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Regression modeling of Iraq Iran war using Lancaster/osipov war models

Kamalu C.I.O., Nwakaudu M.S., Obijiaku J.C., Oghome P., Okoh E., Uzondu F.N.
Department of Chemical Engineering, Federal University of Technology
P.M.B. 1526, Owerri, Nigeria.

***Abstract:** Iran and Iraq war data were obtained from internet and curve-fitted with Lanchester/Osipov war model. It was found that the data obeys the square law and that the war was a mixed one of 10.8% guerilla and 89.2% conventional as depicted by their parameters in the model. Also it was found that Iraq heavily used Chemical weapon (e.g. mustard gas, arsenic, mytotoxic) against Iranian soldiers. This is shown in the chemical casualty graph (Fig. 3). The continuous claim by the Iranians that the war was forced on them is shown in the initial commitment of troops to the war (Iraq (R_o) = 6484, Iran (B_o) = 2962). The inequality in the defensive and offensive parameters of the warring countries is found to be a: b = 12.34:1 signifying unequal fire power.*

Keywords: **Regression, curve-fitting, Iraq, Iran, war, Lanchester, Osipov, conventional guerrilla.**

I. BACKGROUND STUDY

Description of War

War is a conflict between nations or states carried on by force of considerable duration and magnitude by land, sea, or air for obtaining and establishing the superiority and dominion of one over the other for some cause. It is defined more concisely as the state of usually open and declared armed hostile conflict between states or nations [1,2]. Among the causes of war are ideological, political, racial, economic and religious conflicts. According to Karl Von Clausewitz [3] was is a continuation of political intercourse by other means and often occurs after means of compromise and mediation have failed. Throughout history, was has been a topic of analysis for scientist and researchers, especially following World War II. In the shadow of a possible outbreak of nuclear was between the United States and Russia, more research has been done on the subject of war than ever before [3, 4].

The Conventional or Direct Fire Model

This model describes historic battles like those fought in the Napoleonic and Civil Wars. Armies or navies lined up opposite each other and fired until one retreated and the other was victorious. The effectiveness of that fire and the number of combatants in each group will determine the outcome of the battle [5,6].

In the conventional model, the rate at which one force loses its fighters is proportional to the number of opponents. The constant of proportionality is a measure of the quality of armament and the level of ability of the opposing force [6,8].

The Guerrilla Combat Model

This model describes situations like battles fought by guerrilla groups in Lebanon. Soldiers can't see their opponents, but know that they are hiding in a region (perhaps of a city or in the jungle). They fire indiscriminately into the region hoping to hit their opponents. The larger the force in the region, the more likely they are to get hit, so a guerrilla combat unit is generally quite small [7, 9].

In the guerrilla campaign, the rate at which one force loses its fighters is jointly proportional to the number of opponents and the number of its own soldier in the region of combat [10]. The constant of proportionality is a measure of the quality of armament and the level of ability of the opposing force and of the style of combat. It is typically between one hundredth and one thousandth of that for conventional combat (lots of shots are fired that miss their targets).

The Mixed Combat Model

This is a mixture of conventional and guerrilla models. It has the characteristics of both conventional as well as guerrilla warfare [10].

The NBC Combat Model

This technologically-advanced warfare involves using the toxic, nauseating, gasping, suffocating, wheezing, irritating etc. properties of nuclear, biological and chemical (NBC) substances as weapons of war. It has no mathematical combat model presently and belongs to different class of warfare. However, there are NBC substances dissemination models. For instance, chemical agents are classified as having persistent or non-persistent effects [11 – 13].

Combat Modeling

Almost all leading armies in the world now engage in sophisticated combat modeling and war gaming exercises. Many have developed proprietary capability to support their military strategists. In the Western world, organizations such as the RAND Corporation [14, 15] have been engaged in such projects now for over 50 years.

The Lanchester Model of Combat

The state-of-art method for quantitatively projecting the aggregate progress of combat under various combat scenarios is known as the Lanchester Attrition Model [16, 17] and its variations [18 – 20]. Lanchester models are coupled differential equations based on certain

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assumptions and have limited validity as checked against real historical combat data by investigators [21]. But they are the best tools available today for the quantitative assessment of the aggregated dynamics and outcome of a combat engaging two forces,. Different forms of Lanchester models developed progressively since WW now incorporate area/aimed fire, heterogeneity of the fighting forces, limited movements of the combatants on the battlefield, and parameters and terms to approximate the effect of information [22].

