LEVEL II

MEASURING OBSTACLE EFFECTIVENESS

A FRESH PERSPECTIVE

VOLUME I

ENGINEER STUDIES GROUP

Prepared by

Engineer Studies Group
Office, Chief of Engineers
Department of the Army

March 1975

MEASURING OBSTACLE EFFECTIVENESS

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This report was prepared for publication by Mrs. Estelle C. Coleman, under the supervision of Mrs. Doreen A. Myers. The editor was Ms. Jill M. Davis. Mr. Christopher Lew, assisted by Mrs. Eva G. Allen, coordinated the graphics preparation.

CONTENTS

ABSTRACT

This monograph assesses the contribution that obstacles can make to direct-fire weapon effectiveness. Previous studies have addressed the delay aspect of obstacles and barriers. This study addresses the results of small unit combat engagements in which obstacles are used to enhance direct-fire weapon effectiveness. A high resolution model was developed to assess the value of an obstacle. The results of the analysis are discussed in terms of attacker-defender exchange ratios for different force ratios and masses. The sensitivity of the primary results is assessed to determine the optimal firing ranges, obstacle siting distances, delay time, attacker speed, and terrain types. Conclusions are drawn regarding these parameters.

MEASURING OBSTACLE EFFECTIVENESS

* * *

A FRESH PERSPECTIVE

I. INTRODUCTION

1. Purpose. This monograph assesses the contribution obstacles can make to direct weapon firepower.

2. Background. For decades, strategic and tactical planners and analysts have wrestled with the problem of measuring the contribution that obstacles[1/] make in the combat process. Despite general agreement that the contribution is probably significant, they have been frustrated in their attempts to quantify the military worth of obstacles. The need to estimate the utility of obstacles stems from the fact that it takes relatively high resource expenditures to place them in a timely manner--a prerequisite for tactical use. Some critics have suggested that the engineer troops required to place obstacles could be better employed on other tasks or, if there are no other priority tasks, could be traded for other combat troops. These same critics maintain that the combat troops needed (in accordance with doctrine) to cover obstacles with firepower are tied down needlessly and could be more effective in other combat roles. Additionally, they point out

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1/ An obstacle is any obstruction that stops, delays, or diverts movement. A barrier is a coordinated series of obstacles designed to delay, restrict, or stop an attacking force and to impose additional losses of personnel, equipment, and time.

that the introduction of line-of-sight antiarmor weapons such as TOW and DRAGON raises questions regarding the relative worth of obstacles on the modern battlefield. Advocates, on the other hand, sense that larger investments in obstacles would be relatively more beneficial to the combat process than corresponding increases in manpower or weapons.

a. Planners and analysts have agreed that obstacles can delay, canalize, or cause attrition of an attacker. Most efforts to quantify obstacle contributions have concentrated on delaying the attacker with the measure of effectiveness being, "How long have we held the attacker at a particular location?" Little successful effort has been spent quantifying the important effects of canalization and attrition. Simply stated, the analytic efforts that have concentrated on assessing effectiveness in hours or days of delay have not been convincing to the critics of obstacles.

b. During the recent period of austerity, most force requirements and structuring efforts have been aimed at providing more combat power from existing or diminishing manpower levels. The source of the increased combat power has been combat support and combat service support forces. One functional area that has received attention is the force structure and, in particular, the engineer troops that emplace obstacles. The analytic tools and processes used in force requirements and structuring efforts measure obstacle effectiveness in terms of delay (and do that quite inadequately). Decision makers, therefore, have been unable to judge whether the use of engineer troops for obstacle construction is their most worthwhile contribution to overall force effectiveness.

c. The inability of force planners and analysts to assess the contribution that obstacles make in combat operations caused an impasse during the CONAF III study conducted by the Concepts Analysis Agency (CAA).[2/] The problem was underscored by LTG E. H. Almquist, then Assistant Chief of Staff for Force Development (ACSFOR), in a letter to the Chief of Engineers (COE) which requested assistance in resolving the problem of measuring obstacle effectiveness. Annex A contains a copy of LTG Almquist's letter and the COE response. The Engineer Studies Group (ESG) agreed to undertake an original research effort that would attempt to develop measures of obstacle effectiveness based on their interaction with weapon firepower. The goal was to seek evidence of increased attrition of an attacker, rather than just increased delay time.

3. Problem Statement. The firepower measures used in large-scale combat models represent the average frequency of a wide variety of engagement conditions. For example, combat models assign net or average values for each weapon's effectiveness even though different conditions

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2/ DA, US Army CAA, Conceptual Design for the Army in the Field, Phase III (UNCLASSIFIED).

and types of engagements result in different weapons effects figures. The working hypothesis of this monograph is that an obstacle which prolongs the fraction of an engagement spent at ranges favorable to a defender's weapons and which reduces that part of an engagement at unfavorable ranges or conditions, improves (from the defender's point of view) the exchange ratio taken over the whole engagement. Some defender's weapons may be inferior at most ranges; some may be better at all ranges. If an obstacle is misplaced, a prolonged unfavorable condition could reduce the net exchange ratio. Given this situation, the effort reported here answers three questions:

a. What engagement conditions favor the defender?

b. Can an obstacle enhance favorable aspects of an engagement?

c. How large an impact on exchange ratio can an obstacle have? Subsequent research phases will determine how the effects described here can be introduced into typical combat models and, in particular, if they can be used to adjust firepower--however scored.

4. Scope. This monograph is an interim report limited to conclusions regarding the effect that obstacles have on direct-fire weapon effectiveness. It addresses neither the measure of delay nor the effect of canalization. As a part of a broader, on-going effort which seeks to measure barrier effectiveness, this report:

a. Describes the model developed by ESG for use in analyzing obstacle effectiveness.

b. Portrays the results of analysis in terms of attacker-defender exchange ratios relative to the force ratios and force masses of several varying engagements.

c. Assesses the sensitivity of the primary results to variation of the significant model parameters.

d. Makes observations regarding the value of obstacles in enhancing direct weapon firepower.

5. Organization of Paper. This monograph is published in two volumes. Volume I contains the main paper and Annexes A (study request and related material) and B (Bibliography). Volume II contains Annexes C, D, and E. Annex C is a discussion of the data sources. Annex D is a compilation of detailed data and plots for the various sensitivity runs. Annex E is the User's Guide which discusses the input data preparation and model use. Volume II is classified SECRET and is available for use at ESG.

II. MODEL DESCRIPTION

6. General. This section briefly treats the pertinent features of the model ESG developed to address the obstacle effectiveness measurement problem. Specifically, this section describes the various tactical engagements that are modeled; lists the minimal inputs

necessary to initiate an engagement; outlines the primary model-processing events of vehicle movement, target detection and acquisition, and firing sequence; summarizes the type of output generated; cites some limitations of the model; suggests some areas in which refinements can be made; and, comments on the validity of the model.

7. Model Features. The model uses a Monte Carlo process in which the feasible event outcomes are represented by probability distributions. At the time a specific event is considered, a pseudorandom number is selected and compared to the appropriate probability distribution to determine the event outcome. (The word random is used throughout the following text to denote a pseudorandom number.) The model can accommodate a maximum of 10 defender weapons and 10 attacker weapons. The current opponents in the model are T-62 medium tanks for the attacker and any defender mix of 90-mm and 106-mm recoilless rifles (RR), M60A1 medium tanks, and DRAGON and TOW antiarmor guided missiles. The sources of data used in the model are cited throughout this section and are listed in the Bibliography. The model is programed in FORTRAN and is operational on a UNIVAC 1108 using EXEC 8. Input to the model is in card format and printed output is provided. Model size is well within the partition capabilities of the UNIVAC 1108.

