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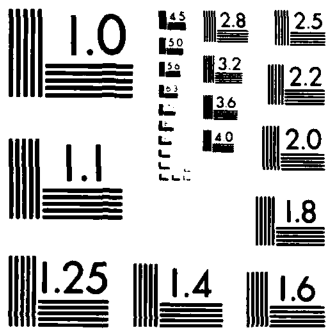

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METHODOLOGIES OF DIRECT-FIRE ALLOCATION AND MANEUVER UNIT ALLOCATION AND PLACEMENT

by

Kenneth D. Boyd

March 1985

Thesis Advisor: S. H. Parry

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This thesis is directed at the derivation of several methodologies associated with the Airland Battle Research Model currently under development at the Naval Postgraduate School. Two systems are presented that derive aggregated distribution allocation plans involving enemy and friendly direct-fire weapon systems. A military tactical scenario is used to present and contrast both systems. Additionally, allocation and placement models for ground force maneuver units are presented. Specifically, these models demonstrate how military units are allocated and placed on a battlefield by various levels of organization. The use of a transportation network illustrates implementation of the models.

Methodologies of Direct-Fire Allocation and Maneuver Unit Allocation and Placement

by

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I. INTRODUCTION

A. BACKGROUND

The object of all operations is to destroy the opposing force. The U.S. Army's basic operational concept is called Airland Battle doctrine. This doctrine is a complex orchestration of combat maneuver units, combat support units, and Army and Air Force aviation units. Success is maximized when critical units are destroyed, thus interrupting enemy tactical operations, disorienting command and control functions, and interdicting critical rear area operations. [Ref. 1: p.1]

The Airland Research Model is a vehicle for the development of modelling methodology for analysis of large scale warfare. Currently under development at the Naval Postgraduate School, the research goal of the model is the initial employment of methodologies to evaluate the Airland Battle doctrine, particularly the rear area interdiction concept. [Ref. 2: p.1]

B. PURPOSE OF THESIS

The purpose of this thesis is to initiate research in two specific areas for ground maneuver forces: direct fire allocation plan, and maneuver unit allocation and placement.

Methodology for direct fire allocation of a single firer has been developed and utilized in other models. However, units do not fight on the battlefield as independent firers but rather as entire fighting units. Therefore, methodologies for determining an entire unit's allocation plan are developed in this thesis. Essentially, the objective of these methodologies is the derivation of an aggregate fire distribution plan.

Within the Airland Battle doctrine, functions and responsibilities of command at different levels of organization are defined. Those at corps, division, and brigade are the only ones that have resources at their disposal to "read the battle." Consequently, these levels of command allocate resources to the battlefield operations. At the battalion level, fighting units are placed to fit the terrain and anticipated threat. Methodologies are presented in this thesis to aid in both the allocation and placement processes. The final outcome of each methodology employed is utilized as a template, or a picture of the allocated or placed units on the battlefield.

The template is the result of executing a set of allocation rules. These rules are employed at different levels of organization and will be discussed in detail in subsequent sections. Through the use of allocation and placement rules, the template becomes a valuable modelling instrument.

The objective of both the allocation and placement templates is to become a part of the modelling effort of the Airland Battle Research Model. In the development of both, it is necessary to describe procedures followed and utilized by military planners. This is done with the overall objective in mind of creating the templates as representations of those procedures to be used by the model.

C. FOCUS OF THESIS

After an introduction outlining the purpose of this thesis, chapter 2 presents two different methodologies, simultaneous and sequential, for deriving an aggregate fire allocation plan. Various sub-versions of each are explored and presented. The chapter concludes with a tactical scenario and the results of each version's allocation plan as applied to the scenario.

Chapter 3 presents a methodology for allocating fighting units to a given tactical scenario. Corps through brigade levels of organization are described with regard to the allocation methodology. Placement of the fighting units, for the purpose of this thesis, is assumed to take place at the battalion level organization. Placement methodologies for the maneuver fighting units, engineer units, and artillery units are described with appropriate examples.

Chapter 4 summarizes the research and provides direction for improvements and other subjects for continued research.

II. FIRE DISTRIBUTION ALLOCATION

A. INTRODUCTION

A Fire Distribution Plan is an allocation of weapon systems against enemy targets with the purpose of total distruction of all targets. Establishing a fire distribution plan of a friendly force engaged in combat with an enemy force requires tactical knowledge and training, an understanding of weapon systems, and an appreciation for the capabilities of the enemy. In short, a commander of such a force makes decisions based on these attributes to derive a final fire allocation plan. To develop an algorithm that can be used to model this process, the modeler must capture that decision-making logic that the commander uses. There are two approaches considered by the commander or modeler for the allocation process: one firer versus multiple targets and multiple firers versus multiple targets. Both approaches apply to direct fire allocation only.

The overall goal of a fire distribution allocation plan is to allocate firers for some future time period. The STAR (Simulation of Tactical Alternative Response) model handles the allocation of firers in an event-sequenced manner. STAR is high resolution, determining allocations for each vehicle for each event. This is a procedure consisting of stochastic events along a time line of unpredictable time durations. An example is that of a tank crew engaging a target; a typical sequence is given in Figure 2.1.

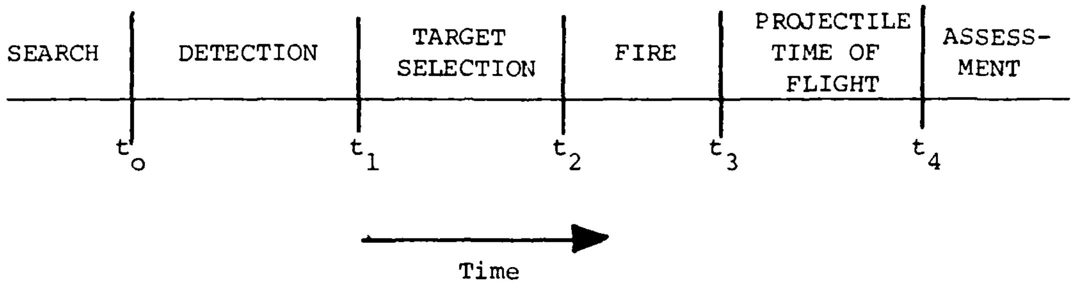


Figure 2.1

In essence, an assignment for each firer is made when a target select event occurs for multiple possible targets.

In contrast to the event step process is the time step procedure. All events, or assignments, are completed at the start of each time block. The tank crew example for a time step process is given in Figure 2.2.

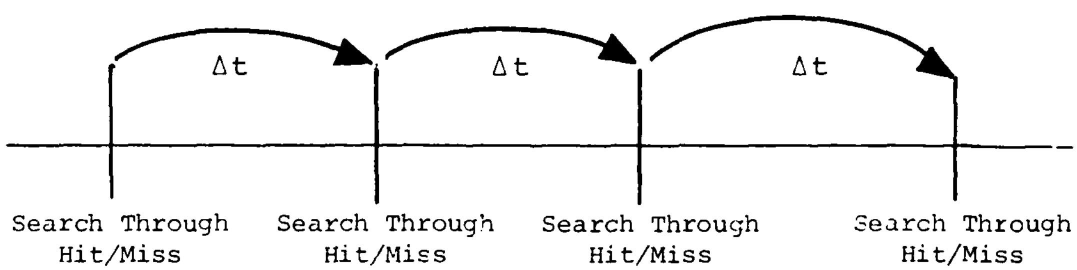


Figure 2.2

Whereas the event step procedure checks each firer with respect to a single event, the time step procedure analyses all assignments at the beginning or end of the time period.

The purpose of this chapter is to develop methodology to achieve an aggregated fire distribution plan. Rather than the STAR model approach of one single firer facing several targets, it is desired to represent entire units and their allocation plan. The key difference is that the unit's allocation plan is pretermined at one time, not one firer at a time. Methodology for determining this aggregate fire distribution plan will be discussed in the following sections.

If simplification was the only criteria for developing a fire distribution allocation plan, a Homogeneous Force Model would suffice. With this type model there is only one parameter, that brings the percent of the total force allocated over some time reference. If a force commander had 100 firers in his unit, he may simply state that 75%, or 75 firers will be allocated for use during the next time period of a conflict. However, there are several problems with this method. First, all weapon systems are not designed with the same capabilities such as ranges of engagement, firing rates, probabilities of single shot kill factors, and specific targets they are designed to engage. Secondly, the enemy forces possess sufficient types of vehicles/weapon systems with different characteristics. Allocation of firing units must consider these differences when allocating specific weapons against specific targets. Thirdly, with regard to the simple 75% example, how does the commander know if that is a sufficient or insufficient number of firers? Finally, the parameter of range or distance from firer to target has not been considered when determining allocation of firers.

This chapter explores the problems mentioned above in an attempt to illustrate alternative methods of fire distribution allocation. Two methodologies, simultaneous and sequential, will be developed, along with versions of each method. Additionally, algorithms are developed and examples provided. The examples illustrate the methodologies in order to show the necessity for and effectiveness of variables such as range, type of firer and type of target. Also, the notion of priorities will be introduced and illustrated.

B. SIMULTANEOUS METHODOLOGY

The simultaneous methodology affords a commander the opportunity to simultaneously consider the utilization of all his assets in order to maximize the potential of each weapon system that is available. Overall, the goal is to allocate a number of firers to engage and destroy a number of enemy targets. Allocating a percent of all available firers against all enemy targets is the simplest version to use in achieving the goal. However, other variables such as range, type of firers, and type of targets are considered in the derivation of other versions. The evolution from simplest to complex is illustrated in the following discussion.

1. Percentage of Firers Allocation

There are three versions of determining the allocation of firers to targets, each differing by the variables introduced. The initial version uses a single percent allocation parameter, whereas the final version uses type of firer, type of target, and range band of target as parameters. In all cases, the computation results in the number of firers allocated per target with the units dependent on whether firer type, target type, and/or range band is being considered.

a. Homogeneous Force Allocation

The homogeneous situation is the simplest of all versions. It depicts a designated percentage as the fire distribution allocation. For example, the commander states that 75% of all available firers will engage and destroy all enemy targets. The parameter, Ψ, is defined as the percentage of firers allocated. If N is the total number of firers and M is the total number of targets, then β, the number of firers per target, is given by $\beta = N \times \Psi / M$.

b. Allocation by Firer/Target Type

This version of a heterogeneous situation accounts for two important variables, type of firer and type of target. It is unrealistic and impractical to envision a battlefield of firers and targets, all of the same type vehicle/weapon system. The weapon systems found today range from the rifle fired by one soldier to complex tank destroyers fired by a crew of several soldiers. Therefore, to achieve an effective allocation plan, the commander must utilize all systems and allocate the correct system against the appropriate target. Capturing this importance requires the consideration of each weapon system's inherent capabilities. This type of firer and type of target are independent of range considerations. Ψij is defined to be the percentage of firer type i allocated against target type j. If Ni is the total number of firers type i and Mj is the total number of targets type j, then β, the number of firers type i per target type j, is given by $\beta = Ni \times \Psi ij/Mj$.

c. Allocation by Firer/Target Type and Range Band

This version is identical to the previous version except for the addition of range dependency. Range is important in assisting the commander in his determination of which firer to allocate against which target. Although a certain system is highly effective against certain types of targets, range may prohibit their use and thus be allocated to other targets within their range capability. Therefore, range is another variable that enhances the effectiveness of the fire distribution allocation plan. The parameter, $\Psi ij\,k$, is defined to be the percentage of firer type i allocated against target type j in range band k. If Ni is the total number of firers type i and $Mj\,k$ is the total number of targets type j in range band k, then β, the number of firers type i per target type j in range band k, is given by $\beta = Ni \times \Psi ijk/Mjk$.

Note that each method described above results in the number of firers allocated per target and differ only in the resolution of input data required. The method used in the Air Land Research Model will be determined by the resolution of the execution model.

2. Target Firepower Factor Allocation Model

a. General Description

In contrast to the methods previously described, a relative weighting technique is developed in this section. Consider the case where the allocation is to be made for firer type i to target type j.

Let,

W_{ij} = Relative weight assigned to the (i,j) pair.

N_i = Total number of firers type i.

M_j = Total number of targets type j.

Then, TFF_{ij} is defined to be the target firepower factor for the (i,j) pair. Further, let

δ_{ij} = Number of firers type i allocated against all targets type j.

Then, $TFF_{ij} = W_{ij} \times M_j$.

Thus,

$$\delta_{ij} = N_i \left\{ \frac{TFF_{ij}}{\sum_j TFF_{ij}} \right\} \qquad (1)$$

Note that equation (1) allocates a portion of the total target firepower factor available to each target type j, dependent on the number of each target type j available.

Two versions of the TFF Allocation Model are developed in the following sections. The first version is the

Ground-Air Model I(IDAGAM I) developed by IDA (Institute for Defense Analyses). The second version was developed by the author to provide an alternative method for determining W_{ij} .

b. IDAGAM I

Part of the model calculates the number of firers type i allocated over all type j targets. With regard to the number of targets type i the IDAGAM I utilizes what is termed a "standard force." A standard force is defined according to its make-up of military sub-units by type. For example, a motorized rifle regiment versus a separate tank regiment is comprised of different sub-units and consequently, would present different types of targets on the battlefield.

The allocation scheme used in IDAGAM I is determined as follows:

$$\delta_{ij} = N_i \left\{ \frac{\psi^*_{ij} \cdot M_j/M_j^*}{\sum_j \psi^*_{ij} \cdot M_j/M_j^*} \right\} \qquad (2)$$

where

δ_{ij} = Adjusted number of firers type i allocated against all targets type j.

N_i = Number of firers type i .

ψ^*_{ij} = Percentage of firer type i allocated against target type j in a "standard" force.

M_j = Number of targets type j .

M^*_j = Number of targets type j in a "standard" force.

Note that equation (2) is the same as equation (1) where,

$$Wij = \psi^{*}ij/M^{*}j$$

This implies that the weighting scheme is based on the ratio of the initial percent allocation for the (i,j) pair against the "standard" force and the number of target type j in the "standard" force.

c. Firing Rate Allocation

(1) Range Independent Allocation. An alternative to the use of a "standard" force within the IDAGAM I has been developed. The allocation scheme is determined as follows:

$$\delta ij = Ni \left\{ \frac{DRij}{RFij} \cdot Mj / \sum_{j=1} \frac{DRij}{RFij} \cdot Mj \right\} \quad (3)$$

where

δij = Adjusted number of firers type i allocated against all targets type j .

Ni = Number of firers type i .

DRij= Desired relative firing rate for firer type i against target type j .

