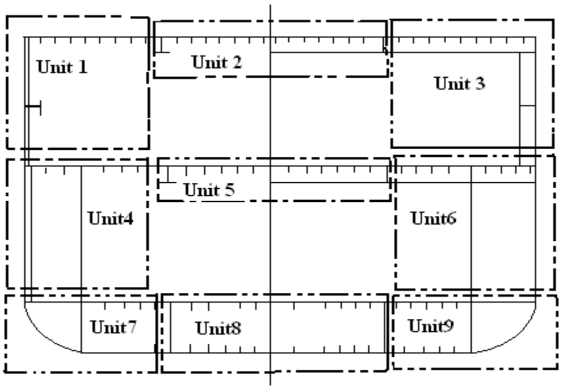
If the maximum crane lifting capacity in the shipyard is limited so that it permits only to apply the 9-units breakdown option then, in order for the shipyard to be able to apply



a: 3-Units breakdown.



b: 6-Units breakdown.



c: 9-Units breakdown.

Fig. 1. Considered hull breakdown cases [2].

Table 1
Fabrication and erection man-hours of 3-units breakdown [2]

Hull unit No.	Hull unit type	Actual fabrication *(Mhrs)*	Actual erection (*Mhrs*)	Unit weight (tone)
1	C-unit (deck + 2sides)	2366.78	345.28	82.62
2	C-unit (deck + 2sides + 2 inner hulls)	3749.16	701.63	110.80
3	Double bottom total unit	4263.56	846.10	80.94
	Grand total	10379.50	2967.80	274.36

Table 2
Fabrication and erection man-hours of 6-units breakdown [2]

Hull unit no.	Hull unit type	Actual fabrication (Mhr)	Actual erection (Mhr)	Unit weight (tone)
1	L-unit (deck + side)	1149.08	406.71	41.80
2	L-unit (deck + side)	1037.66	389.30	40.82
3	L-unit (deck + side + inner hull)	1742.72	578.45	56.82
4	L-unit (deck + side + inner hull)	1583.75	554.97	53.98
5	Double bottom (2side girders + center girder)	2292.83	616.78	41.73
6	Double bottom (2side girders)	1696.23	531.26	39.21
	Grand total	9502.30	5058.30	274.36

Table 3
Fabrication and erection man-hours of 9-units breakdown [2]

Hull unit no.	Hull unit type	Actual fabrication (*Mhr*)	Actual erection (*Mhr*)	Unit weight (tone)
1	L-unit (deck + side)	728.04	304.99	27.59
2	Panel unit	755.43	303.61	27.45
3	L-unit (deck + side)	728.04	304.99	27.59
4	L-unit (deck + side)	1073.80	441.86	36.10
5	Panel unit	1173.11	358..19	38.60
6	L-unit (deck + side)	1073.80	438.40	36.10
7	Double bottom bilge (1side girder)	1100.96	346.43	18.97
8	Double bottom flat (2side girders)	2186.57	678.18	43.00
9	Double bottom bilge (1side girder)	1100.96	346.43	18.97
	Grand total	9920.70	5064.70	274.36

Table 4
Summary of total man-hours for the three cases of breakdown [2]

Breakdown case	Actual fabrication (*Mhr*)	Actual erection (*Mhr*)	Total work content (*Mhr*)	Maximum unit weight (tone) (minimum required lifting capacity)
3-units	10379.50	2967.80	13347.30	110.80
6-units	9502.30	5058.30	14660.60	56.82
9-units	9920.70	5064.70	14984.40	43.00

3-units option, it has to increase this lifting capacity so that it can handle units of weight up to 120 tones. In this case, the decrease in man-hours required for building a ship in terms of *Mhr/CGT* can be estimated as follows:

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

The length of parallel middle body of considered ship is 55 m, 5 times of unit length, consequently the total decrease in man-hours per ship is:

$$\Delta Mhr/\text{ship} = (13347.3 - 14984.4) \times 5$$
$$= -8185.5\ Mhrs/\text{ship}$$

This saving in man-hours per ship is estimated considering only the steel works of parallel middle body. Taking into account fore and after bodies, this saving is expected to be more than the estimated above. After examining similar RO/RO ship, the fore and after bodies steel works can be approximated as twice as for middle body. The saving in man-hours per ship in turn is expected to equal -24556.5 *Mhr*/ship approximately.