8. Tactical Engagement Modes. The model treats three tactical engagement modes that are designed to isolate an obstacle, examine its

interaction with firepower, and measure its effects. The modes are identified and explained below.

a. The attacker closes with the defender and exchanges fire in basic combat confrontation. There is no obstacle in this mode, and no special protective measures are taken to reduce the defender's vulnerability. This mode is called the Base Case, and results from the other two modes are compared against it throughout the remainder of this monograph.

b. An obstacle is sited between the opponents to form an altered basic combat confrontation. The obstacle covers three basic changes in the tactical situation: first, assuming defender observation of the obstacle, the attacker's arrival there will assure a positive detection; second, the attacker's movement is halted for the specific period of time it requires to breach the obstacle; and, third, keeping the attacker stationary at the obstacle accrues a higher kill probability to defender weapons than would apply if the attacker were a moving target. This mode is called the Obstacle Case, and results obtained using this case can be compared against the Base Case results to measure the effect of an obstacle.

c. The defender achieves some advantage by virtue of a situation in which he is able to fire from a protected position. In the Obstacle Mode Case, defenders are considered to be firing from their organic armored vehicles or are in concealed positions but without protection. Because defenders in the Combined Mode Case have the time and resources available to improve their protection, their vulnerability to attacker firepower is reduced. Varying degrees of cover are provided for foot troops, and earth cuts or mounds are prepared for armored vehicles. Results of the Combined Mode Case include both the effects presented in the Obstacle Mode Case as well as the incremental improvement due to protection of the defender's position.

9. Model Inputs. Figure 1 shows the categories of the major input data and lists a set of typical values used in exercising the model. Not all categories are used in each case.

INPUT VALUES

Row	Description	Defender Weapons			
		106-mm RR	M60A1	DRAGON	TOW
A	Atk Start Rng (m)	1,100	1,750	1,000	3,000
B	Obs Range (m)	200	1,500	900	2,800
C	Force Ratio	1:1			
D	Atk Formation	Column			
E	Atk Spd Rng (kph)	0-16			
F	Obs Delay (min)	3			
G	PF	0.65			

Figure 1

a. Rows A and B show, for the weapons indicated, the distance in meters from the defender that the attacker begins his approach (Row A) and the distance the obstacle is sited from the defender (Row B).

b. Row C shows the force size ratio. In this instance, one attacker confronts one defender.

c. The tactical formation used by the attacker is shown in Row D. If the attacker uses a column formation, a defender can engage, at most, two tanks. Other attack options include the echelon and the line; they expose three and five tanks, respectively.

d. The attacker's speed varies between 0-16 km/hr as shown in Row E.

e. The breaching time attributed to an obstacle is shown at Row F. This delay ranged from 1 to 5 minutes in various model production runs but usually was 3 minutes.[3]

f. Row G lists the defender position protection factor (PF) used in the model. This factor, when used, has the effect of reducing the attacker's kill probability by 65 percent. This factor, one of a series of factors, was developed by the Waterways Experiment Station in a series of tests designed to measure the effectiveness of a range of field fortifications against a variety of weapons.[4]

3/ DA, OCE, USAWES, Explosive Excavation Research Laboratory, Project Armor Obstacles II (UNCLASSIFIED).

4/ DA, OCE, USAWES, letter to ESC, Computation of Fortification Protection Factor--Method and Assumptions (UNCLASSIFIED).

10. Primary Model Events. The three major combat process events (attacker movement, target detection and acquisition, and weapon firing) are described below.

a. Attacker movement. In each trial, the attacker moves toward the defender from a specified starting range. The attacker's speed is constant or can vary randomly between two limits. The distance the attacker moves is a combination of its speed and the duration of the situation gamed. For example, using a speed of 10 km/hr and an elapsed time of 60 seconds, the attacker would move 167 meters toward the defender. If an obstacle is encountered, the defender halts for as long as it takes to breach the obstruction. If both the attacker and defender have survived the exchange of firepower during the breaching period, the attacker resumes its forward movement. The model continues the movement event until the distance between attacker and defender reaches zero. If the attacker survives, the trial ends with the model taking note of the survival.

b. Target detection and acquisition. These events are treated differently for the attacker and defender. The defender detects and acquires the attacker using range- and terrain-dependent probabilities, respectively. The attacker, on the other hand, detects the defender only after the defender fires.

(1) The defender detection and acquisition event is a two-step process. The model first determines if the defender can detect

the attacker and then checks to see if enough time is available to fire at the positive detections. After each attacker movement, the model determines whether the attacker has been detected. No communication is assumed between defenders; detections of the attacker by the defender are considered independent events. Simultaneous detections are possible. Once a target is detected, the model considers that it would take 30 seconds for a defender to acquire the target.

(a) ESG used two studies to develop data for the defender detection event. The first, Exercise Lost Horizon, was done in Europe by the British Defense Agency.[5/] The other was experimental work to support the Army's Tactical Effectiveness Testing of Antitank Missiles (TETAM) program conducted by the Combat Developments Experimentation Command (CDEC) at Fort Ord.[6/] Two general observations resulted. First, the capability of the antiarmor weapon crew to detect a tank appears to increase as the tank approaches the weapon's position; therefore, initial detection is range dependent. Second, once a tank is detected, the length of time that the tank will be in view does not

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5/ UK Defense Operational Analysis Establishment, Exposures of Armed Fighting Vehicles (Exercise Lost Horizon) (U) (CONFIDENTIAL). Hereafter referred to as Exercise Lost Horizon.

6/ DA, TRADOC, CDEC, Tactical Effectiveness Testing of Antitank Missiles (TETAM) (UNCLASSIFIED). Hereafter referred to as TETAM.

depend on range but on the distribution of terrain features. Segments of terrain where a tank would be seen without interruption, so-called "windows," are considered to be randomly distributed with respect to suitable defensive positions. Thus, the window length is independent of range but dependent on terrain.

(b) Although range dependent, initial detection appears constant for long intervals in the terrain and is portrayed that way in the model. The distribution of observed segment lengths accounts for the acquisition aspect of the defender's detection event. A generalization of the observed segment length data provided in the TETAM study indicated that their approximate distribution may be expressed by $G(s) = 1-e^{-ps^{0.75}}$. The "p" is a distribution parameter which appears to be related to terrain and "s" is the length in hundreds of meters of exposed or observed segment length. An increasing "p" value represents more difficult terrain. The available data indicate that "p" measures the frequency of interruption in the terrain. As "p" increases, the probability of shorter observed segments also increases. For the same distance of terrain, therefore, there will be correspondingly more losses in line-of-sight.

(c) Figure 2 shows the process used by the model to establish defender detection and acquisition of attacker targets. The curve obtained from the TETAM study is drawn on the left side and the window length from the CDEC data[7] is plotted on the right side. The process used first determines the distance between target and defender (Point A) from which the applicable detection probability is determined (Point B). If comparison to a random number indicates that an attacker has been detected, the defender next determines if he has time to fire. Because window length is independent of range, another random number is used (Point C) to enter the appropriate, terrain-based, distribution of observed terrain segment lengths. The resulting segment (Point D) is combined with the speed of the attacker to determine how much time the defender has available to fire before he loses line-of-sight.

