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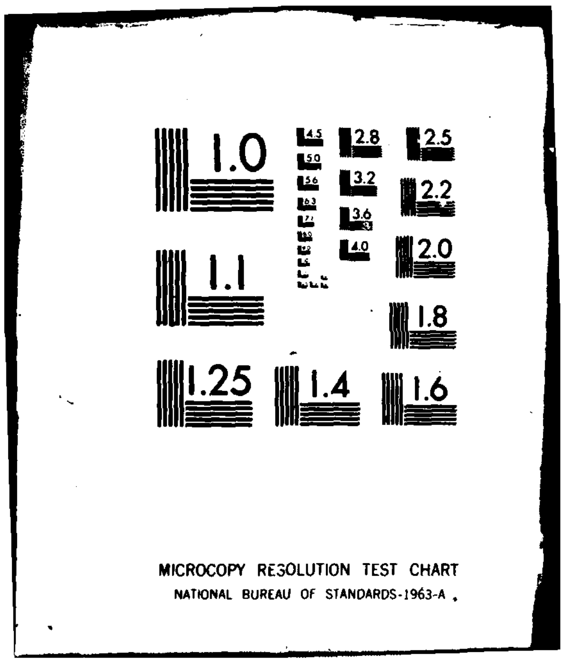
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A synthetic history of vehicular activity in the rear area of a Soviet tank army during a 5-day offensive against U.S. V Corps is developed and described. The history consists of detailed records of 2088 movement events involving 11,266 vehicles. Vehicles are identified in terms of 15 types. The record of each event includes the location of its origin and destination with respect to the FEBA, its departure and arrival times, its composition by numbers and types of vehicles and the kind of unit involved in the move. Various statistical representations of the histoy are presented. Conversion of the history to a computer model of vehicular activity is described. 106 pp. (Author)

A RAND NOTE

A MODEL OF VEHICLE ACTIVITY IN THE WARSAW PACT TACTICAL REAR DURING A CONVENTIONAL ATTACK AGAINST NATO

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PREFACE

As the North Atlantic Treaty Organization continues the search for ways to bolster its defensive capabilities in the Central Region, there is a mounting interest in what has come to be known as battlefield interdiction. Rand has been active in investigating this issue--most recently in a series of studies carried out under the project "Disruption of Warsaw Pact Tactical Rear Area Activities"--as part of its work for Project AIR FORCE.

There is a consensus among researchers that meaningful opportunities for interdiction, in the NATO context, center about the large amount of military vehicular traffic considered to be a necessary concomitant of a large-scale Warsaw Pact offensive. It is somewhat surprising, therefore, to discover that little work has been published describing this expected traffic in any detail.

This Note seeks to improve on this situation, by offering a highly detailed model of the predictable vehicular activity generated by a canonical Soviet attack scenario directed at the U.S. V Corps. While this "synthetic history" of military traffic in the Soviet rear is rigorously derived, it offers but one of many possible views regarding the nature of interdiction opportunities and constraints in the Central Region.

This work is partly an experiment in methodology and partly an attempt to perceive the way in which the large number of vehicles in the enemy's rear area might logically be expected to behave. The Note, therefore, should chiefly interest analysts and others whose concerns are theoretical in nature.

At the same time, some of the material presented here may be useful to commanders and planners, whose images of attack opportunities in the hostile rear may perforce have evolved without benefit of first-hand observation or systematic analysis of the forces that shape and limit those opportunities. No claims are made here for the special fidelity of this model; it is offered simply as an exemplar which the reader may find useful in gauging other views of the subject.

Because the method used to construct the model is experimental and, in the belief of the authors, unique, comment is invited as to its utility and credibility and ways in which it might be extended or improved. The authors are especially interested in knowing how well the portrayal offered here may correlate with the results of other investigations of the issue.

This is one of a series of Rand reports on the analysis of the Warsaw Pact tactical rear area.

SUMMARY

This Note describes a particular image of the vehicular traffic one might expect to encounter in the region beyond the immediate battle area during a canonical Soviet offensive in Central Europe. The forces depicted are those elements of a Soviet tank army that are disposed along a breakthrough axis, projected for a distance of approximately 200 kilometers into the Soviet rear, but excluding units within 5 kilometers of the line of contact.

The research was prompted by a growing need for systematically developed answers to questions like the following:

- How is the vehicular activity in the rear area distributed in space and time?
- When vehicles take the road, how long do they remain exposed before reaching their destinations?
- In what size groups do vehicles travel?
- How does the amount of traffic on the roads compare with the capacity of the available road net?
- What fraction of the traffic is generated by "high-value" targets?
- When and where are high-value targets most likely to appear on the roads?

The activity model described here is based on the premise that the vast majority of the vehicular activity in the hostile rear is rationally ordered, according to Soviet doctrine and operational concepts. Therefore, given a presumption about the content of this doctrine and given also a battle scenario, one should be able to predict with some reasonable confidence when and where the forces in the rear area must move in order to fulfill their various roles in the conduct of the offensive.

The model consists of a detailed record--or "synthetic history"--of each of 2088 movement events spaced over a 5 day period of operations. The activity portrayed includes the regular displacement of artillery units, the progressive movement of second echelon forces before joining the battle, the displacement of combat support and service support elements, and the movement of resupply and replacement vehicles.

Each event in the history is described in terms of some 250 attributes, most of which address various aspects of the classical Who, What, When, and Where kinds of questions. The history thus consists of over 500,000 discrete items of data. Because of this volume, the history has been formatted as a statistical computer file, in order to facilitate access to and reduction of the data.

The 2088 events, collectively, represent almost 75,000 vehicle moves, which generate some 136,000 vehicle-hours of travel. The total number of vehicles in the force exceeds 11,000, divided among 15 classes.

These summary data imply that the "average" vehicle moved about 7 times during the scenario, and that the "average" move lasted a little under 2 hours. It might also be supposed, on the basis of the summary data, that the "average" vehicle spent about 10 percent of the scenario time in movement and the remaining 90 percent at rest (and perhaps concealed).

If all of the activity in the model were distributed uniformly over the time span of the scenario, there would always be some 1133 vehicles moving on the roads in the region of interest, i.e., in an area measuring about 20 kilometers in width by 200 kilometers in depth.

However, the model demonstrates that averages derived in this way may be highly deceptive. Indeed, the most telling conclusion drawn from the analysis is that general statements about the amount of vehicular activity one should expect to find in the Soviet rear area, and about the distribution of that activity in space and time, are apt to be of little value in evaluating interdiction opportunities and constraints. Despite the fact that the model is based upon a single scenario and a rather simple set of assumptions about the way vehicles behave, it nonetheless displays an enormous amount of variability in the way it characterizes these opportunities and constraints, depending upon time and place in the scenario, class of vehicles under scrutiny, and the activity metric one chooses for measuring vehicular traffic.

A second important lesson that can be drawn from this work is that one should be very careful about defining interdiction opportunities. A group of vehicles takes the road to make a move of finite dimensions, creating an "event." The event will involve a certain number of vehicles, which can be equated with the notion of "traffic volume." And these vehicles will generate a calculable amount of "exposure," depending on the duration of the move. Taken separately, these three metrics can lead to quite different views about the nature of vehicular activity in any given scenario.

For the scenario as a whole, from 60 to 85 percent of the activity--depending on the metric used--takes place at night. The division of activity between night and day is, however, quite sensitive to depth. At distances greater than 30 kilometers from the forward edge of the battle area (FEBA), for example, more than 90 percent of the activity occurs at night.

Sixty-seven percent of the total daylight volume--but only 32 percent of the total night volume--takes place within 30 kilometers of the FEBA. For combat vehicles only--tanks, armored personnel carriers (APCs), artillery, and air defense weapons--76 percent of the day volume and 50 percent of the night volume occurs within 30 kilometers of the FEBA.

The duration of events ranges from a low of 3 minutes to a high of 8 hours and 13 minutes. The median event is on the road for only 37 minutes.

The number of vehicles associated with each event also varies widely. Whereas the "average" event might be supposed to consist of 35 to 36 vehicles, the range in the history extends from a low of 1 vehicle to a high of 142, the median value being 31.

Thirty snapshots extracted from the history showed that the number of vehicles on the road at selected moments in time varied from a low of 48 (at 0900 on D+2) to a high of 4054 (at 2400 on D+4). Moreover, when the vehicle populations in these 30 snapshots were examined selectively, it was seen that the number of combat vehicles on the road varied between a low of 18 and a high of 889.

In daylight, within 30 kilometers of the FEBA about 25 percent of the traffic volume is generated by combat vehicles; beyond 30 kilometers only 15 percent is attributable to this subset of the population.

Comparison of the model with the capacity of the road net in the region covered by the scenario shows that, in general, the roads can support the volume of traffic generated by our movement logic. There were only 2 hours in the entire scenario when the threat of congestion reached critical proportions.

We make no special claim for the fidelity of this model to the exclusion of others. We believe, however, that any attempt to visualize the opportunities and the constraints likely to confront an interdiction effort against the Soviet rear area must be undertaken with as much regard for the determinants of ground force behavior under campaign conditions as we have sought to invoke in this synthesis.

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I. INTRODUCTION

IMPETUS AND OBJECTIVES

In the continuing search for better ways of defending NATO's center against a conventional assault by the Warsaw Pact, attention has been drawn more and more to some form of interdiction as a desirable--or even necessary--adjunct to the basic strategy of forward defense. Basically, the thesis seems to be that the improving ground defenses in NATO now promise the ability to deal successfully with the initial echelons of a doctrinaire armored offensive, but that the Pact's ability to mass forces in great depth along selected avenues of attack still threatens to overwhelm the defense at critical points.

Since World War II a considerable amount of study and debate has been devoted to the theory and practice of interdiction, both as a strategy and as a mission for air power. Not surprisingly, this attention has included a number of historical analyses of interdiction experience in WW II, in Korea, and in Vietnam. But, while the historical parts of the inquiry provide important perspectives, they do not shed very much light on the situation that NATO will likely face should the Pact seek to invade Western Europe. This would seem to be the case, at least, where the design of forces, systems, and operational concepts for interdiction in the decade ahead are at issue.

Recent research, at Rand and elsewhere, suggests very strongly that if strikes against the hostile rear are to have a decisive effect on the outcome of battle during the critical early days of an attack on NATO's center, they must be directed at the dynamic components of the enemy force, i.e., those that move forward in a more or less continuous stream with the aim of maintaining the momentum of the attack. These targets stand in marked contrast to fixed targets such as major depots, maintenance shops, arsenals and the like which make up the military infrastructure supporting the armies in the field. The key distinction to be made is between those activities that could influence the battle in the near term, i.e., within hours or days, and those whose impact at the point of combat would not be felt for weeks or months.

Concern with the dynamic elements of the potential target array focuses attention on the large number of military motor vehicles, of all classes, which are a hallmark of the Warsaw Pact armies in central Europe, and on the roads that support their movement in the rear area.* The vehicles of primary interest in the present analysis are those associated with the areas occupied by first echelon armies. In the case of a Soviet tank army, there may be as many as 20,000 such vehicles, virtually all of which will be located within 150 kilometers of the FEBA.

Views about the nature of the activity generated by these vehicles, about their relative values as targets, about the ability of Pact logisticians and traffic managers to orchestrate their movement, indeed about every aspect of the array, are remarkable, both for their variety and for their lack of analytical underpinnings. These views tend to range between two extremes.

At one extreme is the view that the richness of the Central European road net, coupled with the basic simplicity of Soviet operational concepts, virtually guarantees that the Soviet rear will be able to function with acceptable efficacy despite the best efforts of NATO air. Frequently, this

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*For other scenarios--in other parts of the world, for instance--one might reasonably argue that rail traffic is an equally important activity with the movement of automotive vehicles. However the existence of an extensive road net in Central Europe, combined with an evident Soviet preference for motor transport in the forward area, suggests that the focus here should lie with highway traffic rather than rail.

viewpoint is combined with the belief that vehicles in the rear area spend only a small fraction of the time in movement (and hence exposed to attack).

At the other extreme is the view that the pace of operations and the volume of traffic implicit in Soviet offensive doctrine, together with a certain inflexibility attributed to the Soviet soldier, will create a condition in the rear area verging on chaos. This view holds further that Soviet rear area activity threatens to fall of its own weight, and that even a modest push from NATO air power will suffice to topple the entire edifice of organized purposeful activity in the rear area.

The thesis underlying the present work is that the truth --to the extent that it is knowable--probably lies somewhere between these extremes; and that even if the truth is not knowable in an unequivocal sense, a careful dissection and analysis of the many factors bearing on the issue can provide rationally based insights concerning dominant patterns of vehicle activity. Moreover, it seems self-evident that insights gained in this way should, at the very least, be as valuable as the intuition and conjecture that characterize so much of the current debate about the opportunities for and the likely efficacy of interdiction.

What is needed is a systematic examination of Soviet doctrine and the Soviet style of war fighting, as applied to the special circumstances under which major land battles are most likely to be fought in Central Europe. The end product should be a rational, albeit contrived, view of what events are expected to transpire in the Pact rear area, when and where these events must take place, and how they are related to the progress of the battle.

In some recent research at Rand, we have sought to develop such a visualization, using a combination of map exercises and computer simulations to create models of the rear area activity associated with a doctrinaire Warsaw Pact offensive. One of the by-products of this work is an unusually detailed statistical representation of the vehicular activity that might be expected to occur over time throughout the depth of a first echelon tank army in the attack.

The purpose of this Note is to report on the substance of this model, to explain its derivation and structure, and to comment on its utility as a research tool. In particular we will offer some rationally derived, if tentative, answers to such questions as these:

- How is the vehicular activity in the rear area distributed in space and time?
- When vehicles take the road how long do they remain exposed before reaching their destinations?
- In what size groups do vehicles travel?
- How does the amount of traffic on the roads compare with the capacity of the available road net?
- What fraction of the traffic is generated by "high-value" targets?
- When and where are high-value targets most likely to appear on the roads?
- How do the answers to these questions vary according to vehicle class?

