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EFFECTIVE USAGE OF FIXED AMOUNT OF SCATTERABLE MINES ON THE INFANTRY BATTLEFIELD

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Abstract

The basic mathematical tools are developed to determine the optimum emplacement of limited numbers of scatterable mines on the infantry battlefield. A deterministic model is developed for heterogeneous infantry battalion level battle using APL version 7.0. The Helmbold-type combat equation is applied to claculate comparative casulties, and range dependency is also considered to establish the correlation between attrition rate coefficients and the distance of opposing forces. Based on this deterministic model the effective range for employment of scatterable mines is determined. Because mines are primarily effective when employed in conjunction with direct fire weapons, it is inferred that minefield are best employed when used within the maximum effective range of infantry weapons systems such as the M16Al rifle. The model developed verifies this fact.

1. INTRODUCTION

1.1 Background The development of scatterable mines has greatly enhanced the potential impact of mine warfare on combat effectiveness. Scatterable mines present appealing options to the tacticians that were not available with conventional buried land mines. where enemy

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traffic is highly probable, mines can be tactically employed during the coures of the battle by delivery means such as artillery, rotary and fixed-wing aircraft, ground vehicle, and portable equipment.

In a future battle, the importance and the role of mine warfare will be increased due to the flexibility in using scatterable mines. This paper was prepared due to the following points :

First, unlike the terrain in NATO countries, the Korean peninsula is very complex geographically as it has many small streams, mountains, hills, and reservoirs. As a result, it is relatively easy to channalize the enemy's avenues of approach during the attack. Therefore, defense operations using mine warfare are more effective in Korea than in other battle areas. Because of their flexibility, rapid emplacement, and ease in clearing, scatterable mines provide many advantages to the defender. Mines will be the major weapon system to hinder the advance of opposing forces in a future Korean war. On the Korean War, data from the 1st ROK Army, 70% of South Korean tank losses were killed by mine warfare.

Second, to provide information to decision makers as to the value of scatterable mines which are considered for investment and development in the Army 5-year force improvement.

Third, as the ROK Army still does not posses a unigue mine warfare model, this paper can contribute to the development of a conbined wargame model which matches the terrain characteristics of the Korean peninsula.

Finally, each branch of the ROK Army is preparing for the coming 21st Century. In that time frame, the international security environment, battle conditions and weapons systems will be changed. Therefore, the ROK Army engineer development must provide effective countermobility support on the future battlefield. I hope that this study will be a useful addition to developing better tactical concepts in the ROK Army.

1.2 Methodoloqy To build a deterministic model, a typical scenario is employed using a Red(attacker) battalion and Blue(defender) company. Both forces are equipped with only infantry small arms. (e.g., rifles and machine guns; no mortors, anti-tank or artillery fires available.) However, the Blue force can be supported by a division artillery battery which has a limited amount of scatterable mines. Blue artillery can fire the scatterable mines with several methods of employment based on location and density. The Helmbold-type combat equation with the Weiss parameters is applied to compute unit casualties as the equation can handle both the Lanchester Square and Linear Laws. The model is programmed in APL (A Programming Language) which allows efficient handling of attrition rate coefficients and other data vectors/matrices. In the model, the Lanchester Linear Law is utilized for the Blue M203 grenade launcher and the Red RPG-7 rocket propelled grenade, and the Square Law is used for infantry rifles (M16Al, Ak-47) and machine guns (M60, SG). To test the model, a constant time increment of one minute is assumed. Following each increment, we compute attrition rates A_{ij}, B_{ji}, casualties of each weapon system of each side, firepower indices and force ratios. The battle is initiated at a range of 1.1㎞ which is the maximun effective firing range for the M60 machine gun, and the battle is terminated when any one side reaches its breakpoint. Weapon system scores are computed using the Potential Anti-Potential (PAP) method which is defined by the following basic principle :

The value (score) of a weapon system is directly proportional to the rate at which it destroys the value of opposing enemy weapon system.

Thus, the value of a system depends on its kill rates and on the value of the enemy systems it kills. After defining useful measures of effectiveness (MOEs) to the output of the model we compared each battle situation with respect to mine density and its emplacement. Then, based on the scenario, the most effective employment range is determined.

2. TACTICAL USAGE OF SCATTERABLE MINES

The principle purpose of mine warfare is in slowing the enemy advance in order to efficiently employ available direct fire weapons against him. The effects of mines are thus highly interactive with other weapons and can only be measured in conjunction with them. Due to strategic and geographic considerations, South Korea has a defense-based concept for military operations against North Korea. This implies that mine warfare experties is much required by the ROK Army.

The approach taken in this section is to correlate the placement of scatterable mines to the range where infantry unit engagement will most likely occur. This approach is keyed by the dilemma of the attacker when faced with a combination of mines and directed fire weapons. In 1974, Robert A. Lasken applied this to tank/antitank engagement; this is depicted in Figure 1. (Ref. 31). The unit casualties by mines and direct fire weapons are plotted as a function of unit speed. The upper curve represents the combined effects. At low attack speed the offense will minimize the effect of mines through its increased time to detect and avoid them, while at high speeds the offense will reduce the effectiveness of direct fire weapons. However, when both are present the offensive force must compromise and proceed at velocities near V3 in order to minimize its total losses. Mines therefore primarily enhance defensive strength when employed in conjunction with infantry unit/direct fire engagements as the enemy's offensive options are reduced.

Historically, it has been noted that the range-frequency distribution for engagement of tank-freguent distribution to the first interruption in the line of sight for the same terrain.

