A comparative theoretical study of three dozers` productivity

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Abstract: Selection of earth moving equipment selected for a specific construction project is critical to the success of thistype of work. As a step forward for enhancing the information related to such issue this research aims at clarifying the effect of some dozers` design parameters on their productivity. In this regard, three tracked dozers of high reputation brands are selected and some of their performance and design parameters are retrieved from manufacturers` published manuals.The major design parameters we believe are much influencing the have been chosen in the study are; the dozer weight, the dozer blade type, and blade capacity. The selected bulldozers` are having approximately same power to weight ratio. Empirical equations for calculating the productivity for each brand have also been developed by using data-fit program. Finally, it has been concluded that the blade capacity stands as the most significant parameter as the dozer productivity increases by 60% in average whenever the blade capacity increases by 25%.

Keywords:earth moving equipment productivity, track type dozer, dozing distance, dozer design parameters productivity

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1 Introduction

The productivity of dozers depends on their rim pull which in turn is mainly affected by various parameters such as; the terrain section grade, the rolling resistance to dozer motion generated by the soil, the dozer travel speed, and the gear shift used. The main design parameters for selecting an appropriate dozer for a specific job are; the dozer weight, the blade type, and the blade capacity. In the present study the three tracked dozers of different weights, blade dimensions, and blade capacity have been used. The estimated productivity of each dozer has been theoretically calculated, and the dozer operator basic skills, the type of soil, the soil particles gradation, the type of dozing, and the job efficiency havealso been considered.

2 Dozer design parameters and productivity

The major dozer design parameters that might be used for selecting a proper dozer for a certain job are shown in the Table 1; these data are being retrieved from the performance handbooks of the three dozer brands [1, 2, and 3].

Table 1 Selected design parameters of dozers from three different brands

Dozer designation	Dozer Weight, kg	Capacity of dozer Blade, m^3		
		Universal	Semi universal	Straight
	Brand A			
A_1	113000	43.6		
A_2	104600	34.4	27.2	
A_3	66451	22	18.5	
A_4	47900	16.4	13.5	
A_5	38488	11.7	8.7	
A_6	25996	8.34	6.86	5.16
A_7	25455	8.34	6.86	5.16
A_8	20580			4.2
	Brand B			
B_1	131350	45		
B_2	102500	34.4	27.2	
B_3	66990	22	18.5	
B_4	49850	16.6	13.7	
B_5	34560	11.9	9.4	
B_6	38800	11.8	8.8	
B_7	38700	11.8	8.8	
	Brand C			
C_1	35900	11.4	9.1	
C_2	27000		7	
C_3	20530		5.6	4
C_4	15010		4.1	3.1

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The dozers productivity figures as published in manufacturers` manuals for various dozing distances, using two types of blades for each dozer (universal and semi universal) are shown in Table 2 and Table 3.

Table 2 Productivity of dozers from different brands, equipped with universal blade

Dozer designation	Dozer Weight, kg	Dozing distance, m									
		15	30	45	60	75	90	105	120	135	150
Productivity of dozers from Brand A, m^3/h											
A_1	113000	3900	2375	1660	1300	1060	900	800	700	650	600
A_2	104600	3450	2000	1450	1100	900	800	650	600	550	500
A_3	66451	2300	1300	940	700	600	550	450	400	350	300
A_4	47900	1600	950	650	550	450	350	300	290	270	250
A_5	38488	1070	650	450	350	300	250	230	200	180	150
A_6	25996	930	580	370	300	250	220	180	150	120	
A_7	25455	850	500	330	260	220	180	150	130	100	
A_8	20580	580	330	240	180	150	130	100	90	80	
Productivity of dozers from Brand B, m^3/h											
B_1	131350		2600	2000	1425	1200	1000	850	775	625	600
B_2	102500		2200	1425	1100	900	775	625	580	500	420
B_3	66990	2300	1225	810	620	520	425	390	350	300	250
B_4	49850	1800	1000	625	500	400	350	300	250	225	200
B_5	34560	1050	575	400	300	225	200	175	160	150	120
B_6	38800	1000	560	350	250	200	175	150	125	100	80
B_7	38700	900	450	300	225	180	150	130	100	80	70
Productivity of dozers from Brand C, m^3/h											
C_1	35900	1250	750	550	420	350	270	230	190	180	160

Table 3 Productivity of dozers from different brands, equipped with semi-universal blade

Dozer designation	Dozer Weight, kg	Dozing distance, m									
		15	30	45	60	75	90	105	120	135	150
Productivity of dozers from Brand A, m^3/h											
A_1	113000										
A_2	104600	2730	1700	1220	950	800	700	600	550	500	450
A_3	66451	1900	1180	870	700	580	500	450	380	350	300
A_4	47900	1350	850	600	480	380	330	300	270	250	220
A_5	38488	800	500	380	300	240	200	180	150	140	120
A_6	25996	680	430	320	270	230	200				
A_7	25455	620	400	300	250	210	180				
Productivity of dozers from Brand B, m^3/h											
B_1	131350		2800	2025	1575	1225	1025	900	775	700	600
B_2	102500		1800	1300	1000	750	600	550	450	400	375
B_3	66990	2400	1225	800	600	500	425	375	300	275	250
B_4	49850	1800	975	600	425	375	300	250	225	200	190
B_5	34560	825	400	250	180	140	100	90	75	50	40
B_6	38800	1000	500	350	250	200	175	150	120	100	75
B_7	38700	900	450	300	225	175	150	130	100	75	50
Productivity of dozers from Brand C, m^3/h											
C_1	35900	1050	700	500	375	290	250	230	210	180	160
C_2	27000	625	390	270	200	150	125	110	100	90	85
C_3	20530	425	250	180	140	120	100				
C_4	15010	325	200	146	105	90	80				