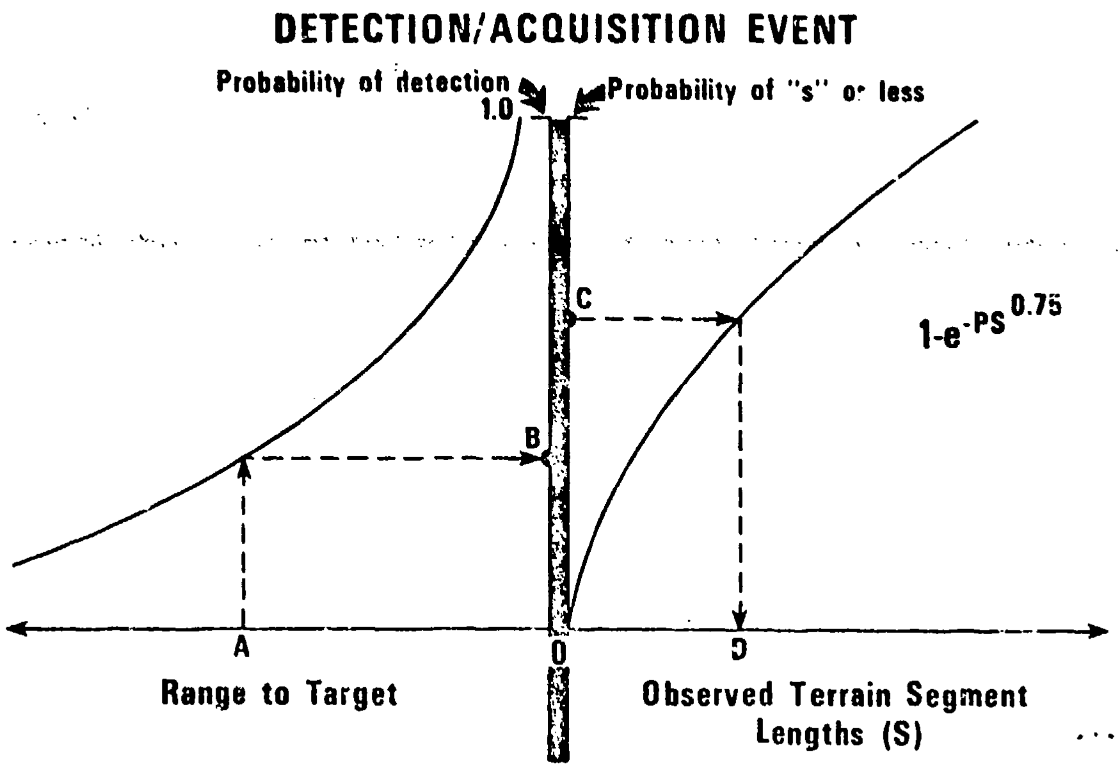

Figure 2

7/ DA, TRADOC, CDEC, On Ground to Ground Intervisibility (UNCLASSIFIED).

(2) The event of attacker detecting the defender depends on the defender firing first and on how many rounds are fired. The model determines if a detection has occurred by comparing a random number to a detection probability. Attackers tend to have a detection advantage in cases involving many weapons of one type. Each attacker knows the number of rounds fired by each defending weapon. With that knowledge, each attacker's detection is then computed as an independent event. This situation leads to each attacker fulfilling an "overwatch" role. Because the defender is stationary, the attacker need not go through an acquisition process. The data source for attacker detections is the extrapolation of Project Pinpoint data by the Research Analysis Corporation (RAC).[8/] Project Pinpoint was a field experiment conducted at Fort Stewart, Georgia in 1955 to obtain information on target detection by tanks in an overwatch role. Project Pinpoint used the 106-mm RR, the 90-mm tank gun, and the 76-mm towed gun. On the basis of relative weapon signatures RAC extrapolated the data to include the 90-mm RR, and DRAGON and TOW antiarmor missiles. The significant Project Pinpoint observation was that the tank's capability to detect the antitank (AT) weapon depends solely on the number of rounds fired and is independent of range and firing duration. Detection gains after the third

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8/ RAC, Operational Effectiveness of Scatterable Land Mines (U) (SECRET).

round were not significant. RAC estimates for DRAGON and TOW were based on using one-third of the 76-mm towed gun probability for the DRAGON and one-half of that value for the TOW. The ESG model uses the same proportions, but bases signature on the 106-mm RR rather than the 76-mm towed gun. This provides for a more optimistic estimate of attacker capability to detect.

c. Weapon firing. The weapon firing event is based on range-dependent distributions of kill probabilities. For those positive detections at which the defender has time for fire, a firing event occurs. Each weapon with a positive detection is allowed to fire a single round in a cycle. Multiple kills of a single target are not permitted even though two or more weapons may detect the same target. If the preceding weapon scores a kill, subsequent weapons will not engage that target. Whether an attacker loss occurs is determined by entering the appropriate probability distribution at the engagement range and comparing the resulting kill probability to a random number. If an attacker loss occurs, it is noted and added to the total losses and that attacker weapon is removed from further consideration in the game. The procedure for assessing defender losses is identical. Due to the sequential execution of the game, a defender firing event occurs before an attacker firi[illegible] event. To prevent the defender from having an unrealistic adv[illegible]ge and in an attempt to model the simultaneous nature of firings poss[illegible] in actual combat, an attacker is allowed to fire at a positive defender detection even though that attacker may have been killed during the immediately preceding defender firing sequence. These distributions are based on work done by the US Army Material Systems Analysis Agency (USAMSAA) for the Tank Antitank/Assault Weapons Requirement Study (TATAWS).[9/]

11. Model Output. The model results are expressed as attacker losses, defender survivals, and the exchange ratio of attacker losses to defender losses. Although several other measures could have been used to assess the obstacle's interaction with direct-fire weapons, the exchange ratio was selected as the most appropriate. It best represents the reality of tactical engagements where the commander must consider both the attrition of the enemy and survivability of his forces. Exchange ratios are very sensitive to small values in defender losses.

12. Weapons Not Addressed. The model is limited to the interaction of obstacles with direct-fire weapons. ESG recognizes that it is a standard tactic to use aerial fire support and/or artillery to place suppressive fires on potential targets or ambush sites. In particular, the new laser beam guided artillery round raises a question regarding whether an obstacle would be needed to help defeat a tank. The problem with considering current or new indirect-fire weapons, however, is that little or no data are available on anticipated kill probabilities

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9/ DA, USAMSAA, Report on Support Provided by Army Material Systems Analysis Agency/Ballistic Research Laboratories for TATAWS III Computer Simulations (U) (SECRET-NOFORN).

and other factors used in the ESG model. The lack of comparable data makes it infeasible to expand the model to treat weapons other than the direct-fire type. Excluding such weapons from the model should not detract from the initial research results.

13. Model Refinements. In the course of building and exercising the model, several areas were defined where refinements could introduce more opportunity for parametric variation. They are recorded below as possible specifications for future model development.

a. Double kills. In a particular time interval, the model does not allow multiple hits on a target that has already been destroyed. The firer must shift his fire to the next target on which there is a positive detection. The confusion of actual battle may result in several hits on a particular target. If this situation were modeled, attacker and defender kills probably would be somewhat lower.

b. Acquisition time. The time a defender needs to fire at a detected target depends on its weapon reload rate, aiming time, and round flight time to the target. In the model, an average of 30 seconds is used for all weapons and all ranges. This time corresponds to reasonable time estimates for firing the weapons used in the model. A more sophisticated arrangement would be to develop and refer to a matrix of acquisition times that is dependent on actual weapon characteristics and the range to the target.

c. Attacker options. As presently modeled, the attacker remains at the obstacle observed by the defender for the duration of the obstacle breaching time. It is questionable that an attacker would fail to use the terrain, smoke his position, or take other evasive action to sever his detection by the defender. Adding this characteristic to the model would probably lead to fewer attacker destructions and a smaller exchange ratio.

d. Firing rate. Regardless of the time interval in the model, each weapon is allowed only one round per interval. More realistic results would be obtained if each weapon used its unique firing rate. The effect of this change on kills or exchange ratio would have to be determined.