II. HISTORY OF THE IRAQ – IRAN WAR

The Iran – Iraq war, also known as the Imposed War and Holy Defense in Iran, was an armed conflict between the armed forces of Iraq and Iran, lasting from September 1980 to August 1988, making it the longest conventional war of the twentieth century [23]. The war began when Iraq invaded Iran, launching a simultaneous invasion by air and land into Iranian territory on 22 September 1980 following a long history of border disputes, and fears of Shia insurgency among Iraq's long-suppressed Shia majority influenced by the Iranian Revolution [24]. Iraq was also aiming to replace Iran as the dominant Persian Gulf state. Although Iraq hoped to take advantage of the revolutionary chaos in Iran and attacked without formal warning, they made only limited progress into Iran and within several months wee repelled by the Iranians who regained virtually all lost territory by June 1982. For the next six years, Iran was on the offensive. Despite calls for a ceasefire by the United Nations Security Council, hostilities continued until 20 August 1988. The war finally ended with a United Nations brokered ceasefire in the form of United Nations Security Council Resolution 598.

The aim of this work is to validate the Lanchester/Osipov war models in predicting the nature, casualty figures, fire power, readiness etc. of the Iran – Iraq war.

Collection of Data

The raw data used in this work was obtained from the internet for the Iranian casualty. The Iraqi casualty was, found based on the claim (assumption) in the internet that to every Iraqi soldier killed, there were approximately 3½ Iranian soldiers killed in return (see Tables 5 and 6).

LANCHESTER/OSIPOV KINDS OF WAR MODELS

The generalized Lanchester's equations are of the form;

$\dot{B}(t) = aR(t)^pR(t)^q$ ………………………….. (1)

$\dot{R}(t) = bB(t)^pR(t)^q$ ………………………… (2)

Dividing equation (1) by equation (2) we have:

$$\frac{\dot{B}}{\dot{R}} = \frac{aR^pB^q}{bB^pR^q} = \frac{aR^{p-q}}{bB^{p-q}}$$

or $b.B^{p-q}, \dot{B} = a.R^{p-q}. \dot{R}$ …………………………… (3)

Integrating both sides of eqn (3) inserting limits of integration we have

$$b.\left|\frac{B^{p-q+1}}{p-q+1}\right|_B^{B_o} = a.\left|\frac{R^{p-q+1}}{p-q+1}\right|_R^{R_o}$$

or $$b.\frac{\left(B_o^{\,p-q+1} - B^{p-q+1}\right)}{p-q+1} = a.\frac{\left(R_o^{\,p-q+1} - R^{p-q+1}\right)}{p-q+1}$$

or $$\left(B_o^{p-q+1} - B^{p-q+1}\right) = a.\left(R_o^{p-q+1} - R^{p-q+1}\right)$$

Let m = p – q + 1, therefore

b.$\left(B_o^m - B^m\right) = a.\left(R_o^m - R^m\right)$………………… (4)

Eqn(4) is the generalized Lanchester mth law war model.

If p-q = O or p = q so that m= p-q+1 = 0+1 = 1

We obtain eqn(5) the Lanchester linear law ancient war model,

$b(B_o - B) = a(R_o - R)$………………………………(5)

If p-q = 1 so that m = p-q+1 = 1+1 = 2, we obtain eqn (6), the Lanchester square law for modern warfare

b($B_o^2 - B^2$) =a $\left(R_o^2 - R^2\right)$………..(6)

If p-q= - 1 so that m = p-q+1 = - 1+1 = 0, we obtain from eqn (3) that $bB^{-1} = aR^{-1}$ R or b $\frac{dB}{B} = a\frac{dR}{R}$ which yields, on integration, eqn(7), the Lanchester logarithmic law war model.

b In

$$\left(B/B_o\right) = aIn\left(R/R_o\right) or \left(B/B_o\right)^b = \left(R/R_o\right)$$ ……………….(7)

Note that for conventional warfare p>0 and/or q >0, and for guerrilla warfare p< 0 and/or q<0.