The compensation coefficient C of *CGT* of 7500 tones deadweight RO/RO ship is 0.9 [6]. Consequently, the considered ship is equivalent to approximately 3270 *CGT*. Thus, the total saving in man-hours per *CGT* is:

$$\Delta Mhr/CGT = -\ 24556.5/3270 = -\ 7.5\ Mhr/CGT$$

4. Increase in manhour-cost

Increasing lifting capacity of erection's crane to the minimum required capacity will lead to increasing the shipyard's manhour-cost in *$/Mhr*. The increase in manhour-cost, *Δ$/Mhr*, can be calculated, as explained in ref. [1and 7], from the following equation.

$$\Delta\$/Mhr = C_A/Mhr_{year} \quad \$/Mhr. \qquad (2)$$

Where, C_A is the annual cost of the new crane(s) and Mhr_{year} is the average man-hours per year.

The increase in manhour-cost, due to increasing the lifting capacity, is a function of many factors [1]. For the purpose of current study, different values for these factors have been considered as given in table 5. It should to be noted that, C_{AO} is assumed to be constant where it may slightly vary. Although Whr_{year} is variable, ranging from 1550 to 2600 working hours per year [8], only a mean value of 1880 hr/year is considered here, where the effect of Whr_{year} is the same as the effect of WN.

Figs. 2 and 3 show the values of *Δ$/Mhr* calculated according to the assumed values shown in table 5. From figs. 2 and 3, one can see that the value of *Δ$/Mhr* may range from less than 0.25 to more than 3.5 *$/Mhr*.

Table 5
Factors affecting *Δ$/Mhr* and their assumed values

Factor	Status	Assumed values
Initial cost (C_I)	Variable	1M$, 5M$, and 10M$
Life time (N)	Variable	5years and 10 years
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, 1000
Average working hours per year (Whr_{year})	Variable	1880 hr/year

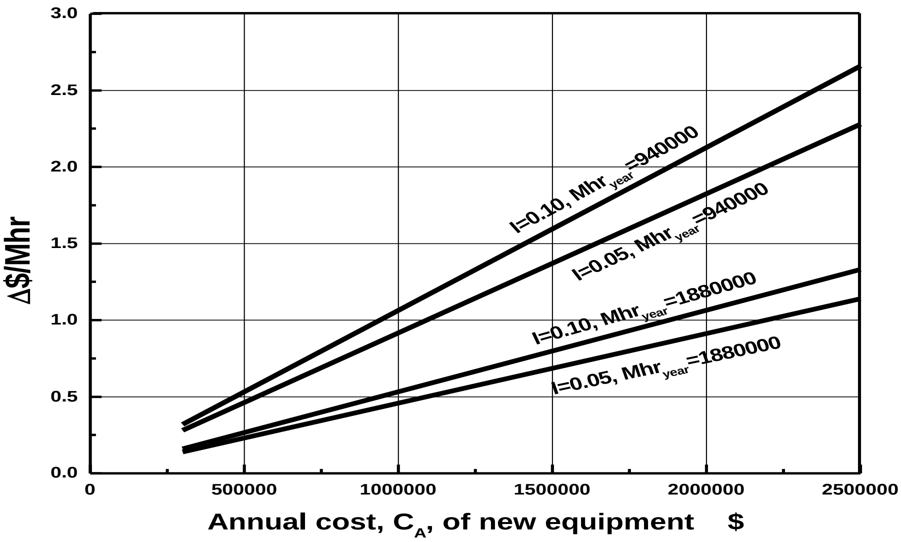


Fig. 2. *Δ$/Mhr* for different values of C_A, *I*, and Mhr_{year} (N=10).