One caveat regarding the focus of this Note is in order. It will be clear from the nature of the foregoing questions that we are concerned here with moving vehicles in the hostile rear as potential targets for attack; we are not concerned with any particular attack system or weapon, preferring instead to let the reader interpret our work in the light of whatever system or issue confronts him at the moment.

Furthermore, we recognize that the road network over which rear area traffic is expected to move may be at least as attractive a target as the vehicles themselves, since the ultimate aim of interdiction is to prevent or slow the arrival of additional enemy combat power--in whatever form--at the front. Indeed, one of the principal findings of the main stream of our research is that selective attacks against the lines of communication (LOCs), with a variety of weapons, may prove to be a preferred form of interdiction in some situations.

THE RESEARCH

Conceptual Approach

The research to be described in this Note proceeds from the premise that the vast majority of the vehicular movement that takes place in the rear areas conforms in an important measure to certain doctrine, operational norms, guidelines, and physical constants, as well as to situational factors such as the rate of advance of the attacking echelon, the rates of attrition and consumption experienced by the force, the scheme of maneuver, the character of the terrain and road net, and the threat of hostile action against the rear. This being true, many of the important characteristics of the vehicular activity, as it might be expected to develop in a given scenario, should be more or less predictable. In other words, it should be possible to construct a detailed "synthetic history" of the vehicular movement likely to be associated with any given scenario. The construction of such a history forms the core of the work described herein.

The basic concept that guided the work, as well as the nature of the important assumptions required, can best be illustrated by reference to a simple example.

Consider the case of an artillery battalion supporting the attack from positions located in rear of the FEBA. Suppose that the relevant artillery doctrine requires that the pieces be positioned well forward, but not closer to the FEBA than 5 kilometers. Suppose further that the battalion is equipped with howitzers having a maximum range of 15 kilometers. Now, if the attacking force is advancing at a rate of 5 kilometers per hour it will be necessary for the artillery battalion to displace forward not less frequently than once every two hours, in order to remain in supporting range. Each such displacement will cover a road distance roughly equivalent to 10 kilometers. And one can reasonably infer that each displacement will involve the movement of whatever complement of vehicles may be associated with the battalion TO&E. Finally, the time required to complete each displacement can be computed from the battalion's rate of travel, which depends in turn on march doctrine, quality of the roads, capabilities of the vehicles, and the prevailing driving conditions.

Activity of the sort just described may be thought of as a form of "station-keeping," which is paced primarily by the movement of the FEBA. A conceptually similar pattern of station-keeping activity can be imputed to virtually every ground force unit that has a role to play in prosecuting or supporting a Warsaw Pact ground offensive. Our models suggest that from 60 to 80 percent of the total traffic generated in the rear area during a Pact offensive will be of this general form.

The remaining 20 to 40 percent of vehicular activity--excluding that involving troops in contact--will consist of logistics traffic generated to meet the demands of the force for replenishment of consumables and replacement of losses. Given the necessary assumptions about the rates of consumption and attrition, plus descriptions of the supply and replacement systems, it is also possible to incorporate this activity in the synthetic history.

Admittedly there will be a certain amount of military traffic on the roads which, by its nature, will escape the notice of the prediction scheme suggested here. This will include, for example, couriers and messengers, convoys that become lost and therefore follow circuitous routes, and the evacuation of damaged vehicles. The premise adopted here is that the volume of traffic thus generated will not obscure the dominant pattern of vehicular activity, though it may add a small increment of uncertainty to others already inherent in the approach.

Research Procedure

The procedure followed in transforming the conceptual approach into a synthetic history of activity consisted of five main steps.

- First, it was necessary to adopt a campaign scenario so as to (1) provide a basic battle plan for the attacker, (2) establish the progress of the FEBA with time, (3) provide the basis for defining the attacker's forces, and (4) establish the attrition and consumption rates needed to generate logistics traffic. The scenario and the enemy force are described in Appendix A.
- Next, the attacking force was defined, first in the large, then in terms of march units, and finally in terms of the vehicle complement of each march unit. A march unit here refers to an aggregation of vehicles the composition of which remains fixed throughout the scenario and which moves together to generate a single movement event. The division of the force into march units follows the organizational structure of the appropriate TO&Es, as shown in Appendix A.
- Rules were then devised for the station-keeping activity of each march unit. These were applied to a large-scale map display to create a record of each successive position occupied by each march unit during the course

of the scenario. The procedure is described in detail in Appendix A.

- The demands for replenishment supplies and replacements were calculated and translated into the specific time-ordered responses required of the logistics system (including the return of empty supply trucks to their points of origin). These events were also recorded with the aid of the map and incorporated in the model as the logistic component of the history.
- Finally, the completed history was transcribed as a computer file, in a format compatible with one of the statistical analysis programs in service at the Rand Computation Center. This feature was used to enrich the history, produce statistical descriptions of the activity, provide a convenient storage and retrieval medium, and make possible a wide range of particular applications of the data. A complete description of the resulting model is given in Appendix B.

Clearly, the model of vehicular activity that results from following this procedure is heavily dependent on the scenario we have chosen and on the various interpretations of Soviet doctrine and operational practice that underlie the movement rules we have used.

Also, the reader should be aware that the procedure just outlined does not provide for any representation of the possible effects of interdiction on the movement portrayed in the history. In other words, the record of Soviet rear area activity was allowed to develop as though the activity were completely unmolested.

The procedure outlined above produced a wealth of data purporting to describe the behavior of all of the vehicles in a large segment of a Soviet tank army during the first five days of a war in the Central Region. In Sec. II of the Note the data have been arranged so as to present an explicit view of the vehicular activity in the Soviet rear in terms of the questions posed earlier. An appreciation of the scope of the model is given below.

PRINCIPAL FEATURES OF THE MODEL

The synthetic history, which we have termed MOVER (for Movement of Vehicles in the Enemy Rear), consists of a minute-by-minute record of the activity of some 9600 military vehicles in TO&E units; these vehicles are divided into 10 classes, each of which is accounted for separately in the history. Another 1,647 vehicles, divided among 5 classes, are also introduced as replacements during the course of the history.

The history is made up of 2088 separate movement events, ranging in size from single vehicles to groups of more than 100. About 60 percent of the events represent station-keeping activity, and 40 percent are logistics events. Logistic activity includes the rearward movement of empty supply trucks as well as forward deliveries.

In the model, each of these events is described in terms of the classical intelligence questions, Who, What, Where, When. Each of these basic questions has been elaborated upon extensively, as described in Appendix B.

As a further measure of the activity generated in this model, there are 74,262 instances of a vehicle undertaking a move, either as a single vehicle or in company with others. The total amount of activity represented involves 135,987 vehicle-hours of travel.

All of the activity in the history takes place along a breakthrough axis measuring about 20 kilometers in width. In depth, the region evaluated extends from 5 kilometers to about 200 kilometers beyond the FEBA. Since this area is presumed to advance in pace with the FEBA, the total geographical extent of the scenario measured about 400 kilometers from west to east, i.e., from front to rear.

Finally, a history of successive moves by a vehicle or a unit implies a corollary history of quiescence by those same vehicles and units. The periods of inactivity--during which the vehicles might be presumed to be concealed and hence immune to attack--are made explicit in MOVER, with the aid of the statistical computer program referred to earlier. On average, vehicles in the history are at rest about 9 hours for each hour they spend on the road, but there is a great deal of variability according to time in the scenario, distance from the FEBA, and class of vehicle.

However this is not to say that there are long periods of inactivity by the force as a whole. In fact, if all of the movement represented in the history were distributed uniformly over the 120 hours of the scenario, there would always be something over 1100 vehicles of one sort or another moving on the roads somewhere in the defined area of interest.

Perhaps the most important attribute of the model is the variability in the character of the vehicle activity that can be seen as one's attention shifts from place to place in the rear area, from time to time in the scenario, and from one class of vehicles to another within the total vehicle population. As will be seen in the next section, there is no general, yet meaningful, way of characterizing the opportunities one should expect to find for attacking vehicular traffic in the hostile rear.

While MOVER is but one among many possible representations of rear area activity, the research that produced this particular model strongly suggests that a similar degree of variability should be present in any such model. An important corollary to this proposition is that images and models that ignore or obscure this variability are apt to be seriously misleading.

II. DESCRIPTIONS OF THE ACTIVITY

MOVER contains over 500,000 discrete items of information; the exact number is arrived at by multiplying the number of events in the history (2088) by the number of attributes, or variables, used to describe each event (the number currently is 247, but see Appendix B regarding the propensity of this number to grow as new research applications are explored).

No attempt will be made to display all of this information here. Indeed, to do so would run counter to one of the minor themes of the research, namely, that the computer form of the history allows the analyst to retrieve the data selectively and in a form that requires little or no reduction, in accord with his particular needs and purposes.

Rather, our purpose in this section is to present a sampling of the data from the history, comprising a commentary on some of the broader issues regarding interdiction opportunities. In the process, we hope to illustrate some of the richness of the model, to suggest something of its versatility, and to identify several important limitations. In general, the kinds of information selected for presentation are those that respond to the questions posed rhetorically in Sec. I.

ACTIVITY METRICS

Before addressing the data directly, it is important to agree on some distinctions regarding the quanta to be used in describing the vehicular traffic in the Soviet rear area. Our experience with interpreting the data makes it abundantly clear that the choice of an activity metric will determine the nature of the conclusions one draws from the data. This is especially apparent where the conclusions have an operational orientation, such as, for example, conclusions about strategies for attacking particular classes of vehicles. Three such metrics will be used throughout this section of the Note, namely, "events," "volume," and "exposure"; they are defined as follows:

Events

An "event" is a single move by a march unit and is the basis for a single record in the MOVER file. The 247 variables used to characterize vehicular activity are attributes of each event as well as the constituents of each file record.

Volume

The number of vehicles associated with an event is an expression of the "volume" of traffic or activity represented by that event.

Exposure

The term "exposure" is used here to indicate the amount of time the vehicle population is engaged in movement activity. The variant that will be encountered below is "vehicle-hours," the product of the number of vehicles in an event and the duration of the event in hours.

The usage and meaning of these three metrics are amplified in the following illustration. A march unit consisting of 20 vehicles, which moves from point A to point B, departing at 1900 hours and arriving at 2030 hours, will generate

One "event."
A "volume" of twenty vehicles.
Thirty vehicle-hours of "exposure."

Consider, now, a second march unit consisting of 60 vehicles, which moves from point C to point D, also departing at 1900 hours but arriving at 1920 hours; and a third march unit, consisting of 10 vehicles, which moves from point E to point F, departing at 1900 hours and arriving at 2300. The following comparisons will be evident:

Metric	Move 1	Move 2	Move 3
Events	1	1	1
Volume	20 veh	60 veh	10 veh
Exposure	30 veh-hr	20 veh-hr	40 veh-hr

On the basis of "events," all three moves can be accorded equal weight. But if these three events are to be weighed in terms of the attack opportunities they present, it is clear that they should be evaluated differently. Move 2, for example, generates two-thirds of the total volume in the set of three moves but only two-ninths of the exposure. Move 3, in contrast, accounts for one-ninth of the volume but four-ninths of the exposure. The point is that the criterion used to evaluate attack opportunities should be chosen with considerable care.

HIGH-VALUE TARGET DISTINCTIONS

Most advocates of an interdiction strategy in the defense of NATO's center will agree that the success of such a strategy will depend heavily on a careful selection of the targets for interdiction strikes. Our research over the past three years supports this view.

Despite the Soviet reputation for achieving a high "teeth to tail" ratio--at least by American standards--our investigations show that there are important distinctions to be made among the vehicles found in the Soviet rear area, with respect to the immediacy of their contribution to battle outcome. In MOVER, vehicle populations have been segregated according to type and function with a view toward preserving these distinctions and making them readily available to the analyst. The division of the population is described in Appendix B.

The characterization of particular classes of vehicles as high in value is a debatable topic. A great deal of attention focuses quite naturally on the combat vehicles that make up the combat power of the follow-on echelons awaiting commitment to the battle. But our research on the Warsaw Pact tactical rear area also shows that certain other vehicles--notably, ammunition resupply trucks--can also have an important and immediate effect on the course of the battle, at certain times and places.

Apart from the question of what kinds of vehicles ought to be treated as high-value targets, there is the further issue of their proximity to the battle. It can be argued, for example, that no vehicle will venture close to the FEBA unless its presence there bears some important relationship to the combat power of the engaged forces. This being true, some types of vehicles may enter or leave the high-value category as they approach or draw away from the FEBA.

In short, the choice of vehicles to be regarded as high in value will depend on a number of factors, including the scenario and a rather more searching definition of interdiction strategy and tactics than will be undertaken here. But for purposes of illustrating differences in interdiction opportunities that different classes of vehicles might present, two possible subsets of activity will be singled out in the following discussion for comparison with the history as a whole. In general, these two subsets consist of (1) combat vehicles and (2) combat vehicles plus selected logistic support vehicles, respectively. The two classes of activity--which will be referred to as "combat" and "high-value"--are defined more fully in Table 1.

INTRA-SCENARIO DISTINCTIONS

One further word of introduction to this discussion is necessary. From the point of view of the attacking Soviet army, the scenario can be divided into four reasonably distinct operational phases, as described in Appendix A. Phase IV in

Table 1

HIGH-VALUE VEHICLES IN MOVER

Vehicle Class	High-Value Group: Combat Vehicles	High-Value Group: All High-Value Vehicles
In TO&E units:		
Tanks	x	x
APCs	x	x
Artillery	x	x
Air Defense (AD) weapons	x	x
Ammunition trucks	--	x
POL trucks	--	x
In logistics activity:		
Replacement tanks	x	x
Replacement APCs	x	x
Replacement artillery	x	x
Replacement AD weapons	x	x
Ammunition resupply trucks*	--	x
POL resupply trucks*	--	x

*Includes only loaded trucks and trailers outbound in the resupply cycle.

that partitioning consists of the final pursuit by the Soviet force, culminating in its arrival at the Rhine River. By the nature of the scenario we should expect the pattern of rear area activity in this phase to be different from that in other phases, since the FEBA advances almost 100 kilometers in a single 12 hour period. In analyzing the data in MOVER, therefore, it is advisable to consider the pursuit phase apart from the first three phases; accordingly, some of the following discussion will treat Phases I through III in the aggregate and will omit Phase IV. At the same time, it will be of interest to observe certain of the differences between the activity in Phase IV and that in the balance of the scenario. These distinctions will be carefully identified wherever they appear.