RFij= Combat rate of fire of one firer type i against one target type j .

Mj = Number of targets type j .

Note that equation (3) is the same as equation (1) where,

$$Wij = DRij/RFij$$

This implies that the weighting scheme is based on the relative amount of firepower desired against each target type j from firer type i ; a user input.

This allocation scheme uses two variables; the desired relative firing rate and the combat rate of fire. The desired relative firing rate is a user input. For example, if DR11 = 4 (M-1 Tank vs. T-72 Tank) and DR12 = 1 (M-1 Tank vs. BMP), this says that the user desires to fire four times as many rounds from firer type 1 (M-1 Tank) against target type 1 (T-72 Tank) than at target type 2 (BMP). The combat rate of fire is according to the specific type of weapon system and depends on the time horizon of allocation. Although schemes (2) and (3) produce the same result, they are dependent on different inputs.

The IDAGAM I Model depends on different inputs for each "standard" force. For example, a different ψ^*ij is required for each "standard" force that the user may access. Consequently, for each "standard" force, a different M^*j is defined for each respective force. Scheme (3) does not use a "standard" force, but rather the two variables previously discussed. However, it is noted that determining the desired relative firing rates and quantifying that desired action could prove difficult.

(2) Range Dependent Allocation. The firing rate allocation model can be adapted to the consideration of range bands as follows.

This version of the derived adjustment of firers type i against targets type j is similar to the previous one except for the addition of the variable, range. The user now has the ability to adjust his number of firers allocated to targets by type, but also according to the range from firer to target. This allows the user to better utilize the capabilities of each weapon system with respect to the types of targets they are designed to destroy and the maximum effective range where target destruction can occur. Overall, the result is the adjustment of the number of firers allocated, with all three variables being utilized.

$$\delta ijk = Ni \left\{ \frac{DRijk}{RFijk} \cdot Mjk / \sum_j \sum_k \frac{DRijk}{RFijk} \cdot Mjk \right\} \quad (4)$$

where,

Ni = Number of firers type i.

Mjk = Number of targets type j, in range band k.

$RFijk$ = Combat rate of fire of one firer type i against one target type j in range band k.

$DRijk$ = Desired relation firing rate for firer type i against target type j in range band k.

Note that equation (1) now becomes,

$$\delta ijk = Ni \left\{ \frac{TFFijk}{\sum_j \sum_k TFFijk} \right\} \quad (5)$$

where,

$TFFijk = Wijk \times Mjk$

$Wijk = DRijk/RFijk$

The IDAGAM I Model has no provisions for the consideration of range bands.

C. SEQUENTIAL METHODOLOGY

The sequential methodology is based on the concept of specifying a priority order of enemy target coverage. In addition to the determined percentage of firers type i allocated to targets j in range band k, a table of priorities of the allocation of firers to targets is required. The goal is to determine the number of firers to allocate to each designated priority.

Introducing the variable Pk (Probability of Single Shot Kill) is a necessary element in a multi-step procedure to achieve the overall desired representation. The variable Pk is used to determine the estimated number of rounds needed to kill target type j by firer type i . This estimate is then divided by the estimated rate of fire of firer type i against target type j in range band k to derive the expected time one firing system i needs to kill one target system j in range band k . The desired number of kills per minute by firer type i versus target type j in range band k is multiplied by the expected time for a firer type i to destroy a target type j . This results in the determination of the desired number of firers allocated per designated priority.

This mathematical multi-step procedure is illustrated in later examples. It is important to note that the rate of fire of firer type i versus target type j in range band k, and the desired number of kills per minute by firer type i versus target type j in range band k are user inputs. Values are established and accepted figures for various weapon systems.

1. Sequential Allocation by Firer/Target Type

The initial sequential allocation method is range independent, with the priority focused on target types. Establishing the priorities is done solely on the basis of the types of acquired targets that exist on the battlefield, with the allocation of firers being a function of those types of targets.

For example, suppose a commander is facing an enemy force comprised of tanks and BMP vehicles. He decides that the tank targets are priority #1 and the BMP vehicles are priority #2. That decision is instrumental in his allocation of firers with regard to covering the first priority targets and then the second priority. The goal is to establish a priority scheme based on target type that assists in determining an allocation plan.

2. Sequential Allocation by Firer/Target Type and Range

This allocation method, with range band dependency, is a function of the types of targets on the battlefield, as well as the range bands in which they are located. A priority table is established based on the type of firer, type of target, and range band. The allocation of firers is then determined for each priority. Table I illustrates an example of a priority scheme with one firer type i against two target type j's. The use of the priority scheme is illustrated in subsequent sections.

Table I

Priority Scheme
Tank Firer Versus
Tank & BMP Targets

	Tank Target	BMP Target
RB 3 (2-3 km)	5	6
RB 2 (1-2 km)	2	4
RB 1 (0-1 km)	1	3

The desired number of firers type i to allocate against target type j in range band k is calculated as follows:

$$\delta ij\ k = Dij\ k \cdot TYij\ k \qquad (6)$$

where

$Dij\ k$ = The desired number of target type j kills/minute by all firers type i in range band k .

$TYij\ k$ = Expected time for one firer type i to kill one target type j in range band, k .

Note: The time unit of minutes is used for illustrative purposes only.

The expected time to achieve one kill is given by:

$$TKijk = \frac{NRij\ k}{RFij\ k} \qquad (7)$$

where

$NR_{ij\ k}$ = The number of rounds needed to kill target type j by firer type i in range band k .

$RF_{ij\ k}$ = The combat rate of fire of firer type i against target type j in range band k .

The number of rounds required to kill a target is given by:

$$NR_{ij\ k} = \frac{1}{PK_{ij\ k}} \qquad (8)$$

where

$PK_{ij\ k}$ = Probability of single shot kill of firer type i against target type j in range band k .

An important note involves the input variable $D_{ij\ k}$, or the desired number of kills per minute by firer type i against target type j in range band k. This variable may be given as a desired percentage of target type j kills by firer type i in range band k per minute of firing.

$$D_{ij\ k} = DP_{ij\ k} \cdot M_{j\ k} \qquad (9)$$

where

$DP_{ij\ k}$ = The desired percentage of target type j kills/min by firer type i in range band k .

$M_{j\ k}$ = The number of targets type j in range band k .

Once $D_{ij\ k}$ has been determined, it is one of the inputs to equation (6) in determining the desired number of firers to allocate. The important difference in the alternative of equation (9) is that the number of targets of type j is considered in the desired allocation scheme.

It is important to note that both $D_{ij\,k}$ and $DP_{ij\,k}$ are user inputs. Because of this fact there is potential difficulty in determining values for either input. Both inputs are easier to determine if the user knows the number of enemy targets by type in each range band. Knowing this, the user then must decide the desired number of targets by type or percentage of targets by type (for one minute in either case) to be killed by firers by type in all range bands. This decision algorithm is based on overall tactical plan with several considerations such as the available number of firers by type. Overall, the user must make several decisions in arriving at the $D_{ij\,k}$ or $DP_{ij\,k}$, which is not a simple process.

3. Sequential Constraints

There are several constraints or conditions that a user may chose to impose on a given priority or priorities. Regardless of the determined desired number of firers for a particular priority, a maximum number of firers to allocate may be designated. For example, a commander may possess a limited number of a particular firer type i and desires to utilize one-third of them for each designated priority. If N_i equaled nine, then a maximum number of three would be allocated to each priority, even if the determined desired number was greater.

In another situation, a user has decided that a particular range band has limited importance and desires no more than 30% of all firers be allocated to that range band regardless of priority. Suppose that N_i equals 20 firers and that 8 firers are determined to be necessary to cover that designated range band. With the imposed 30% constraint, a total of 6 firers would be allocated with a result of 75% coverage of the range band.

The user may also impose a constraint on a priority based on the ammunition status of firer type i . A particular priority may not be executed if the amount of ammunition is equal to or less than a pre-determined amount. This constraint and the others discussed are only a few examples of the ways a user can impose conditions on any of the designated priorities.

D. MULTIPLE FIRERS VS. MULTIPLE TARGETS EXAMPLE

The following example illustrates the notion of multiple firers versus multiple targets through the use of two types of firers against two types of targets. A designated priority scheme is used without any constraints. Tables of $PK_{ij\ k}$, $RF_{ij\ k}$, and $D_{ij\ k}$ are also utilized as input data. Data contained in the tables are used to determine $\hat{\psi}_{ij\ k}$, the desired number of firers for each priority. The overall result is a final fire distribution allocation plan.

Table II

Priority Scheme

	T1	T2	T1	T2
RB 3	9	12	10	11
RB 2	3	8	4	7
RB 1	1	6	2	5

Note: 1 equals 1st priority, 2 equals 2nd priority, etc.

Table III

PK_{ijk}

	i=1		i=2	
	j=1	j=2	j=1	j=2
k=3 (2-3km)	.08	.08	.75	.75
k=2 (1-2km)	.44	.44	.78	.78
k=1 (0-1km)	.86	.86	.78	.78

Table IV

RF_{ijk}

	i=1		i=2	
	j=1	j=2	j=1	j=2
k=3	1	1	2	2
k=2	2	1	1	1
k=1	2	2	.5	.5

Table V

D_{ijk}

	i=1		i=2	
	j=1	j=2	j=1	j=2
k=3	.5	.5	1	1
k=2	1	1	.5	.5
k=1	1	1	.25	.25

The results are shown in Table VI.

Table VI

Example Results

Priority No.	NRijk	TKijk	ψijk	Remaining Firers N1	N2
1	1.16	.58	.58	9.42	4
2	N/A	N/A	N/A	9.42	4
3	2.27	1.14	1.14	8.28	4
4	N/A	N/A	N/A	8.28	4
5	1.28	2.56	.64	8.28	3.36
6	N/A	N/A	N/A	8.28	3.36
7	1.28	1.28	.64	8.28	2.72
8	N/A	N/A	N/A	8.28	2.72
9	12.50	12.50	6.25	2.03	2.72
10	N/A	N/A	N/A	2.03	2.72
11	1.33	.67	.67	2.03	2.05
12	N/A	N/A	N/A	2.03	2.05

In summary, a sequential fire distribution allocation plan has been determined utilizing approximately 8 firers of one type (N1= 10) and approximately 2 firers of another type (N2 = 4). This example enables the commander to develop his allocation plan without using all available firers. The desired number of both type firers was determined using the given input data. This input data can be changed and/or modified according to the weapon systems available to the commander.

E. COMPARISON OF METHODOLOGIES

1. Simultaneous vs. Sequential

The simultaneous methodology determines a fire distribution allocation dependent on the variables that are introduced. The most complex version illustrated involves the type of firer, type of target, and range band of the target. Using the simultaneous methodology, the user is afforded an opportunity to consider using all assets simultaneously. The process allocates all available firers regardless of their total number, unless restricted by an external constraint. In essence, all firers are distributed through the allocation plan according to the specified parameters.

The sequential methodology requires the user to develop a priority scheme of targets. The user determines a table of sequential priorities based on the types of targets he will engage (simplest version) or the types of targets and the range band when they exist (complex version). Firers are then allocated, starting at the first priority and continuing through to the last priority. However, in contrast to the simultaneous methodology, the number of firers may be exhausted before all priorities are considered, or all firers may not be allocated.

2. Homogeneous vs. Heterogeneous

The homogeneous model is the simplest of all versions discussed. This simplicity has an advantage with respect to the allocation of firers. A user needs to consider only the total number of his firers and then decide on a portion or all of them to engage and destroy an enemy force. However, simplicity is also a disadvantage. By not incorporating additional variables, the final allocation plan is not realistic and thus, may not be effective.

For the heterogeneous version, variables concerned with improving the efficiency of the allocation process are introduced. Variables such as type of firer, type of target, and range from firer to target enhance the calculation of determining the desired number of firers to allocate. These variables enable a commander to analyze the battlefield and more accurately match firers against targets in range bands.

3. Range Considerations

Weapon systems are designed to effectively acquire, shoot, and destroy enemy targets. A limitation of all systems is the range within their designed mission can be successfully accomplished. As range increases, the system's Pk (Probability of Single Shot Kill) decreases. Although a commander may effectively match and allocate types of firers against types of targets, the probability of target destruction generally diminishes as range to the target increases.

The range band in which types of targets exist cause a commander to more carefully analyze his choice of the type of firer. Considering the variable, range, in conjunction with the variables type of firer and type of target, increases the chances of achieving target destruction for a given allocation plan.

4. Consideration of Number of Targets

Knowing the strength of the enemy force is vital information to a commander organizing his firers to face the threat. Without knowing the number of targets that exist, the best a commander can do is to allocate firers by type against targets by type in designated range bands. However, what if the mix of types of targets is drastically different than expected?

For example, suppose a commander determined his allocation plan assuming enemy targets were 70% tanks and 30% BMP's. In reality, the mix was 90% tanks and 10% BMP's which reduces the effectiveness of the number of firers by type allocated to targets by type. In this case there will not be enough firers allocated to the tank type targets.

Consequently, consideration of the number of targets causes an adjustment in the number of firers to be allocated. It is another variable which contributes to a more accurate allocation plan.

F. TACTI. L SCENARIO

In order to contrast the simultaneous and sequential methodologies, including sub-versions of each, an overall battlefield scenario is necessary. Using one standard scenario will allow the differences between methodologies and versions of each to be more apparent and illustrate the impact of certain variables.

The time frame is early 1985, and the location is the eastern boundary of the Federal Republic of Germany and Czechoslovakia. U.S. forces have been placed on full alert and are presently occupying their go-to-war battle positions. Narrowing the entire NATO battle plan, a single mechanized infantry battalion is the focus of this example scenario. This battalion faces a Soviet motorized rifle regiment in their assigned section of the battlefield. Figure 2.3 depicts the graphical outlay of each force as they are situated on the battlefield.