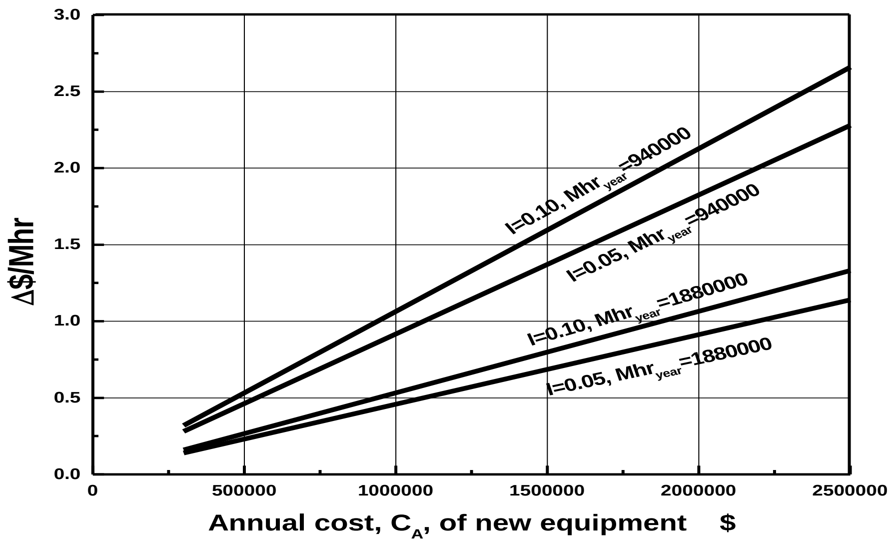


Fig. 3. *Δ$/Mhr* for different values of C_A, *I*, and Mhr_{year} (N=5).

5. CCP improvement

To investigate the influence of increasing lifting capacity of the erection's crane on CCP, different values of CCP, representing 9 different hypothetical shipyards, are considered. These magnitudes of CCP are plotted on cost competitive position chart as shown in fig. 4 to show the relative position of each shipyard with respect to the productivity and manhour-cost parameters.

Initial and new productivity, manhour-cost, CCP and the improvement of CCP for the different shipyards are shown in table 6. One can see from table 6 that the influence of increasing the crane lifting capacity on a CCP differs from shipyard to another. In addition, the improvement in CCP increases as the initial productivity of a shipyard increases. Fig. 5 gives the percent of improvement values of CCP for different values of shipyard's initial productivity and clarifies the importance of initial productivity for shipyards for the technology change. Also fig. 6 shows the relationship between the percent improvement of CCP with different values of initial manhour- cost. From figs. 5 and 6, one can notice that increasing the lifting capacity of erection's crane has a positive effect on CCP of shipyards have high initial productivity and high initial manhour-cost. On the contrary, increasing the crane lifting capacity has a negative effect on CCP of shipyards that have low initial productivity and low initial manhour-cost.

It should be noted that shipyards 1, 4, and 7 have maximum CCP improvement due to increasing the lifting capacity of erection's crane due to their high productivity and high manhour-cost. However, the high crane's lifting capacity is expected to be originally available in these shipyard. Therefore, shipyards number 5, 6, 8, and 9 with low productivity will be considered in the remainder part of this section.

The CCP improvement has been clarified for single value of *Δ$/Mhr* which is equal to 1.875, so that the change in the manhour cost *Δ$/Mhr* will be examined. As a matter of fact, *Δ$/Mhr* is based on certain value of C_I, N, i, C_{AM}, C_{AO}, SV, and Mhr_{year}. To emphasize the influence of the increase of lifting capacity of erection's crane on CCP, it is important to estimate CCP improvement for various values of *Δ$/Mhr.* Table 7 shows values of *Δ$/Mhr* for different values of C_I, N, i, and WN. Fig. 7 illustrates values of CCP improvement percent due to increasing the erection's crane(s) lifting capacity for the different values of C_I, i, N and WN, for different values of *Δ$/Mhr* shown in table 7, for shipyards 5, 6, 8, and 9. These shipyards have low and moderate productivity, 120 *Mhr/CGT* and 60 *Mhr/CGT*.

From this figure it can be seen that, for low productivity shipyards 6 and 9 the percentage of CCP improvement ranges from -14%, at worst case to approximately + 6%, at best case whereas, it ranges from 3% to approximately 12.4% for moderate productivity shipyards 5, and 8. Thus, for low productivity and low mahour-cost shipyards, the influence of technology change, such as increase of the lifting capacity of erection's crane, on their cost competitiveness is expected to be slight if any.