It has been suggested that current NATO target acquisition and strike systems are ill-suited to attacking vehicles in the rear area except when the vehicles are on the road and, by implication, moving. Debate of this issue is outside the scope of the present Note, although our research tends to confirm such a view. Of greater immediate interest is the marked difference between NATO's ability to attack moving vehicles when visibility is good and its abilities against those same targets at night and during bad weather. In its present form, MOVER contains no weather distinctions, but it does make a clear distinction between activity occurring at night and in daytime; this latter distinction will be highlighted in the following discussion.

HOW MUCH VEHICULAR ACTIVITY CAN BE EXPECTED IN THE REAR?

In the Aggregate

The Soviet forces depicted in MOVER contain a total of 11,266 self-propelled vehicles. Of this number, 9628 are in the TO&E units of the force, while the remaining 1638 are introduced at various times as replacements.

Combat vehicles number 2454 or 22 percent of the vehicle population in the Soviet force. High-value vehicles, as defined in Table 1, number 4832 and thus account for 43 percent of the total population.

The total activity in MOVER comprises 2088 discrete movement events. Forty-nine percent of these--1016 events--contain 1 or more combat vehicles. One or more high-value vehicles is included in each of 1586 events, or 76 percent of the total.

In terms of volume, there are 74,262 instances of a vehicle taking the road in the history. Of this total, 19 percent (13,827 vehicle moves) are attributable to combat vehicle activity, and 43 percent (31,982 vehicle moves) are generated by high-value vehicles.

In terms of exposure, all of the activity in the history amounts to 135,987 vehicle-hours of movement. Somewhat surprisingly, combat vehicles account for only 16 percent--22,420 vehicle-hours--of the total. High-value vehicles account for 43 percent or 59,020 vehicle-hours of exposure.*

Direction of Movement

Most, but not all, of the activity recorded in MOVER is generated by vehicles moving toward the FEBA. Presumably, this is the traffic that will command attention when interdiction opportunities are evaluated.

At the same time, we will observe in passing that the traffic bound away from the FEBA--all of which is logistics traffic, in MOVER--accounts for about 20 percent of the events in the history, but only 8 percent of the volume and 8 percent of the exposure.

In the discussions which follow, the distinction between traffic moving forward and that which is moving rearward will, for the most part, be ignored.

Measures of "Average" Activity

Several characterizations of the history as a whole can be derived from the data given above. Since there are 11,266 vehicles in the Soviet force, which make a total of 74,262 moves, one might infer that the "average" vehicle moves between 6 and 7 times during the scenario. By the same logic, the "average"

*The total vehicle-hours of exposure is also given elsewhere in this section as 136,116. The discrepancy, which has a value of approximately .0009, results from using two slightly different expressions at different times to convert the product of vehicle population and movement time in minutes to vehicle-hours.

combat vehicle moves between 5 and 6 times; and the "average" high-value vehicle moves 6 or 7 times.

A similar averaging procedure might imply that each event involves between 35 and 36 vehicles. Events with combat vehicles have an average of 13 to 14 combat vehicles in their consists; and the events containing high-value vehicles have an average of about 20 such vehicles in their makeup.

Because there are 120 hours in the scenario, the average number of vehicles on the road at any instant might be thought to be about 1133. Of this number, 186 would be combat vehicles, and 492 would belong in the more inclusive high-value category.

Finally, it can be calculated that the average vehicle is on the road for a total of just over 12 hours, or about 10 percent of the time span of the history. The average for combat vehicles is about 9 hours, or less than 8 percent of the time; and the average for high-value vehicles is just over 12 hours, or 10 percent of the time.

Variabilities in the Character of Vehicle Activity

Because of the particulars of the scenario, of Soviet force organization, and of the doctrine governing rear area activity, the implied averages quoted above are useful only for conveying a very general sense of the behavior of the forces found in the rear area. There is in fact an enormous amount of variability with respect to most of the activity parameters that bear on interdiction opportunities and constraints. The remaining discussion in the Note will emphasize this variability.

One aspect of the variability is that it is virtually impossible to treat time and space distributions as mutually exclusive attributes of the history. Consequently, a certain amount of overlap and redundancy will be inevitable in the discussion to follow.

A sense of the variability, with respect to hourly traffic levels, can be obtained by evaluating each hour of the scenario independently. Table 2 summarizes the results of such an evaluation. The table shows that, while the median volume for all daylight hours is not far removed from the implied average noted above, the actual hourly volume for all hours ranges from 0 (characteristic of only one hour in the scenario) to a high of nearly 6000 vehicles. Even more important is the marked disparity between activity levels during the hours of darkness and the levels during daylight.

The complete distribution of hourly activity levels is given in the form of cumulative distributions in Fig. 1. The data are given separately for Phases I-III and for Phase IV, emphasizing the contrast between the level of activity experienced during the pursuit and levels for the rest of the scenario.

Table 2

HOURLY ACTIVITY LEVELS

	Phases I-III	Phase IV
Number of vehicles on the road, daylight hours:		
Least active hour	0	*
Average hour	1,303	*
Median hour	1,012	*
Most active hour	2,538	*
Number of vehicles on the road, night hours:		
Least active hour	595	1,536
Average hour	2,212	4,109
Median hour	2,478	4,349
Most active hour	4,545	5,814

*Phase IV consists entirely of scenario period 10, which is a night period.

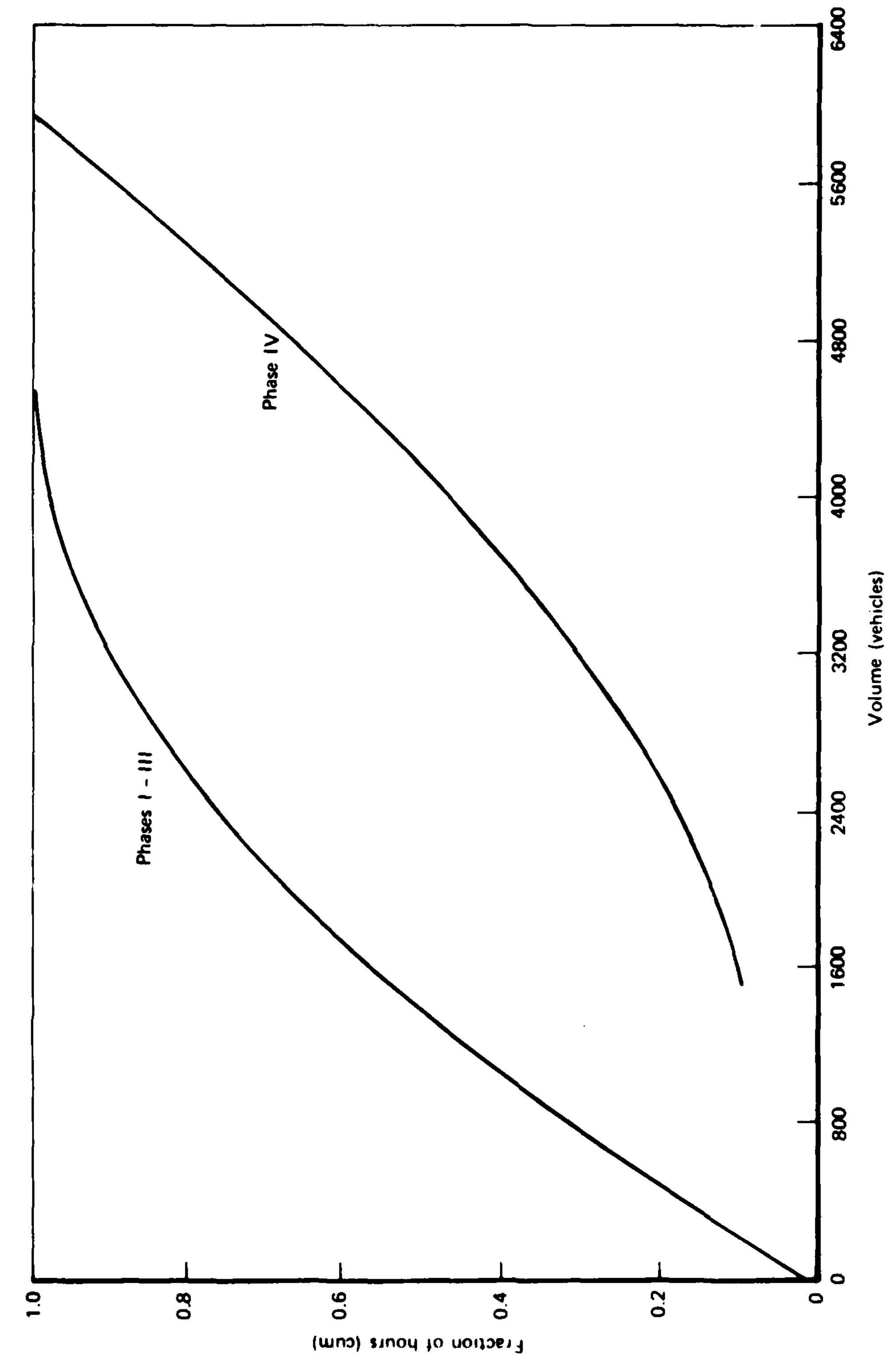

Fig. 1 — Hourly levels of traffic volume

A somewhat different perspective is afforded by a set of snapshot inventories of the vehicles on the road at particular points in time during the scenario. The times chosen here--somewhat arbitrarily--are 0300, 0900, 1200, 1500, 2100, and 2400 hours on each day of the scenario. The data are displayed in Table 3.

HOW IS THE VEHICULAR ACTIVITY IN THE REAR AREA DISTRIBUTED IN SPACE?

In MOVER, the spatial focus is on the distance beyond the FEBA at which the various events begin and end. For most of the research issues with which we have been concerned, it is this implied depth of penetration into hostile territory that has commanded the most attention. Sometimes the issue is the survivability of penetrating aircraft; at others, it is the question of the reach of target acquisition and tracking systems; and occasionally it is a matter of the range to which surface-to-surface missile systems must aspire in order to exploit the attack opportunities presented by vehicular traffic in the enemy rear.

One approach to describing the spatial character of these attack opportunities is to compile a series of tables showing the activity during each hour of the scenario in each of 22 geographic zones already defined in the model; the zones, as described in Appendix B, are depthwise partitions of the Soviet rear area, drawn at 10 kilometer intervals. Such a compilation would include, altogether, 120 tables similar to Table 4.*

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*Table 4 is for hour 88 in the scenario. This hour--from 2100 to 2200 on D+3--exhibits the highest volume of traffic for any hour in Phases I to III. The reader may find it instructive to compare this table with the data for 2100 on D+3 given in Table 3.

The data in Table 4 do not show the depthwise distribution of activity precisely but are only an approximation. This is because the computer procedure used to construct the

Table 3

NUMBER OF VEHICLES ON THE ROAD AT SELECTED TIMES

Day and Hour		All Vehicles	High-Value Vehicles	Combat Vehicles
D-Day	0900	433	221	88
	1200	779	332	193
	1500	584	244	132
	2100	933	518	306
	2400	2425	1297	642
D+1	0300	2092	818	106
	0900	90	66	18
	1200	522	176	112
	1500	198	113	68
	2100	1427	843	438
	2400	3394	1959	773
D+2	0300	2298	1259	226
	0900	48	28	18
	1200	328	146	63
	1500	824	657	91
	2100	676	490	24
	2400	1198	680	99
D+3	0300	888	566	68
	0900	719	234	129
	1200	622	227	116
	1500	903	515	131
	2100	1381	796	192
	2400	1248	598	183
D+4	0300	1694	726	215
	0900	274	184	145
	1200	1394	543	380
	1500	1138	599	251
	2100	2689	1193	672
	2400	4054	1709	889
D+5	0300	2519	987	483

Table 4

ACTIVITY DURING HOUR 88 (2100-2200, D+3),
DISTRIBUTED BY ZONE

Zone	Events	Volume
5-10 km	68	2216
10-20 km	83	2684
20-30 km	28	1017
30-40 km	26	439
40-50 km	31	404
50-60 km	35	543
60-70 km	33	868
70-80 km	9	222
80-90 km	11	228
90-100 km	11	297
100-110 km	4	135
110-120 km	3	100
120-130 km	3	100
130-140 km	1	76
140-150 km	1	76
140-150 km	1	76

NOTE: See the footnote, pp. 21-24, for a cautionary word on the interpretation of the data in this table.

Such a presentation of the data would be so badly fragmented, however, that it would fail to convey a good sense of the distribution of activity in either space or time. But the data can be easily reduced--with the aid of the computer --to a series of graphic representations that give a much clearer view of the salient features of the distribution.

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table has selected all of the activity that impinges on hour 88; some of this activity impinges on other hours as well. The computer next reports the zones on which the selected activity intrudes, regardless of whether the intrusion occurs in hour 88 or, for instance, in hour 87. Similarly, each event may intrude on more than one zone, in which case it will appear more than once in the listing given here. There are, in fact, only 140 events and 3598 vehicles active in hour 88; both numbers are substantially smaller than the totals obtained by summing the values given in Table 4.

A histogram showing the amount of activity occurring at various depths conveys a much clearer picture than does the tabular format. Figure 2 contains such a histogram, showing the variability in volume across the first 18 of the 22 ten-kilometer zones mentioned above. The data are for the first three phases of the scenario, i.e., from 0600 on D-Day through 1800 on D+4. Each segment of the histogram has been partitioned so as to distinguish between daylight activity and that which occurs at night.

Inspection of Fig. 2 shows that most of the daylight activity--about 70 percent in fact--occurs at depths of 30 kilometers or less. At night, the distribution of activity is still strongly skewed toward the shallower zones, but a significant fraction of the night activity takes place at depths greater than 30 kilometers.

Corresponding histograms for combat vehicles and for high-value vehicles are given in Figs. 3 and 4, respectively.