Curve-Fitting Lanchester/Osipov Generalized War Models using Multiple Regressions

The generalized Lanchester/Osipov war models are given as:

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$\dot{R} = bB^pR^q$ ………………………………………… (1)

$\dot{B} = bR^pB^q$ ………………………………………… (2)

Dividing (1) by (2) we have,

$$\frac{R}{B} = \frac{b}{a}\left(\frac{B}{R}\right)^{p-q}$$ ……………………………………………………………… (8)

Taking log of both sides in equation (8) we have

$$\text{In}\left(\frac{R}{B}\right) = Inb - Ina + (p-q)InB - (p-q)InR$$

$$\text{In}\left(\frac{R}{B}\right) = f_2 - f_1 - (p-q)\ \text{In}\ \frac{R}{B}$$

or $Y_1 = f_2 - f_1 - (p-q)X_1$ …………………(i)

or $Y_1 = K_1 - \alpha_1 X_1$ …………………………..(ii)

Multiplying (i) by (ii) we have;

$\dot{R}\dot{B} = ab(RB)^{p+q}$ …………………………….(9)

Taking log of both sides of equation (9) we obtain

$\text{In}(\dot{R}\dot{B}) = \text{In } a + \text{In } b + (p+q)\ \text{In}(RB)$

or $Y_2 + f_1 - f_2 + (p+q)X_2$ …………………(iii)

or $Y_2 = K_2 + \alpha_2 X_2$ ………………………… (iv)

Applying least square method to solve equation (ii) we have

$$S = \sum (Y_1 - K_1 - \alpha_1 X_1)^2$$

Which yields (v) and (vi)

$$\sum Y_1 - nK_1 - \alpha_1 \sum X_1 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots v$$

$$\sum Y_1 X_1 - K_1 \sum X_1 - \alpha_1 \sum X_1^2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots vi$$

Similarly applying the least square method in equation (iv), we have

$$S = \sum (Y_2 - K_2 - \alpha_2 X_2)^2$$

Which yields (vii) and (viii)

$$\sum Y_2 - nK_2 - \alpha_2 \sum X_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots vii$$

$$\sum Y_2 X_2 - K_2 \sum X_2 - \alpha_2 \sum X_2^2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots viii$$

Use the values

$\sum Y_1, \sum X_2, \sum Y_1 X_1, \sum Y_2 X_2, \sum X_2^2 and \sum X_1^2$ and gotten from Table 2.

Substituting the values for the variables and solving equations (v) and (vi) simultaneously.

$- 10.4289 - 9K_1 + 10.4289\alpha_1 = 0$ ……………… (v)

$- 12.72306 + 10.4289K_1 - 12.72306\alpha_1 =$ …….. (vi)

or $K_1 = 0$ and $\alpha_1 = 1$

Similarly substituting the values of the variables and solving simultaneously equations (vii) and (viii)

$160.5732 - 9K_2 - 186.1768\ \alpha_2 = 0$ …………….. (vii)

$3346.34 - 185.1768K_2 - 3882.776\ \alpha_2 = 0$ ………… (viii)

or $K_2 = 1.56$ and $\alpha_2 = 0.784$

so that from the correlation table 3

$q = -0.108$ and $p = 0.892$

$f_2 = f_1 = 0.78025$

$a = e^{0.78025 = 2.1820}$

Since $f_1 = f_2 = 0.7802$ hence $a = b = 2.1820$

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Having obtained the values for a, b, p and q, substitute into the equations (1) and (2) to obtain the model for the Iraqi and Iranian warfare respectively.

$$\dot{R} = 2.182 B^{0.892} R^{-0.108} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

and

$$\dot{B} = 2.182 R^{0.892} B^{-0.108} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

From equation (4)

$$B^m = B_o^m - \frac{a}{b}\left(R_o^m - R^m\right)$$

Since m = p – q + 1 = 0.892 + 0.108 + 1 = 2 (Square law of modern warfare).