Table 6
Initial and new values of productivity, manhour-cost, and CCP of the different shipyards considered for *ΔMhr/CGT* = 7.5, *Δ$/Mhr* = 1.875, and WN=500

Ship-yard no.	Initial			New			
	Productivity (*CGT/Mhr*)	Manhour-cost (*$/Mhr*)	CCP ($/CGT)	Productivity (*CGT/Mhr*)	Manhour-cost (*$/Mhr*)	CCP (*$/CGT*)	CCP improvement (%)
1	0.05	50	1000	0.08	51.875	648.43	35.1563
2	0.0167	16.7	1000	0.019	18.575	975.18	2.48125
3	0.0083	8.33	1000	0.0089	10.205	1148.0	-14.806
4	0.05	100	2000	0.08	101.875	1273.4	36.3281
5	0.0167	33.4	2000	0.019	35.275	1851.9	7.40313
6	0.0083	16.7	2000	0.0089	18.575	2089.6	-4.4844
7	0.05	150	3000	0.08	151.875	1898.4	36.7188
8	0.0167	50	3000	0.019	51.875	2723.4	9.21875
9	0.0083	25	3000	0.0089	26.875	3023.4	-0.7813

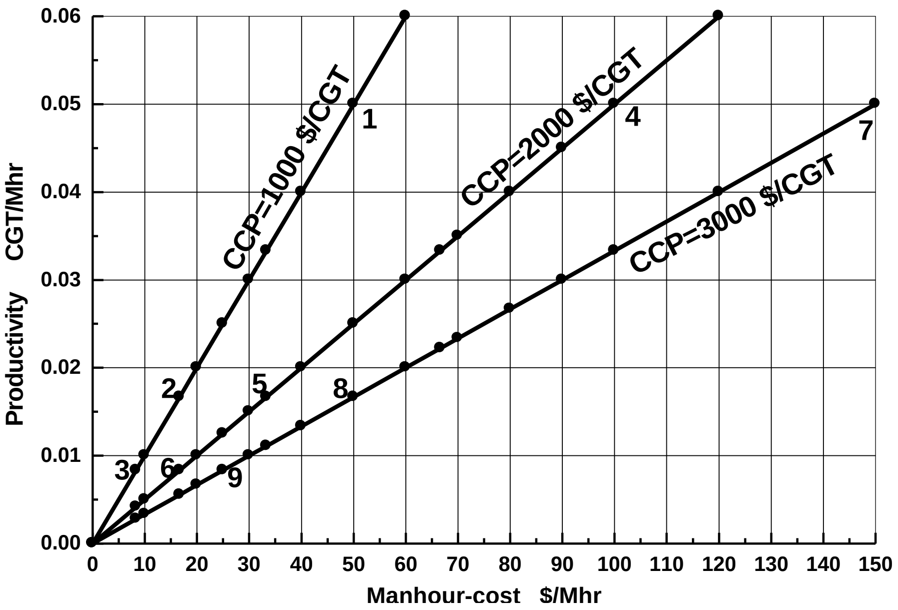


Fig. 4. Initial CCPs of the nine shipyards.