2.1 Effect of dozer weight of productivity

The weight of the dozer is considered as the operating weight including operator, lubricants, coolant, full fuel tank, hydraulic controls and fluids, front pull device and standard service crankcase guard. It has been found that the dozer weight affects its productivity; productivity increases as dozer operating weight increases, this is shown in Figure 1, Figure 2 and Figure 3. This is because the dozer can push more as its weight increases and this means more material being dozed and pushed so accordingly the productivity of the dozer increase.

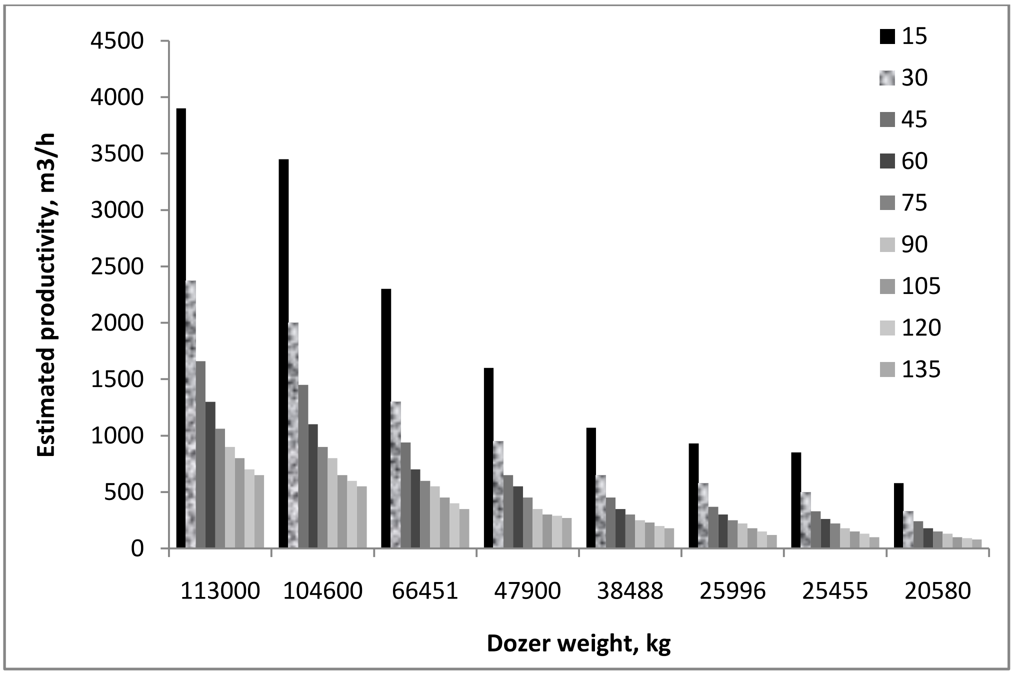

Figure 1 Productivity of dozers from different brands, universal blade, Brand A

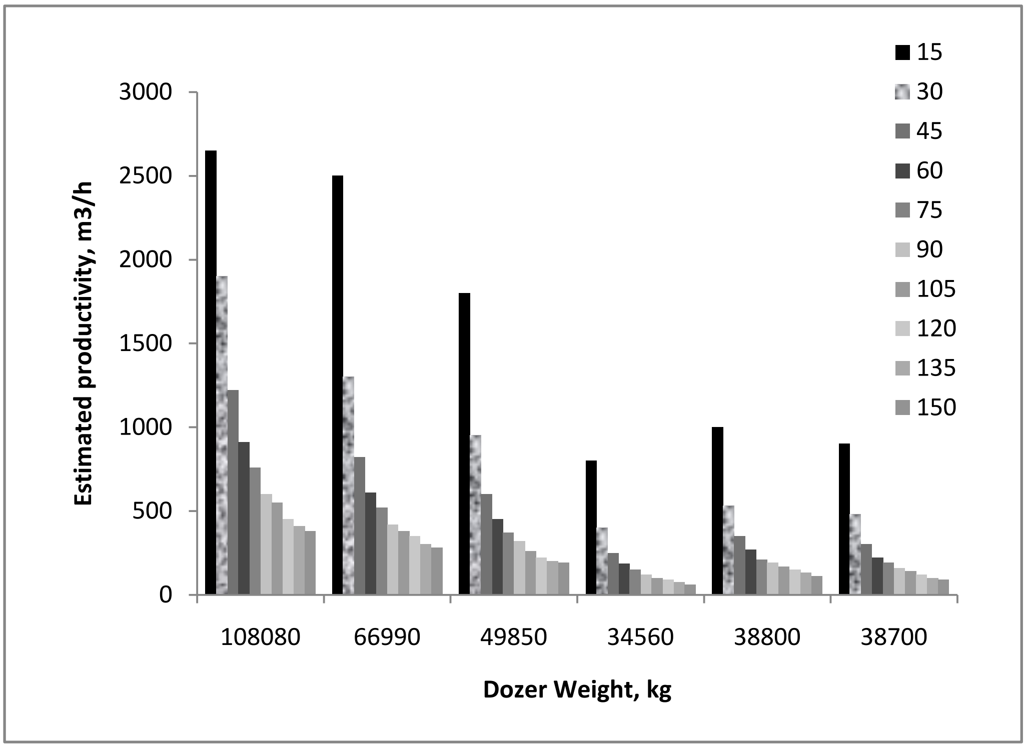

Figure 2 Productivity of dozers from different brands, semi-universal blade, Brand B

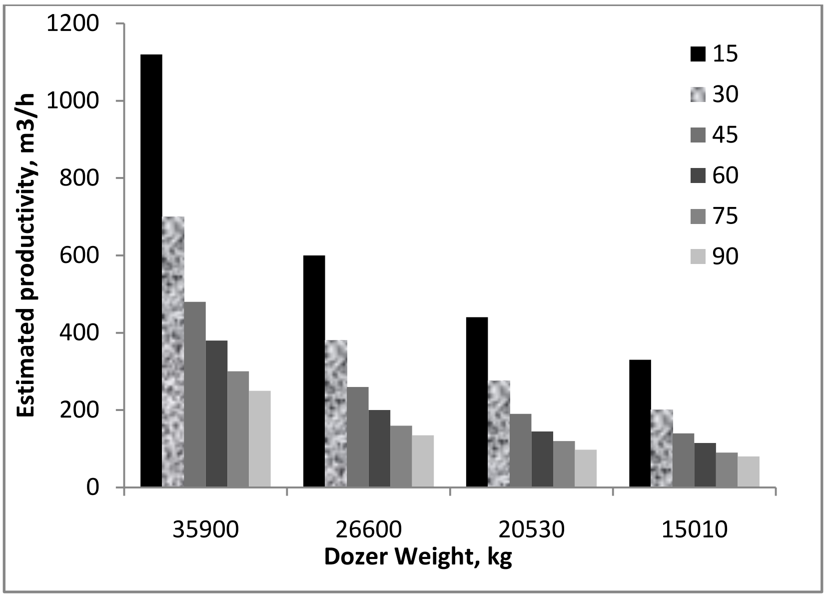

Figure 3 Productivity of dozers from different brands, semi-universal blade, Brand C

It also can be concluded from the below Figures that the dozing distance affect the dozer productivity; productivity decreases as the dozing distance increases that can be declared by as longer dozing distance means more material needed to be pushed so the pushing force needed is bigger and the available force needed for dozing is less.