14. Model Validity. "How valid is the model?" is a question that often arises when a combat engagement is being depicted. While the ESG model was being built and exercised, extensive searches were conducted to locate relevant data. As always in analytic endeavors, the conflicting data that existed were supposed to represent similar events. To offset this problem, the model was exercised in its Base Case and the results were compared against a model of a tank duel.[10/] The results were comparable with only a 2 percent difference in expected kills.

10/ DA, USAMSAA, A Compilation of Single Tank Versus Single Tank Duel Results (U) (CONFIDENTIAL).

It can be concluded that the model is suitable for the limited purposes intended and could accommodate different data should it become available.

III. RESULTS

15. General. This section summarizes the results achieved by exercising the model in the three tactical engagement modes described earlier (paragraph 8). The results of analysis are expressed in terms of attacker-defender exchange ratios relative to varying force ratio and force mass for the several engagements treated. The displays regarding these topics come from about 300 runs of the model which provided enough cases to gain perspective regarding obstacle-weapons interaction. Subsequently, the sensitivity of these primary results were assessed by varying the model parameters. Sensitivity analyses results are based on about 1,000 runs of the model which led to a thorough understanding of significant factors bearing on the obstacle-weapons interaction. For illustrative purposes, the 106-mm RR results are displayed in the following figures.

16. Direct-fire Enhancement. This paragraph discusses an obstacle's enhancement of direct-fire effectiveness for differing force ratios and masses.

a. Force ratio. Figure 3 lists the results of the model runs for four weapons of interest. As an illustration, the data for the 106-mm RR are plotted in Figures 4 and 5 for increasing force ratios.

EXCHANGE RATIOS FOR SEVERAL FORCE RATIOS AND MASS VARIATIONS

Weapon	Force Ratio	1:1						2:1						3:1						4:1	
	Mass	1:1		2:2		3:3		2:1		4:2		6:3		3:1		6:2		9:3		4:1	
	Mode a/	Ex	%	Ex	%	Ex	%	Ex	%	Ex	%	Ex	%	Ex	%	Ex	%	Ex	%	Ex	%
106-mm RR	B	1.9	-	.8	-	.6	-	.8	-	.5	-	.4	-	.6	-	.4	-	.4	-	.6	-
	O	2.2	16	2.5	213	2.0	233	1.3	63	1.1	120	.9	125	1.0	67	.9	125	.8	100	.9	50
	C	6.4	237	6.1	663	7.2	1,100	3.8	375	3.8	660	4.6	1,050	2.6	333	3.1	675	4.4	1,000	2.1	-
M60A1	B	2.6	-	1.4	-	1.3	-	1.2	-	.9	-	.7	-	.9	-	.7	-	.6	-	.8	-
	O	6.9	165	9.7	593	9.8	654	4.1	215	3.1	244	2.3	229	2.4	167	1.9	171	1.6	167	2.1	163
	C	17.4	569	24.0	1,614	29.6	2,177	10.1	677	7.9	778	8.8	1,157	6.1	578	6.4	814	6.0	900	5.0	525
DRAGON	B	5.8	-	2.8	-	1.9	-	3.2	-	1.8	-	1.1	-	2.2	-	1.2	-	.8	-	1.6	-
	O	12.1	109	8.7	211	6.9	263	5.3	66	3.5	94	2.8	155	3.3	50	2.3	92	1.6	100	2.3	44
	C	29.6	410	17.6	529	18.1	853	13.1	309	9.9	450	9.3	745	10.4	373	7.1	492	5.7	613	6.3	294
TOW	B	20.8	-	35.4	-	39.3	-	15.1	-	10.3	-	9.2	-	8.8	-	5.3	-	4.1	-	5.4	-
	O	249.0	1,097	999.0	2,722	-	-	163.5	983	285.4	2,671	249.8	2,615	33.4	280	50.4	851	58.9	1,337	20.4	278
	C	499.0	2,299	-	-	-	-	329.7	2,083	399.6	3,780	999.3	10,762	91.1	935	110.5	1,985	172.7	4,112	43.8	711

a/ B=Base Case, O=Obstacle Case, and C=Combined Mode.

NOTE: For example: When the 106-mm RR is providing covering fire in the 1:1 case for the obstacle, the exchange ratio is 2.2. This is a 16 percent enhancement as compared to the Base Case.