The same data used to construct Fig. 2 can also be shown in the form of cumulative frequency distributions, as seen in Fig. 5. This form of presentation is somewhat more useful than the histograms for exploring such questions as, "to what depth must an attacking air force penetrate in order to reach (say) 75 percent of the vehicular activity in the enemy rear?"

Figure 5 shows, for example, that a penetration depth of 40 kilometers will cover the region in which 75 percent of the daylight activity occurs, but only 55 percent of that which occurs at night. To be sure of reaching 75 percent of the night activity, the interdiction weapon must penetrate to a depth of about 65 kilometers.

Similar distributions could be constructed for high-value vehicle activity and for combat vehicle activity. They would show, in the case of high-value vehicles, that 75 percent of the daylight volume appears within 50 kilometers of the FEBA

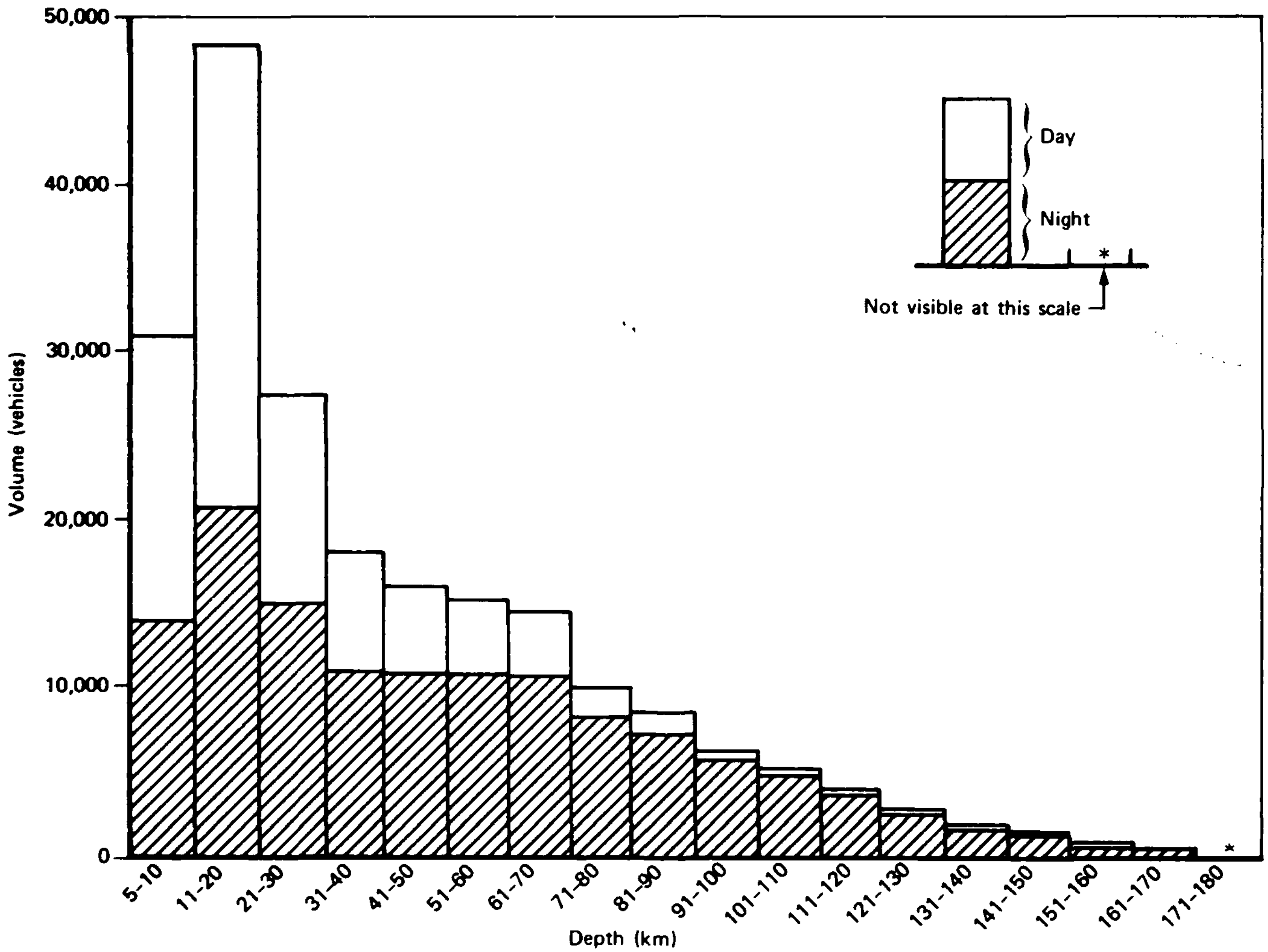


Fig. 2 — Distribution of all traffic according to depth (Phases I - III)

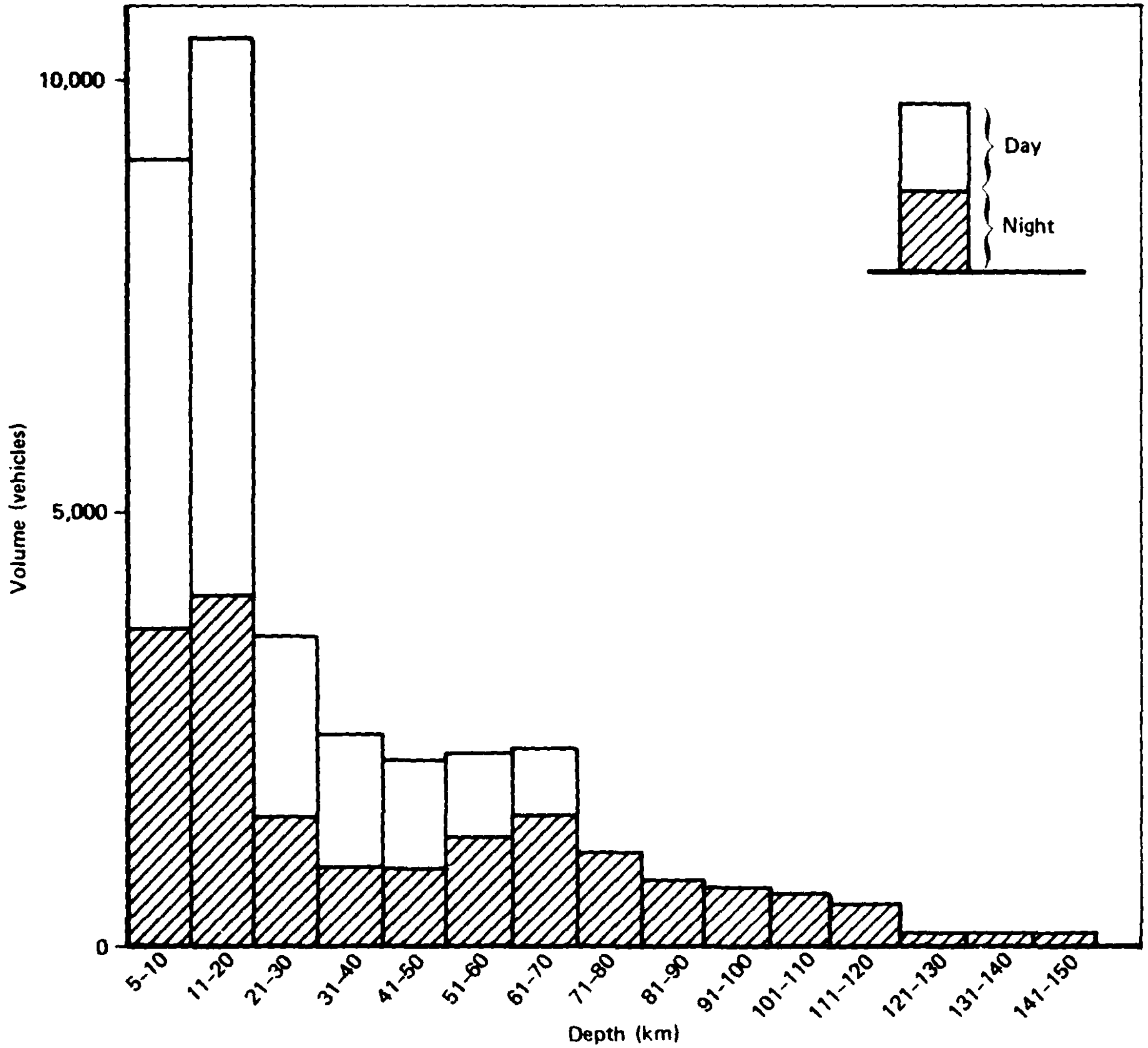


Fig. 3 — Distribution of combat vehicle traffic according to depth (Phases I - III)

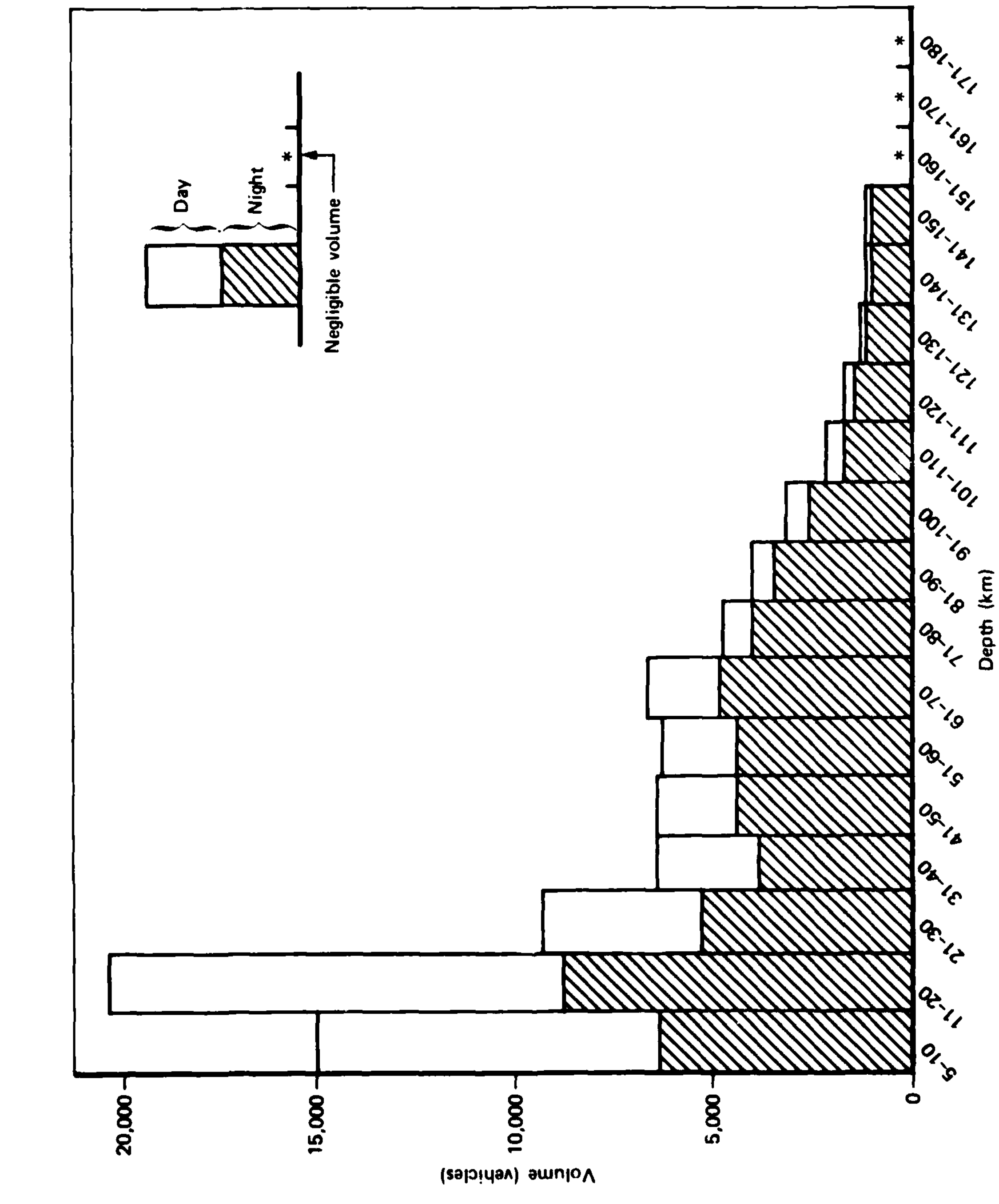


Fig. 4 — Distribution of high-value traffic according to depth (Phases I - III)

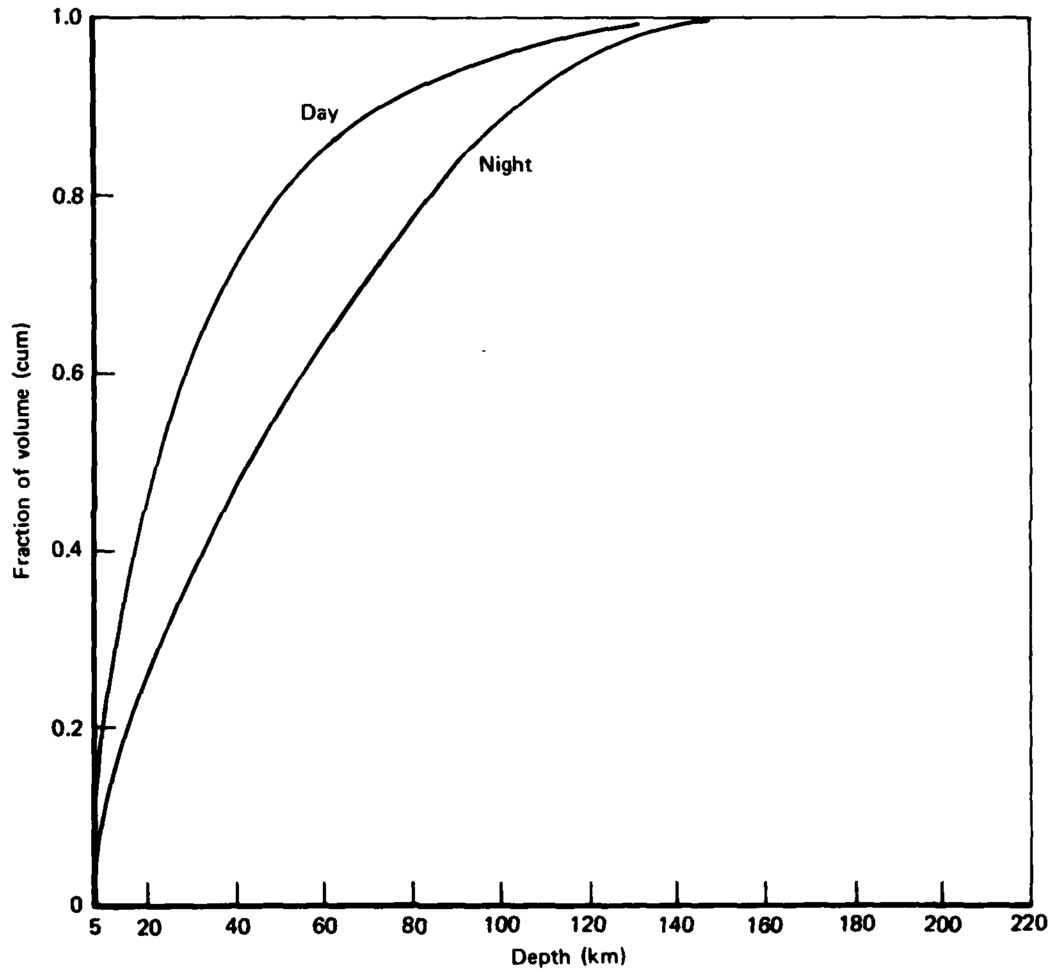


Fig. 5 — Cumulative distribution of volume according to depth (Phases I - III)

and 75 percent of the night volume is within 50 kilometers of the FEBA. For combat vehicles, the 75 percent level is reached at 30 kilometers in daylight and 70 kilometers at night.