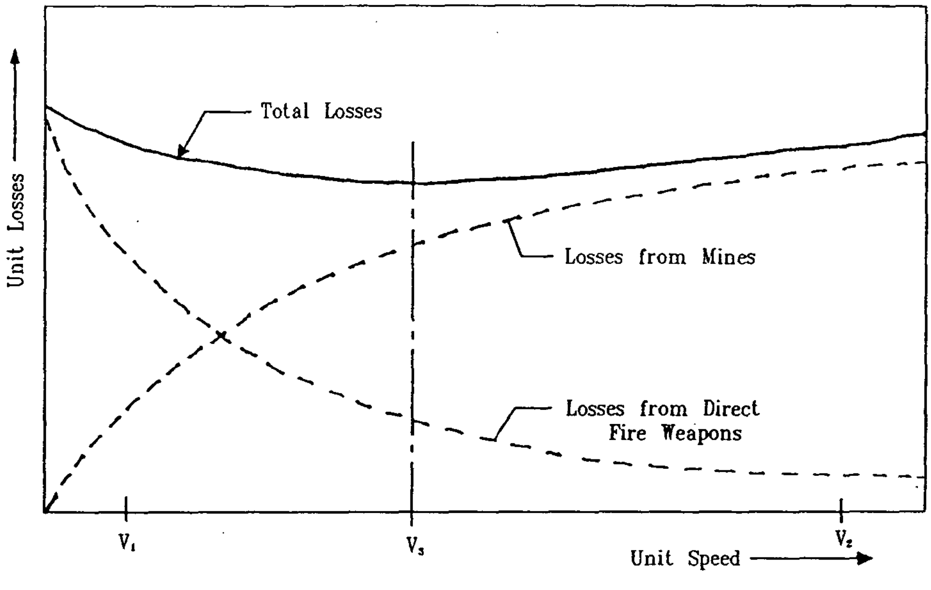

Fig. 1 Unit casualties versus unit speed

[Ref. 3]. This interesting correlation has led to the hypothesis that given two intelligent adversaries, one trying to maximize the range of engagement while the other is trying to minimize it, the range of engagement will tend toward the first interruption in line of sight. The following section develops a model to determine where infantry unit engagements are likely to occur and then infers from this the critical range for emplacing scatterable mines.

3. MODEL DEVELOPMENT

3.1 Tactical scenario One company level Blue force unit is defending in the fortified defense zone (GOP, COP, etc). The opposing forceagainst this Blue force is one battalion. Red force has three heterogeneous weapon systems (AK47, SG, RPG-7) and Blue force has corresponding four heterogeneous weapon systems (M16A1, M60, M203, Mines). Initial force elements of both sides are shown in Table 1.

Table 1. Initial force elements

Blue (friendly)		Red (enemy)	
M16A1 :	152	Ak47 :	447
M60 :	10	SG :	26
M203 :	9	RPG-7 :	24
*MINES :	96		

* based on M692/731 artillery delivered anti-personnel scatterable mines density (0.001/m^2)

Data for Table 1 are assumed with referring to Ref. 4, 5. Battle in the scenario is executed with multiple Lanchester type equations. In other words, rifle and machine gun are used for aimed fires, and M203 and RPG-7 are used for area fires. It is considered mixed infantry forces X, Y, as shown :

$$X = (x_1(t),\ x_2(t),\ x_3(t),\ x_4(t))$$

$$Y = (Y_1(t),\ Y_2(t),\ Y_3(t))$$

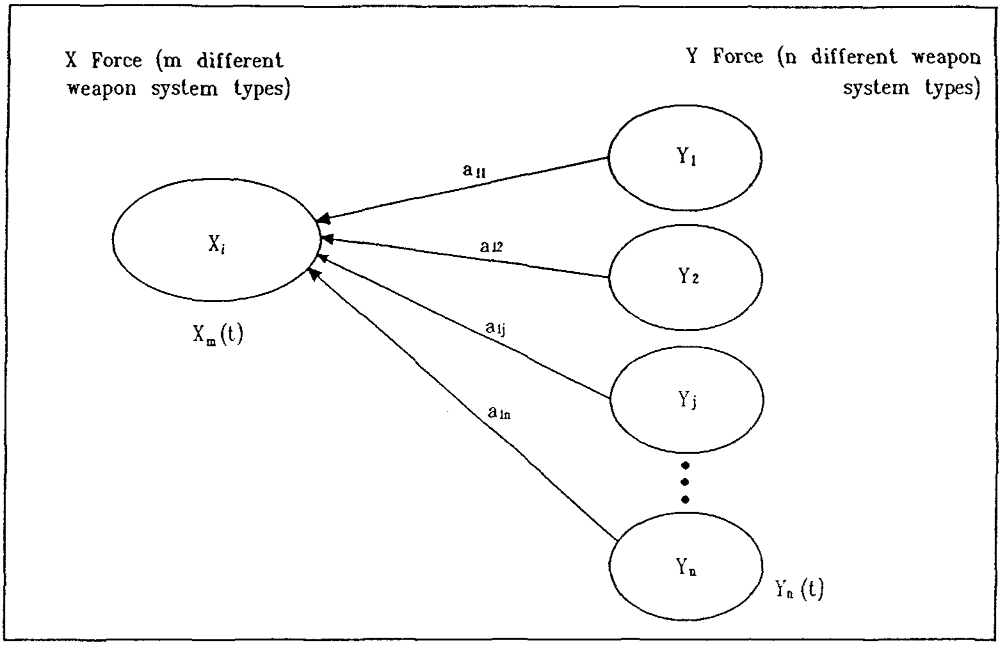

Fig. 2 Heterogeneous Combat x_i system vs. Y force

where $x_i(t)$ = number of X survivors of weapon system i at time t. A Lanchester type model for attrition assessment will involve 4+3 differential equations assessing the casualty rate for each X_i, Y_j separately. If we select a single x_i system and consider attrition to that system it would resemble Figure 2. Therefore, it can be assessed the attrition to a single system as

$$\frac{dx_i}{dt} = \sum_{j=1}^{3} \text{(attrition of } X_i \text{ systems caused by } Y_j \text{ systems)}$$

(Note : the attrition may be 0 for some j if Y_j does not kill X_i)

Artillery as the means for mine delivery is used because the mines can be quickly emplaced in desired locations.