For ease of discussion, only two types of vehicle/weapon systems are considered for each force. U.S. forces will be referred to as firers with Soviet forces as targets. The Soviet force consists of 40 T-72 tanks and 90 BMP infantry vehicles. The U.S. force consists of 17 M-1 tanks and 26 M-2 infantry vehicles. The number of targets of type j in each range band represents the real scenario. Each allocation scheme depicts how the firers would be allocated for this

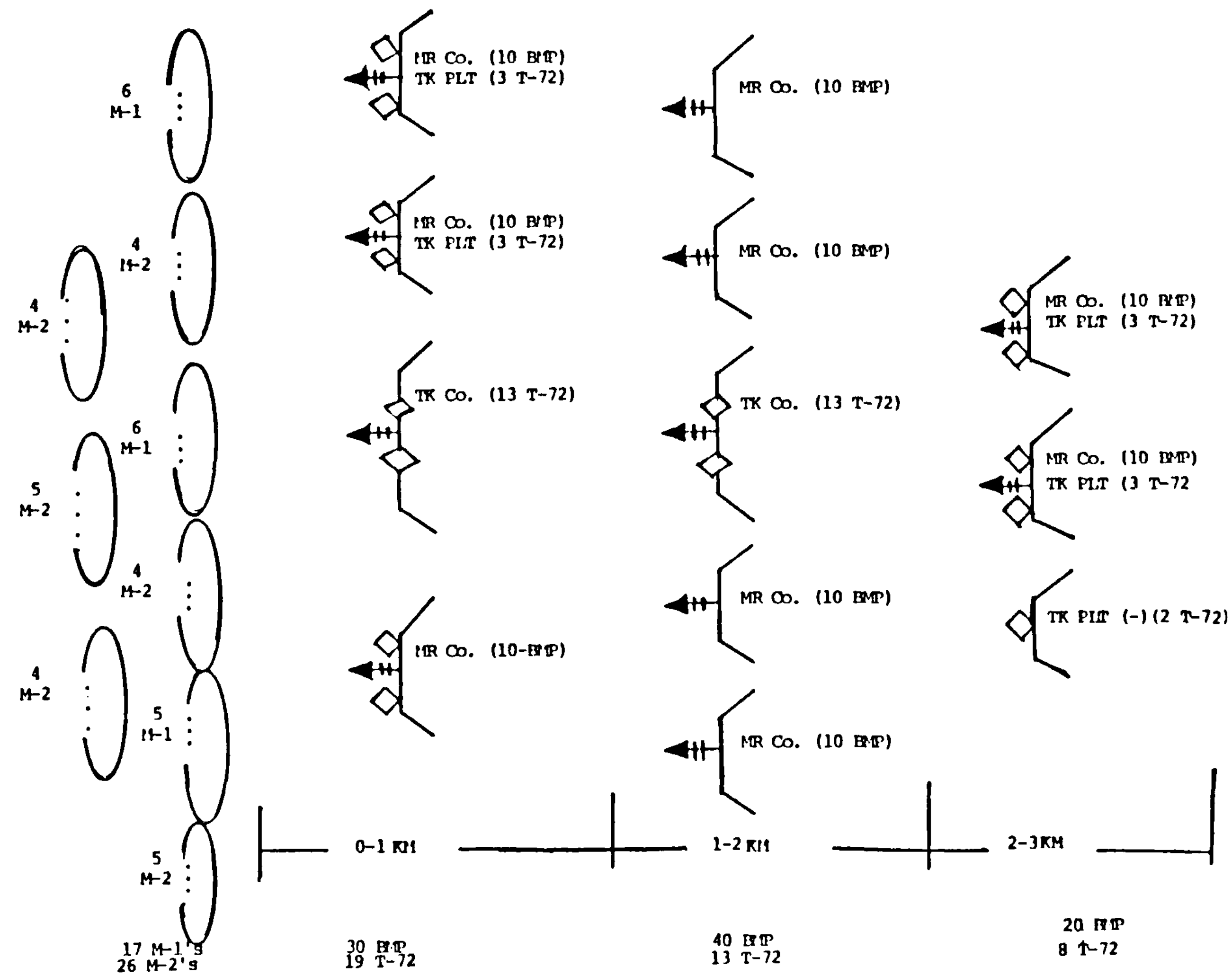


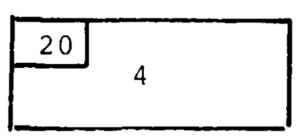
Figure 2.3 Tactical Scenario

example. It is important to note that the methodologies and schemes to be discussed are for acquired targets. Other algorithms will determine acquisition of targets in the Airland Battle Research Model.

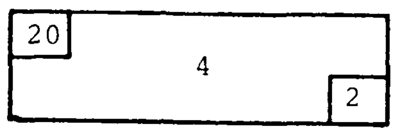
1. Simultaneous vs Sequential Methodology

Two methodologies have been developed which result in a fire distribution allocation plan. Within each methodology different versions exist which are characterized by the types of variables considered. Basically, the simultaneous method determines an allocation plan as if all assets were allocated "all at once." In contrast, the sequential method determines an allocation plan based on a priority scheme; in essence, one priority at a time. Homogeneous versus heterogeneous versions and the consideration of range and the number of enemy targets are important variations. Differences and similarities between the methodologies were discussed in previous sections.

Each version of both methodologies is depicted by means of a table. Notation is identical for all tables. N1 and N2 represent the number of firers of type 1 and 2 respectively, while M1 and M2 represent the number of targets of type 1 and 2 respectively. Range from firer to target is divided into three range bands; RB3 (2-3 km), RB2 (1-2km), and RB1 (0-1 km). Each block of the table is as follows:



Where 20 represents the number of targets by type in a particular range band and 4 represents the number of firers allocated to that number of targets. It is important to note that for illustration purposes, duplication of blocks will exist for each type firer. In reality, that number of targets would be the same vehicles, not additional numbers for each firer. Additionally, a priority number has been added to those tables for the sequential methodology. The priority is in the lower right hand corner and the blocks appear as:



2. <u>Simultaneous Allocation</u>

a. Homogeneous Force Allocation

The user has determined that 75% of his total number of firers will be allocated against all targets. Allocation of firers is calculated by multiplying the percentage (ψ) of one firer against one target by the number of targets by type in each range band. The allocation plan is derived using the same ψ for each combination of type of firer, type of target, and range band. The allocation, β , is determined from equation $\beta = N \times \psi / M$.

Homogeneous Force Allocation

	N1(17)		N2(26)	
	M1	M2	M1	M2
RB 3	[8] 2	[20] 5	[8] 2	[20] 5
RB 2	[13] 3.3	[40] 10	[13] 3.3	[40] 10
RB 1	[19] 4.8	[30] 8	[19] 4.8	[30] 8

Given: M1 = 40 T-72's

M2 = 90 BMP's

N = 43 Firers

M = 130 Targets

Allocate 75% of N firers to M targets

Define: $\beta = \frac{N(.75)}{M} = \frac{43(.75)}{130}$

β = .25 firers per target

b. Allocation by Firer/Target Type

The user has specified the percentage of firers type i to be allocated to targets type j (ϕ_{ij}) for each firer against each target. ϕ_{ij} is multiplied by the number of available firers type i and this product then divided by the number of targets type j . This number represents the number of firers type i, allocated against one target type j ; it is multiplied by the number of targets that exists in a particular range band to achieve the final allocation of firers. This distribution is driven only by the relative number of targets in each range band. The allocation is determined from equation $\beta = Ni \times \psi ij/Mj$.

Allocation by Firer/Target Type

	N1 (17)		N2 (26)	
	M1	M2	M1	M2
RB 3	8 / 2.7	20 / .8	8 / 3.7	70 / 1.8
RB 2	13 / 4.4	40 / 1.6	13 / 6.0	40 / 3.6
RB 1	19 / 6.5	30 / 1.2	19 / 8.8	30 / 2.7

Given: M1 = 40 T-72's and M2 = 90 BMP's

$\psi_{11} = .80 \rightarrow \beta_{11} = .34$

$\psi_{12} = .20 \rightarrow \beta_{12} = .04$

$\psi_{21} = .70 \rightarrow \beta_{21} = .46$

$\psi_{22} = .30 \rightarrow \beta_{22} = .09$

c. Allocation by Firer/Target Type and Range Band

The commander has determined the percentage of firers type i to be allocated to targets type j in range band k. ψikj is multiplied by the number of available firers type i. This represents the number of firers allocated to the number of targets type j in that specified range band k. This allocation is determined from equation $\beta = Ni \times \psi ijk/Mjk$.

Allocation by Firer/Target Type and Range Band

	N1 (17)		N2 (26)	
	M1	M2	M1	M2
RB 3	8 / 1.7	20 / 0	8 / 13	20 / 3.9
RB 2	13 / 3.4	40 / 0	13 / 2.6	40 / 2.6
RB 1	19 / 9	30 / 5.2	19 / 2.6	30 / 1.3

$\psi_{111} = .50 \rightarrow \beta_{111} = .45$

$\psi_{112} = .20 \rightarrow \beta_{112} = .26$

$\psi_{113} = .10 \rightarrow \beta_{113} = .21$

$\psi_{121} = .20 \rightarrow \beta_{121} = .11$

$\psi_{122} = 0 \rightarrow \beta_{122} = 0$

$\psi_{123} = 0 \rightarrow \beta_{123} = 0$

$\psi_{211} = .10 \rightarrow \beta_{211} = .14$

$\psi_{212} = .10 \rightarrow \beta_{212} = .20$

$\psi_{213} = .50 \rightarrow \beta_{213} = 1.6$

$\psi_{221} = .05 \rightarrow \beta_{221} = .04$

$\psi_{222} = .10 \rightarrow \beta_{222} = .07$

$\psi_{223} = .15 \rightarrow \beta_{223} = .19$

Given: M11 = 19 T-72's

M12 = 13 T-72's

M13 = 8 T-72's

M21 = 30 BMP's

M22 = 40 BMP's

M23 = 20 BMP's

3. Firing Rate Allocation

a. Range Independent Allocation

Adjusting the number of firers by type is derived from equation (3). Tables containing DRij and RFij are used as input for the equation. This adjustment accounts for the known number of enemy targets by type.

<u>Range Independent Adjustment</u>

	N1(17)		N2(26)	
	M1	M2	M1	M2
RB 3	[8] 2.0	[20] 1.6	[8] 2.2	[20] 3.4
RB 2	[13] 3.1	[40] 3.2	[13] 3.6	[40] 6.8
RB 1	[19] 4.6	[30] 2.4	[19] 5.3	[30] 5.1

$\delta_{11} = 9.7 \rightarrow .24$ Firers per Target

$\delta_{12} = 7.3 \rightarrow .08$ Firers per Target

$\delta_{21} = 11.1 \rightarrow .28$ Firers per Target

$\delta_{22} = 14.9 \rightarrow .17$ Firers per Target

<u>DRij</u>

$DR_{11} = 3$

$DR_{12} = 1$

$DR_{21} = 5$

<u>RFij</u>

$RF_{11} = 1.7$

$RF_{12} = 1.7$

$RF_{21} = 1.2$

<u>Targets</u>

M1 = 40 T-72's

M2 = 90 BMP's

b. Range Dependent Allocation

Adjusting the number of firers by type is derived from equation (4). Tables VII and VIII containing DRijk and RFijk are used as input for the equation.

Range Dependent Allocation

	N1(17)		N2(26)	
	M1	M2	M1	M2
RB 3	(8) 1.1	(20) 1.4	(8) 2.7	(20) 2.2
RB 2	(13) 1.9	(40) 2.8	(13) 5.8	(40) 4.4
RB 1	(19) 5.4	(30) 4.2	(19) 4.2	(30) 6.7

$\delta_{111} = 5.4$ $\delta_{211} = 4.2$

$\delta_{112} = 1.9$ $\delta_{212} = 5.8$

$\delta_{113} = 1.1$ $\delta_{213} = 2.7$

$\delta_{121} = 4.2$ $\delta_{221} = 6.7$

$\delta_{122} = 2.8$ $\delta_{222} = 4.4$

$\delta_{123} = 1.4$ $\delta_{223} = 2.2$

Targets		
M11 =	19	T-72's
M12 =	13	T-72's
M13 =	8	T-72's
M21 =	30	BMP's
M22 =	40	BMP's
M23 =	20	BMP's

Table VII

DRijk

	j=1		j=2	
	j=1	j=2	j=1	j=2
k=3	1	5	3	1
k=2	2	1	2	.5
k=1	4	2	.5	.5

Table VIII

RFijk

	j=1		j=2	
	j=1	j=2	j=1	j=2
k=3	1	1	2	2
k=2	2	2	1	1
k=1	2	2	.5	.5

4. Simultaneous Contrasts

The Homogeneous Force Allocation is the simplest version for a user to implement. It requires no information about enemy targets and does not consider different types of friendly firers.

Allocation by Firer/Target Type requires the user to analyze enemy target types and establish what percent of each firer will engage each type target. This allows the user to better utilize the capabilities of each type firer and allocate them against the types of targets they are designed to destroy. For example, the user decides to allocate 80% of his tank firers to engage and destroy tank targets and the remaining 20% against other targets. The user is capitalizing on the fact that tanks are designed to destroy tanks.

By introducing the variable, range, the allocation by Firer/Target Type and Range Band version further enhances the firer's inherent characteristics. The user can now allocate his firers with range in mind, as well as the type of target. For example, the M-2 weapon system is designed for long range engagements (Range Band 3) rather than short range (Range Band 1). In this version, the user has the capability to capitalize on this and allocate a greater percentage to longer ranges.

The versions of the Target Firepower Factor Allocation Model are similar in format to the two previously discussed. However, the versions utilize a relative weighting technique in consideration of acquired enemy targets. With the IDAGAM I version the weighting scheme is based on the ratio of the initial percent allocation for the (i,j) pair against a "standard" force and the number of target type j in the "standard" force. In contrast, in the firing rate allocation version, the weighting scheme is based on the relative amount of firepower desired against each target type j from firer type i .

All versions, in computation of allocation of firers, use a term called firers per target.

5. Sequential Allocation

a. Sequential Allocation by Firer/Target Type

Allocation of firers is derived by using equations (6), (7), and (8) with range not considered. Tables containing PKij, RFij, and Dij are used as input for the equations.

Sequential Allocation by Firer/Target Type

	N1(17)		N2(26)	
	M1	M2	M1	M2
RB 3	8; 1.02; 1	20; 1.02; 2	8; 1.42; 1	20; 1.42; 2
RB 2	13; 1.02; 1	40; 1.02; 2	13; 1.42; 1	40; 1.42; 2
RB 1	19; 1.02; 1	30; 1.02; 2	19; 1.42; 1	30; 1.42; 2

Priority #1 → M1

Priority #2 → M2

δ_{11} = .8 → 1.02 Firers vs. M1 in all Range Bands

δ_{12} = .8 → 1.02 Firers vs. M2 in all Range Bands

δ_{21} = .6 → 1.42 Firers vs. M1 in all Range Bands

δ_{22} = .6 → 1.42 Firers vs. M2 in all Range Bands

RKij	RFij	Dij
PK_{11} = .46	RF_{11} = 1.7	D_{11} = .8
PK_{12} = .46	RF_{12} = 1.7	D_{12} = .8
PK_{21} = .77	RF_{21} = 1.2	D_{21} = .6
PK_{22} = .77	RF_{22} = 1.2	D_{22} = .6

Targets
M11 = 19 T-72's
M12 = 13 T-72's
M13 = 8 T-72's
M21 = 30 BMP's
M22 = 40 BMP's
M23 = 20 BMP's

b. Sequential Allocation by Firer/Target Type and Range

Allocation of firers is derived by using equations (6), (7), and (8). Tables containing PKijk, RFijk, and Dijk are used as input for the equations.