A comparison between the dozers` productivity from three different brands is shown in Figure 4. The dozers from each brand and using semi-universal blades are selected such that they have approximately same power to weight ratio; (0.0061 to 0.0065). It is clear from Figure 4 that the dozers from brand (A) have highest productivity.

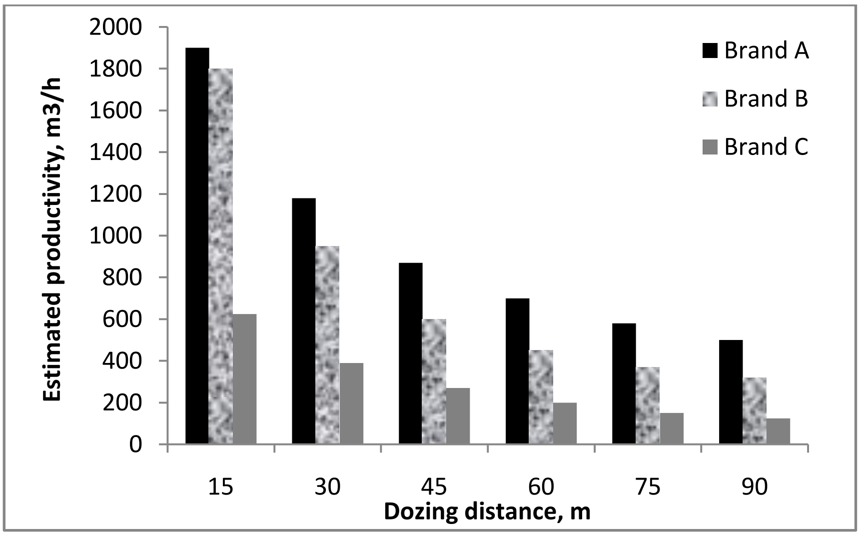

Figure 4 Productivity of dozers from different brands, semi-universal blade

2.2 Effect of type of blade on dozer productivity

Effect of type of blade on dozer productivity is dealt with into two parts: the kind of blade and the capacity of blade. It has been found that the dozer productivity of the dozer increase as the blade capacity increase and this is true for various dozing distance as illustrated in Figure 5, Figure 6 and Figure7. This can be explained as the blade capacity increases this means that the ability of the blade to doze more material increase so correspondingly the productivity of the dozer increases. It is found that the effect of blade capacity is the same for all the three different brands and for different blade types.