3.2 Assumptions The assumptions and description of the scenario are as follows :

1. An infantry rifle company (Blue force) vs a light infantry battalion (Red force) battle.

2. Blue force entrench in prepared defensive positions with the Red battalion force deployed tactically across the width of the defensive sector.

3. The battle starts at a distance of 1.1㎞(M60 machine gun maximum effective range).

4. Within a given time increment, the distance between opposing weapon systems is averaged based on a constant rate of advance at a given speed in the initial stage and then decreased based on the correlation between range and speed.

5. All weapon systems are inter-visible but subject to the acquisition paramenters of their fire control system.

6. Terrain and weather provide no restrictions to movement.

7. Scenario dose not account for the air-ground battle nor for chemical warfare.

8. Both indirect fire weapon systems are not represented, other than the delivery means for scatterable mines is Blue artillery 155㎜ howitzer.

9. The ADAM(Area Denial Artillery Munition) rounds are used for Blue scatterable mines emplacement. An ADAM round contains 36 AP mines.

10. Whenever the Red force reaches a minefield, it requires more time to bypass than to breach the minefield. Therefore, the Red force will choose to break through.

3.3 Algorithm The rule for representing the battle is based on discrete time steps. The battle clock will begin when the Red force reaches the maximun effective range of the M60 machine gun(1.1㎜). The flow chart of this model is given in Figure 3.

3.4 Unit Casualties It is assumed that casualties in battle are caused by direct fire weapons and mines.

3.4.1 Direct Fire First, to determine casualties from direct fires, the Helmbold equations are utilized. Based on consideration of historical data, Helmbold has proposed a modification of Lanchester's equation for "modern warfare" to account for inefficiencies of scale for the larger force when force sizes are grossly unequal. His basic idea is to modify the relative force attrition(or fire effectiveness) capability by a multiplicative factor dependent only on the force ratio.

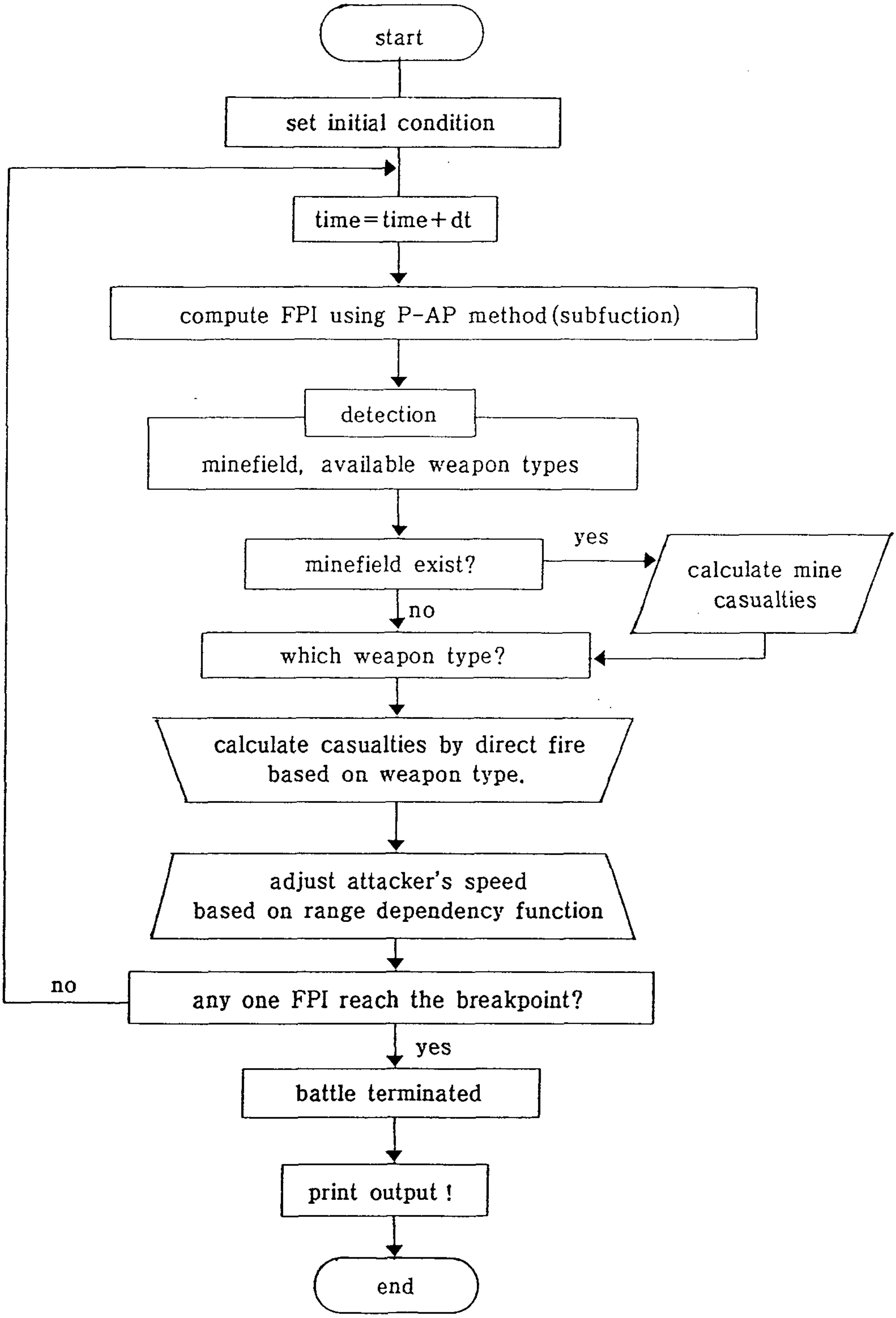

Fig. 3 Model flow chart

Helmbold considered the special case in which the fire effectiveness modification factor is a power function. In this case, the casualty rates of X and Y are