Sequential Allocation by Firer/Target Type and Range

	N1(17)		N2(26)	
	M1	M2	M1	M2
RB 3	8 / 6.3 / 9	20 / 6.3 / 12	8 / .7 / 10	20 / .7 / 11
RB 2	13 / 1.1 / 3	40 / 1.1 / 8	13 / .7 / 4	40 / .7 / 7
RB 1	19 / .6 / 1	30 / .6 / 6	19 / .7 / 2	30 / .7 / 5

M11 = 19 T-72's

M12 = 13 T-72's

M13 = 8 T-72's

$\delta_{111} = 1$ → .6 N1 Firers in Range Band 1

$\delta_{112} = 1$ → 1.1 N1 Firers in Range Band 2

$\delta_{113} = .5$ → 6.3 N1 Firers in Range Band 3

$\delta_{121} = 1$ → .6 N2 Firers in Range Band 1

$\delta_{122} = 1$ → 1.1 N2 Firers in Range Band 2

$\delta_{123} = .5$ → 6.3 N2 Firers in Range Band 3

$\delta_{211} = .25$ → .7 N1 Firers in Range Band 1

$\delta_{212} = .5$ → .7 N1 Firers in Range Band 2

$\delta_{213} = 1$ → .7 N1 Firers in Range Band 3

$\delta_{221} = .25$ → .7 N2 Firers in Range Band 1

$\delta_{222} = .5$ → .7 N2 Firers in Range Band 2

$\delta_{223} = 1$ → .7 N2 Firers in Range Band 3

Targets	
M11 = 19	T-72's
M12 = 13	T-72's
M13 = 8	T-72's
M21 = 30	BMP's
M22 = 40	BMP's
M23 = 20	BMP's

Table IX

PKijk

	i=1		i=2	
	j=1	j=2	j=1	j=2
k=3 (2-3km)	.08	.08	.75	.75
k=2 (1-2km)	.44	.44	.78	.78
k=1 (0-1km)	.86	.86	.78	.78

Table X

RFijk

	i=1		i=2	
	j=1	j=2	j=1	j=2
k=3 (2-3km)	1	1	2	2
k=2 (1-2km	2	2	1	1
k=1 (0-1km)	2	2	.5	.5

Table XI

Dijk

	i=1		i=2	
	j=1	j=2	j=1	j=2
k=3 (2-3km)	.5	.5	1	1
k=2 (1-2km)	1	1	.5	.5
k=1 (0-1km)	1	1	.25	.25

6. Sequential Contrasts

Sequential allocation by Firer/Target Type utilizes the priority scheme with reference to types of targets. The user establishes his priority scheme after deciding, for example, that tank targets are more important and thus priority #1 with other targets receiving a descending importance and priority. A target's priority does not change regardless of the position of the target on the battlefield.

The second version of sequential allocation is identical to the first except that range band is also a consideration. Because of range band consideration, each target type j in each range band being engaged by firer type i has a specific priority. This allows the user to more accurately develop a priority scheme.

G. ANALYSIS OF ALLOCATION METHODOLOGIES

The Summary Allocation Chart, Table XII, illustrates the allocation of firers according to firer type i against target type j in range band k for both methodologies and subversions of each. An example of analysis of several allocations will be presented to highlight their differences.

Contrasting A, B, and C, look at N1, T1, RB1 . This example is a firing tank versus a target tank in range band 1. For A, .25 firers per target were allocated, independent of firer, target type, or range band, resulting in 4.8 firers allocated. For B, .34 firers per target were allocated, independent of range band, resulting in 6.5 firers allocated. For C, .45 firers per target were allocated, resulting in 9 firers allocated.

The important thing to note is that in Case A, there is no ability to concentrate on tank versus tank allocation. In Case B, there is no ability to concentrate on the close-in targets. Note also the large number of tank firers allocated to BMP targets in the far range band by Method A, resulting in a disproportionate allocation of tank firers to those targets.

Table XII

Summary Allocation Chart

	N1														N2													
	T1							T2							T1							T2						
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
RB 3	2	2.7	1.7	2.0	1.1	1.02	6.3	5	.8	0	1.6	1.4	1.02	6.3	2	3,7	1.3	2.2	2.7	1.42	.7	5	1.8	3.9	3.4	2.2	1.42	.7
RB 2	3.3	4.4	3.4	3.1	1.9	1.02	1.1	10	1.6	0	3.2	2.8	1.02	1.1	3.[illegible]	6.0	2.6	3.6	5.8	1.42	.7	10	3.6	2.6	6.8	4.4	1.42	.7
RB 1	1.8	6.5	9	4.6	5.4	1.02	.6	8	1.2	5.2	2.4	4.2	1.02	.6	1.8	1.8	2.6	5.3	4.2	1.42	.7	8	2.7	1.3	5.1	6.[illegible]	1.42	.7

A = Simultaneous/Homogeneous

B = Simultaneous/Heterogeneous (ij)

C = Simultaneous/Heterogeneous (ijk)

D = Simultaneous/Firing Rate Allocation (ij)

E = Simultaneous/Firing Rate Allocation (ijk)

F = Sequential/Heterogeneous (ij)

G = Sequential/Heterogeneous (ijk)

H. CHAPTER SUMMARY

Tactically, fire distribution allocation plans are derived in as many ways as there are commanders. This chapter presented two methodologies that illustrated ways to determined desired numbers of firers allocated against numbers of targets. Versions of each methodology were shown starting from the simple (no variables involved) and developing into the complex (several variables involved).

In the development of a fire distribution allocation plan, a commander needs to maximize the effectiveness of each available weapon system. This can be accomplished by analysis of the targets by type, the firers by type that will engage the targets, and the ranges between firers and targets. These variables were developed independently and finally cummulatively within each methodology. The development of a priority scheme by the commander was instrumental in being used as a vehicle to sum all the variables into one analytical tool.

With regard to flexibility, priority constraints were explored as a means to implement command perogatives on select priorities. Trade-offs between the number of firers to be allocated and the amount of coverage per priority was illustrated. Overall, following a multi-step procedure within either methodology, led to a determined fire distribution allocation plan.

Two methods were presented discussed, one that utilities a percentage while the other a relative weight. The selection of one over the other should be determined in consultation with the users of the model.

III. UNIT ALLOCATION AND PLACEMENT

A. INTRODUCTION

Establishing any battlefield operation requires information about enemy forces, friendly forces, terrain, road networks, and other contributing factors. Two key steps in the development of an operations plan are the allocation and placement of fighting units. These procedures are accomplished by the various levels of organization found in the U.S. Army today. The procedures explored and defined in this chapter will focus on the U.S. Army hierarchy as shown in Figure 3.1. For comparison purposes found in later discussions, Figure 3.2 shows the enemy hierarchy.

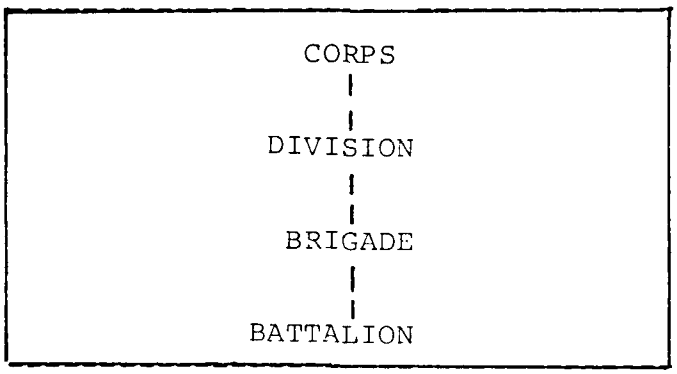


Figure 3.1 U.S. Army Levels of Organization

The purpose of this chapter is to explore and define methodologies which will enable the model user to allocate fighting units from one level of organization to a lower one and eventually place those fighting units at specific locations

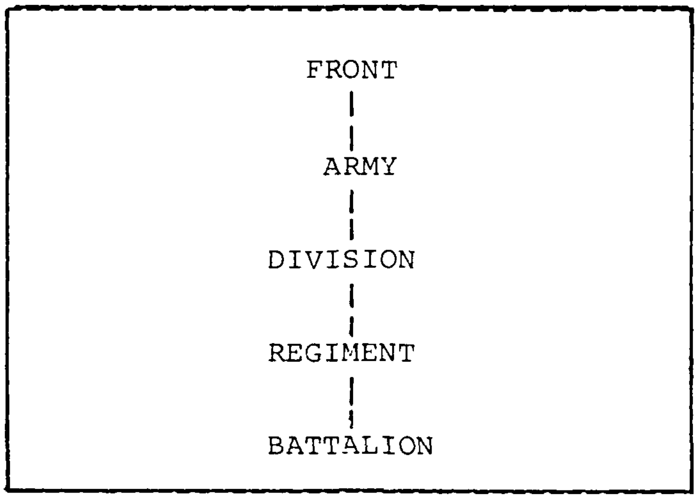


Figure 3.2 Enemy Levels of Organization

on the battlefield. It is important to note that throughout this chapter corps, division, and brigade are those levels of organization that are allocating fighting units while Battalion is placing the fighting units. The tool to be used for both allocation and placement methodologies is called a template.

A template is defined as the result of implementing a set of allocation rules. In essence, the template becomes a picture of how units are allocated or placed on the battlefield. By doctrine, military planners study a map of the battlefield, analyzing terrain, obstacles, road network systems, and enemy avenues of approach. Here, an avenue of approach is defined as a route for a force of a particular size to reach an objective or key terrain. With assigned boundaries of geographic responsibilities, an assigned mission, and an anticipated threat, the military planners begin the process of allocating and placing fighting units. This process is initiated with consideration for several factors. First, the assigned mission is a determinant in how and where units will be allocated and placed. Secondly, the terrain is analyzed as to how it best supports the mission. Lastly, any constraints that may exist are examined such as the number of available units. This is a lengthy and time consuming process for the military planner.

The overall goal of a template is to aid the modeller in the allocation and placement process when confronted with various situations. When a particular situation arises, the modeller employs one of his templates (allocation or placement) without having to perform a complete analysis of that given situation; that analysis was performed earlier to create the template. Both the allocation and placement templates will be developed in this chapter along with appropriate examples.

Network structures representing larger, real transportation systems are used in the placement methodology and for definition of avenues of approach for allocation. Networks are used to represent the transportation characteristics of the terrain. In addition, they can also be employed to represent possible movement paths by the insertion of arcs and nodes. [Ref. 3: pp. 17-18]

B. ALLOCATION TEMPLATE

The allocation template is network independent. Essentially, the allocation of fighting units will be based on the assigned mission, geographic boundaries of responsibilities, and avenues of approach within those boundaries. Corps, division, and brigade levels of organization will be addressed throughout this section with emphasis placed on their respective part of the allocation methodology. For purposes of this thesis, a level of organization considers allocating units two levels of organization lower than itself and establishing command and control headquarters one level lower than itself.

1. Corps Allocation

Figure 3.3 depicts the situation as it exists on a given piece of terrain. The 2nd Corps (US), comprised of the 11th and 15th Divisions (US) is facing an enemy Front-size avenue of approach. Both divisions have been assigned the mission to execute a prepared defense in their respective assigned areas of responsibility. Existing U.S. Army Operation Plans (OPLANS) dictate corps level boundaries of responsibilities. These graphics are classified and thus are not covered in this thesis. However, the point being that boundaries used in the following examples are not totally arbitrary.

At the corps level, the key decision to be made is how much combat power is to be allocated to each avenue of approach. The avenues of approach being considered are those capable of holding enemy Army-size units versus division-size units. This decision is reached only after a multi-step procedure which analyzes the terrain, enemy avenues of approach, and the available friendly combat power (number of brigade-size units). It

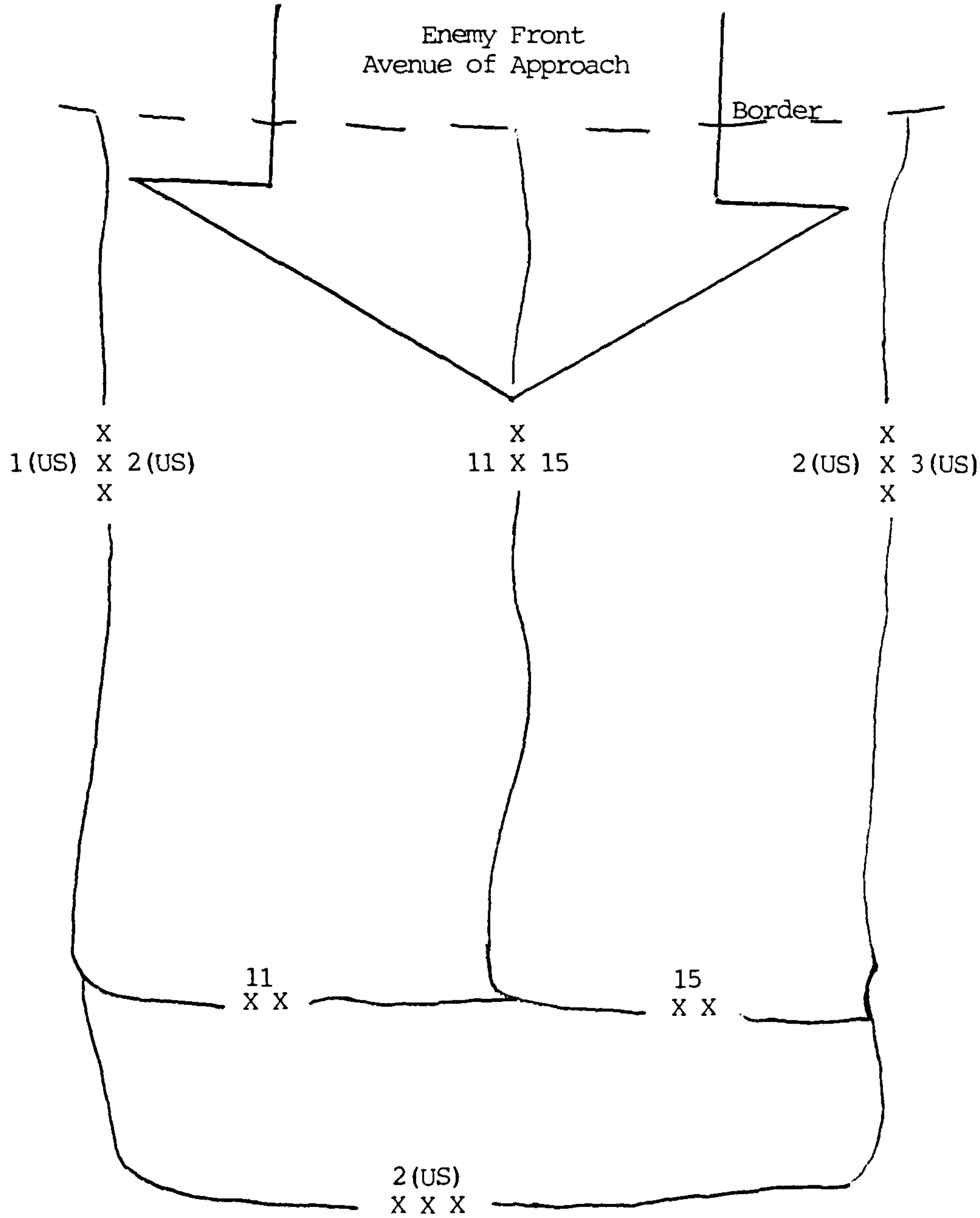


Figure 3.3
Corps Level Situation

is important to distinguish between those data initially input to the Airland Research Model (such as possible avenues of approach) and data generated as input to the templates during model execution. Each step describes explicitly the source of the data. The multi-step procedure is defined as follows:

1. After a careful study of the terrain within the Corps sector, possible enemy Army-size avenues of approach are identified and initially input to the model based solely on the terrain configuration.