Figure 3

EXCHANGE RATIO VALUES FOR 106-mm RR

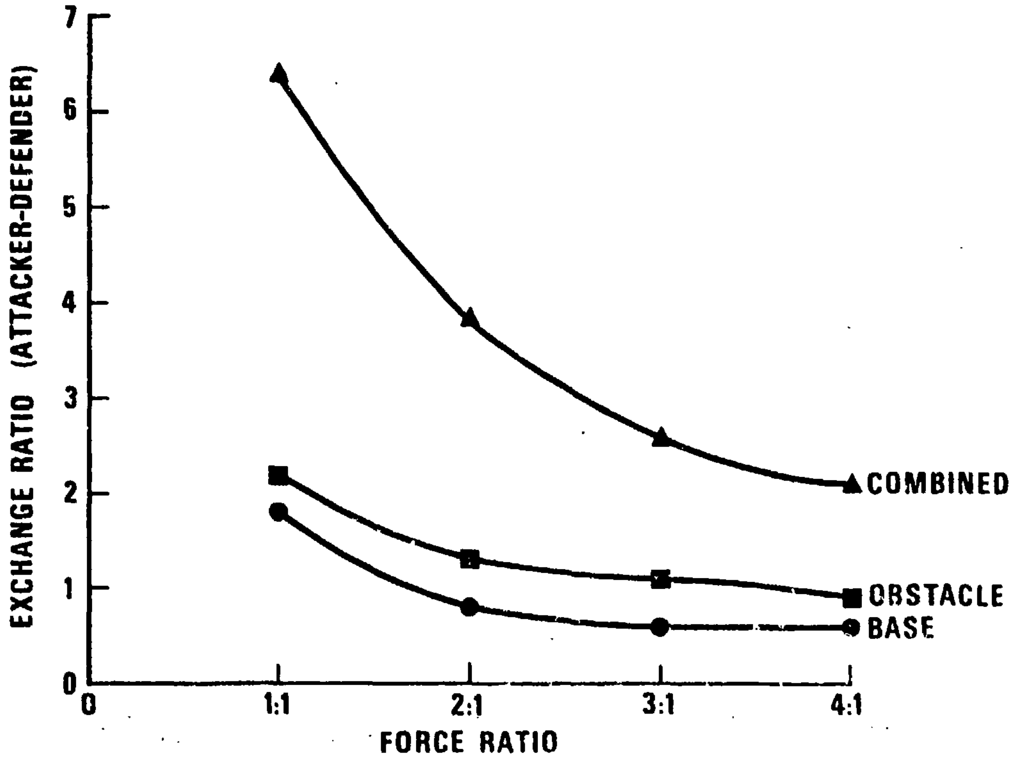

Figure 4

ENHANCEMENT OF EXCHANGE RATIO vs FORCE RATIO -- 106-mm RR

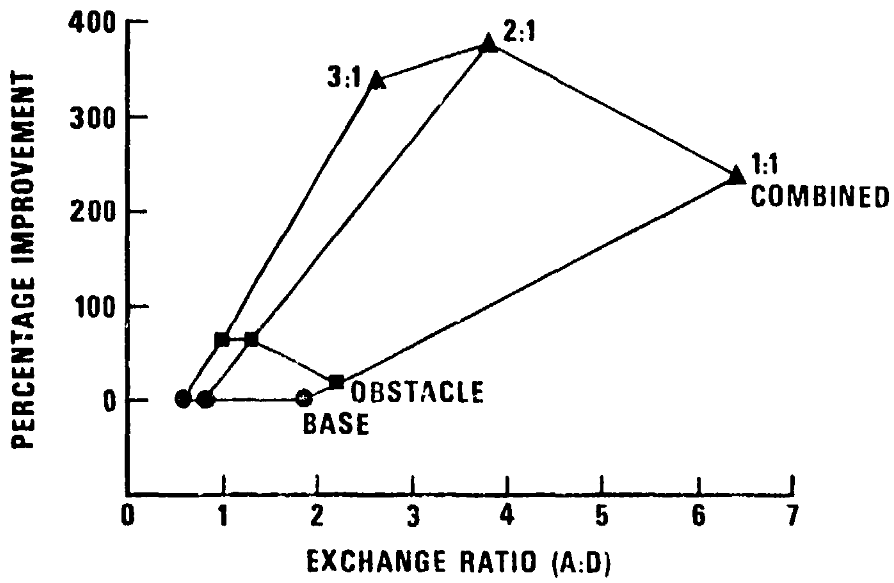

Figure 5

Figure 4 shows that the exchange ratio decreases in each mode with increasing force ratios. With increasing attacker strength, the possibilities for the attacker to detect the defender increase exponentially. Defender losses increase and attacker losses decrease to produce a decreasing exchange ratio. Figure 5 reiterates these changing exchange ratios, and shows the percentage by which the exchange ratios of the obstacle and combined modes differ from the Base Case. Force ratios exceeding 1:1 stabilize enhancement in the 50-65 percent range due to the obstacle. The corresponding values for the other weapons show similar results. In the higher force ratios, the enhancement of exchange ratio due to the obstacle settles around 160 percent for the M60A1, 50 percent for the DRAGON, and 300 percent for the TOW (Figure 6). These enhancement values apply in situations where a single defender is used in relation to a single obstacle. The obstacles in the runs for the M60A1 and TOW were sited near or beyond the maximum range of the T-62. It is reasonable, therefore, to expect that the obstacle would be of more value to these weapons than to the 106-mm RR and DRAGON where the obstacle was sited much closer to the defender, within the range where the T-62 is much more lethal.

b. Mass. An additional aspect of force ratio was addressed by considering the effect of increasing mass (weapon strength) of the opponents in a constant ratio. For the 106-mm RR, Figures 3 and 7 show that

EXCHANGE RATIO ENHANCEMENT DUE TO OBSTACLE
(Single Defender)

Weapon	% Enhancement
106-mm RR	50-65
M60A1	160
DRAGON	50
TOW	300

Figure 6

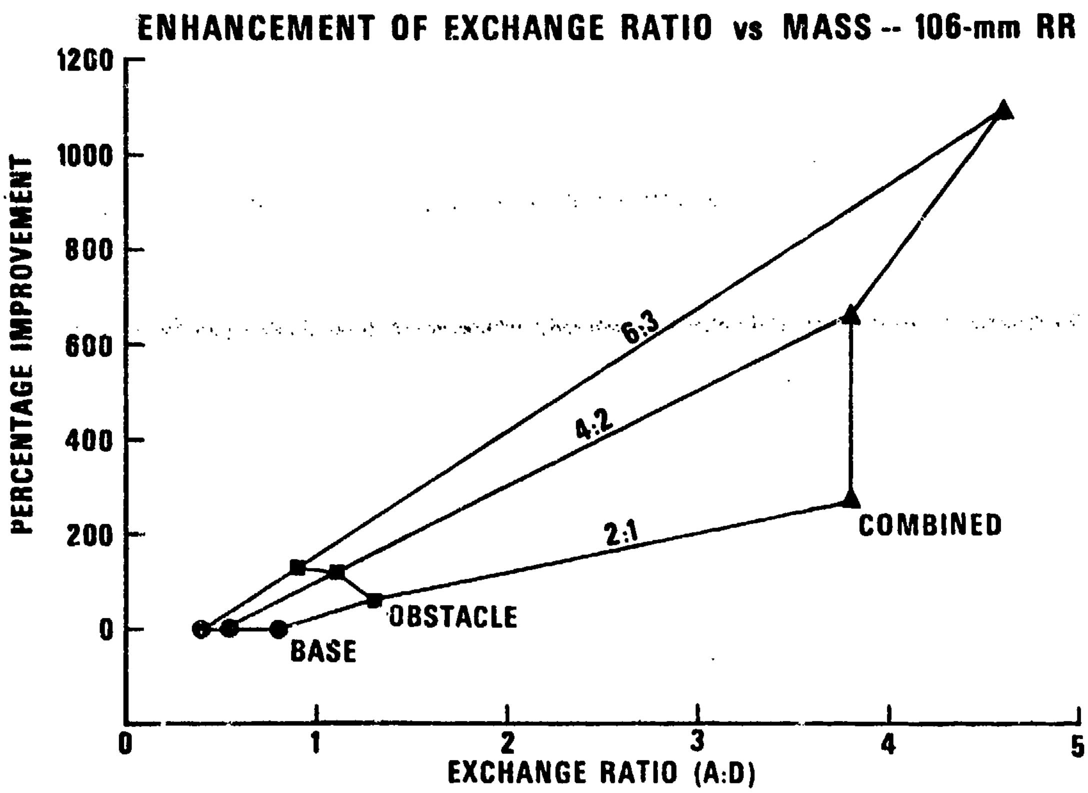

Figure 7

increasing mass in a 2:1 or 4:2 ratio (for example) results in a 50-65 percent enhancement due to the obstacle in the 2:1 case (that is, a single defender) and settles around 120 percent for multiple defender 106-mm RRs. Figure 8 contains corresponding figures for other weapons and constant force ratios. The weapons used to achieve the mass cases are identical within the case. No mixing of weapon types is discussed in these results. For the 2:1 cases, the enhancement due to the obstacle settles around 230 percent for multiple M60A1's and 2,600 percent for multiple TOWs. However, the enhancement due to the obstacle for the DRAGON seems to increase with increased mass. Additional test runs are needed to confirm or deny this observation. These enhancement values would be used in situations where several defenders are considered. The high values for the TOW missile result from the simplicity of the model. The best obstacle siting ranges for the TOW are well beyond the range of the attacker's weapons. Because the model does not play other suppressive fires, TOW is infrequently fired at and rarely destroyed. Thus, the exchange ratio increases cited are logical and are not aberrations of the model.

17. Sensitivity Analysis. The sensitivity of the primary results was assessed by varying the significant model parameters. The following subparagraphs treat each of these factors in turn: range from defender to obstacle; time for attacker to breach the obstacle; attacker speed; defender protection factor; and, the terrain parameter.