One of the interesting differences between the activity generated during the pursuit phase of the scenario and the other phases concerns the distribution according to depth. As might be expected, movement tends to be distributed over a substantially greater depth during the pursuit than is the case during other nighttime periods. For Periods 2,4,6, and 8 in the aggregate, 50 percent of the traffic volume appears in the first 40 kilometers beyond the FEBA, whereas in Period 10 --the pursuit--only 25 percent of the volume appears that close to the leading elements of the Soviet force. To reach 50 percent of the traffic during the pursuit, an attacker would have to penetrate to a distance of about 80 kilometers. The complete distributions are compared in Fig. 6.

Still another view of the data is given in Fig. 7, which shows how the volume of activity is divided between day and night, in Phases I to III, within each 10 kilometer zone. Here it may be seen that in the shallower regions--i.e., at depths of 30 kilometers and less--the division of activity between night and day is roughly equal, whereas at greater distances from the FEBA most of the activity occurs at night. The reason for this difference is that much of the traffic that is generated close to the FEBA is more urgently related to the battle and cannot be deferred until darkness; deeper traffic, in contrast, is not so urgently related to battle outcome and can therefore be scheduled so as to take advantage of the concealment afforded by darkness.

While Figs. 3 and 7 are taken from the same data, they address different aspects of interdiction opportunity and constraint.

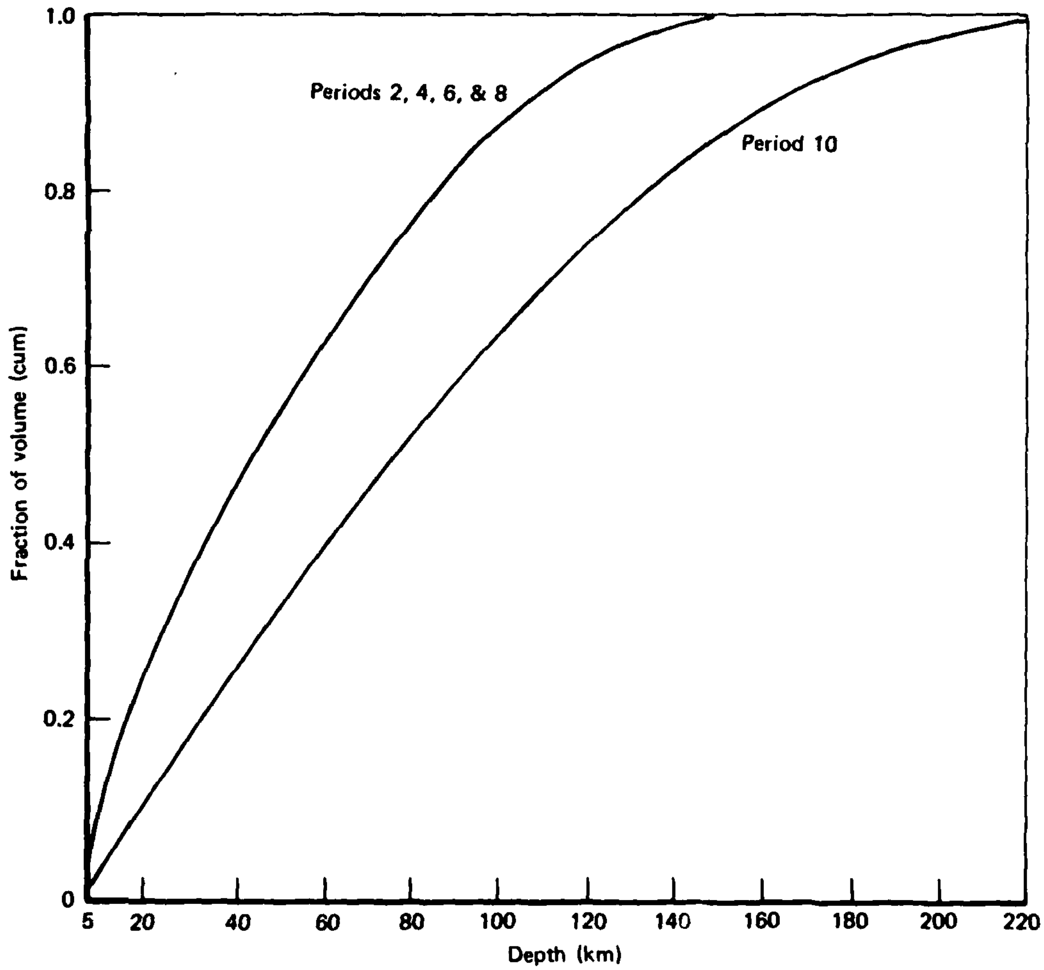


Fig. 6 — Cumulative distribution of volume according to depth
(Phase IV compared with other night periods)

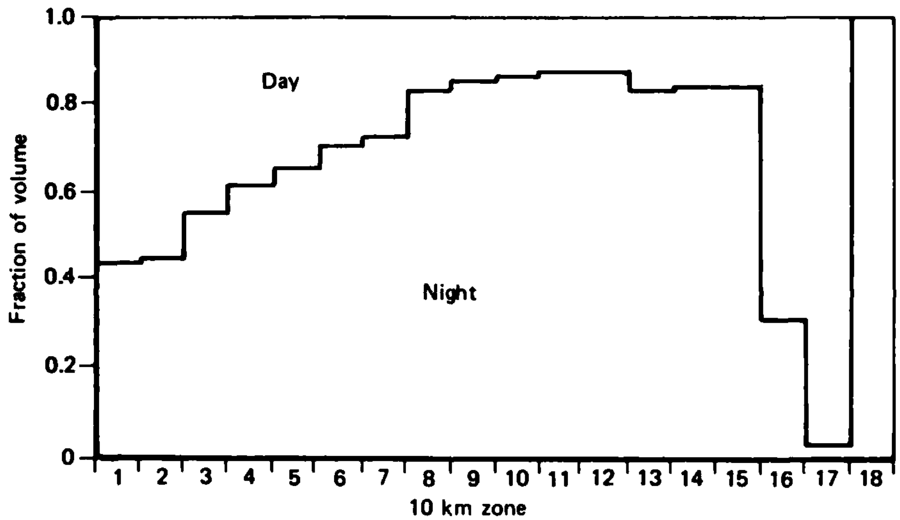


Fig. 7 — Distribution of volume between day and night, as a function of distance from the FEBA (Phases I - III)

- o Figure 7 suggests that at distances greater than 70 or 80 kilometers beyond the FEBA, there are many more interdiction opportunities at night than in the daytime. At the same time, Fig. 7 also seems to say that if one wishes to conduct an interdiction campaign at these depths, he must be prepared to use tactics and weapons that are effective against night activity.
- o Figure 3, on the other hand, shows that the absolute numbers of interdiction opportunities at depths of 70 kilometers and more may be so small as to be of little interest. Indeed, it appears that the daylight opportunities in the first 30 kilometers beyond the FEBA far outnumber all opportunities--day and night--at depths greater than 30 kilometers.

Presentations similar to that in Fig. 7 are given for combat vehicle activity, in Fig. 8; and for high-value vehicle activity, in Fig. 9.

The most notable difference among the three distributions in Figs. 7, 8, and 9 is that the large fraction of activity seen to occur during daylight hours in the 150 to 170 kilometer region in Fig. 7 is missing from the diagram in Fig. 9. This is explained by the fact that the former includes traffic bound for the rear, whereas the latter does not. The particular activity in question consists mainly of empty supply vehicles that were unable to complete the return trip to the supply points where they began the resupply cycle, during the hours of darkness. Since these vehicles are empties moving to the rear, they do not appear in the high-value data. The point is included here (a) to highlight the need for a certain amount of care in deciding on the activity to be included in the high-value category, and (b) to illustrate the capacity of the model to isolate the desired data once this issue has been resolved.

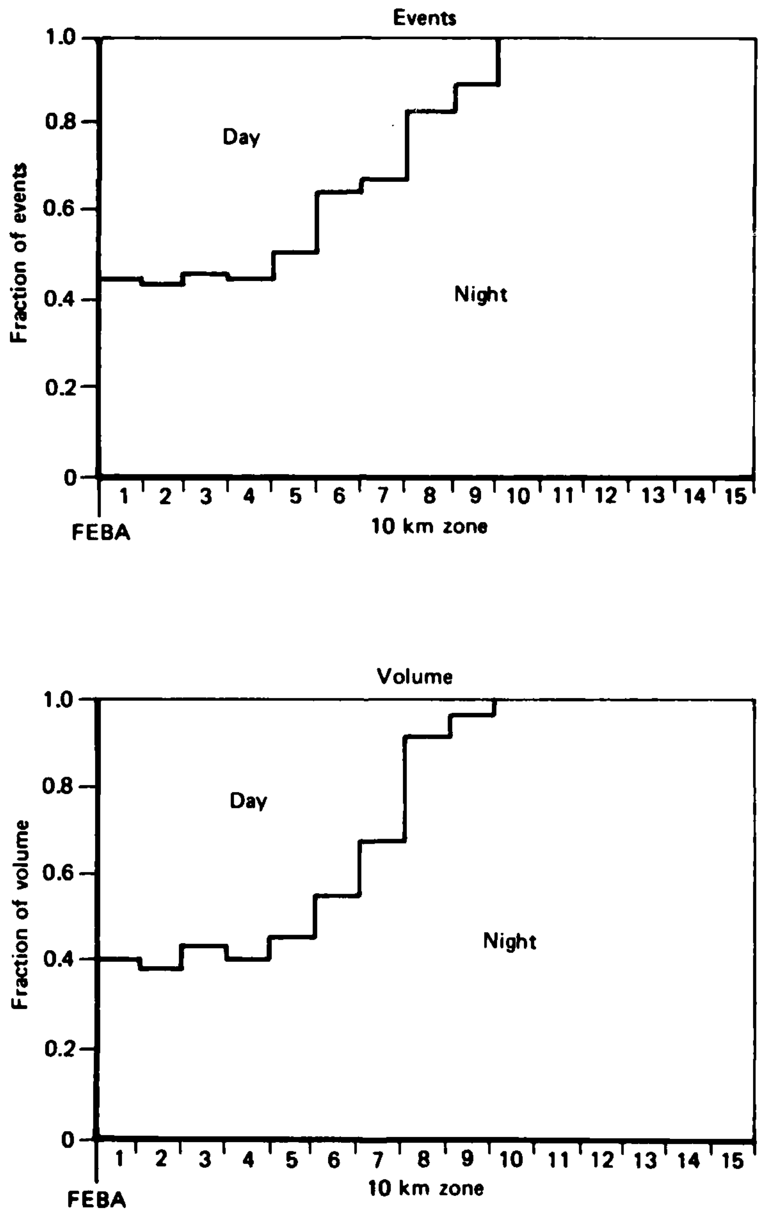
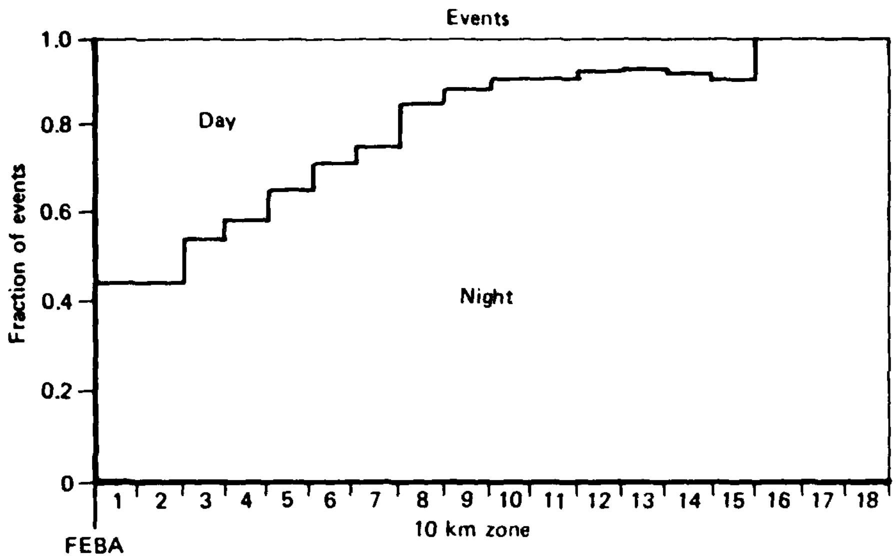


Fig. 8 — Distribution of combat vehicle activity between day and night, for each 10 kilometer zone (Phases I - III)



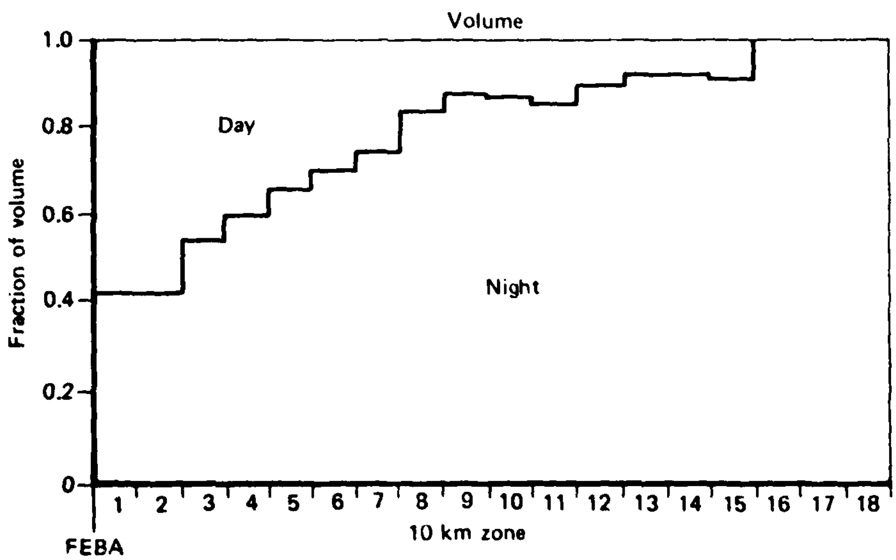


Fig. 9 — Distribution of high-value traffic between day and night, as a function of distance from the FEBA (Phases I - III)

The division of traffic among combat vehicles, other high-value vehicles, and other vehicles, as a function of depth, is shown graphically in Fig. 10. The data are given separately for day and night activity.