2. These avenues of approach provide a visualization of the possible size of the enemy force. By considering enemy doctrine, it can be determined what formations and sequences that enemy unit will travel through that avenue of approach. This is a manual process derived from the military planner's analysis and is done for every identified avenue of approach. Figure 3.4 depicts the result of this study and illustrates the possible enemy avenues of approach along with the possible enemy unit size that could use that approach. After determining the size of the enemy unit that can use a given avenue of approach, enemy doctrine will illustrate that unit's tactical formation of sub-units through the avenue.

3. At this point, determination of an acceptable combat ratio must be made. A combat ratio is defined as the ratio of friendly forces to enemy forces and is an input to the model based on friendly doctrine and operational experience of the military planner. This ratio is then applied to the available number of brigade-size units and appropriate allocations are made to each avenue of approach.

4. How many brigades can a division effectively control? This is a corps level decision when implementing the last step, that of allocating subordinate command and control headquarters. After completing the first three steps, which included an analysis of the enemy's tactical movement formations and selection of a combat ratio of, for example, one friendly unit to six enemy units, the corps allocated five brigades to the 11th Division and four brigades to the 15th Division. This allocation has been dynamically generated by the template. The type of unit as well as the number of units is also generated.

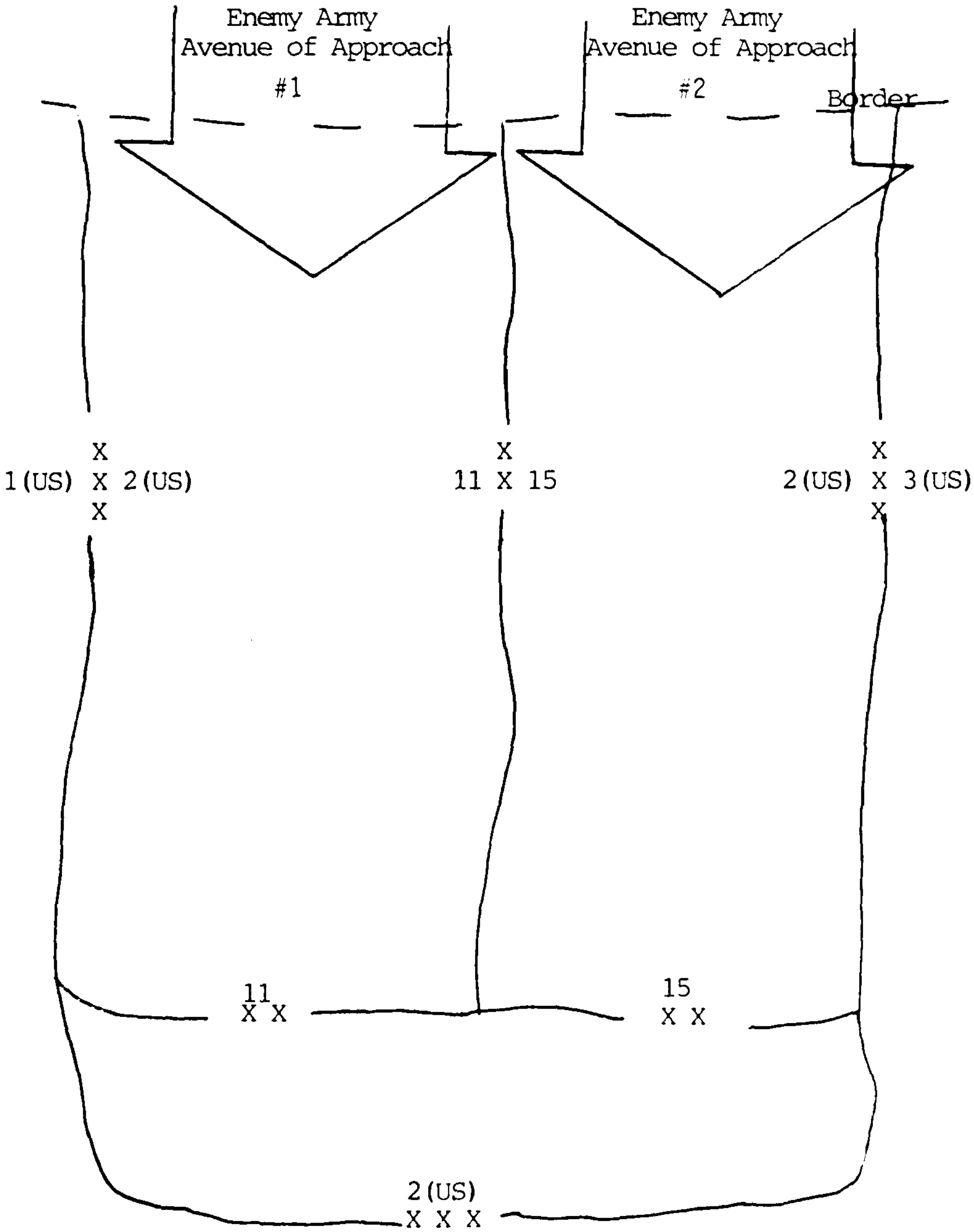


Figure 3.4
Corps Level Avenues of Approach

For example, if the enemy's lead unit on the avenue of approach is motorized (versus a tank unit), then the defending unit would likely be a mechanized unit and not a tank unit. Figure 3.5 illustrates the final allocation of brigades and division headquarters.

Defend on Avenue of Approach 1 with 5 Brigades	==>	11th Division
Defend on Avenue of Approach 2 with 4 Brigades	==>	15th Division

Figure 3.5 Corps Combat Allocation

How do these steps derive the corps allocation template? The steps represent the detailed, time consuming analysis that leads to a final allocation based on given tactical parameters, primarily, enemy avenues of approach. The template now gives a picture of how to allocate a given number of battalion-size units to the two avenues of approach previously illustrated. This allocation template replaces the necessity of repeating the procedure of implementing the allocation rules each time a corps is given the mission of a prepared defense.

2. Division Allocation

At the division level, combat power (battalion-size units) are allocated for the conduct of the assigned mission, prepared defense. Figure 3.6 illustrates the 11th Division's sector as assigned by corps.

The allocation procedure at the division level is the same multi-step methodology at the corps level. When determining enemy avenues of approach, division is analyzing a

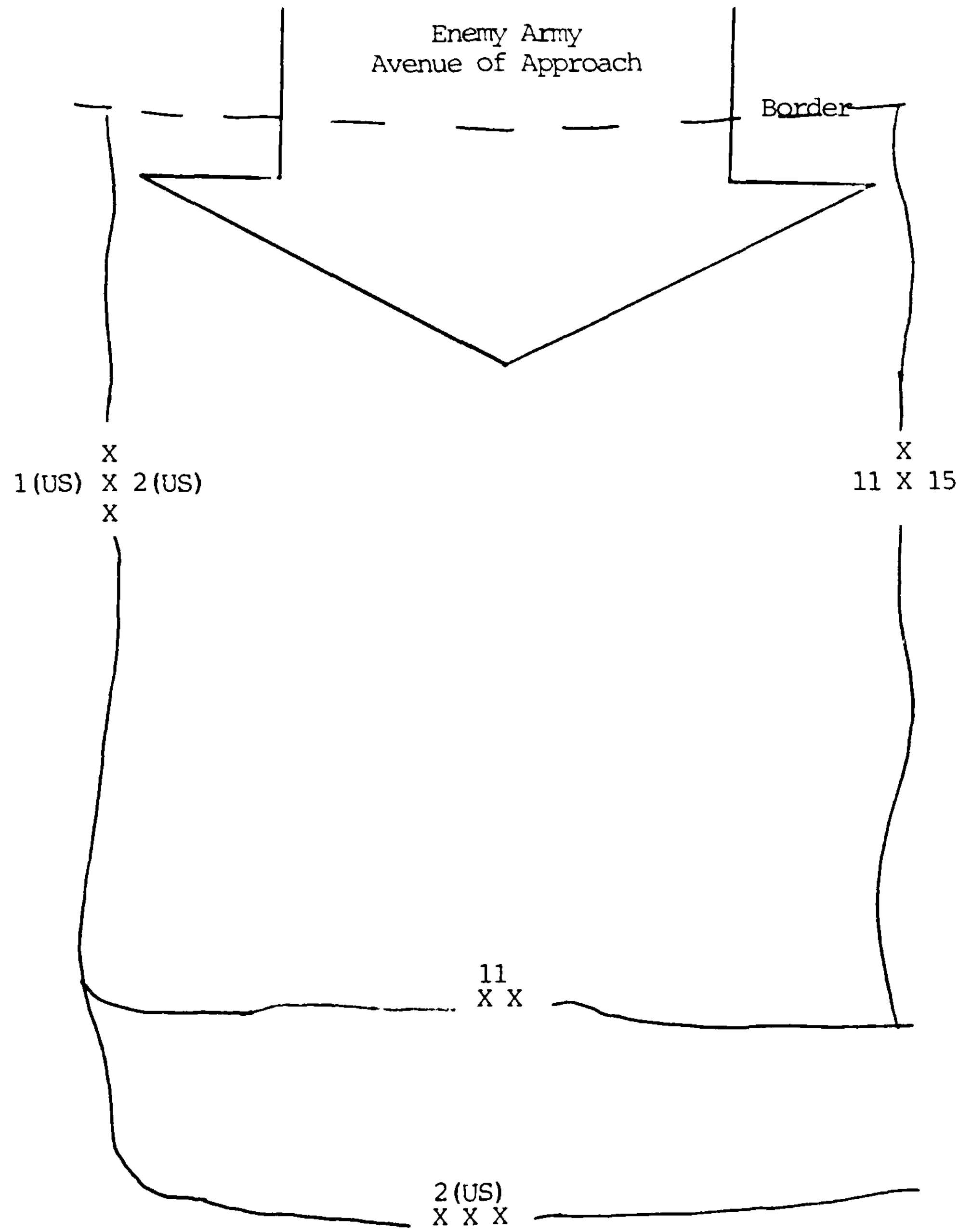


Figure 3.6
Division Level Situation

smaller sector as well as an overall smaller enemy size unit. This in turn causes division to consider the doctrine of the smaller unit (Army-size in this case) and determine enemy movement formations that conform to the avenues of approach. Figure 3.7 illustrates the result of this analysis.

For ease of illustration, division selects the same combat ratio (1 to 6), and allocates the appropriate number of units. As with the Corps allocation process, the division allocation process differentiates between manual input data and that data generated by the template. The geographic avenues of approach, enemy doctrine, and the accepted combat ratio are inputs to the model. In turn, the allocation rules generate the types and numbers of defending units; the result is a template. In the final step, brigade-size command and control headquarters are allocated. Figure 3.8 illustrates the final allocation of battalions and brigade headquarters.

Assuming three battalions per brigade, division's allocation leads to fifteen battalions allocated against six enemy avenues of approach.

The allocation template illustrated is a division level template when assigned a mission of prepared defense and six particular enemy avenues of approach are within the assigned sector of reponsibility.