EXCHANGE RATIO PERCENTAGE ENHANCEMENT DUE TO OBSTACLE

Weapon	Resulting Force Ratios of Larger Masses[a] 1:1	2:1	3:1
106-mm RR	220	120	Increases[b]
M60A1	Increases[b]	230	160
DRAGON	Increases[b]	Increases[b]	100
TOW	Increases[b]	2,600	Increases[b]

a/ Based on three or more defenders.
b/ Insufficient data to determine limiting value.

Figure 8

a. Range from defender to obstacle. Several otherwise identical runs were made in which the range from defender to obstacle was progressively increased. The data for the 106-mm RR is shown in Figure 9. The exchange rate remains essentially steady out to 200-300 meters and then drops off with increasing obstacle range. For this reason, the most effective obstacle range for the 106-mm RR was chosen as 200 meters. The results for the other weapons indicate an increasing exchange rate with increasing obstacle range. It seems that it is most profitable for these weapons to site obstacles at extreme ranges where the T-62 is less effective. Consequently, the ideal obstacle ranges from the firing position were 1,500, 900, and 2,800 meters, respectively, for the M60A1, DRAGON, and TOW.

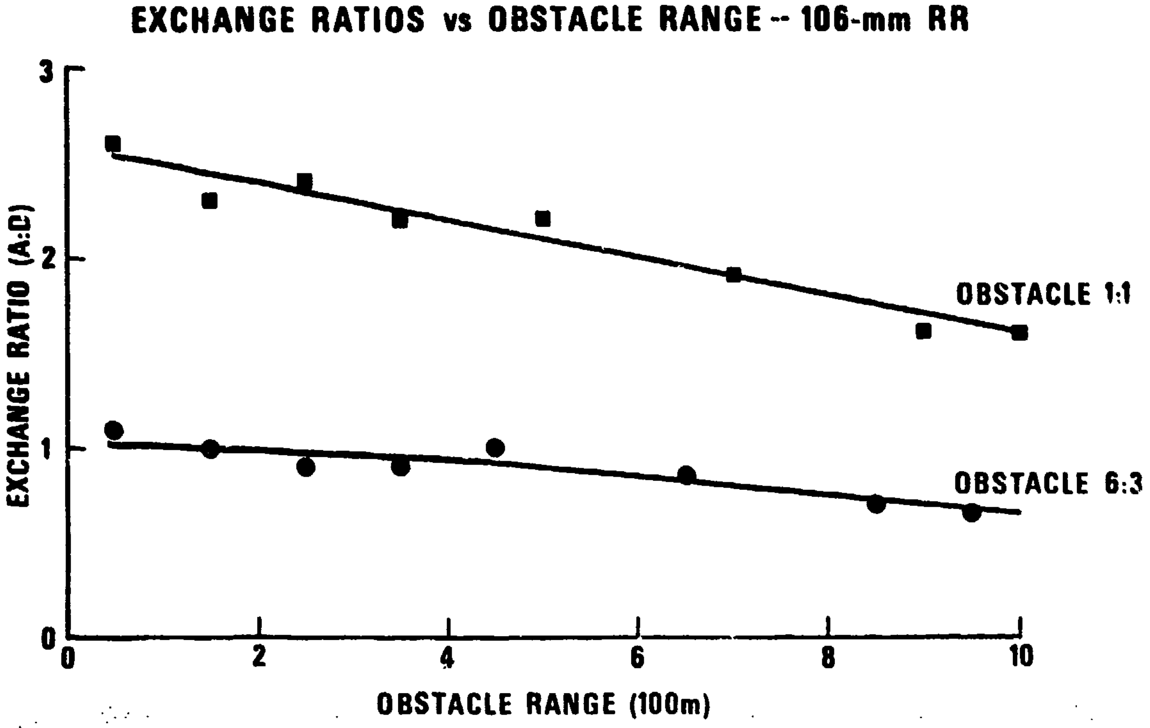

Figure 9

b. Time for attacker to breach. Another obstacle parameter that was systematically varied was the delay time imposed on the attacker at the obstacle. Figure 10 shows that the exchange ratio for the 106-mm RR remains constant with increasing delay time. Intuitively, this observation seems backwards. It would seem that the longer the attacker is delayed the more rounds the defender can fire and the more severe should be the attacker's losses. Test runs indicate that attacker losses increase, as do defender losses resulting in a relatively constant exchange rate. The results for the other weapons show a similar conclusion for the DRAGON, and a progressively favorable exchange rate for the M60A1 and TOW with increasing delay time. Those weapons which can fire on an obstacle sited at or beyond T-62 range show that an increasing delay will increase the exchange ratio in the defender's favor.

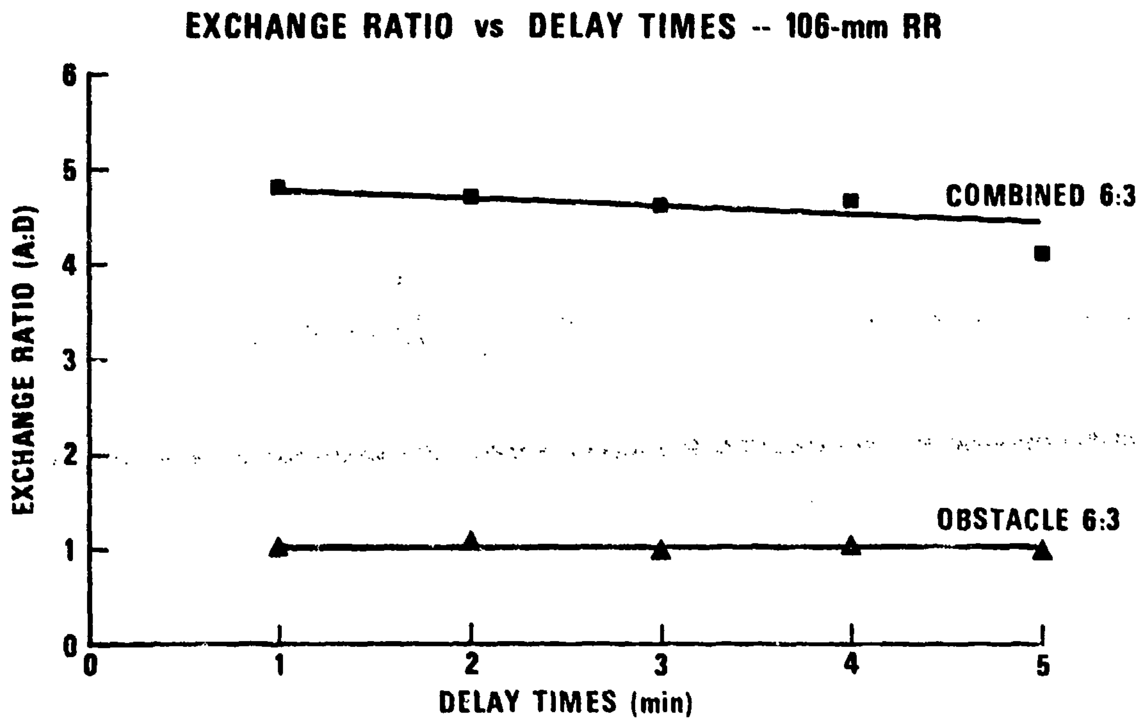

Figure 10

c. Attacker speed. Attacker speed was varied randomly between 0-16 km/hr. Subsequent runs were made with speeds varying between 0-24, 0-32, and 0-40 km/hr. The results for the 106-mm RR are shown in Figure 11. It is readily apparent that the exchange ratio is generally independent of the attacker's speed. An interaction similar to that described for obstacle delay time also applies to attacker speed. Data from test runs show that slower attacker speeds result in both increased attacker losses and (because of the increased defender firing events) increased defender losses. Comparing these losses reveals a fairly uniform exchange rate despite varying attacker speed. A similar observation can be made for the exchange rates of the other weapons except for the TOW. For the TOW, increasing speed results in less enhancement.