The daylight portion of Fig. 10 tends to contradict some of the conventional wisdom and therefore deserves a word of explanation. Specifically, the figure asserts that high-value vehicles account for less than half of the traffic volume close to the FEBA; but they account for virtually all of the volume at depths greater than 100 kilometers. The explanation of this facet of the model lies in the definition of high-value vehicles and in the rules governing movement during the hours of daylight.

Under our rules, vehicles move in daylight only if their failure to do so would clearly have an adverse effect on the progress of the battle. Consequently, the daylight activity in the first 80 kilometers of depth includes a substantial amount of movement by TO&E units; and a high proportion of the vehicles in these units are excluded from our illustrative definition of high-value--proximity to the FEBA notwithstanding.

In contrast, the daylight activity that takes place beyond 100 kilometers consists almost entirely of ammunition convoys made up exclusively of high-value vehicles. But it is also important to remember that the absolute level of activity at these depths is quite small in comparison with the level in the region closer to the FEBA (again see Fig. 2).

Figure 10 also says quite plainly that there would be little likelihood of finding combat vehicles on the road in daylight at distances greater than 70 kilometers beyond the FEBA.*

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*However, see the caveat in the concluding portion of this section regarding this feature of MOVER.

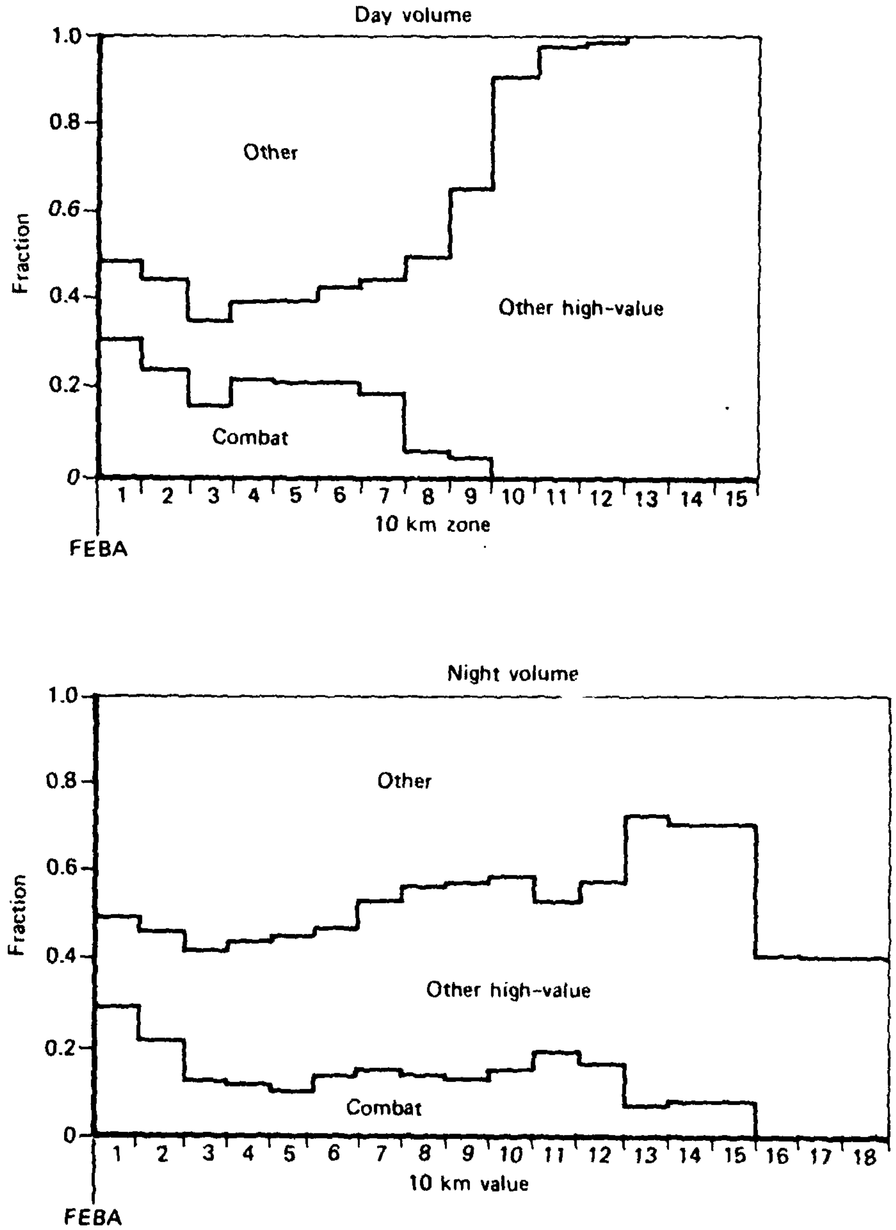


Fig. 10 — Volume generated by combat vehicles and other high-value vehicles as a fraction of all forward volume, distributed by distance from the FEBA (Phases I - III)

HOW IS THE ACTIVITY DISTRIBUTED IN TIME?

There are a number of ways of viewing the distribution of activity according to time, most if not all of which have been mentioned earlier in the discussion. These include divisions according to light, according to phase of the scenario, according to period of the scenario, and according to the hour within the period.

Distribution by Light Condition

As suggested earlier, one of the most important distinctions to be made with respect to time has to do with the distribution according to light. This particular parameter also provides a striking example of the different answers yielded by the three different activity metrics defined above, as seen in Table 5.

The table shows that for the scenario as a whole, all three metrics indicate that a larger number of attack opportunities are presented at night than in the daytime. But whereas the disparity between night and day opportunities appears somewhat marginal as measured by "events" and "volume," the "exposure" metric reveals a rather dramatic difference between the two light conditions.

Table 5

FRACTIONAL DISTRIBUTION OF ACTIVITY ACCORDING TO LIGHT, ALL PHASES, 3 METRICS

Activity Metric	All Traffic		Combat Vehicles		High-Value Vehicles	
	Day	Night	Day	Night	Day	Night
Events	.34	.66	.47	.53	.40	.60
Volume	.40	.60	.49	.51	.41	.59
Exposure	.16	.84	.23	.77	.16	.84

These observations seem to hold good without regard to distinctions between the general population of vehicles and the vehicles of high value, although it will be noted that the bias toward night activity is not quite as pronounced where combat vehicles are concerned as it is with other vehicles.

The raw data from which Table 5 was taken can also be restructured to describe a different aspect of interdiction opportunity. The question can be put, rhetorically: "How does the division of traffic between high-value activity and other activity vary as a function of light condition?" Table 6 gives a fractional distribution of the activity between high-value traffic and other traffic, for night and for day, using all three activity metrics.

Table 6 may seem at first to contradict itself because of the lack of consistency between the "events" metric, on one hand, and the "volume" and "exposure" indices, on the other. The explanation of this apparent contradiction is quite simple: The great majority of the march units in the force include--by design--at least 1 POL truck, and since the POL truck has been designated a high-value vehicle, a very large fraction of the events fall into the high-value category. In this case, both the "volume" and the "exposure" metrics are the preferred indices for evaluating interdiction opportunities. Therefore, the

Table 6

DIVISION OF ACTIVITY BETWEEN HIGH-VALUE VEHICLES AND OTHERS, ACCORDING TO LIGHT

Activity	Events	Volume	Exposure
Daylight Activity:			
High-value vehicles	.89	.43	.41
Other vehicles	.11	.57	.59
Night Activity:			
High-value vehicles	.69	.43	.44
Other vehicles	.31	.57	.56

data in the table suggest that, if one were to attack vehicles on the road indiscriminately, either in daylight or at night, he would be directing his efforts at high-value targets between 40 and 45 percent of the time.

Knowing that combat vehicles represent a yet smaller fraction of the total vehicle population, one would expect to encounter one of these an even smaller percentage of the time, and Table 7 shows that this would in fact be the case, at least in the MOVER scenario. But Table 7 also shows that, for the rear area as a whole, there is a much better chance that a random attack will encounter a combat vehicle in the daytime than at night.

Table 7

DIVISION OF ACTIVITY BETWEEN COMBAT VEHICLES AND OTHERS, ACCORDING TO LIGHT

Activity	Events	Volume	Exposure
Daylight Activity:			
Combat vehicles	.67	.23	.23
Other vehicles	.33	.77	.77
Night Activity:			
Combat vehicles	.39	.16	.15
Other vehicles	.61	.84	.85

As was the case with high-value vehicles, the combat vehicle data in Table 7 show that while a large majority of the daylight events contain at least 1 combat vehicle, combat vehicles themselves are in the minority; and they generate but 23 percent of the daylight exposure in the model.

Variability with Depth

The data given earlier in Table 5 are for the entire geographic area occupied by the Soviet force. If one divides the region depthwise at, say, a line 30 kilometers beyond the FEBA, the activity in the two zones exhibits some interesting differences with respect to the division of activity between day and night. These differences are shown in Table 8, for the aggregate of all vehicles.

Regardless of which metric one consults, it is clear from Table 8 that nighttime opportunities far outnumber daytime opportunities at depths beyond 30 kilometers; this dominance is less pronounced in the region closer to the FEBA.

While these fractional distributions of activity are of interest, they do not reveal anything about the absolute levels of activity that one would wish to know in order to evaluate attack opportunities. Some appreciation for these absolute levels can be obtained by inspection of the period-by-period and phase-by-phase content of the history.

Table 8

FRACTIONAL DISTRIBUTION OF ACTIVITY ACCORDING TO LIGHT AND DEPTH, ALL PHASES, 3 METRICS

	5-30 km		> 30 km	
Metric	Day	Night	Day	Night
Events	.33	.67	.04	.96
Volume	.47	.53	.08	.92
Exposure	.23	.77	.03	.97

Distribution by Phase of the Scenario

A phase-by-phase distribution of all of the activity in MOVER is shown in Table 9, in terms of events, volume, and exposure. The fractional distribution of activity across the 4 phases, shown parenthetically in the table, further illustrates the importance of choosing the activity metric with care.

Table 9

TOTAL TRAFFIC ON THE ROAD IN EACH PHASE OF THE SCENARIO

	Length (hours)	Events	Volume	Exposure
Phase I	24 (.20)	475 (.23)	16,017 (.22)	24,109 (.18)
Phase II	48 (.40)	770 (.37)	25,313 (.34)	40,487 (.30)
Phase III	36 (.30)	692 (.33)	24,795 (.33)	24,294 (.18)
Phase IV	12 (.10)	151 (.07)	8,137 (.11)	47,097 (.35)
All phases	120 (1.00)	2,088 (1.00)	74,262 (1.00)	135,987 (1.00)

Distribution by 12 Hour Period

A period-by-period distribution of the activity in MOVER is given in Table 10, also in terms of events, volume, and exposure.

Distribution by Hour Within the Period

One additional view of the distribution of activity according to time will be presented here, not for any particular operational or systems implications but as a further point in the methodological discourse. The view is of the distribution of activity within each of the 12 hour periods into which the scenario is divided.

In planning air operations against the Soviet rear on a day-to-day basis, it might conceivably be important to know when during the night or day the highest levels of activity are expected to occur. A special set of parameters in MOVER classifies the activity according to the hour within the 12 hour period and thus gives some insight concerning this issue.

Table 10

TOTAL TRAFFIC ON THE ROAD IN EACH PERIOD OF THE SCENARIO

Period	Events	Volume	Exposure
Period 1	210	9,401	5,835
Period 2	265	6,616	18,274
Period 3	82	3,573	2,669
Period 4	258	8,388	24,140
Period 5	129	4,864	2,466
Period 6	301	8,488	11,212
Period 7	165	6,893	4,300
Period 8	392	12,359	12,038
Period 9	135	5,543	8,085
Period 10	151	8,137	47,097
Day periods	721	30,274	23,355
Night periods	1357	43,988	112,761
All periods	2088	74,262	136,116

Figures 11 and 12 show the distribution of activity, hour by hour within each period, for the day periods and night periods respectively.