3. Brigade Allocation

As previously described, corps and division allocate combat power against avenues of approach. Ultimately, combat

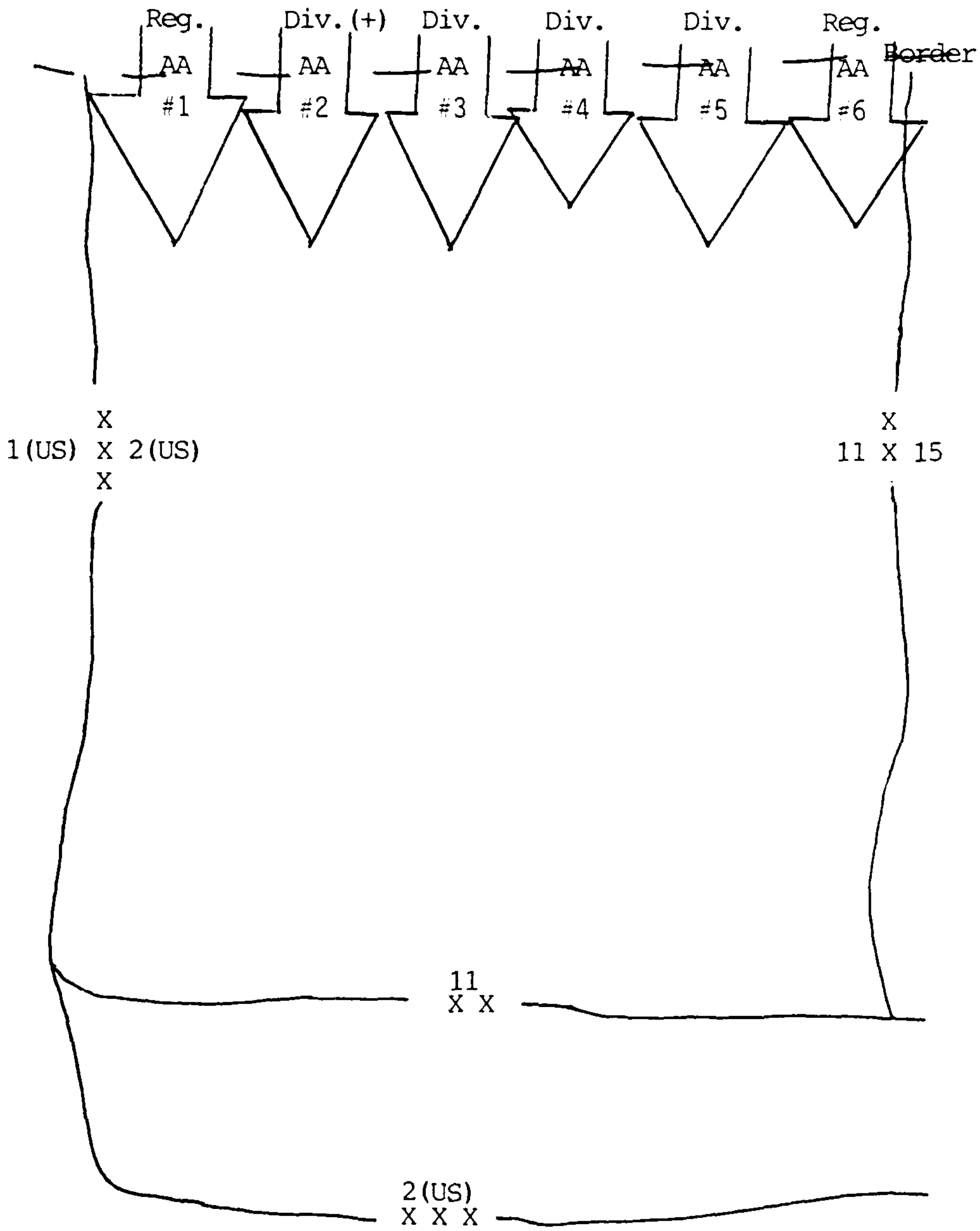


Figure 3.7
Division Level Avenues of Approach

Defend Avenue	1	with	1	Battalions	==>	1st & 2nd
"	2	"	4	"		Brigades
Defend Avenue	3	with	3	Battalions	==>	3rd Brigade
Defend Avenue	4	with	3	Battalions	==>	4th Brigade
Defend Avenue	5	with	3	Battalions	==>	5th Brigade
"	6	"	1	"		

Figure 3.8 Division Combat Allocation

units must be positioned on the assigned terrain. Since positioning (Placement Template) will be the responsibility of the battalion, the brigade level of organization allocates units with the same multi-step allocation procedures previously described. Figure 3.9 illustrates the 2nd Brigade's sector as assigned by division.

The sector of responsibility has been analyzed and five avenues of approach identified, each capable of holding particular enemy size units. Figure 3.10 illustrates the result of the brigade analysis.

To complete the allocation methodology, corps through brigade, brigade uses the same combat ratio (1 to 6) and allocates the appropriate number of company-sized units to each avenue of approach. Finally, battalion-sized command and control headquarters are allocated. Figure 3.11 illustrates the final allocation of companies and battalion headquarters.

As with the corps and division templates, the brigade template portrays a specific picture derived from the allocation rules. Given the mission of a prepared defense, area of

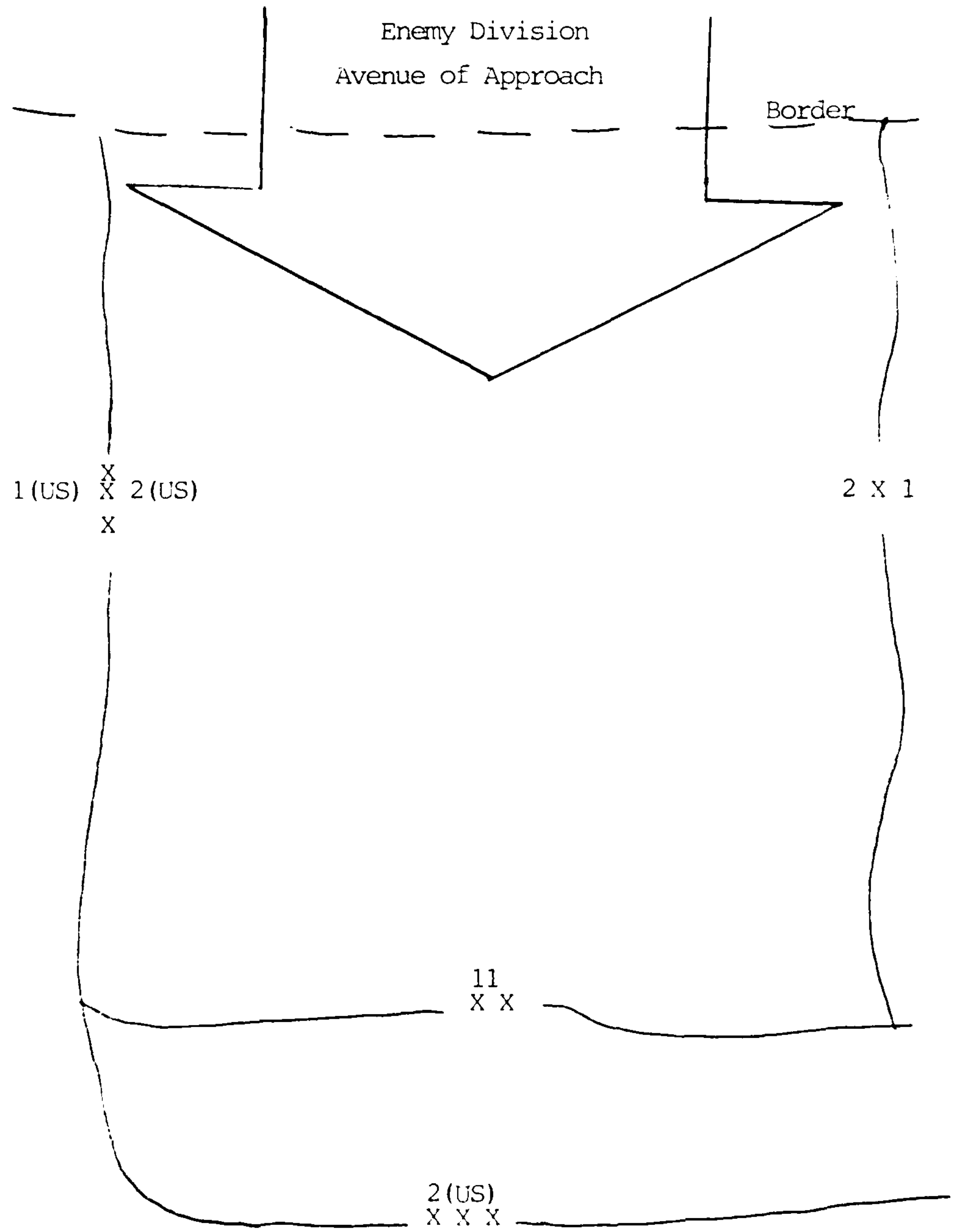


Figure 3.9
Brigade Level Situation

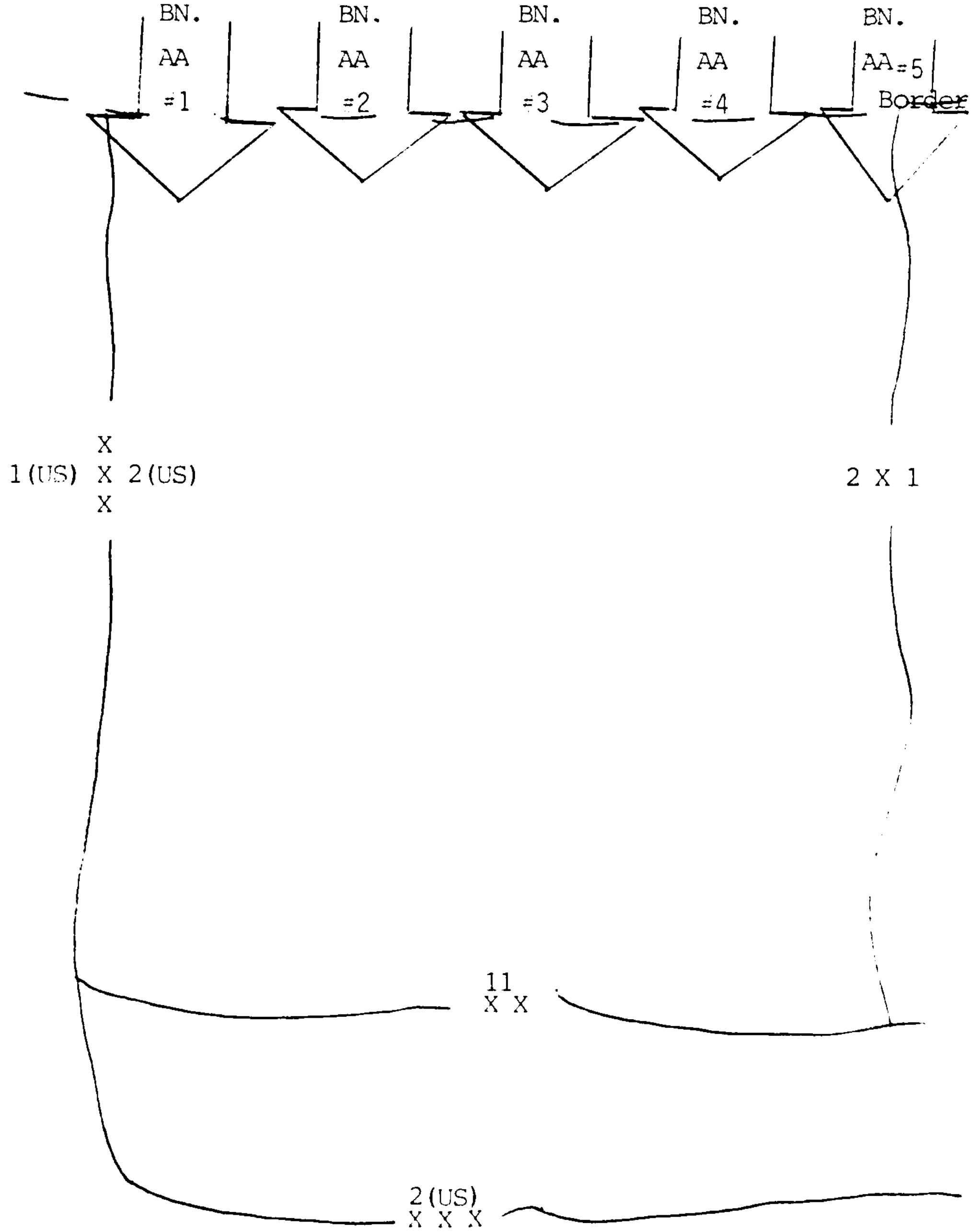


Figure 3.10
Brigade Level Avenues of Approach

Defend Avenue	1	with	1	Companies	==>	1	Battalion
"	2	"	1	"			
Defend Avenue	3	with	1	Companies	==>	1	Battalion
"	4	"	1	"			
Defend Avenue	5	with	3	Companies	==>	1	Battalion

Figure 3.11 Brigade Combat Allocation

responsibility, and analyzed enemy avenues of approach, an allocation of units was derived. The final picture of the brigade template is one of seven companies allocated to five enemy avenues of approach under the command and control of three separate battalion headquarters.

C. PLACEMENT TEMPLATE - MANEUVER UNITS

1. Introduction

The placement template is network dependent and implemented at the battalion level. Figure 3.12 illustrates the situation of the 1st Battalion, 9th Armor. The 9th Armor is defending against an enemy Regiment-size unit on an avenue of approach and must decide where to place the available four tank companies. That decision will be based on a set of placement rules with dependency on arc characteristics, perceived threat, and the Standard Units of Armament (SUA) values of the companies. SUA values are the Soviet equivalent to Firepower Scores and Weapon Effectiveness Indicator/Weapon Unit Value (WEI WUV). Parts of the network are defined in this section as well as the placement rules and the arc characteristics. A final model is presented for placing all available fighting units.

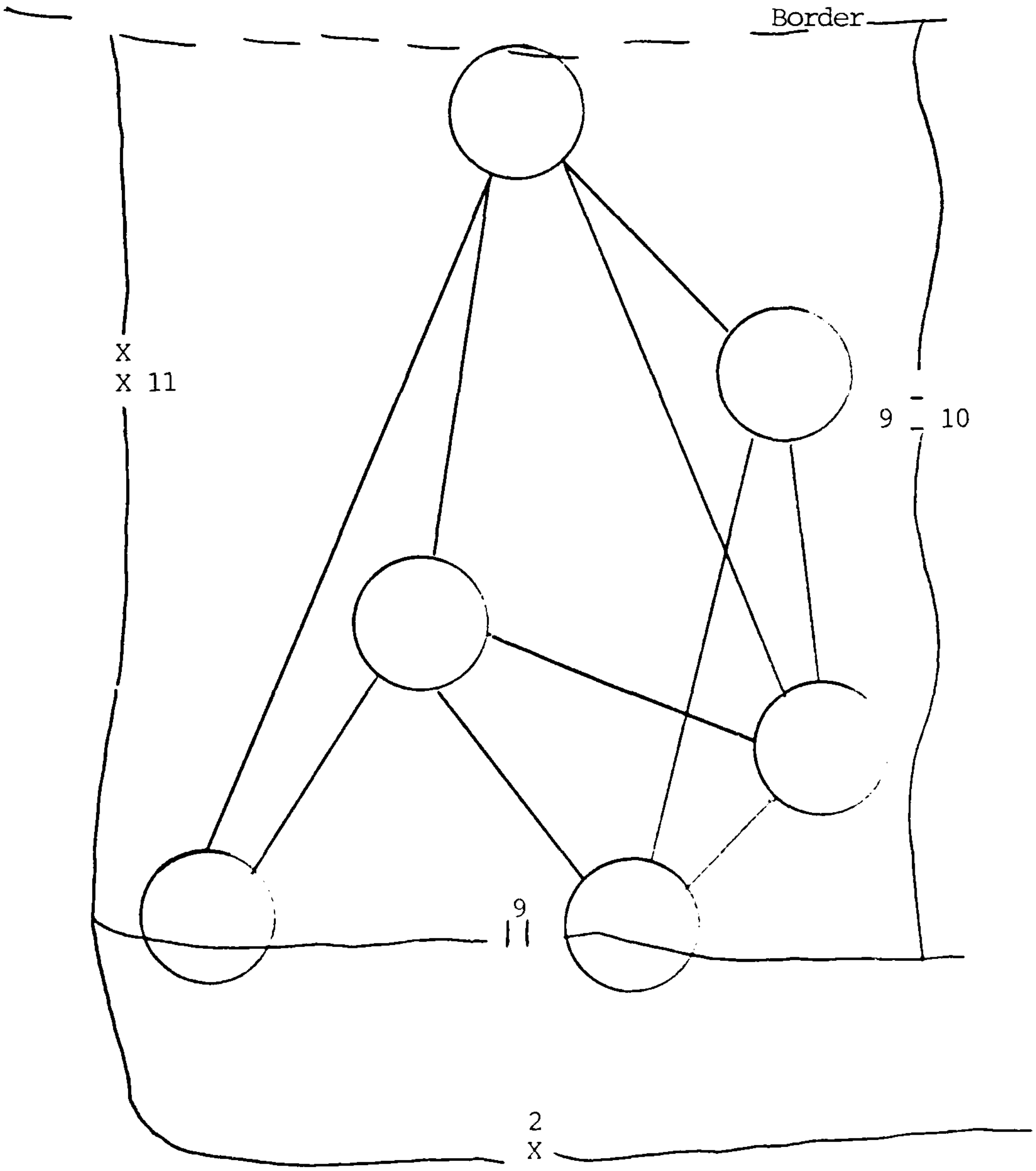


Figure 3.12
Battalion Level Situation

In addition to the placement templates for the maneuver units, methodology for the placement of engineer and artillery units will also be addressed.