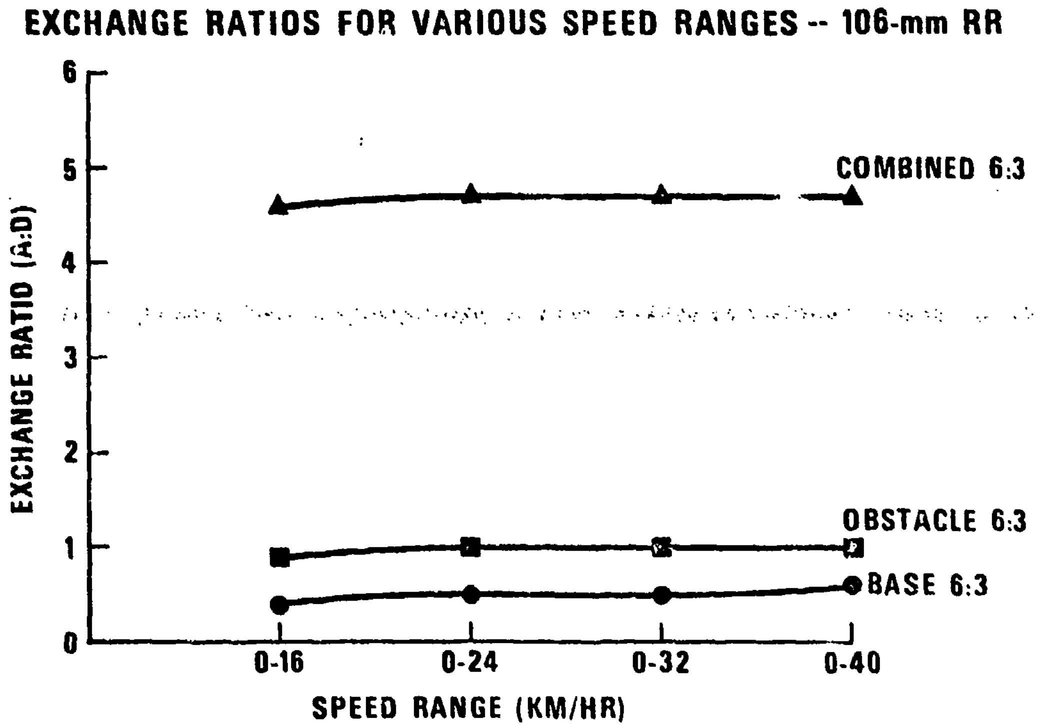

Figure 11

d. Protection factor. In addition to the 0.65 protection factor used in the Combined Mode Case, the PF was varied in subsequent runs for values of 0.35, 0.60, and 0.70. The results for the 106-mm RR are shown in Figure 12. They confirm the intuitive belief that the better the defender is protected, the more effective he will be. Results for the other weapons are similar.

EXCHANGE RATIOS FOR VARYING PROTECTION FACTORS -- 106-mm RR

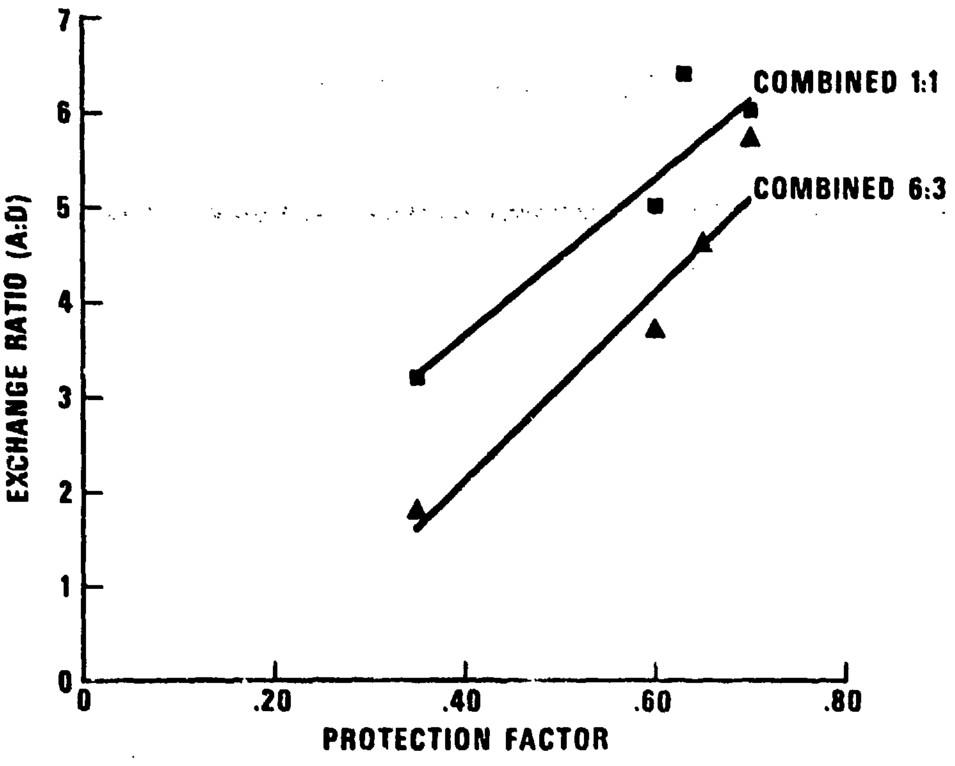

Figure 12

e. Terrain. Terrain affects a defender's capability to see an attacker and, for a moving target, determines how long the defender may have to sight his weapon and fire. Thus, terrain affects the detection and acquisition process previously described.

(1) Terrain is modeled, for the acquisition event, as a function of the probability of having a given window length. From the discussion of detection and acquisition, it is noted that the value of this probability was dependent on the parameter, p. This parameter may be varied to introduce the effect of terrain on acquisition.

(2) Because the data used for the defender detection event were for only one type of terrain, the sensitivity of the model to terrain is limited. Detection data in at least one other type of terrain will make it possible to vary the probability of detection according to terrain and range.

f. Summary of sensitivity analyses. Figure 13 summarizes the results of varying the model parameters. Given these results several observations can be made as follows:

(1) Obstacles covered by DRACON, TOW, or M60A1 tanks should be sited at the maximum effective distance from the defender (considering range and terrain).

(2) Obstacles covered by the 106-mm RR should be sited within 200 meters of the weapon to give the defender the benefits of high kill probability and surprise.

SUMMARY OF OBSERVATIONS

As These Variables Increase	For These Defender Weapons	Effectiveness, Measured by the Exchange Ratio: (Attacker Kills/ Defender Kills)	The Relative Percent Enhancement of Exchange Ratio:
1. Range from Defender to Obstacle	106-mm RR	Decreases	Decreases
	DRAGON, TOW, M60A1	Increases	Increases
2. Attacker Breaching Time At Obstacle	106-mm RR, DRAGON	Remains Constant	Remains Constant
	TOW, M60A1	Increases	Increases
3. Defender PF (Range .35-.70)	106-mm RR, DRAGON, M60A1	Increases	Increases
	TOW	Increases	Increases
4. Attacker Speed	106-mm RR, DRAGON M60A1	Remains Constant	Remains Constant
	TOW	Decreases	Decreases
5. Terrain Irregularities	The model is only partially sensitive to terrain.		