So that from eqn (4)

$$R^2 = R_o^2 - B_o^2 + B^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Table 1: Regression Analysis Table

T(years)	R	B	$\dot{R}$	$\dot{B}$	$\dot{R}/\dot{B}$	$\dot{R}\dot{B}$	RB	R/B	Y_1=In(R/B)
0	0	0	0	0	0	0	0	0	0
1	5710	20000	5710	20000	0.2855	1E+08	1E+08	0.2855	-1.2535
2	17150	60000	8575	30000	0.2858	3E+08	1E+09	0.2858	-1.2523
3	5713	20000	1904.3	6666.7	0.2857	1E+07	1E+08	0.2857	-1.253
4	28570	100000	7142.5	25000	0.2857	2E+08	3E+09	0.2857	-1.2528
5	85720	300000	17144	60000	0.2857	1E+09	3E+10	0.2857	-1.2527
6	54280	190000	9046.7	31667	0.22857	3E+08	1E+10	0.2857	-1.2529
7	17150	60000	2450	8571.4	0.2858	2E+07	1E+09	0.2858	-1.2523
8	5708	20000	713.5	2500	0.2854	2E+06	1E+08	0.2854	-1.2539
9	20000	30000	2222.2	3333.3	0.6667	7E+06	6E+08	0.66667	-0.4055
$\sum$							Summation		-10.429

Y_1=In($\dot{R}/\dot{B}$)	Y_2=In($\dot{R}\dot{B}$)	X_1=In(R/B)	X_2=In(RB)	Y_1X_1	Y_2X_2	X_1^2	X_2^2
0	0	0	0	0	0	0	0
-1.25351	18.55346	-1.25351	18.55346	1.571295	344.2309	1.571295	344.2309
-1.25235	19.36556	-1.25235	20.75185	1.568371	401.8712	1.568371	430.6394
-1.25299	16.35676	-1.25299	18.55399	1.569979	303.4832	1.569979	344.2504
-1.25281	19.00045	-1.25281	21.77304	1.56954	413.6975	1.56954	474.0652
-1.2527	20.7515	-1.2527	23.97038	1.569248	497.4214	1.569248	574.5791
-1.25287	19.47317	-1.25287	23.05669	1.569679	448.9869	1.569679	531.611
-1.25235	16.86003	-1.25235	20.75185	1.568371	349.8769	1.568371	430.6394
-1.25386	14.39423	-1.25386	18.55311	1.572174	267.0577	1.572174	344.2179
-0.40547	15.81799	-0.40547	20.21244	0.164402	319.7202	0.164402	408.5427
-10.4289	160.5732	-10.4289	186.1768	12.72306	3346.346	12.72306	3882.776

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Table 2: Nomenclature and Correlation between the parameters used

$\dot{B}(t)$ = rate of change of blue forces	$\alpha_1 = p - q$
$\dot{R}(t)$ = rate of change of red forces	$\alpha_2 = p + q$
B(t) = strength of blue forces at time t	$K_1 = f_2 - f_1$
R(t) = strength of red forces at time t	$K_2 = f_1 - f_2$
a = attrition parameter for red forces	f_1 = In a
b = attrition parameter for blue forces	f_2 = In b
p = exponent parameter of attacking force	$X_1 = In\left(\frac{R}{B}\right)$
q = exponent parameter of defending force	$X_2 = InRB$
n = $\alpha_2 = P + q$	$Y_1 = In\left(\frac{R}{B}\right)$
v = 1 – n	X_2 = In $\dot{R}\dot{B}$
m = 2p + v = p-q+1	

3D Solution of Lanchester/Osipov Generalized War Model Equations Using the Product of the Two Forces

$\dot{R}$ = bB^pR^q --------------------------- - 1

$\dot{B}$ = aR^pB^q --------------------------- - 2

Multiplying the rates of casualties from both sides, we have;