$$\frac{dx}{dt} = -a(t)\left(\frac{x}{y}\right)^{1-w} y \quad \text{with } x(0) = x_0 \tag{1}$$

$$\frac{dy}{dt} = -b(t)\left(\frac{y}{x}\right)^{1-w} x \quad \text{with } y(0) = y_0 \tag{2}$$

where "w" is the Weiss parameter, and equations (1) and (2) are the equations for Helmbold-type combat. These equations are particularly significant because a simple generation of them gives a much better fit to the casualty rate curve used in several important contemporary large scale combat models than does Lanchester's classic model of modern warfare. As for the case of constant attrition rate coefficients, the equations for Helmbold type combat yield that Square Law when $w=1$, the Linear Law when $w=1/2$, and the Logarithmic Law when $w=0$. When range dependency is considered, attrition rate coefficients for each side increase as the Red force approaches the Blue position. Plotting attrition rate coefficients as a function of range shows how the different values of μ(power factor based on different weapon types) affect battle outcomes. Figure 4 shows the

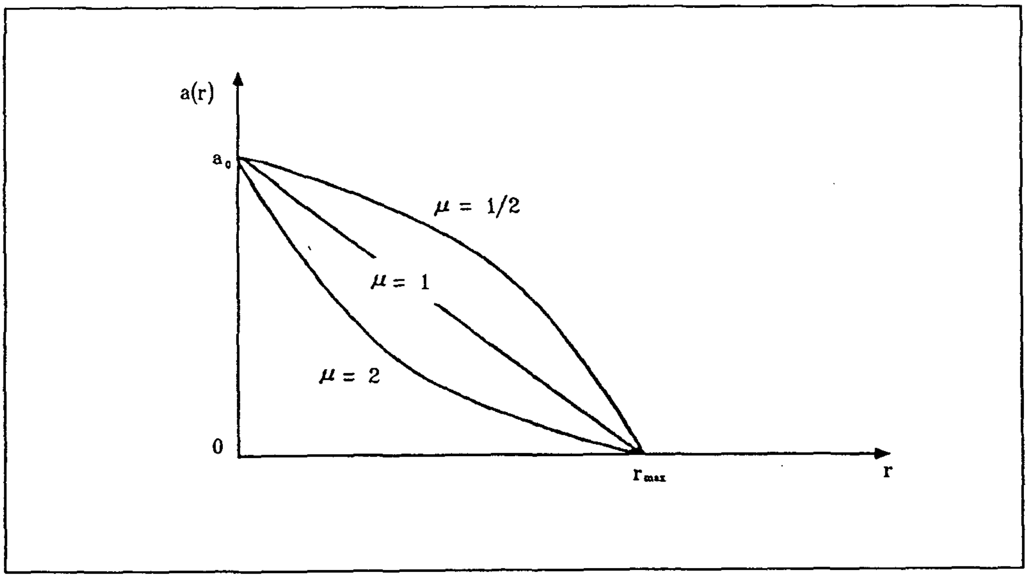

Fig. 4 Relationship between range and attrition coefficient

relationship between range and attrition rate coefficients.

The following equations used in this deterministic model represent both range dependency and the Weiss parameter.

$$\frac{dx}{dt} = -a_0 \left(1 - \frac{r_c}{r_{max}}\right)^{\mu_y} \left(\frac{x}{y}\right)^{1-w_y} y \qquad (3)$$

$$\frac{dy}{dt} = -b_0 \left(1 - \frac{r_c}{r_{max}}\right)^{\mu_x} \left(\frac{y}{x}\right)^{1-w_x} x \qquad (4)$$

where

x : Red force size

y : Blue force size

a_0 : maximum attrtion rate coefficient to Red from Blue

b_0 : maximum attrition rate coefficient to Blue from Red

r_0 : current range between Red force and Blue force

r_{max} : maximum range between the Red force and the Blue force (different from each weapon's effective firing range)

μ_y : power factor, based on Blue weapon types

μ_x : power factor, based on Red Weapon types

w_y : measure of efficiency which the Blue force engages the Red force

w_x : measure of efficiency which the Red force engages the Blue force.

Equation (3) is used for Red casualties while Equation (4) is used for Blue casualties during a specific time increment. Note that different values of μ and w are used for the Red and the Blue forces.

It will now be discussed the method to determine the initial attrition coefficients (A_{ij} and B_{ji}). An attrition coefficient is defined as the rate at which a single firer "i" kills a target system "j", or

a_{ij} = number of j casualties / [(i firer) * (unit of time)] Since there is no dimensional equivalence between the force ratio value and casualties/firer*time, it is necessary to develop attrition coefficients as a function of those variables that contribute to production of casualties. The method used to illustrate this approach and considered as the principal example of the analytical firepower technique is :

$$A_{ij} = \alpha_{ij} * \nu_{ij} P_{ssk} \qquad (5)$$

where α_{ij} : acquisition rate of target i by firer j

ν_{ij} : allocation rate of target i by firer j

P_{ssk} : the probability of a single shot kill

3.4.2 Minefields The area fire assumptions of the "Lanchester Linear Law" are applied to indirect fire patterns of aritillery. Artillery scatterable minefields also exhibit these same patterns, and therefore the Lanchester Linear Law equations are appropriate for assuming minefield attrition. The equation for minefield casualties is given in equation (6).