In evaluating the data in these two figures, it is important to keep in mind the preference imputed to the Soviets, in our model, for moving at night in the rear area. Given this preference, the movement that takes place in daylight occurs because of an operational necessity tied directly to the advance of the FEBA. Consequently, its distribution tends to vary among the several daylight perio reflecting the periodic variations in FEBA movement.

Night movement, on the other hand, consists largely of activities that can be scheduled so as to take best advantage of the hours of darkness, subject to procedural constraints and the availability of usable roads. Therefore, the same general hourly distribution of activity can be seen in most of the night periods. As soon as darkness has fallen, resupply activity begins in the forward area. As the derivative demands generated by this activity are felt at the deeper echelons of the logistical system, additional traffic appears on the roads.

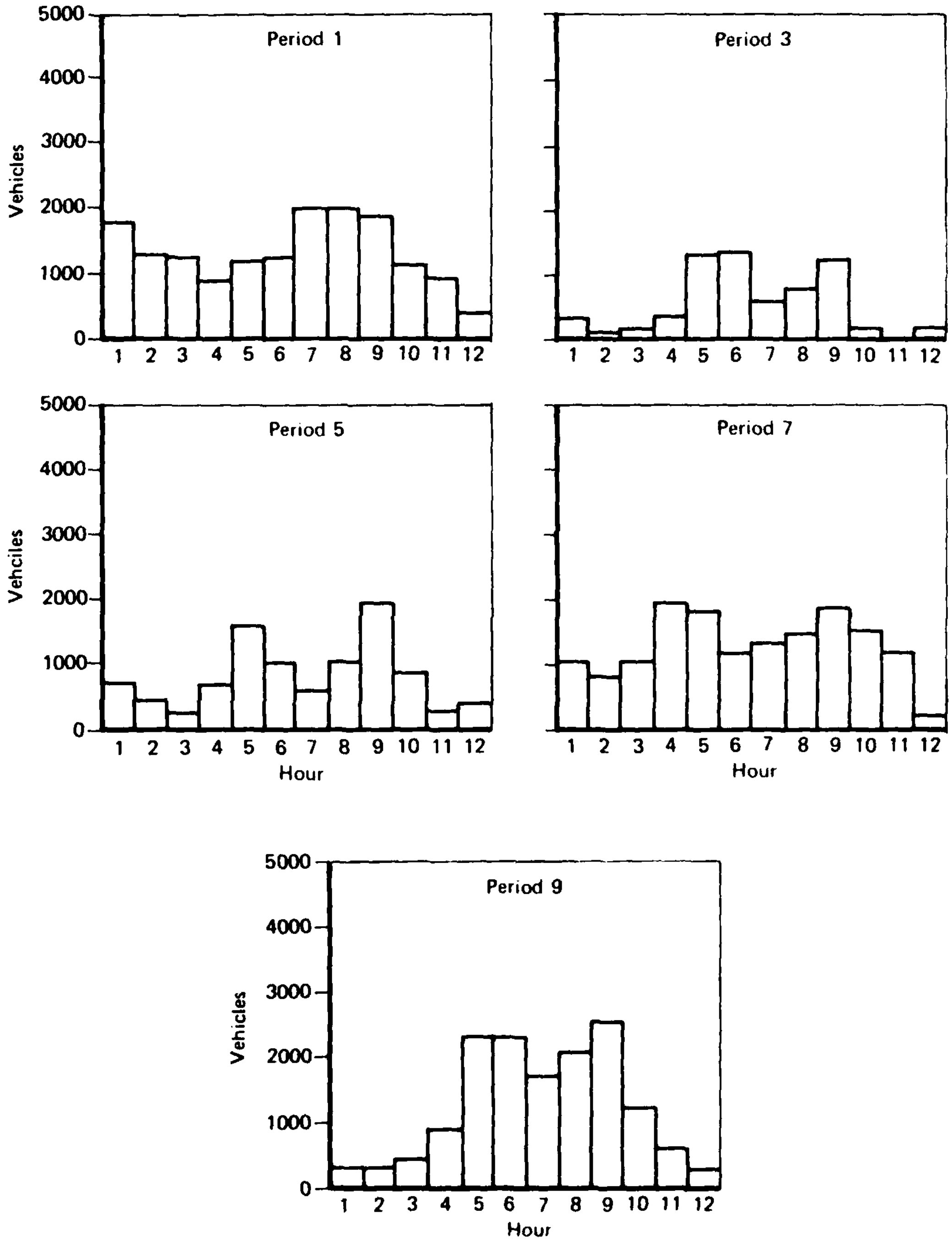


Fig. 11 — Hourly volume within each period (day periods)

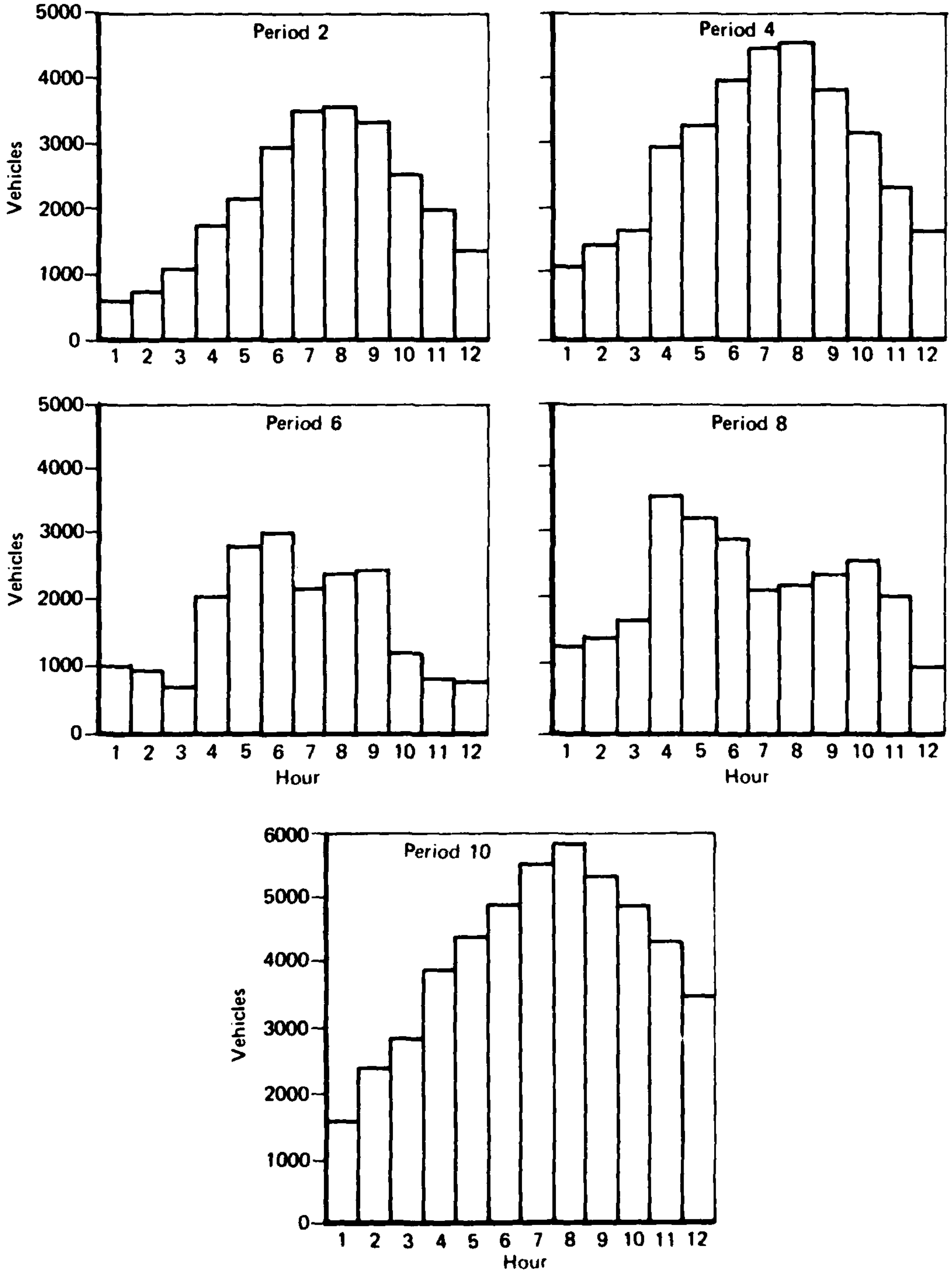


Fig. 12 — Hourly volume within each period (night periods)

As midnight approaches, the empty resupply vehicles are returning from the forward area at the same time that their replenishment is beginning to move forward from the deeper echelons in the system. As the two converge toward the intermediate logistical nodes, their combined activity produces a peak volume near the middle of the period, i.e., around midnight. The precise rules that result in this particular pattern of activity are given in Appendix A.

WHEN VEHICLES TAKE THE ROAD, HOW LONG ARE THEY IN TRANSIT BEFORE REACHING THEIR DESTINATIONS?

When considering the practicality of attacking moving targets in the enemy rear, no issue commands more attention than does the question of target perishability. Moving targets are, by definition, fleeting targets and so the question of perishability begets a certain number of concomitant questions about the responsiveness of attack systems and concepts. The concern is especially acute where the target system consists of second echelon combat forces and other high-value vehicles.

At the same time, some of the data presented thus far suggest that there will always be a fairly substantial amount of military traffic moving along the roads in the Soviet rear area. It might be argued, therefore, that the issue of attack system responsiveness is largely irrelevant. However, this argument seems to have merit only if (1) it is possible to locate and attack targets in an armed reconnaissance mode of operation, and if (2) one is satisfied with the grab bag of targets that the general population of vehicles presents to an armed reconnaissance strike system.

If, on the other hand, a commander wishes to commit his strike forces only against targets that have been firmly acquired--and perhaps evaluated--by, say, some sort of cooperative surveillance and tracking system, then the distribution of the target population according to transit times would become quite important in ensuring that the responsiveness of the strike system is reasonably matched to the expected life of the target. Target perishability would also be significant if it could be shown that there is a positive correlation between transit time and such other parameters as target size, target composition, depth of activity, or other useful discriminators.

In the graphs and tables that follow, we show some of the statistical descriptions of target perishability for the activity represented in MOVER. In examining these data it is important to remember that they are highly dependent upon the rate of advance of the FEBA, as stipulated by the scenario, and upon the station-keeping intervals given in Appendix A.

Table 11 shows the minimum, maximum, median, and average movement times for all of the events occurring in Phases I to III of the scenario, i.e., before the final pursuit by the Soviet force. The data are given separately for day and night activity, and for the aggregate of both conditions.

Histograms showing the distribution of events by duration, for both day and night, for Phases I-III, are given in Fig. 13.

One of the important messages contained in this figure is that strike systems that take as long as an hour to respond

Table 11

DURATION OF MOVEMENT EVENTS, PHASES I-III

	Day	Night	All
Minimum	12 min	3 min	3 min
Average	42	85	69
Median	20	43	37
Maximum	307	493	493

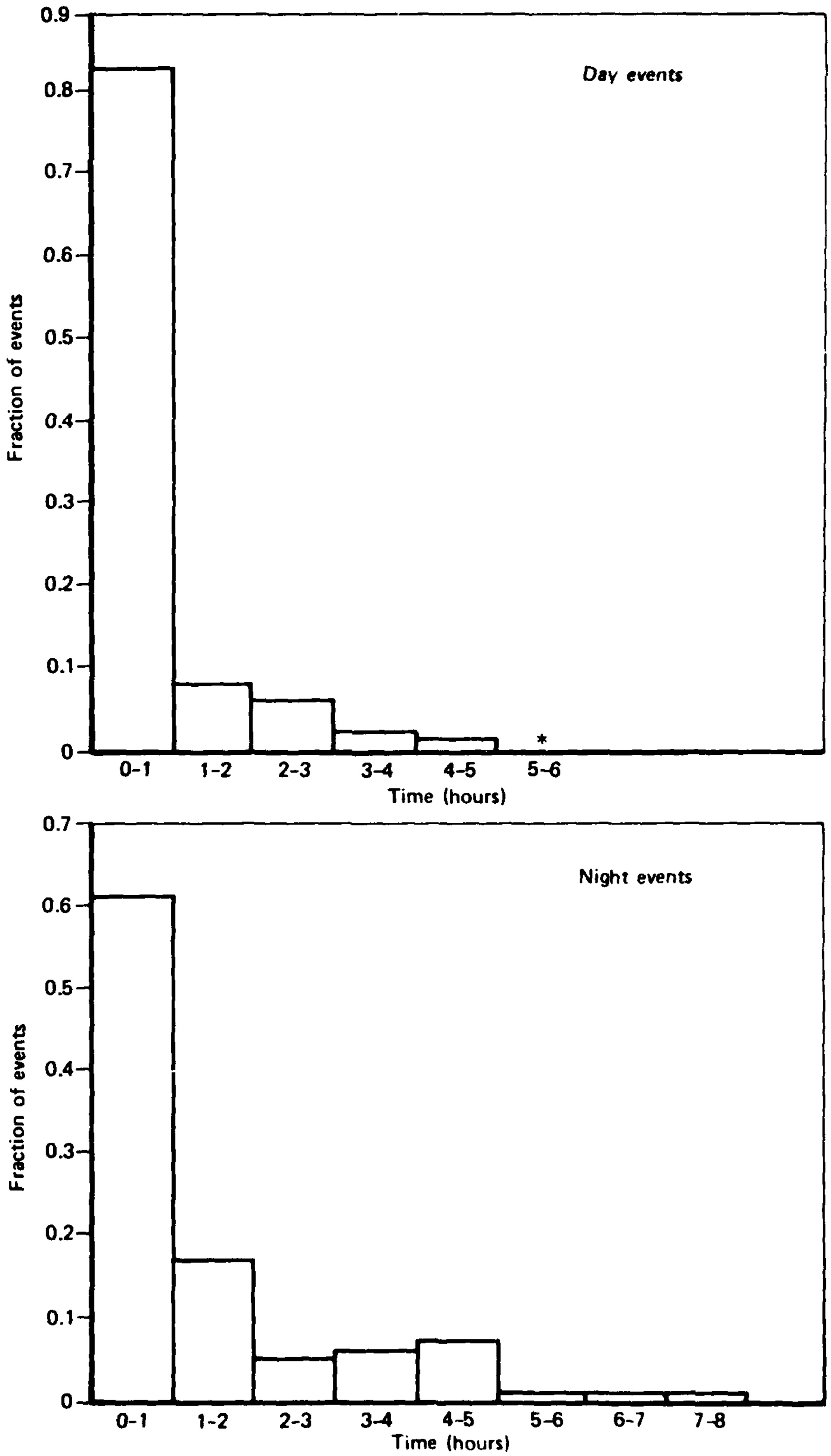


Fig. 13 — Distribution of activity according to duration, events in Phases I - III

to a particular target acquisition--i.e., to proceed to the target area, find the target, and commence the attack--should expect to arrive while the target is still on the road in no more than about 20 percent of the cases in daylight and in about 40 percent of the cases at night. A success rate of 75 to 80 percent--from the standpoint of timeliness--requires a system response time of under 30 minutes in either day or night circumstances.