$\dot{R}\dot{B}$ = $ab(RB)^{p+q} = ab(RB)^n$ i.e n = p + q

Or $\frac{dR}{dt}\frac{dB}{dt} = abR^nB^n$

Taking double integration

$$\iint \frac{dR}{R^n}\frac{dB}{B^n} = ab \iint dt\ dt$$

Solving the integration of red (R) force;

$$ab \int_t^0 dt \int_t^0 dt = \int_B^{B_o} \frac{dB}{B^n} \int_R^{R_o} \frac{dR}{R^n}$$

$$-abt \int_t^0 dt = \left.\frac{R^{1-n}}{1-n}\right|_R^{Ro} \int_B^{B_o} \frac{dB}{B^n}$$

$$= \frac{R_o^{1-n} - R^{1-n}}{1-n} \int_B^{B_o} B^{-n}\, dB$$

Solving the integration of blue (B) force;

$$Abt^2 = \frac{R_o^{1-n} - R^{1-n}}{1-n} \left.\frac{B^{1-n}}{1-n}\right|_B^{B_o}$$

$$= \frac{R_o^{1-n} - R^{1-n}}{1-n} \frac{B_O^{1-n} - B^{1-n}}{1-n}$$

$$(1-n)^2\ abt^2 = (R_o^{1-n} - R^{1-n})(B_o^{1-n} - B^{1-n})$$

Let v = 1 – n, i.e. v – 1 – p – q, therefore;

$$V^2abt^2 = (R_o^v - R^v)(D_o^v - B^v)$$

……………… (11)

Plotting the model eqn (10) with MATLAB toolbox shows a misfit if the parameters a = b. But if $C = \frac{b}{a}$, a good fit of R^2 = 0.9981 is obtained (Fig. 1 and Table 4).

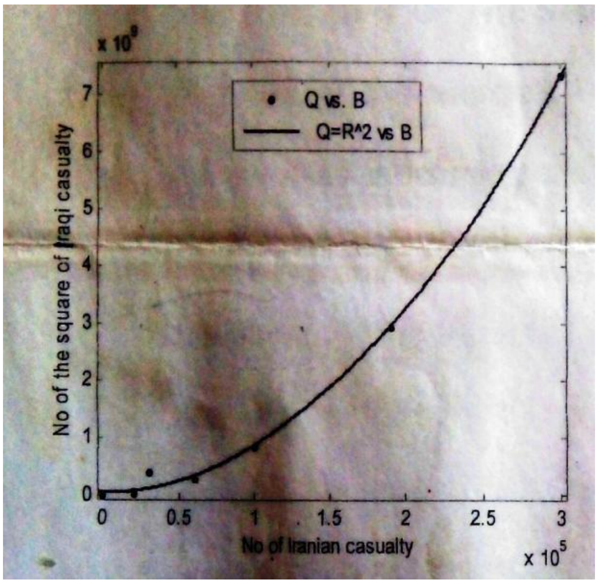

Fig 1: No of square of Iraqi casualty versus time (raw data)

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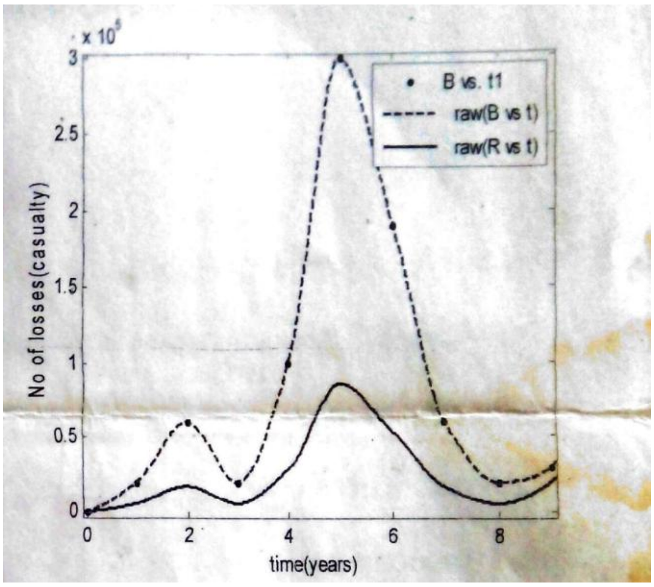