$$SM_{cas} = a * Y(t) * N(t) \qquad (6)$$

where a : attrition coefficient of a scatterable mine

$Y(t)$: number of infantry men traversing the scatterable minefield at time t

$N(t)$: number of mines in minefield at time t

3.5 Unit Speed The attacker's speed in this model is reduced based on direct fires and minefields.

3.5.1 Direct Fire To update the location of the Red force in the direct fire region, equation (7) is used to calculate the Red force speed during each time step. The equation shows that unit speed decreases as the range between opposing forces decreases, but falls no less than a specified minimum speed.

$$S_{new} = S_{old} * \left(1 - \frac{a_c}{a_0}\right)^{\nu} + S_{min} \qquad (7)$$

where ν : power factor, based on different weapon types

S_{new} : updated speed of attacking force

S_{old} : speed of attacking force for past time step

S_{min} : minimum speed for the attacking force

a_c : current attrition rate coefficient

a_0 : maximum attrition rate coefficient

3.5.2 Minefields Basically, when the attacking force suddenly encounters a minefield, its speed is decreased abruptly at first and then increased gradually as all mines are neutralized. Based on this concept, equation (8) is developed.

$$S_{new} = d * S_{in} + k * (DEPTH)^{Z} \tag{8}$$

where d : decreasing rate when attacker reached minefield first

S_{in} : attacker's speed when he reached minefield at first

k : constant value for all mine density

DEPTH : distance of minefield depth left for the attacker to traverse

Z : power factor for attacker's recovering speed according to minefield depth.

4. MODEL OUTPUT ANALYSIS

4.1 Overview To obtain the required data for analysis, the model is expanded. The model named COMBAT can produce unit casualties and speeds for only one battle situation in which the scatterable mines are emplaced with a specified density in a certain area. The mine density is defined as two types, 0.001/M^2(low) and 0.002/M^2(high). If the Blue force selects low density fill, then Blue artillery can make the minefield depth as great as 350*m*. A high density scatterable minefield can only be 175*m* deep, or approximately one half of a low density fill. However, the total number of mines is the same in both emplacements.
The matrix form of output of this model is shown in Figure 5, and this depicts how many friendly and enemy weapons have been destroyed when the battle is finished. The model COMBAT can also show when and how the battle is terminated.

The advanced version of COMBAT, the model COMBAT 2, can produce not only total unit casualties for both sides but also Red to Blue casualty ratio for all battle situations no matter where the mines are emplaced. The output of the model COMBAT2 is shown in Figure 6.

Concerning the unit speed, Figure 7 depicts how it changes according to time increments. Figure 7 shows that the Red force speed in high density minefields is generally slower than in low density minefields.

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RED FORCES WIN WHEN RANGE = 159.04, TIME = 66

★★★★★★ BLUE CASUALTY MATRIX ★★★★★★           Low density (Red wins)

BY     (AK47)     (SG)      (RPG-7)     (SUM)
       55.799     11.499    10.789      78.088
        1.4498     2.2792    3.8175      7.5464
        1.422      4.2005    2.0237      7.6463

★★★★★★ RED CASUALTY MATRIX ★★★★★★

BY     (M16A1)     (M60)      (M203)     (MINES)     (SUM)
       162.17      18.902     11.239     39.922      232.23
         4.4227     4.7983     9.1766     2.3221      20.72
         3.4399     2.83553    2.108      2.1435      10.527

BLUE FORCES WIN WHEN RANGE = 160.97, TIME = 63

★★★★★★ BLUE CASUALTY MATRIX ★★★★★★           High density (Blue wins)

BY     (AK47)     (SG)      (RPG-7)     (SUM)
       53.781     11.17     10.374      75.325
        1.4058     2.2197    3.6723      7.2978
        1.3748     4.0858    1.9529      7.4136

★★★★★★ RED CASUALTY MATRIX ★★★★★★

BY     (M16A1)     (M60)      (M203)     (MINES)     (SUM)
       163.14      19.157     10.806     48.844      241.95
         4.4494     4.8629     8.8277     2.841       20.981
         3.4606     2.87353    2.0343     2.6225      10.991
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Fig. 5 Output of the model COMBAT

〔Note : The mines are emplaced from a range of 750*m* to 1,100*m* for low density and from a range of 925*m* to 1,100*m* for high density〕.

SMSP	MT (MOE1)	RT (MOE2)	BT (MOE3)	RT/BT (MOE4)
1100	44, 388	263. 47	93, 281	2, 8245
1000	37, 688	267. 64	93. 135	2. 8736
900	46. 448	257. 73	92, 755	2. 8197
800	45. 165	258. 73	91. 755	2. 8197
700	49. 259	263. 22	90. 964	2. 8936
600	53. 578	269. 25	90. 58	2. 9725
500	55. 921	270. 24	89. 728	3. 0118
400	44. 178	260. 32	93. 577	2. 7819

Low Density
Depth = 350m

SMSP	MT (MOE1)	RT (MOE2)	BT (MOE3)	RT/BT (MOE4)
1100	54. 307	273. 92	90. 037	3. 0423
1000	63. 08	272. 75	83. 447	3. 2685
900	60. 07	274. 72	86. 693	3. 1689
800	56. 957	272. 26	88. 228	3. 1689
700	67. 945	270. 11	80. 506	3. 3552
600	64. 99	274. 11	83. 992	3. 2635
500	79. 94	276. 18	73. 905	3. 7369
400	79. 835	276. 8	77. 125	3. 589
300	72. 184	284. 09	86. 737	3. 2753