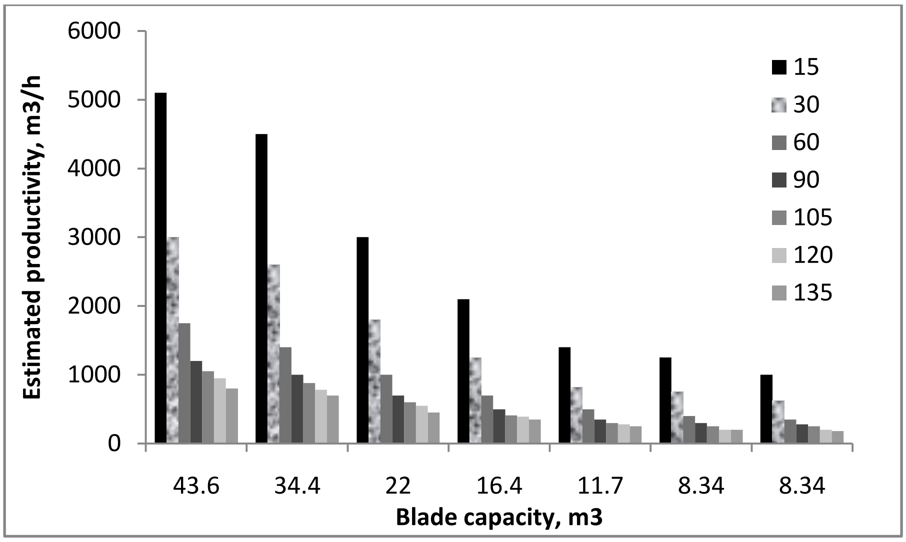

Figure 5 Productivity at different dozing distance of dozer equipped with universal blade for brand (A)

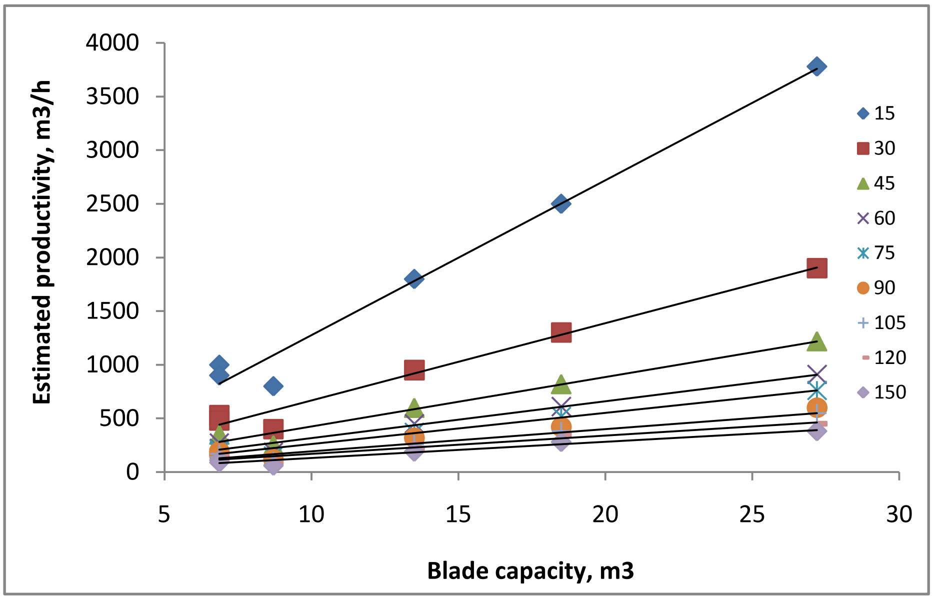

Figure 6 Productivity at different dozing distance of dozer equipped with semi universal blade for brand (B).

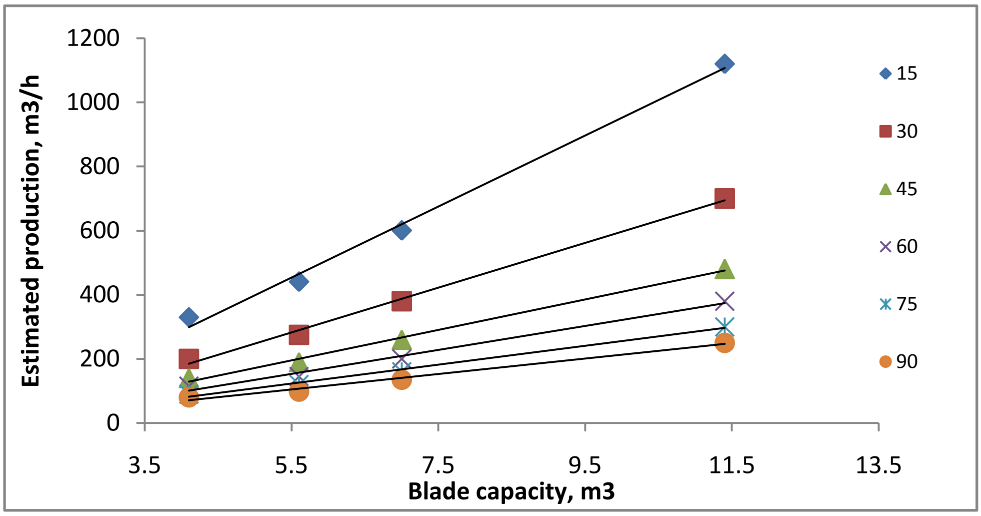

Figure 7 Productivity at different dozing distance of dozer equipped with semi universal blade for brand (C).