2. Network Description

The network depicted in Figure 3.12 is an example of a transportation network. The components of the network (nodes and arcs) describe locations and routes respectively, and together form an abstraction of the terrain being modelled. [Ref. 4: p. 36] An arc represents a route which is used for the movement of a unit from one location to another. A node represents a fixed location on the terrain and is the intersection of one or more arcs.

The attributes of the arcs necessary as inputs to the model are as follows:

1. Capacity of the arc to physically hold a fighting unit.
2. Minimum acceptable site preparation time.
3. Maximum effective range that an arc can offer to a weapon system.
4. Length of an arc; measured in kilometers.
5. Standard Units of Armament (SUA) for each friendly fighting unit.

The capacity of an arc is measured in terms of how many fighting units can be physically located on that particular arc.

All possible placement sites must have a minimum amount of time available to the placed unit to prepare the site for the assigned mission. This minimum time is based on the time necessary to establish those elements of a battlefield position (e.g., obstacles, camoflauge, fields of fire). Assume the battalion was given twelve hours to place all units and have all preparations complete. If the minimum acceptable preparation time is six hours, then all possible placement sites can be no further than six hours travel time from the current location of the unit.

Every weapon system has as a characteristic a maximum effective range. Maximum effective range is defined as the maximum distance at which a weapon system may be expected to fire accurately to achieve the desired result. [Ref. 5: p. 1-73] Every placement site will have as an input the maximum line-of-sight distance that site can offer to a weapon system. For example, assume all the tank weapon systems in the 9th Armor have a maximum effective range of 3000 meters. If Arc A has a 2500 meter capability, and Arc B has a 2000 meter capability, then Arc A is a more desirable placement site and would be chosen over Arc B.

The length of an arc, measured in kilometers, is the actual length of the segment of a route represented by that arc. This distance is converted into a measurement of time signifying the total amount of travel time over the arc. This computation is derived from characteristics of the arc and the unit. [Ref. 6: p. 117]

The SUA is the method by which forces are compared as to combat potential and it is the SUA value which is degraded during execution using some attrition process. [Ref. 7: p. 117] During the model play, transition takes place from the execution model to appropriate planning models at such times that specified thresholds are exceeded. For any entry to the planning models, the current SUA values for each unit are known. The assumption made in the placement methodology is that the unit with the highest SUA is placed first, the second highest SUA next, and so forth.

3. Placement Rules

At the battalion level, placement of the available companies is the primary concern. After attributes of the arcs have been established, the placement template is derived from a methodology consisting of the following five rules:

1. Determine the minimum time path for enemy movement through the network. This calculation can be done using a technique called the shortest path algorithm. Essentially, the shortest path through the network is calculated summing the times along all utilized arcs.

2. Determine the specific mission of the friendly battalion-size unit. For example, within the mission, "Prepared Defense," there is a difference between "Delay" and "Delay and Destroy." This is a factor if two placement sites have the same maximum effective range value, meet the minimum acceptable preparation time requirement, but are located different distances from the enemy. If the mission is delay, the site closest to the enemy may be chosen so that the maximum amount of terrain can be used for maneuvering and subsequent positions.

3. The minimum time path is now used for selection of the placement sites. The equation involving the total mission time, travel time, and minimum acceptable preparation time is used (Figure 3-13). The objective of the placement template is to illustrate the positioning of all available fighting units throughout the network.

The minimum time path is determined so that positioning of units can maximize the enemy's time to move through the network. This is in direct conflict with the enemy's objective of minimizing its travel time through the network. Recalculation of the minimum time path is necessary after each company has been placed. Since the objective is the initial placement of all available units, only one site is established for each company. Subsequent placement sites are not examined at this time. The Airland Attrition Research Model (ALARM), a module of the Airland Battle Research Model, currently under development by Rolands and Associates recomputes both expected attrition to both sides, as well as the increased travel time on the arc resulting from the placement of the company [Ref. 8: p. 5]. For purposes of the example presented below, the enemy unit travel time is increased by a factor of two to illustrate the placement model.

4. The maximum effective range of the primary weapon system of each unit is determined for each feasible site. The site with the largest maximum effective range is chosen as the placement site.

5. Place the maneuver unit with the highest SUA value on the selected placement site. The initial SUA values for each unit are inputs of the ALARM module previously discussed.

The model in Figure 3.13 illustrates the overall placement methodology.

4. Placement Model Example

Figure 3.14 illustrates the same network representing one avenue of approach shown in Figure 3.12. However, values for the lengths (in hours) of each arc and letters identifying each node have been added. Additionally, the maximum effective range that an arc can offer is in parenthesis next to the arc's length. Placement of the four tank companies of the 1st Battalion, 9th Armor, will be determined using the described methodology. For illustration all arcs are feasible placement

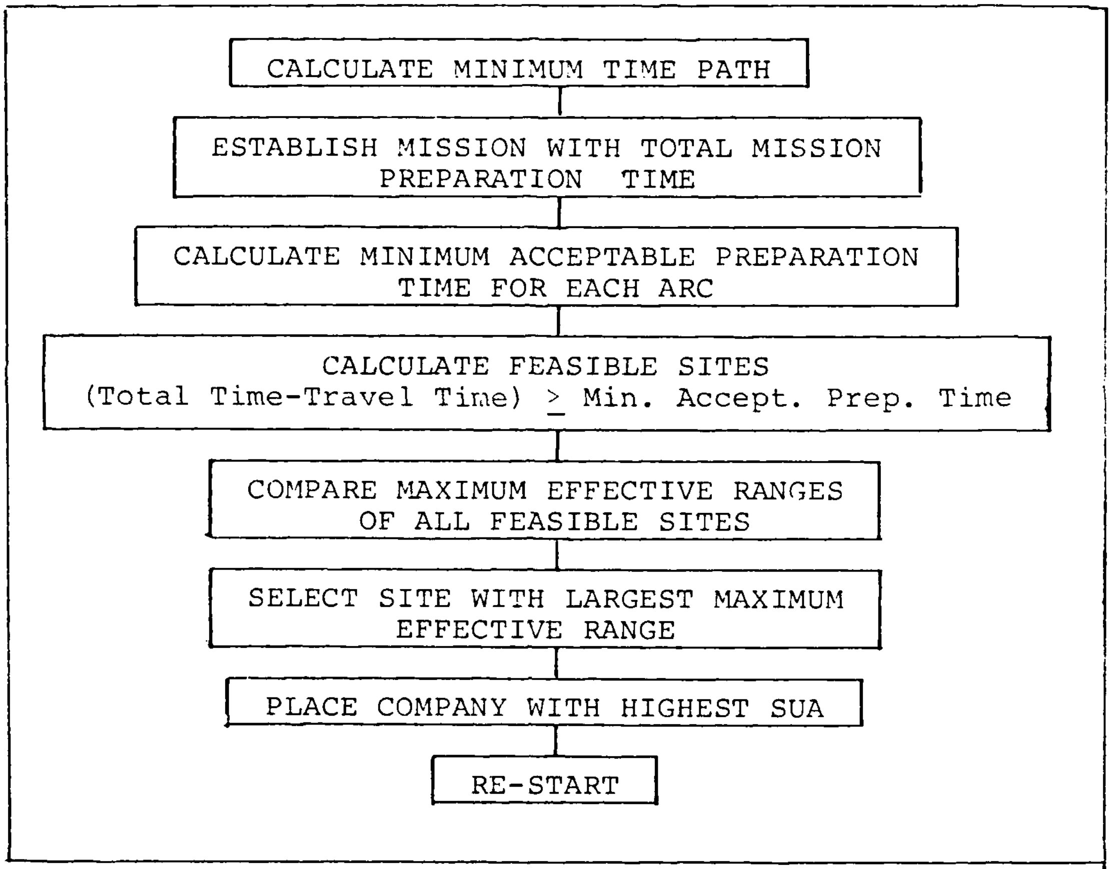


Figure 3.13 Placement Model

sites, and all arc capacities are limited to one unit. Recall that for purposes of this example, the placement of a unit on an arc doubles the travel time on that arc for all enemy movement.

Using the shortest path algorithm originating at node A and ending at either node E or F, the initial minimum time path is calculated to be A-C-E. This path represents the route that would take the enemy through the network in the least amount of time. Because Arc A-C offers a greater effective

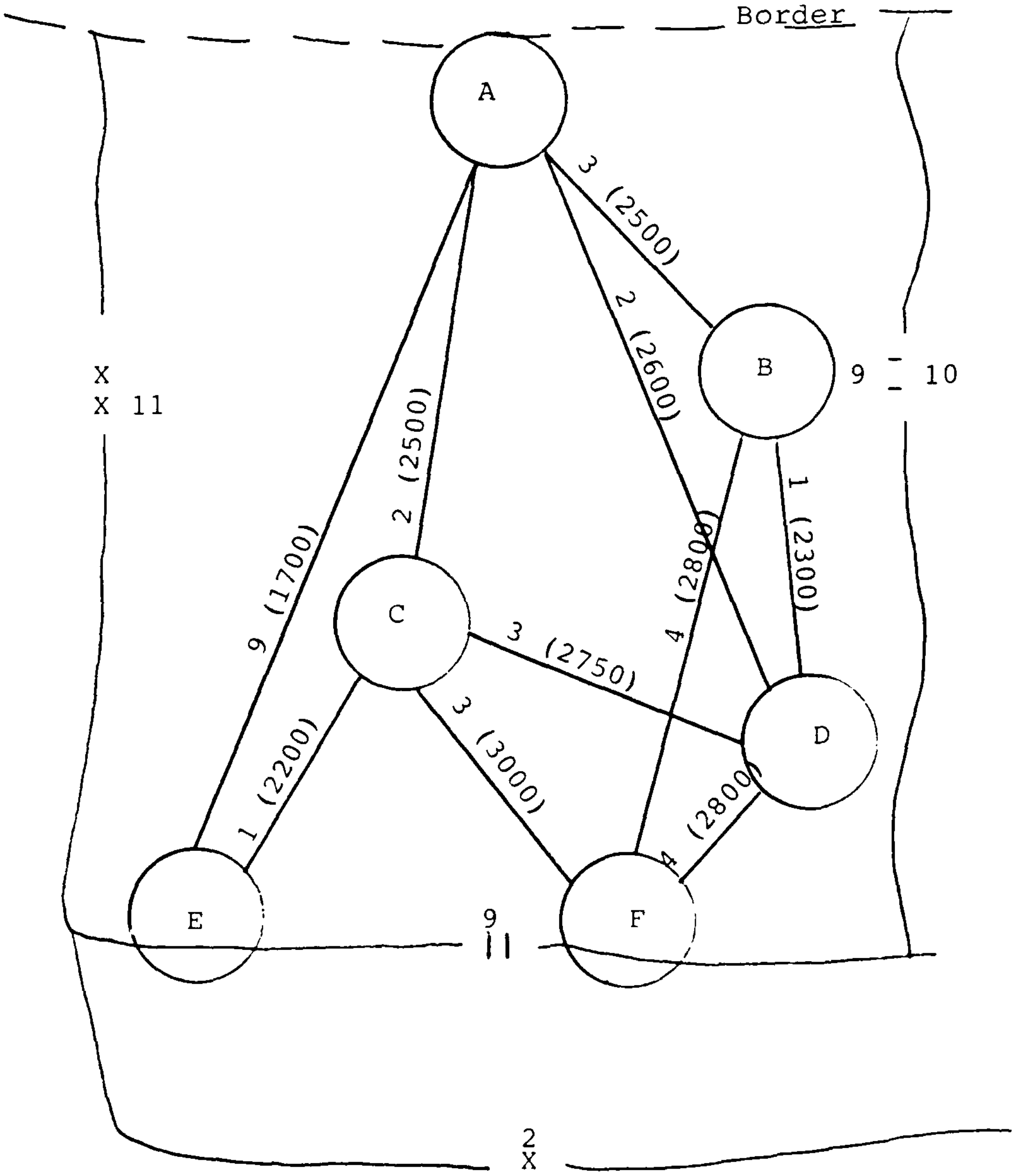


Figure 3.14
Network Values

range over Arc C-E, it is chosen as the placement site for the first company with the highest SUA value.

Since the placement of the first company now doubles the travel time on Arc A-C, path A-C-E is no longer the minimum time path, and another one is determined. It is important to note that even with the increased travel time on Arc A-C, path A-C-E could conceivably remain the minimum time path considering different time values existing on other arcs. The new minimum time path is calculated to be A-D-F. Because Arc D-F offers the greater effective range, it is chosen as the placement site for the company with the next highest SUA.

Another minimum time path is calculated and determined to be A-B-F. Because of the maximum effective range consideration, Arc B-F is chosen as the placement site for the company with the third highest SUA.

A minimum time path is calculated again and determined to be A-D-C-F. After considering the maximum effective range of all arcs, Arc C-F is chosen as the placement site for the fourth and last company.

All four companies have been placed using the placement methodology previously outlined. Figure 3.15 illustrates the picture of the placement template depicting the tactical graphics of a Battalion defending against an enemy Regiment on a given piece of terrain described by the network.