For interpretation, as the range to the obstacle increases for a defender armed with a TOW, the exchange ratio increases and the relative percent enhancement of the exchange ratio is increased by the use of the obstacle. Thus, for the defender armed with TOW, the obstacle becomes more effective as it delays the attacker at longer ranges.

Figure 13

(3) Obstacles providing the greatest inherent delay times should be sited near the maximum effective range of the defender's long-range weapons.

(4) The defending weapons should be protected as time permits, with priority going to those sites where the distance to the obstacle is within the attacker's effective range.

IV. OBSERVATIONS

18. Results of Research. An obstacle can have a significant, positive effect on the attacker-defender exchange ratio in defense situations where one or more direct-fire weapons of a single type are employed.

a. As the force ratio increases against a single defender, an obstacle's improvement to exchange ratio increases to nearly constant levels of 50 percent for DRAGON, 50-65 percent for 106-mm RR, 160 percent for the M60A1, and 300 percent for TOW.

b. As the force ratio increases against multiple defenders (higher force masses), an obstacle's improvement to exchange ratio increases (although somewhat less consistently) to nearly constant levels that almost double the improvements in the single defender cases. (The improvement for the already effective TOW is relatively higher simply because obstacles were placed beyond the effective range of attacker weapons.)

19. Implications of Research. An obstacle improves the exchange ratio principally because it can enhance the defensive phases of tactical engagement by:

a. Letting some defensive weapons engage later (closer) than if no obstacle were present. Without an obstacle, the tendency is for the defender with shorter range weapons to fire as the attacker comes within maximum effective range to assure that at least one round can be delivered. With an obstacle at a favorable, known range, the defender can afford to wait until the attacker reaches the obstacle with assurance that the defender's first round can be delivered with greater effect at a slowed or stopped (and possibly distracted) attacker.

b. Holding an attacker in a defensively preferred window longer than if there were no obstacle. The primary benefit is that the defender can fire more rounds, if required, at preferred range at a slowed or stopped (and possibly distracted) attacker than if the attacker continued to move through and finally beyond the window. (Certainly when the obstacle causes the preferred defensive range to be greater than the attacker's effective range, the benefit is obvious.)

c. To the extent that the defense delivers more of its rounds under conditions of increased hit/kill probabilities, an obstacle offers some economy in rounds. At a time when the trend is toward very expensive rounds and possibly reduced resupply, even slight savings in rounds can become significant.

20. Some Implications Beyond the Research. Although the research to date did not include trials of defenses consisting of weapons of two or more types, the results for one-weapon defenses suggest the following speculations:

a. The emplacement of defensive weapons of different types at their different preferred ranges from an obstacle can create a defensive "super window," an even more effective killing zone.

b. Confronted by a mixed-weapon, multirange defense, the attacker's detection and firing performance should suffer.

c. A mixed-weapon, multirange defense can employ many different and misleading firing orders. Defensive weapons with the highest first round hit/kill probabilities can create enough shock that less capable defensive weapons can then fire with less danger of detection and hence greater effect.

21. Use of This Research and Directions for Future Work. This research effort has yielded a more relevant perspective regarding the effectiveness of obstacles in the combat process. The primary measures of obstacle effectiveness result from estimating the contribution obstacles can make to weapon firepower. For small tactical operations, delay should be relegated to a secondary measure of effectiveness. The results reported in this monograph are relevant to small unit tactical engagements and should only be applied in combat models that simulate

such operations. It remains for subsequent research (to be conducted at ESG) to determine if these results can be applied to a coordinated series of obstacles (barrier) and if they then can be used to adjust firepower scores in typical theater-level combat models.

ANNEX A

STUDY REQUEST

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT CHIEF OF STAFF FOR FORCE DEVELOPMENT
WASHINGTON, D.C. 20310

DAFD

17 DEC 1973

MEMORANDUM FOR: CHIEF OF ENGINEERS

SUBJECT: Barrier Analysis

1. In the process of conducting the Conceptual Design for the Army in the Field Study (CONAF III), the US Army Concepts Analysis Agency (USA-CAA) attempted to assess the contribution of barriers to combat operations. Despite excellent support to the barrier study team by the Engineer Strategic Studies Group (ESSG), the results were inconclusive. The purpose of this memorandum is to secure your increased attention to the barrier analysis problem.

2. The USACAA/ESSG work shows that:

a. Doctrine for barriers is well developed and coherent, but the effects of interaction of obstacles with defensive positions and covering fires are not clear enough for quantification.

b. Current combat simulation models do not portray the role of barriers in such a way as to make credible the assessment of their combat worth. Most models treat barriers as simply another, albeit difficult, type of terrain and consequently create the erroneous impression that barriers are divorced from the defensive or offensive maneuvers of the forces.

3. The primary effects of barriers obviously include imposition of losses of time, personnel, and equipment on the opposing force. Our inability to quantify these effects leads to uncertainty about the value of barriers and consequently impinges upon our confidence in allocating the necessary resources. Several attacks on this problem are underway or proposed:

a. USACAA is sponsoring a modest contractual effort, entitled "Historical Evaluation of Barrier Effectiveness", which is aimed at developing data which may be utilized for development of such quantification; CPT James Campbell of ESSG is your representative on the Study Advisory Group for this effort. A draft study report is due at the end of January 1974.

DAFD
SUBJECT: Barrier Analysis

b. TRADOC has included in its FY74 study program an effort entitled "Barrier/Counterbarrier Operations", to be aimed at evaluating the effects of barriers against selected threats. Recent coordination with the Engineer Center indicates that no effort has been expended as yet, nor is any anticipated during this fiscal year due to the press of other projects.

c. Your FY74 study program also includes a proposed effort, entitled "Barrier Effectiveness" on which no effort has been expended.

d. A NATO Research Study Group, which met in March 1973 to address the anti-armor defense problem in Europe, included in its list of "relevant areas requiring further study" the following statement:

> No attempt has been made in our study to quantify the contributions made by barriers and minefields, or to examine whether larger investments in these systems would be justified in respect of force capability as a whole. Further analytical studies and simulations would be required to assess the value of such contributions.

4. I enlist your continued support of the USACAA effort and I encourage your increased attention toward the resolution of the overall problem.

E H Almquist

E. H. ALMQUIST
Lieutenant General, GS
Assistant Chief of Staff
for Force Development

DAEN-ZA 21 December 1973

MEMORANDUM FOR: ASSISTANT CHIEF OF STAFF FOR FORCE DEVELOPMENT

SUBJECT: Barrier Analysis

1. I agree with your memorandum of 7 December, subject as above. Analyses to date have been inconclusive, and we currantly lack the capability to quantify the effects of barriers and covering fires sufficiently well to influence force planning.

2. In recognition of these problems, we already have planned the barrier effectiveness effort you referred to in your memorandum. The research we have devoted to this general topic convinces me that we should significantly improve our representations of barrier effects in combat simulation models. A nine month to one year effort by appropriately experienced and trained personnel should yield some worthwhile results.

3. I have tasked the Engineer Strategic Studies Group to follow through on its proposed barrier effectiveness study as a matter of priority.

W. C. GRIBBLE, JR.
Lieutenant General, USA
Chief of Engineers

ANNEX B

BIBLIOGRAPHY

ANNEX B

BIBLIOGRAPHY

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