Fig 2: No of Iranian and Iraqi casualties versus No of Iranian casualty

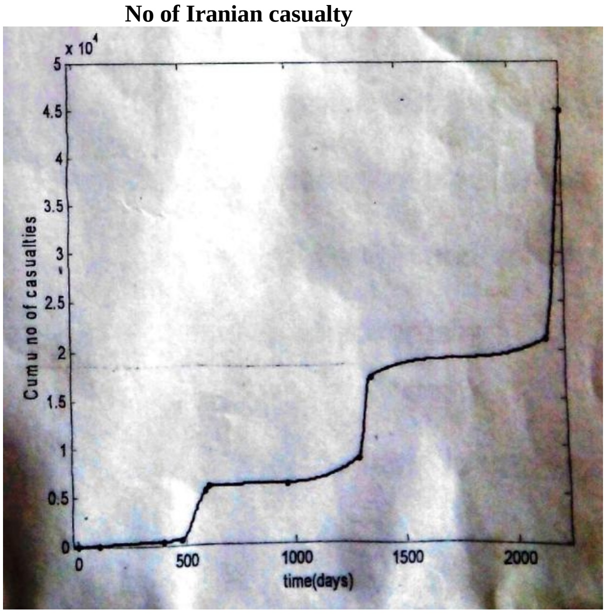

Fig 3: Cumulative number of Iranian casualty due to Iraqi chemical weapon against time

Table 3: Coefficient and goodness of fit for equation 10

Coefficient (with 95% confidence bounds	Goodness of fit
B_0 = 2962 (-4.14 e +010, 4.146 e +010)	SSE = 9.331 e +016
R_0 = 6484 (-1.535 e +009, 1.535 e +009)	R^2 = 0.9981
c = 0.08104 (0.07714, 0.08494)	R-Adj = 0.9975
	RMSE = 1.155 e +008

$F(X) = R_0^2 - cB_0^2 + cX^2$, where $F(X) = R^2 = Q$

Hence, $a \neq b$ (as calculated) but b = ca. This will affect f_1, f_2, k_1 and k_2 but not p, q, α_1, α_2 and m. Values, so that

$$\dot{R} = 0.1768\ B^{0.8927}\ R^{-0.1073}$$ …………………… (1)

$$\dot{B} = 2.1820\ R^{0.8927}\ B^{-0.1073}$$ …………………… (2)

Table 4: Recomputed Model Casualty Values

B	$f(X) = Q = R^2$	R
0	41,335,300	6,429.25
30,000	114,271,000	10,689.76
60,000	333,079,000	18,250.45
90,000	697,758,000	26,415.11
120,000	1,208,310,000	34,760.75
150,000	1,864,730,000	43,182.52
180,000	2,667,030,000	51,643.30
210,000	3,615,190,000	60,126.45
240,000	4,709,230,000	68,623.83
270,000	5,949,140,000	77,130.67
300,000	7,334,920,000	85,644.15

If v = 1 – p – q = 1 – 0.892 + 0.108 = 0.216 and from table 4, since a = 2.182, b = ca = 0.08104 (2.182) = 0.1768, B_o = 2962, R_o = 6484

Eqn(11) becomes $0.01813t^2 = (5.622 - B^{0.216})(6.658 - R^{0.216})$ … (11)

Fig. 2 is the raw data plot of the number of losses (casualty versus time for both Iran (B) and Iraq (R).

III. DISCUSSION

The tables containing the raw data with which the above plots were done are Tables 6 and 7.The Iran – Iraq war was clearly obeying the Lanchester/Osipov square law modern warfare (m = 2). And when the raw data was plotted with the square law (Fig. 1), it fitted to a degree of R^2 = 0.9981 and declared initial commitment of troops from both sides: Iraq (Red) = 6484 and Iran (Blue) = 2962. However, Iraq attacked first with 6430 soldiers before Iran's commitment of troops into the war (Table 5) proper. The offensive of Iraq (a = 2.182) and the defensive of Iran (b = 0.1768) were not equal initially, though the war seemed to balance b save the higher sacrifice (casualty) of Iran, due to Iraqi heavy use of chemical weapons (Fig.3).

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The war was a mixed one with guerrilla style of 10.8% (q = - 0.108) and conventional style of 89.2% (p = 0.892). This is real since the desert has few places for hiding except trenches etc. (characteristic of guerrilla warfare).