The possibility exists for all companies being placed on the same arc as long as it remains part of the minimum time

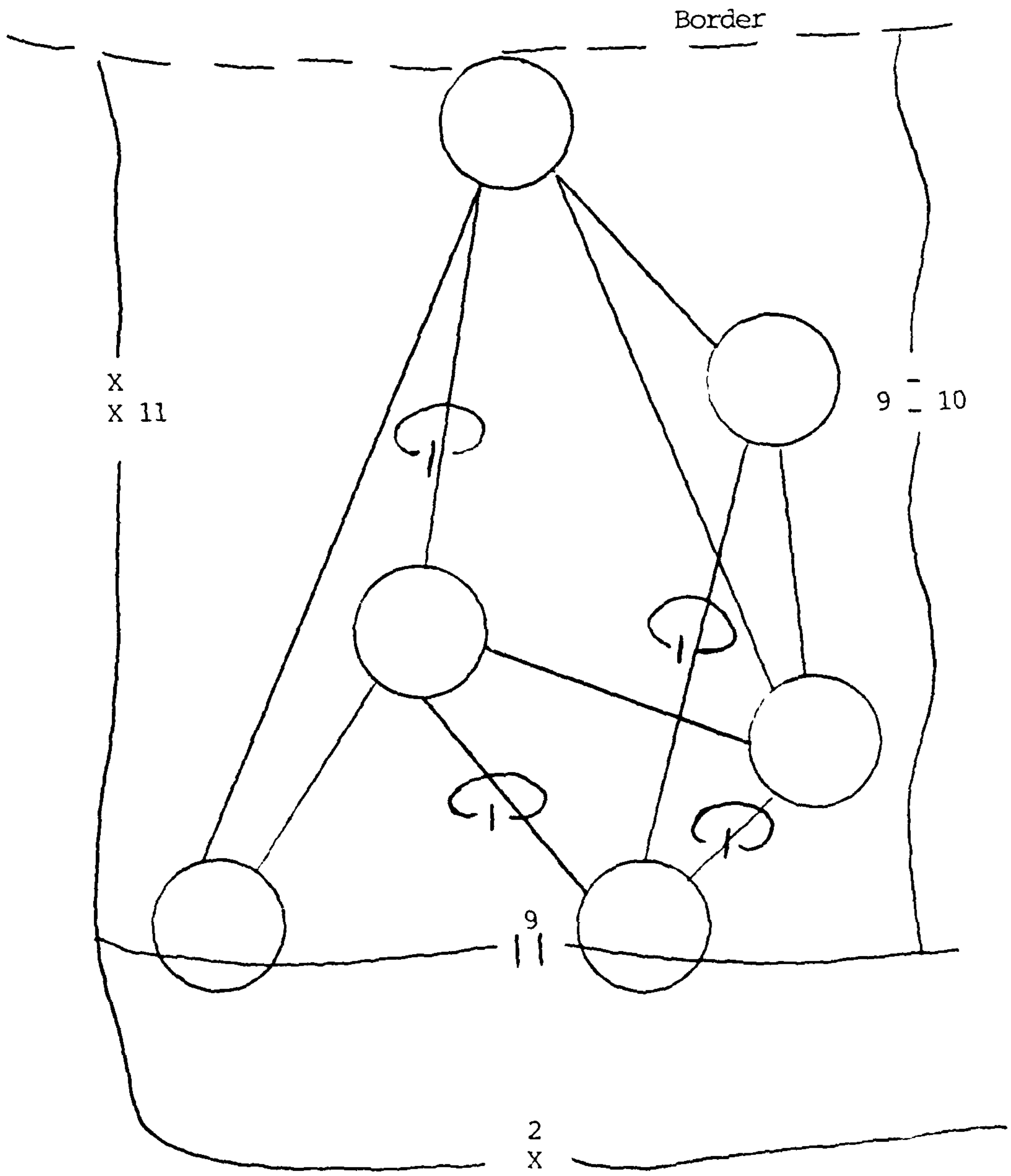


Figure 3.15
Placement of Units

path and possess the greatest maximum effective range compared to other arcs on the same path. Future research will develop additional placement rules to avoid this situation and provide guidance for any desired placement adjustments.

D. PLACEMENT TEMPLATE - ENGINEER UNITS

Engineer units are placed on the network after maneuver units have been assigned a placement site. An engineer unit may vary by size, usually a squad of 8-10 men with limited equipment, which is placed on the network to establish defensive obstacles. A single unit may establish several obstacles within the same total mission time applicable to maneuver units. The purpose of the engineer assets is to interdict transportation networks. Research has been conducted that has derived prescriptive algorithms which allocate engineer resources. [Ref. 9: p. 10]

The placement of engineer resources is addressed here only as the second unit in a three unit placement process. After maneuver and engineer units, the last type of unit to be placed on the battlefield are artillery resources. The engineer model and algorithms referenced previously do not consider the placement of artillery units. Placement rules similar to those for maneuver units will be addressed in the next section.

E. PLACEMENT TEMPLATE - ARTILLERY UNITS

1. Placement of Artillery Fires

The placement of artillery units is done after all maneuver units have been assigned a placement site and all engineer resources allocated to place obstacles on the network. However, primary concern is not the placement of the artillery units themselves, but rather the generation of desired locations for artillery fires. These locations may take the form of final protective fires (FPF's), triggering or pre-planned target areas and/or anticipated areas for targets of opportunity.

Once these desired locations for artillery fires have been selected, the placement of the actual artillery units is treated as a function of range, or the distance from the desired locations with regard to the effective range of the artillery weapon. Developing an algorithm or placement model to handle these desired locations for artillery fires is not a simple task. Consequently, the first attempt at deriving an artillery placement template will take the form of the following general artillery fire considerations:

1. Arcs entering the network within the assigned area of maneuver responsibility.
2. Arcs that maneuver units do not occupy.
3. Arcs that do not contain an engineer obstacle.
4. Arcs that do contain an engineer obstacle.

A military planner wants the ability to strike at the enemy the greatest distance possible. Artillery indirect fire affords that opportunity. The consideration of artillery fire on arcs entering the network allows the overall maneuver force to strike the enemy as early as possible. The objective is to inflict destruction and confusion before the enemy enters the assigned area of responsibility, thus disrupting enemy movement and disorganizing formations. Therefore, these arcs are relatively better locations for artillery fires.

Within any assigned sector on any existing network, the chances are great that there will be more unoccupied arcs than those occupied with maneuver units. Assigning those unoccupied arcs as locations for artillery fires adds considerable strength to a battlefield plan. For example, if an enemy unit bypassed the emplaced maneuver units, execution of artillery fire on the arc being used by the enemy, may cause sufficient confusion and time delay so that maneuver units could be re-positioned.

As with any asset, engineer resources are limited. Perhaps the best obstacle plan would result from unlimited time and engineer units. This is a situation never found within a battlefield operation. Consequently, arcs will exist where no engineer obstacle has been placed. Covering these arcs with artillery fire adds another dimension to the overall engineer obstacle plan.

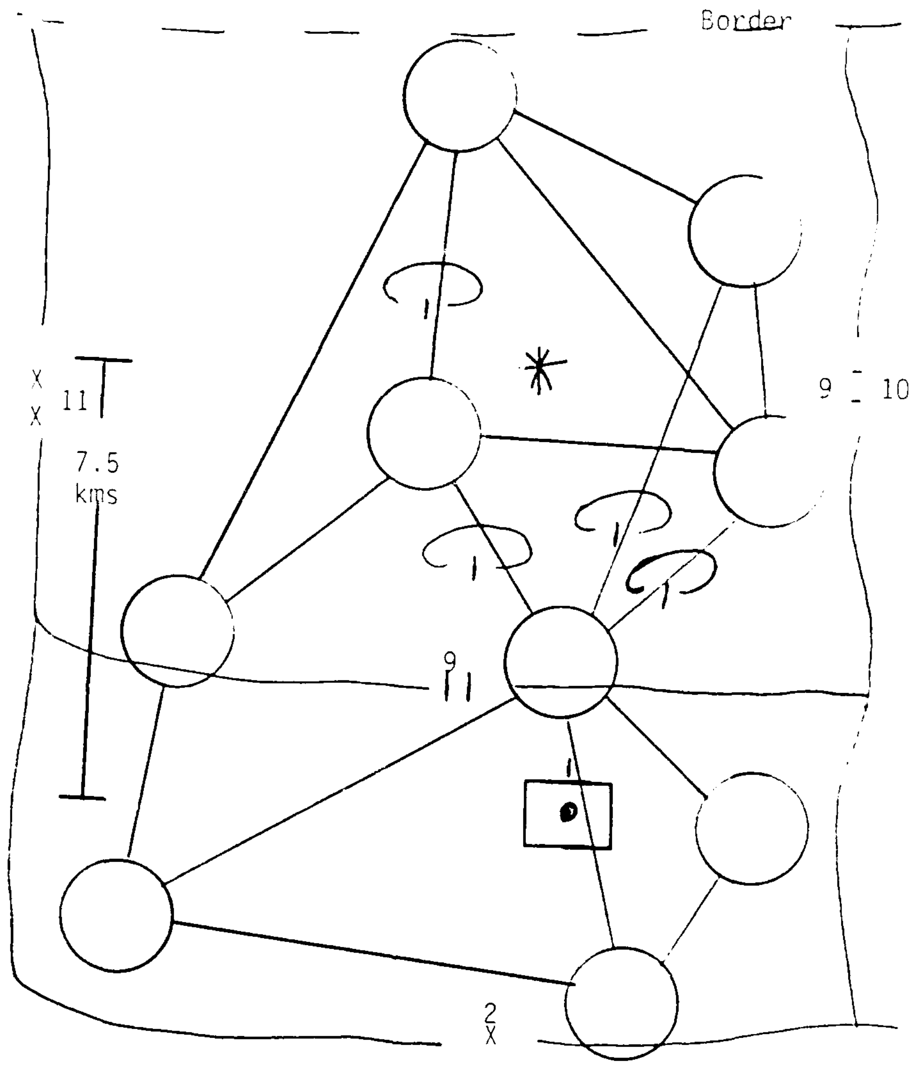
Military doctrine states that obstacles are covered by direct and/or indirect fires. [Ref. 10: p. 4-109] After enemy units become trapped by an obstacle or attempt to breech the obstacle, direct and/or indirect fire can engage those enemy units and destroy them or make their breeching attempt impractical. In essence, obstacles are excellent locations for consideration of artillery fire.

2. Placement of Artillery Units

The previous section discussed the placement of artillery fires in a general format. Follow-on research will attempt to develop algorithms that specifically generate considerations for artillery fires on a given network. However, derivation of a placement template for the units can be accomplished using the following multi-step procedure:

1. Determine the location of the geographic center of mass of all companies located on the network.
2. Determine the maximum effective range of the artillery weapon system being employed to support the maneuver unit.
3. Starting at the center of mass location, place the artillery unit a distance one-half of its maximum effective range to the rear.

For example, Figure 3.16 illustrates the 9th Armor Battalion with all four armor companies placed on the network. The maximum effective range of the employed artillery weapon system is fifteen kilometers and the depth of the battalion sector is eight kilometers. Starting at the center of mass of the battalion, the artillery unit should be placed approximately



* = Center of Mass of Unit

Figure 3.16
Placement of Artillery Unit

seven and one-half kilometers to the rear. The artillery unit should be placed on an arc that is not a part of the enemy's minimum time path. Rather, an arc should be chosen that will not interfere with potential future placement sites for maneuver units.

IV. SUMMARY

A. FIRE DISTRIBUTION ALLOCATION

The objective of any fire distribution allocation plan is maximizing available combat power so that weapon systems are allocated against enemy forces for some future time period. Two methodologies were presented that derive fire distribution allocation plans employing different sets of criteria. This thesis illustrated both systems with a tactical scenario using specific numbers of two types of enemy and friendly weapon systems.

Both systems, and subsystems of each, are inherently limited by the number of weapon systems illustrated. As greater numbers of a particular weapon system are included in the methodologies, the derivation of the allocation plan becomes more involved and time consuming. This applies to the addition of different types of weapon systems as well. Additional types of weapon systems create the need for smaller increments of the variable range. For example, the range band one-two thousand meters would not accurately reflect the impact of a Light Antitank Weapon (LAW) which has a range of only two hundred meters.

The number and type of enemy weapon systems are direct inputs to the computation of the fire distribution allocation plan. As with friendly weapon systems, the addition of increased numbers of a type of weapon system or increased numbers of different types, results in a more lengthy process. These inputs are based on enemy battlefield doctrine and consequently are not precisely known figures. Even with this assumption, the methodologies presented offer an alternative method of establishing fire distribution allocation plans other than simply utilizing all available weapon systems.

B. UNIT ALLOCATION AND PLACEMENT

When developing battlefield operation plans a great deal of time is expended with analysis of varying aspects such as terrain, avenues of approach, enemy tactical formations, and capacities of road networks. Additionally, planning a tactical operation requires sequential processing of combat arms units. Thus, the development of allocation and placement methodologies was limited to maneuver, engineer, and artillery units.

Chapter 3 has employed a tactical scenario demonstrating a corps size unit with a mission of prepared defense. The first step in developing the defensive plan is the assigning of areas of responsibility and allocating units to those areas. This is done for corps, division, and brigade levels of organization. An allocation template was developed and introduced to derive unit allocations based on enemy avenues of approach within areas of responsibility. Templates were developed for those levels of organization previously mentioned. Allocation templates were derived for maneuver units only at each level.

In developing the operations plan, the placement of units is initiated after allocations are complete. This thesis assumed placement of units was done at the battalion level of organization. A placement template was introduced using a set of rules that led to the actual locations units occupied on the road network. Engineer and artillery units were included demonstrating their placement on the road network as well as maneuver units.

The overall objective in deriving both types of templates was to introduce template methodology so that analysis time could be reduced. Either type of template can be employed when a military planner is facing the dilemma of allocating or placing units to a sector containing designated enemy avenues of approach. Replacing the lengthy analysis process, the allocation template that most closely aligns with those avenues of approach is quickly employed. Since the allocation and placement rules remain constant regardless of tactical situation, the templates are results of applying the respective set of rules to various situations. The result is a savings in valuable planning time as well as the number of units needed for allocation. The same procedure is used for the placement of maneuver, engineer, and artillery units.

It is important to note that both types of templates were derived with the modeller utilizing them in the Airland Battle Research Model. However, these templates may be appropriate for use by the military planner as well. When confronted by various situations, the templates become labor saving tools. Substitution for complete analysis that may have been done for a previous similar situation lends itself to faster writing of operation plans.

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