High Density
Depth = 175m

Fig. 6 Output of the model COMBAT 2

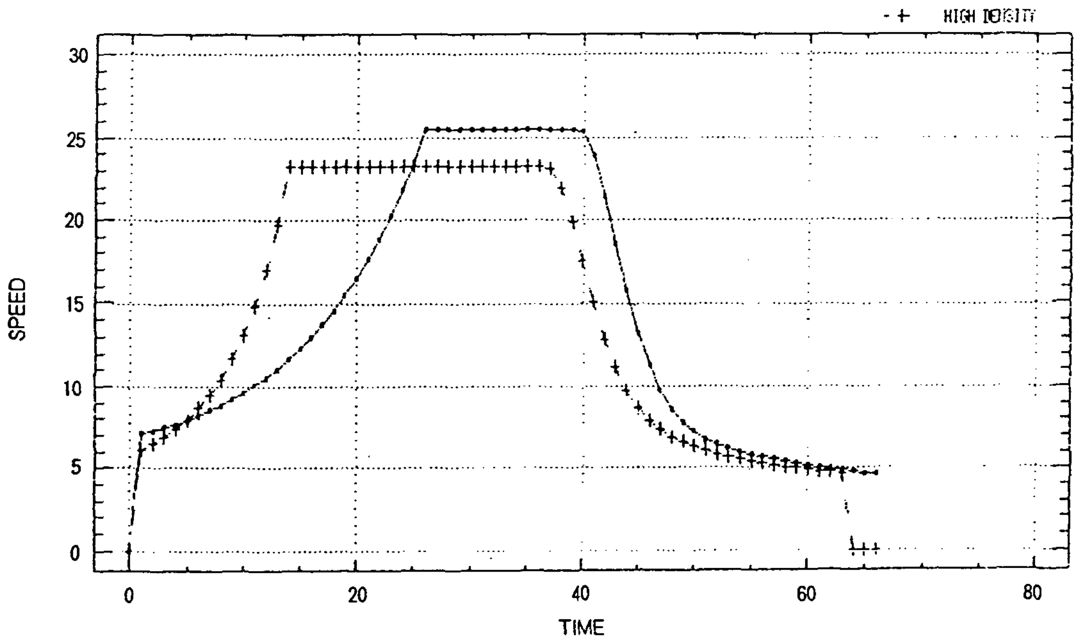

Fig. 7 Unit speed vs. time step

4.2 Comparison of Mine Density To compare differences between the two types of mine densities, 0.001/M and 0.002/M, it is assumed that all mines are scattered with a maximum range of 1,100*m* from the defending position (maximum effective range of M60). This implies that mines shall be emplaced within ranges 750-1,100*m* for low density minefields, and range of 925-1,100*m* for high density. The Measures of Effectiveness (MOE) are defined to give a basis of comparison as follows :

MOE-1 : total Red casualties by mines (column 2 in Fig. 6)
MOE-2 : total Red casualties by Blue force (col. 3 in Fig. 6)
MOE-3 : total Blue casualties by Red force (co. 4 in Fig. 6)
MOE-4 : Red to Blue casualty ratio (column 5 in Fig. 6)

All larger MOE values, except MOE-3, favor Blue force. Figure 5 shows that high density is absolutely advantageous to Blue force.

4.3 Comparison of Mine Emplacement The MOE-1 (Red casualties from mines) and MOE-4 (Red/Blue casualty ratio) are compared to observe how they change based on mine placement. The first column SMSP (Scatterable Mine Starting Point) in Figure 6 shows the forward edge of minefield at the range when Red force contacts the field; the two sections of the figure relate to mine density. Figure 8, 9 show that the values of MOE-1 and MOE-4 are maximized when mines are emplaced in front of friendly positions from 150*m* to 500*m* (with mine depth 350*m*) for low density and from 325*m* to 500*m* (with mine depth 175*m*) for high density.

In this case, both minefields will be within the M16A1 rifle's maximum effective range (460 *m*). This surely verifies the hypothesis that the effectiveness of mines is maximized in conjunction with direct fire weapons. In the model, machine gun fire (M60) did not effectly impact on the attacking forces. The comparisons of MOE-2 and MOE-3 are attached as appendix C.

4.4 Sensitivy Analysis Through the preceeding sections, the best emplacement of scatterable mines was determined. High denity is better than low density and the best SMSP