In Figure 8, the effect of shape of the blade used on productivity is shown. It has been found that the dozers from brand (A) equipped with universal blade have the highest productivity relative to dozers from the two other brands. This is due to fact that the surface area of the universal blade, refer to Figure 9. As the surface area of the dozing blade increases, the moved soil material in front the blade will be more and accordingly the productivity of the dozer increases.

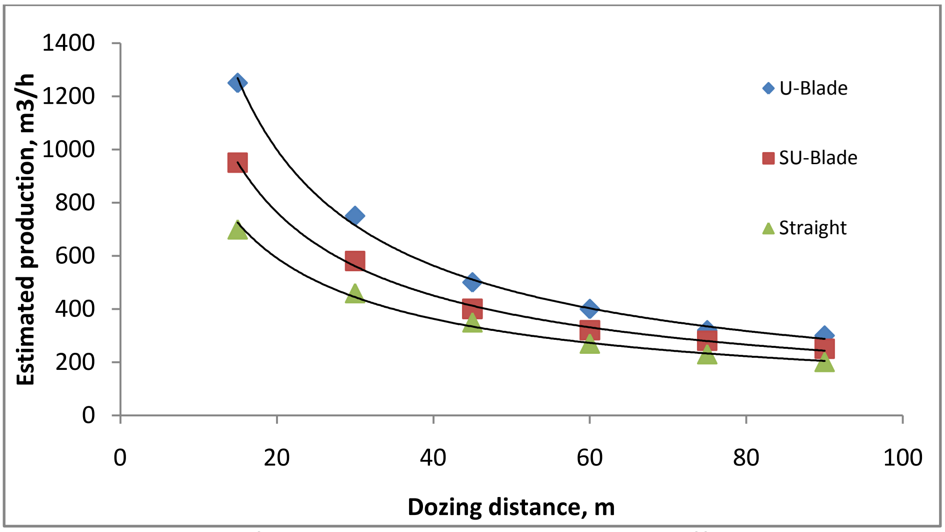

Figure 8 Dozer productivity for various dozing distance and with different blade shapes attached

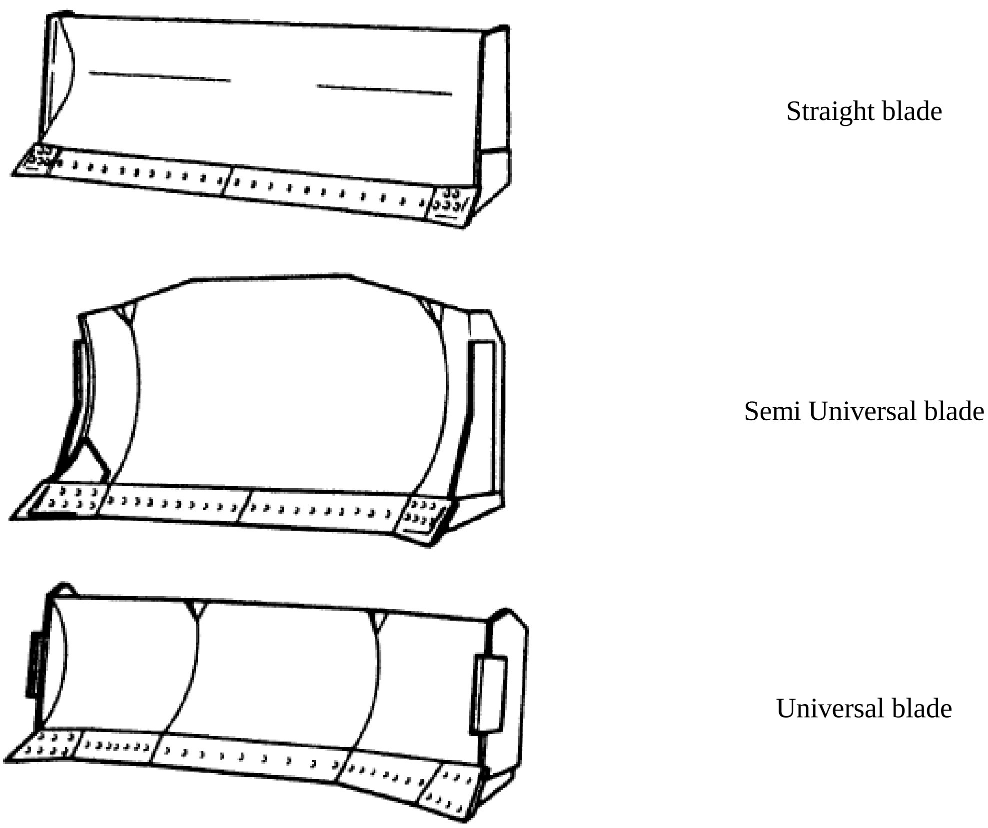

Figure 9 Shapes of various dozer blades

3Empirical equations for calculating dozers` productivity

In this study, data fit program is used to develop an empirical equation for each dozer brand that enables calculating its productivity. The dozer data such as; power to weight ratio, shoe width, blade capacity, and dozing distance are used as input data. The estimated productivity of the track-type dozer retrieved from dozers manuals has been compared against the results obtained from productivity empirical equations.