From Fig. 2 it is, also, noticed that there was more Iranian casualty than Iraqi casualty. The peak casualty of Iraq was about 85000 while that of Iran was about 300000. There is a similarity between the two curves in that the casualty variation with time follows the same trend.

Fig. 3 was done to show the drastic effect of chemical weapons in warfare. After 500days into the war the increase of casualty surged high signifying great casualty response to the chemical weapons used by the Iraqi troops. Each surging up signifies a new drop of lethal chemical weapons. Within 0 – 500days into the war, the Iranian casualty changes with time echelon-wise. At 500days, 1400days, 2250days there were steep increases in the number of Iranian casualty probably as a result of the adverse effect of chemical weapons used against them.

IV. CONCLUSION

After series of calculations, curve-fittings, and data analysis the following conclusions can be drawn:

- The Lanchester square model fits the Iraq-Iran war data having an R-square value of 0.9981 which signifies a good fit.
- The attrition parameters of the two forces are not equal i.e. $a \neq b$, showing unequal fire power (Iraqi NBC weaponry could have weakened the Iranian fire power).
- From the regression computations it is observed that the ware-type parameter is negative i.e. q = - 0.108, this implies that the war was guerrilla in nature, and, also, the war-type parameter is positive i.e. p = 0.892 signifying conventional warfare. We could conclude that the war was mixed one having approximately 10.8% guerrilla and 89.2% conventional nature.
- The war is heavily marred with excessive use of chemical warfare agents by the Iraqi on the Iranian troops as depicted by Fig. 3.
- Initial commitment of troops were Iraq (R_o) = 6484, Iran (B_o) = 2962. Also, Iraq attack Iran first with 6430 soldiers when Iran has not yet committed troops to the war, thus, proving the claim by Iran that Iraq forced the war on her (Iran).

V. RECOMMENDATIONS

The following are the recommendations to operational research departments and the military.

- Lanchester Equations should be applied in a homogeneous weapon use scenario.
- There should be a stronger campaign on the disarmament of nuclear, biological and chemical (NBC) weapons since their use can obliterate a nation completely.

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AUTHOR BIOGRAPHY

Kamalu, C.I.O. is an Associate Professor of Chemical Engineering in Federal University of Technology , Owerri, Nigeria. He has Bachelors, Masters and Doctorate degrees in Chemical Engineering with a specialization in Energy Engineering. He has more than sixty published papers to his credit.

Nwakaudu M.S. is an Associate Professor of Chemical Engineering in Federal University of Technology , Owerri, Nigeria. He has Bachelors, Masters and Doctorate degrees in Chemical Engineering with a specialization in Raw Material Processing and is a Fellow of Nigeria Society of Chemical Engineers and Associate Dean of School of Engineering.

Obijiaku J.C. holds a Masters Degree from the Department of Chemical Engineering in Federal University of Technology, Owerri, Nigeria. He also had his Bachelor's degrees in Chemical Engineering from same institution, and has great teaching skills.

APPENDIX (Referred Tables)

Table 5: Iraq-Iran War Death Data (extracted from graph based on the assumption that for every Iraqi casualty there were 3 ½ Iranians)

Year	Time(t)	Iran Annual Death (B)	Iraq Annual Death (R)
1979	0	0	0
1980	1	20000	5710
1981	2	60000	17150
1982	3	20000	5713
1983	4	100000	28570
1984	5	300000	85720
1985	6	190000	54280
1986	7	60000	17150
1987	8	20000	5708

Table 6: Deaths and Casualty Data of Iran Troops as a result of Chemical and Biological Weapons used by Iraqi Troops (extracted from graph)

S/No.	Date	Days	Death	Casualty
1.	22/9/1980	0	0	0
2.	27/10/1982	100	4	68
3.	15/8/1983	293	19	318
4.	9/11/1983	86	4	70
5.	1/3/1984	113	1200	5000
6.	17/3/1984	16	23	400

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7.	9/3/1985	357	10	200
8.	5/2/1986	333	35	2500
9.	3/4/1986	58	700	8500
10.	1/6/1988	790	60	4000