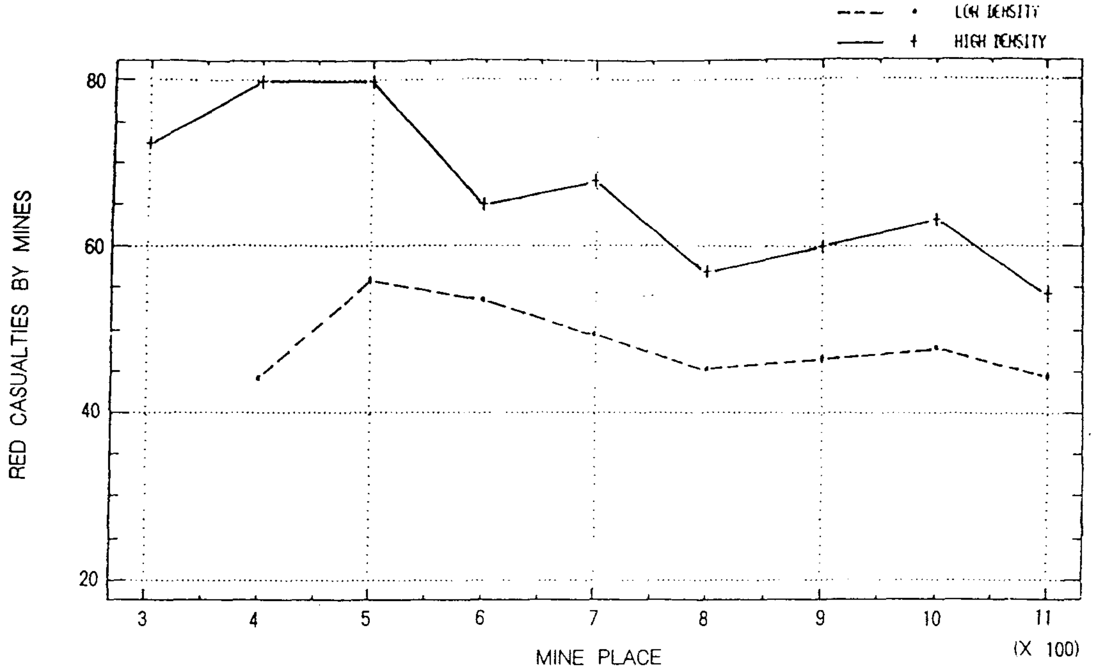

Fig. 8 Comparison of MOE-1 based on mine placement

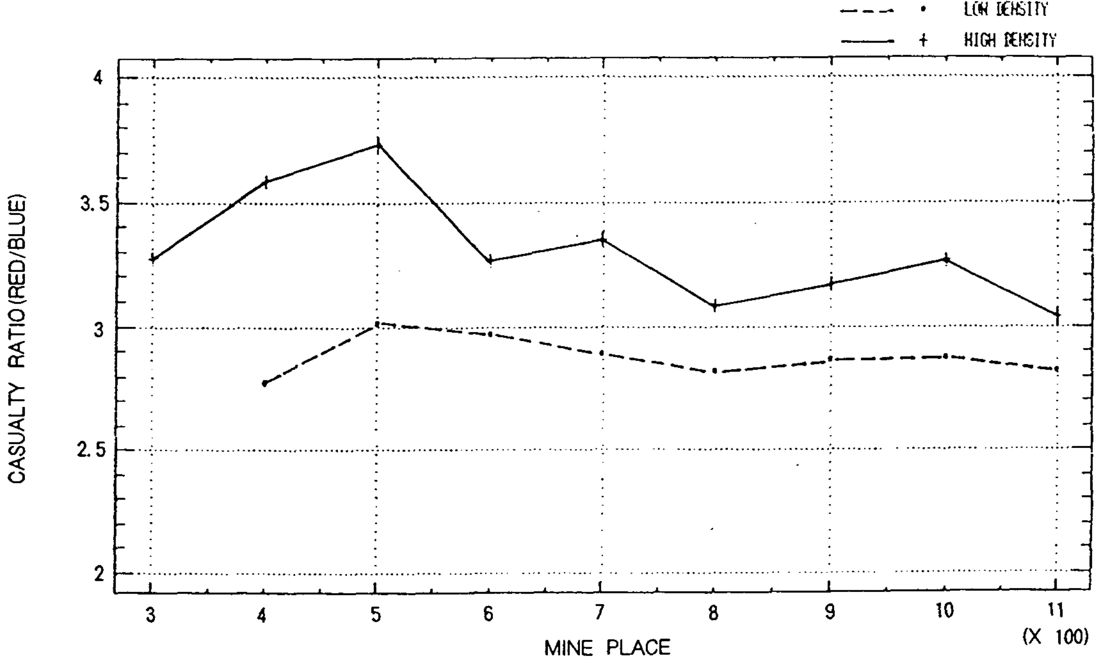

Fig. 9 Comparison of MOE-4 based on mine placement

is 500m. Here, sensitivity analysis is conducted in this specific case (using high density in 500m of SMSP for mine emplacement) to evaluate the effectiveness of the initial attrition rate components.

Among the three components (allocation rate, acquisition rate, single shot probability), when the first two elements increase the MOE-4 (Red to Blue casualty ratio) decreases. However, when the single shot probability is increased, MOE-4 also increases. Figure-10 shows how the MOE-4 changes when the single shot probability of each Blue weapon system (M16A1, M60, M203) is doubled independently. Figure 10 also tells us that improvement of M16A1 firing skills for Blue soldiers is the most effective in increasing MOE-4 in this model.

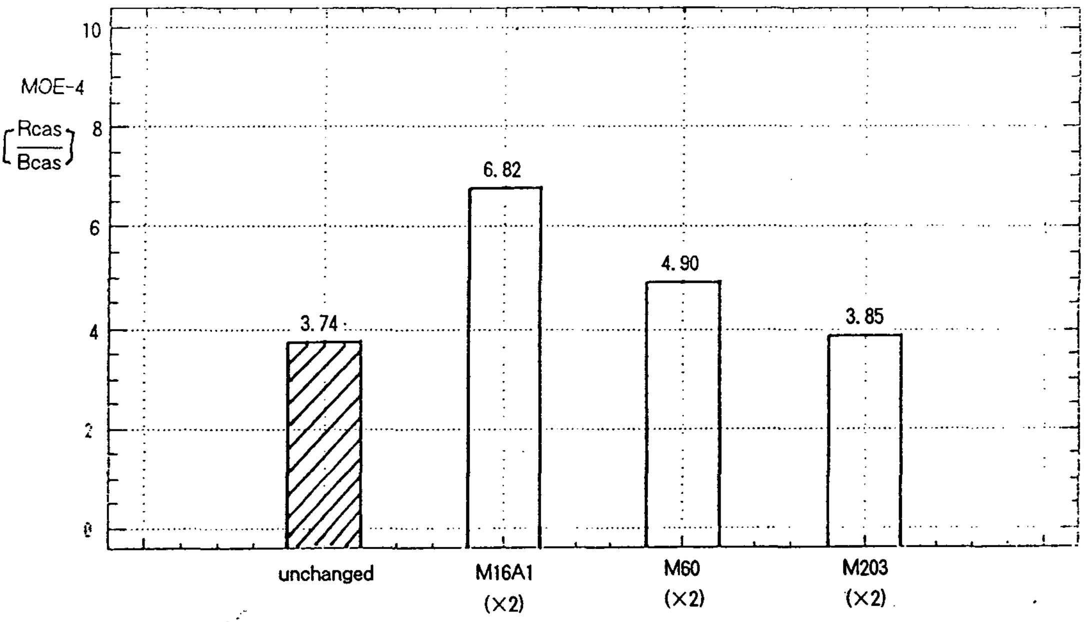

Fig. 10 Sensitivity analysis (Blue's Pssk)