3.1 Empirical equation for dozer brand A

For developing a productivity empirical equation (Equation 1) for dozer brand A, eight different models were used, and their data have been introduced. Finally the following equation has been obtained;

Y_A= exp (a_AX_1+ b_AX_2+ c_AX_3+ d_AX_4+e_A) (1)

Where:

Y_A = productivity for brand A,

X_1 = dozing distance,

X_2 = power to weight ratio,

X_3 = width and

X_4 = blade capacity.

a_A= - 0.02027694731,

b_A= -65.01613574,

c_A= -2.277912459,

d_A= 0.05894368162

e_A= 8.364750586.

A comparison between the estimated productivity retrieved from the performance handbook of dozer brand A and the calculated productivity from the above empirical equation is shown in Figure 10 for five dozer models.

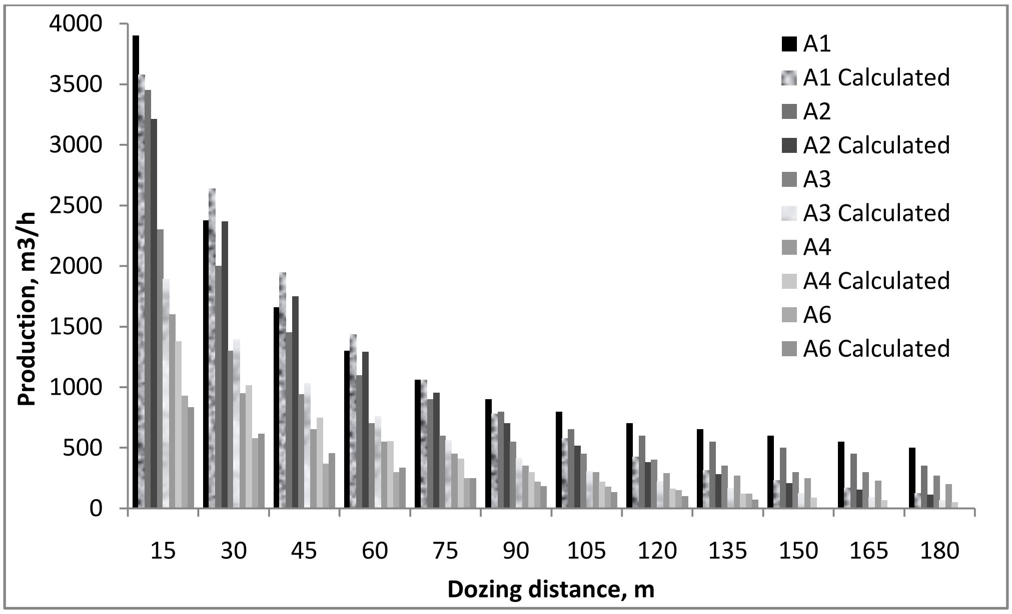

Figure 10 Comparison between estimated and calculated dozer productivity for brand A.

3.2 For brand B

For developing an empirical equation to calculate productivity for dozer brand B, seven different models were used, and the empirical equation is written as following Equation 2.

Y_B= exp (a_BX_1+ b_BX_2+ c_BX_3+ d_BX_4+e_B) (2)

Where;

a_B= - 0.01679468253,

b_B= -62.41600132,

c_B= -4.786156406,

d_B= 0.07958380743

e_B= 9.211688575.

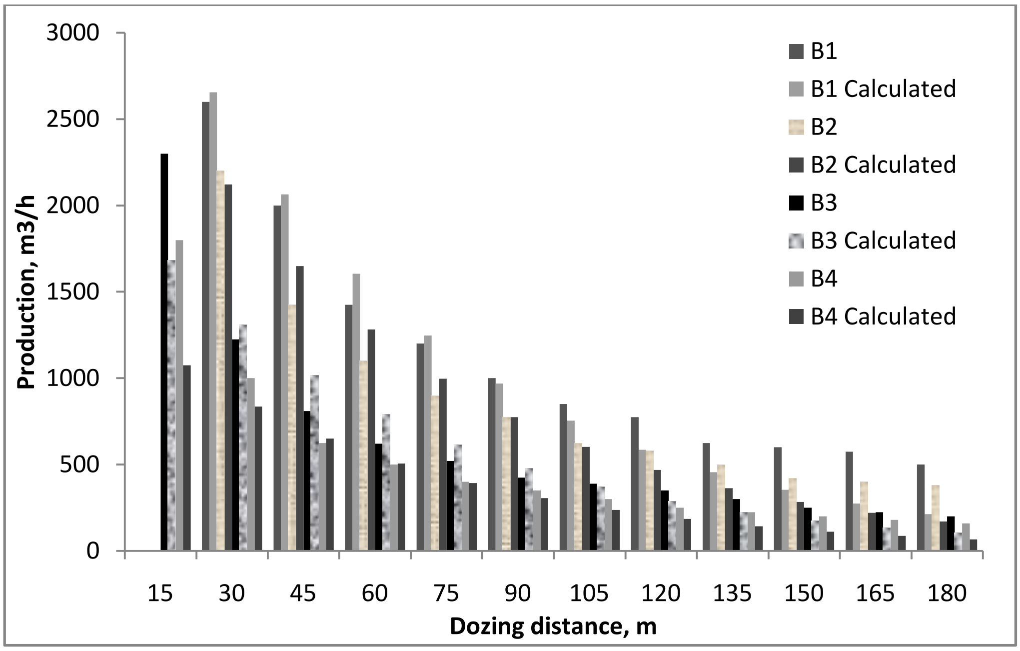

Figure 11 Comparison between estimated and calculated dozer productivity for brand B.