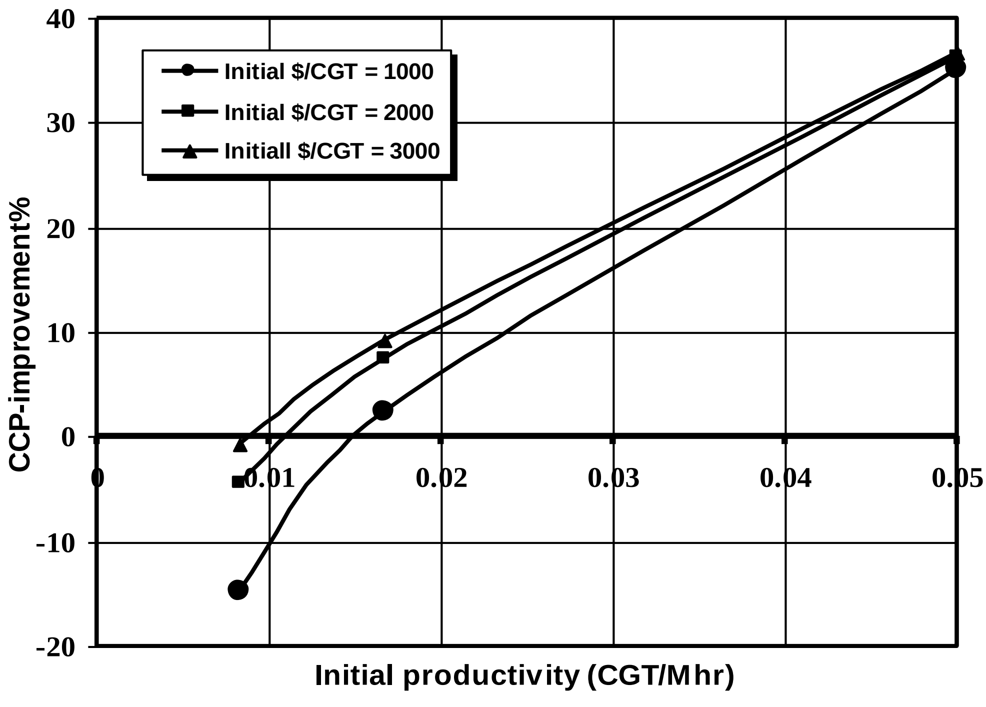


Fig. 5. Relationship between CCP improvement % and initial productivity for $\Delta Mhr/CGT$=7.5, $\Delta\$/Mhr$ = 1.875, and WN=500.

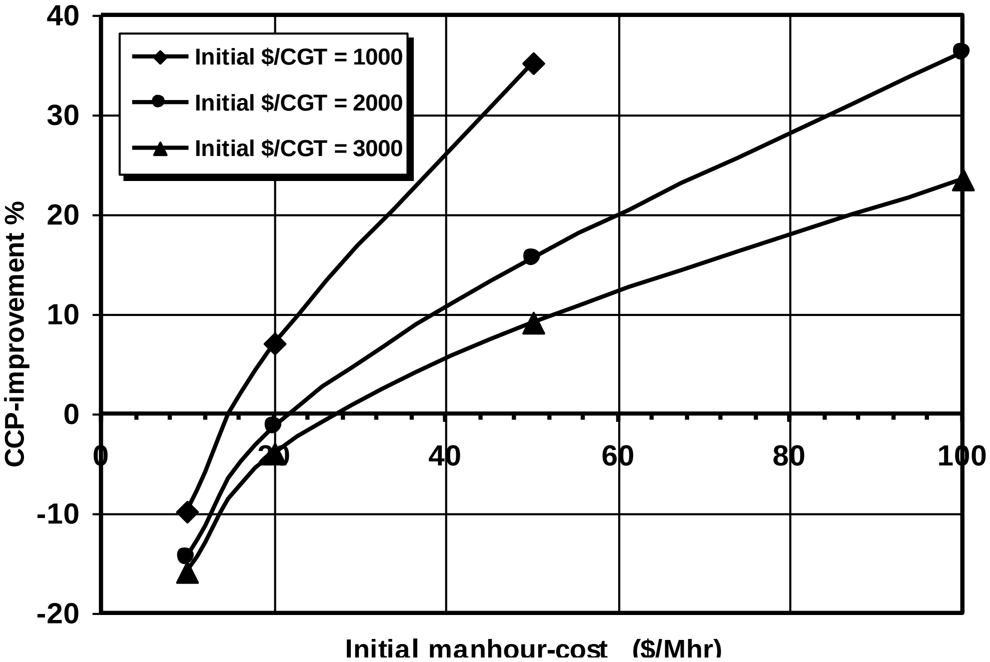


Fig. 6. Relationship between CCP improvement % and initial manhour-cost for $\Delta Mhr/CGT$ = 7.5, $\Delta\$/Mhr$ = 1.875, and WN=500.