5. CONCLUSIONS

The critical range for employment of scatterable mines is provided based on the model developed in this study. Because mines are particularly effective when employed in conjunction with direct fire weapons, it is inferred that anti-personnel mines will be most effective when placed within the maximum effective range of the M16A1 rifle. As expected, the effectiveness of high density of mine employment is generally grater than that of low density employment. The conclusions reached in this study is that we should use scatterable mines where infantry engagements most often occur, that is within the maximum effective range of the defender's infantry rifles. This will maximize the synergistic effect of the mines and direct fire weapons and enhance the overall strength of the defensive positions.

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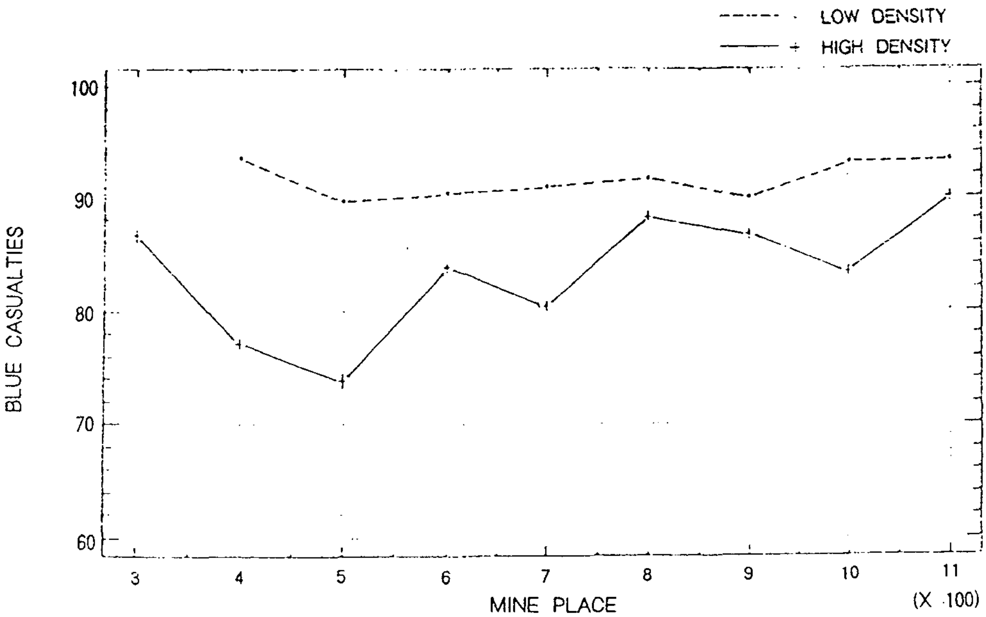
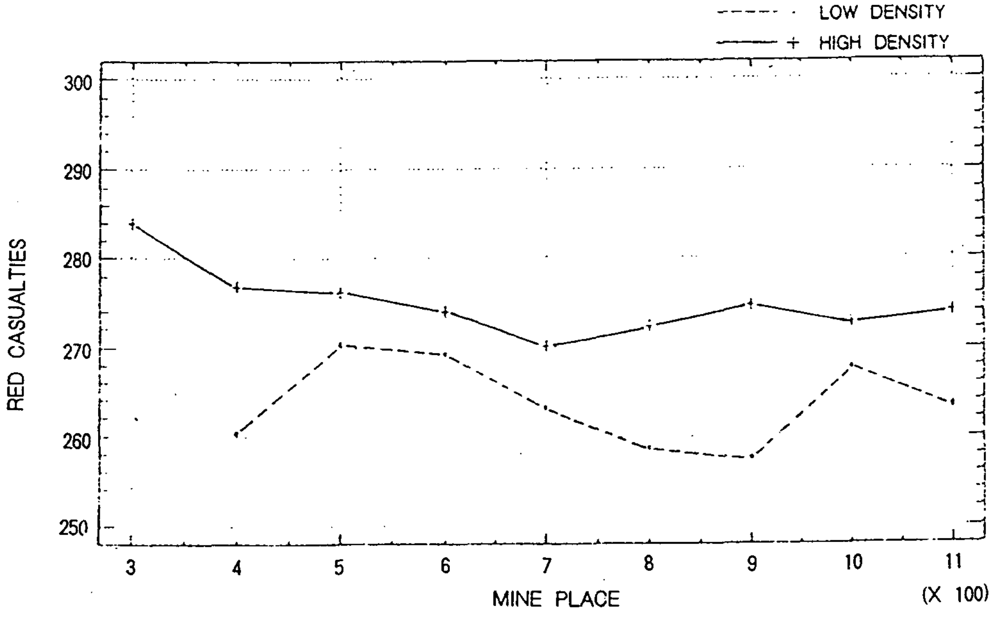
APPENDIX A



MINE PLACE VS. BLUE CASUALTIES



MINE PLACE VS. RED CASUALTIES