A comparison between the estimated productivity retrieved from the performance handbook of dozer brand B and the calculated productivity from the above empirical equation is shown in Figure 11 for five dozer models.

3.3 For brand C

For developing an empirical equation to calculate productivity for dozer brand C, four different models were used, and the empirical equation is written as following Equation 3.

$$Y_C = \exp (a_C X_1 + b_C X_2 + c_C X_3 + d_C X_4 + e_C) \quad (3)$$

Where;

a_C= - 0.01830648415,

b_C= -38.86771788,

c_C= 1.2024502,

d_C= 0.2207064179

e_C= 4.5772012.

A comparison is shown between the estimated productivity taken from the performance handbook of brand C and the calculated productivity from the above empirical equation for brand C is shown in Figure 12.

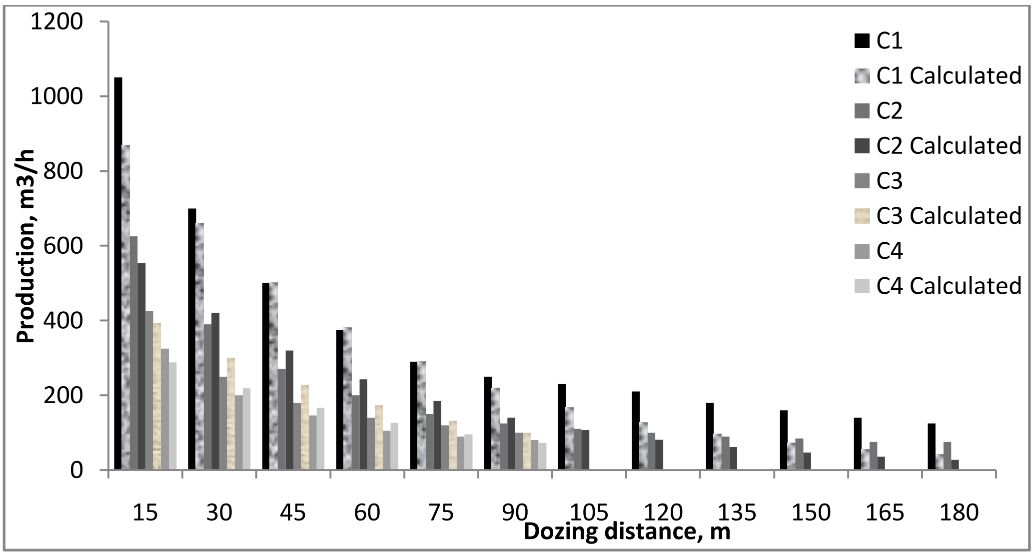

Figure 12 Comparison between estimated and calculated dozer productivity for brand C.

3.4 Dozer productivity general empirical equation

For developing dozer productivity general empirical equation data of twenty different dozer models from the brands were used and the following empirical Equation 4 has been obtained.(see Figure 13)

$$Y= \exp (aX_1+ bX_2+ cX_3+ dX_4+e) \quad (4)$$

Where;

a= - 0.0186489297,

b= -205.6459675,

c= -1.374016965,

d= 0.05296703336

e= 8.769771788.

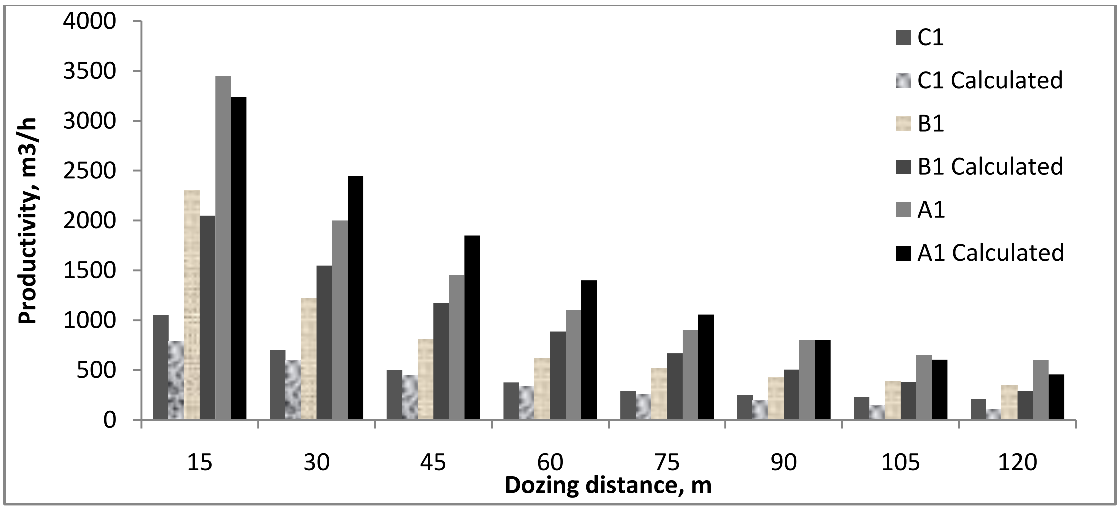

Figure 13 Comparison between the estimated and calculated productivity for dozers from three brands by using the developed general empirical

4 Effect of dozer design parameters on productivity

By using the productivity empirical equation for brand (A), it has been found that with increasing the blade capacity by 25 % the dozer productivity has increased 65% approx.