Table 7
Values of $\Delta\$/Mhr$ for different values of C_I, N, i, and WN

<table>
<tr><th colspan="3">C_I = 1M$</th><th rowspan="2">Δ$/Mhr</th><th colspan="3">C_I = 5 M$</th><th rowspan="2">Δ$/Mhr</th><th colspan="3">C_I = 10 M$</th><th rowspan="2">Δ$/Mhr</th></tr>
<tr><th>N (year)</th><th>i</th><th>WN</th><th>N (year)</th><th>i</th><th>WN</th><th>N (year)</th><th>i</th><th>WN</th></tr>
<tr><td>5</td><td>0.05</td><td>500</td><td>0.37</td><td>5</td><td>0.05</td><td>500</td><td>1.62</td><td>5</td><td>0.05</td><td>500</td><td>3.19</td></tr>
<tr><td>5</td><td>0.05</td><td>1000</td><td>0.185</td><td>5</td><td>0.05</td><td>1000</td><td>0.81</td><td>5</td><td>0.05</td><td>1000</td><td>1.595</td></tr>
<tr><td>5</td><td>0.05</td><td>2000</td><td>0.0925</td><td>5</td><td>0.05</td><td>2000</td><td>0.405</td><td>5</td><td>0.05</td><td>2000</td><td>0.7975</td></tr>
<tr><td>5</td><td>0.1</td><td>500</td><td>0.41</td><td>5</td><td>0.1</td><td>500</td><td>1.814</td><td>5</td><td>0.1</td><td>500</td><td>3.58</td></tr>
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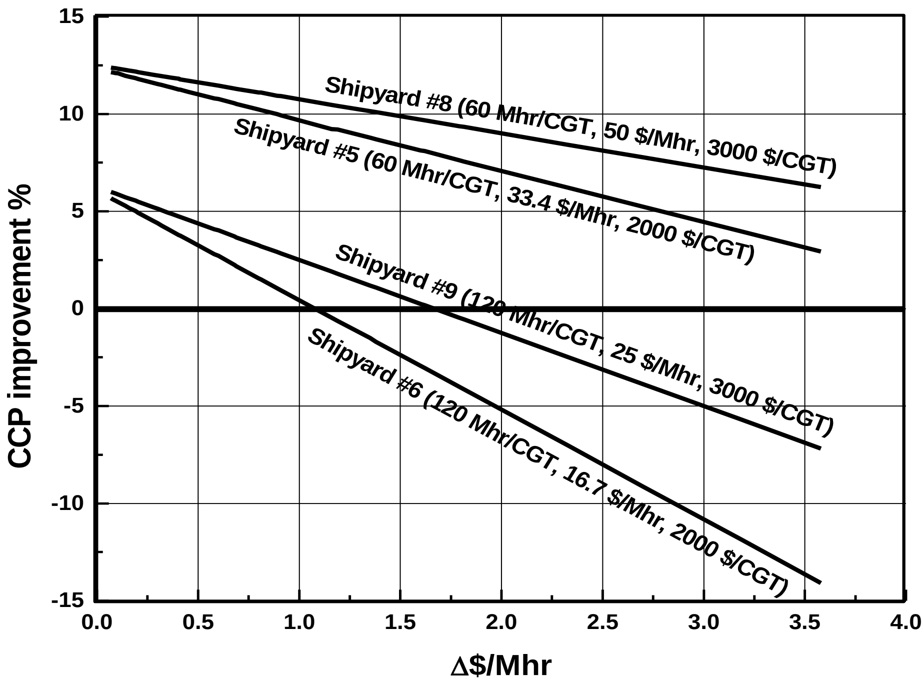

Fig. 7. CCP improvement % for different values of *Δ$/Mhr*.

6. Conclusions

From this study it can be concluded that:

1. For shipyards with low productivity, the increasing in the productivity due to increasing lifting capacity of the erection's crane is expected to be small.
2. The increase in initial productivity of shipyard will in turn increase the productivity change due to increasing the lifting capacity of crane.
3. In order to improve CCP of low productivity shipyards, it is preferred to utilize their maximum capacities of existing production technology before performing any technology changes, that is, increase the initial productivity.
4. Technology change with low annual cost, C_A, and great saving in manhour-cost, *Mhr/CGT*, is most suitable for shipyards of high average man-hours per year, Mhr_{year}.
5. For low productivity and low manhour-cost shipyards, the CCP improvement due to technological change is expected to be small.

Acknowledgement

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