On the other hand by decreasing of the dozer track shoe width by 12% the productivity has been increased by 25%.

Reducing the power to weight ratio by 15% the productivity has been increased by 7.5%.

Similarly, the empirical equation for brand B has been used and it has been found that by increasing the dozer blade capacity with same percent as brand A the productivity has been increases by 54% and with reduction of the dozer track shoe width by 12% the productivity has been increased by 61%. In case the power to weight ratio has been decreased by 15% the productivity would be increasing by 7%.

For brand C, the following it has been found that the dozer productivity increases by 64% with increase of blade capacity by 25%, and by reducing the dozer power to weight ratio by 15% the productivity increases by 4.3%. Meanwhile, the dozer track shoe width has no significant effect on the productivity.

Figure 14 shows the evolution of dozer productivity with variation of blade shape, dozer power-to-weight ratio, and track shoe width.

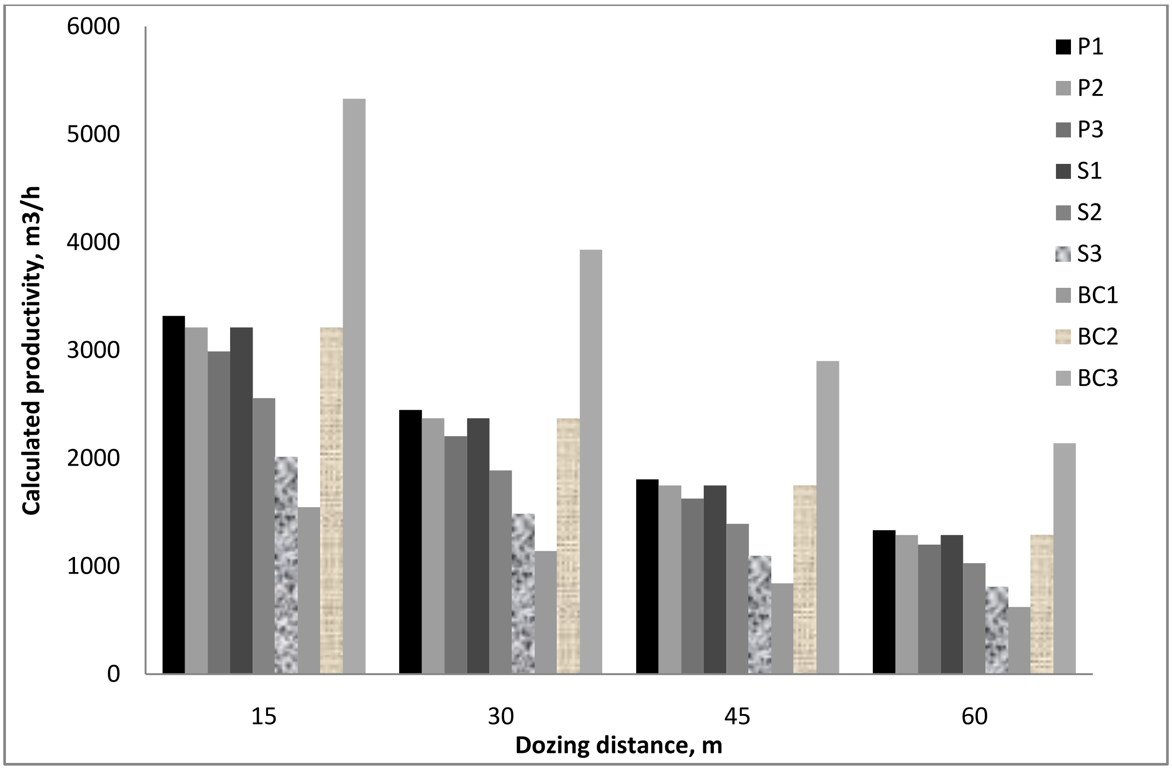

Figure 14 Evolution of dozer productivity with variation of blade shape, dozer power-to-weight ratio, and track shoe width.

5 Conclusions

Based on some design parameters of tracked dozers from three different brands, four empirical equations for calculating the dozer productivity have been developed; one for each brand and the last one is a general equation for any brand. Three different dozer design parameters have been considered in developing these equations; they are namely blade capacity, power to weight ratio and track shoe width. Finally it has been concluded that the blade capacity is the most effective parameter that considerably affects dozers` productivity; it increases by 60% if its capacity increased by only 25%. The power to weight ratio has a least effect on productivity as if it is reduced by 15%, the dozer productivity increases by only 6%.

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