A comparison between the "event" and "volume" metrics for night activity in Phases I-III is given in Fig. 14. This figure shows that if "volume" is taken as the measure of activity, a response time of an hour would suffice for about 55 percent of the nighttime traffic, rather than the 40 percent suggested by the distribution of event transit times.

It was pointed out earlier that the character of the pursuit phase of the scenario sets it apart from the rest of the activity in some important respects. One of these has to do with the duration of events. The unusual character of the pursuit in this regard can be seen by comparing the distribution for Phase IV with the night event distribution given earlier for Phases I to III; the comparison is shown in Fig. 15.

IN WHAT SIZE GROUPS DO VEHICLES TRAVEL?

The division of the Soviet rear area forces into march units has been described earlier. This partitioning of the force gives some idea of the number of vehicles one might expect to encounter, moving as a group or "target" on the road. The 1052 march units that make an appearance in the synthetic history range in size from 1 vehicle to 142; the complete distribution is shown graphically in Fig. 16.

Since there is a great deal of variability among march units with respect to the frequency with which they move and the duration of their moves, the distribution in Fig. 16 cannot be relied upon to give an accurate representation of the group sizes one might expect to encounter on the roads

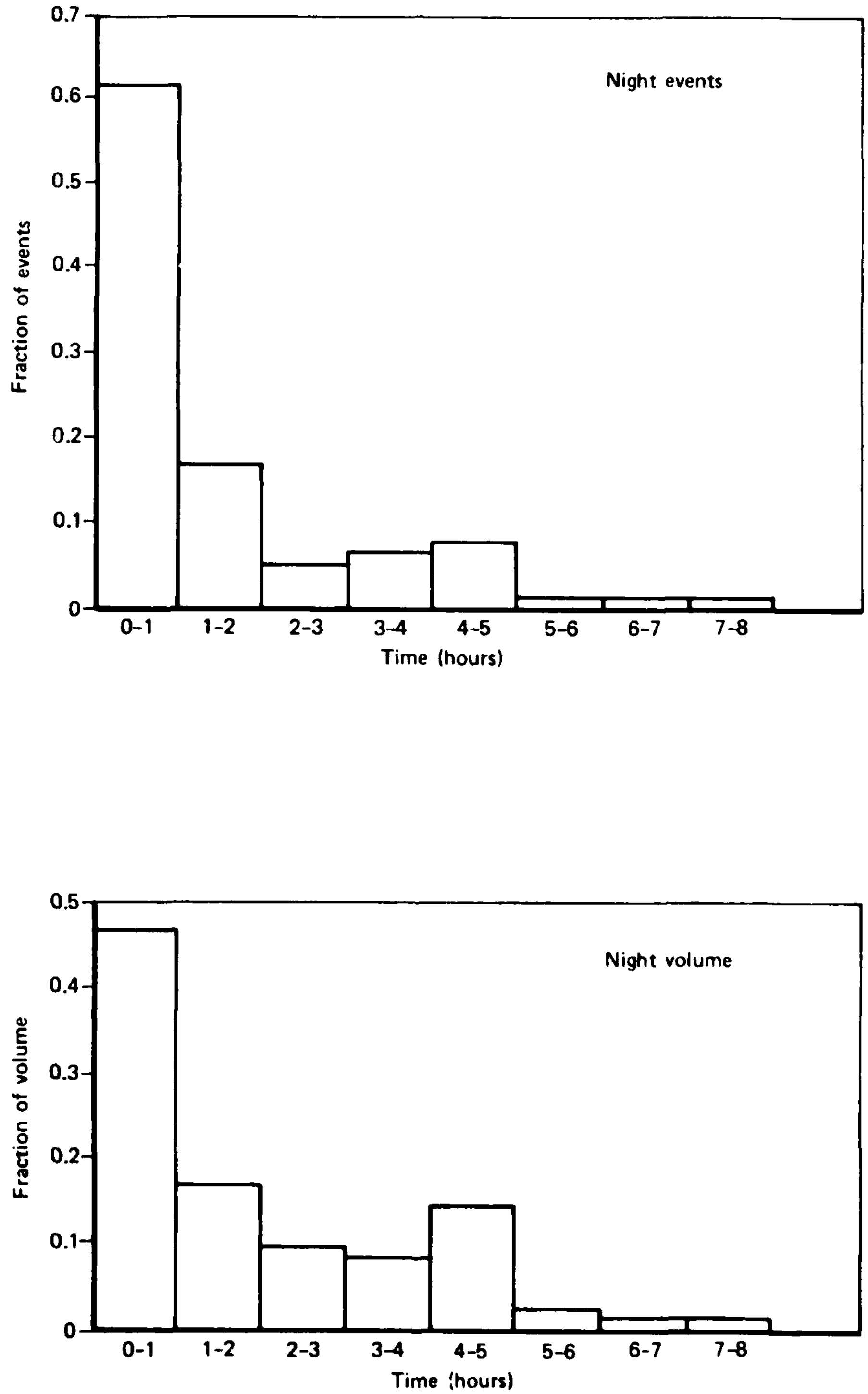


Fig. 14 — Distribution of activity according to duration, night events and night volume in Phases I - III)

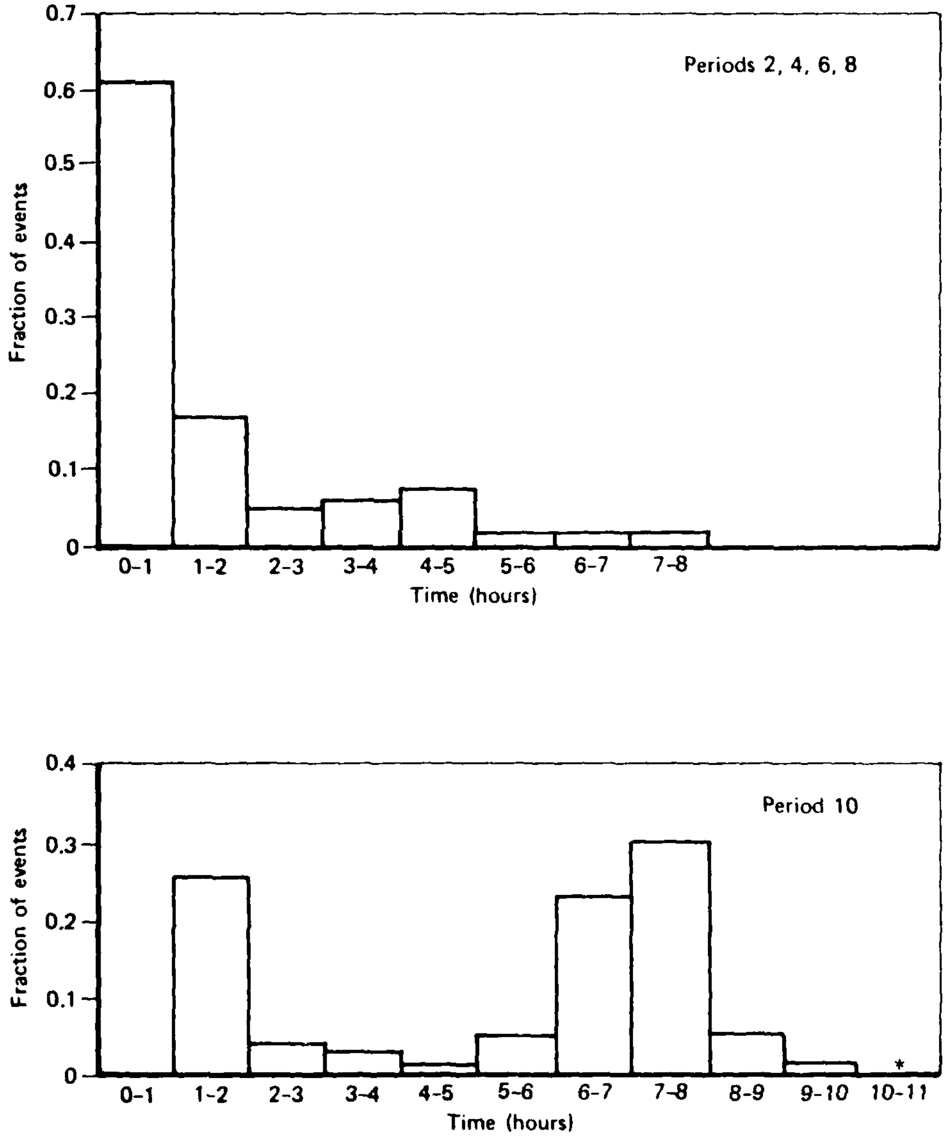
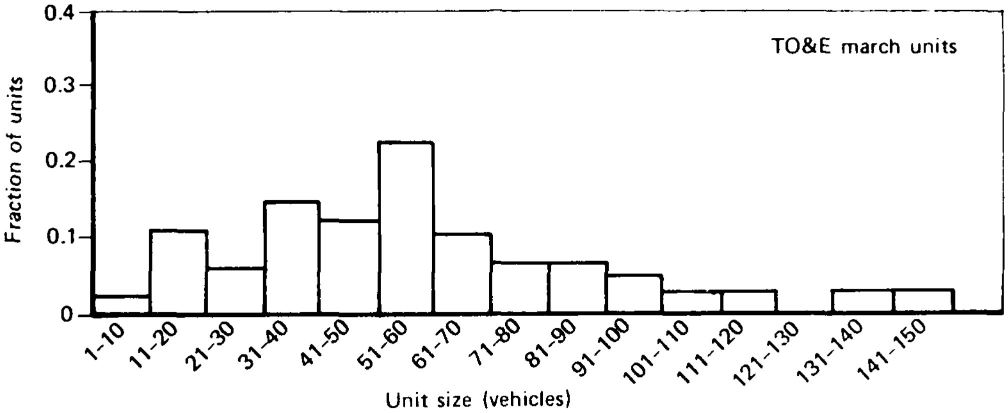


Fig. 15 — Distribution of activity according to duration, night events in Phases I - III compared with events in Phase IV



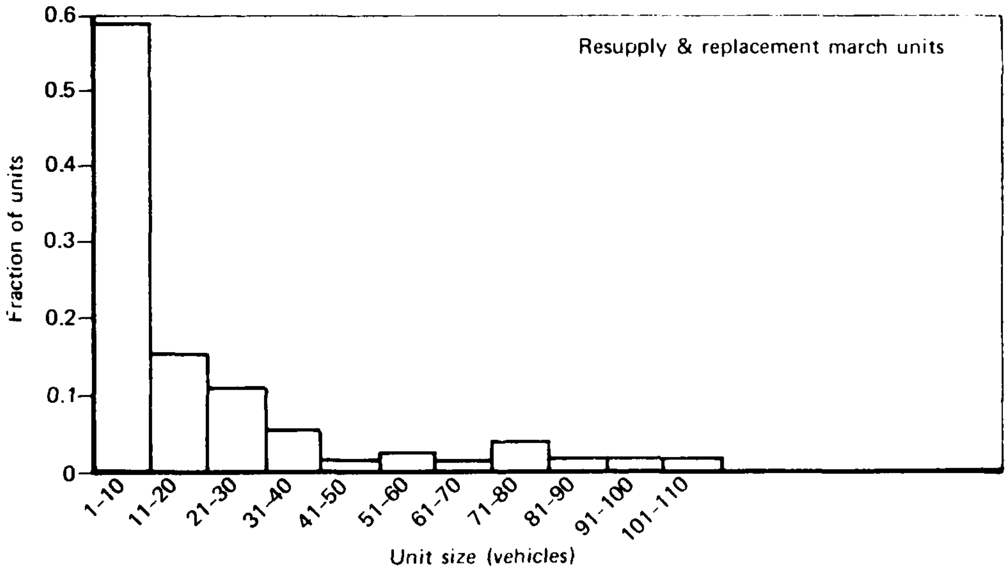


Fig. 16 — Distribution of march units according to size

throughout the scenario. As mentioned earlier, some units move but once during the entire scenario while others make as many as 22 moves.

When all of the activity in the history is considered, the distribution according to group size is as shown in Fig. 17. If these data are divided into their day and night components, it will be found that the two light conditions exhibit different distributions, particularly with respect to the "event" and "volume" metrics, as seen in Figs. 18 and 19.

This series of figures offers two rather interesting comparisons between the distribution of march unit sizes, as given in Fig. 16, and the activity patterns that dominate the history as shown in Figs. 17, 18, and 19.

- o The first is the similarity between the distribution of TO&E march unit sizes, as given in Fig. 16, and the distribution of active group sizes in daylight, as given by the top histogram in Fig. 18. Since both of these distributions are quite unlike the distribution given for logistic march units in Fig. 16, there is a strong inference that daylight activity is dominated by the movement of TO&E units, as is indeed the case.
- o There is a second and corresponding similarity between the distribution of logistics march unit size, as seen in Fig. 16, and the distribution of event size at night, as shown in Fig. 18. The inference here is that nighttime activity is dominated by logistical movements. The similarity of the two distributions in this case owes much to the fact that each logistical march unit makes 1 or 2 moves at most and is then disbanded. A reading of the material in Appendix A will suggest that there should indeed be a high degree of correspondence, in MOVER, between logistical unit size and the size of groups moving at night.

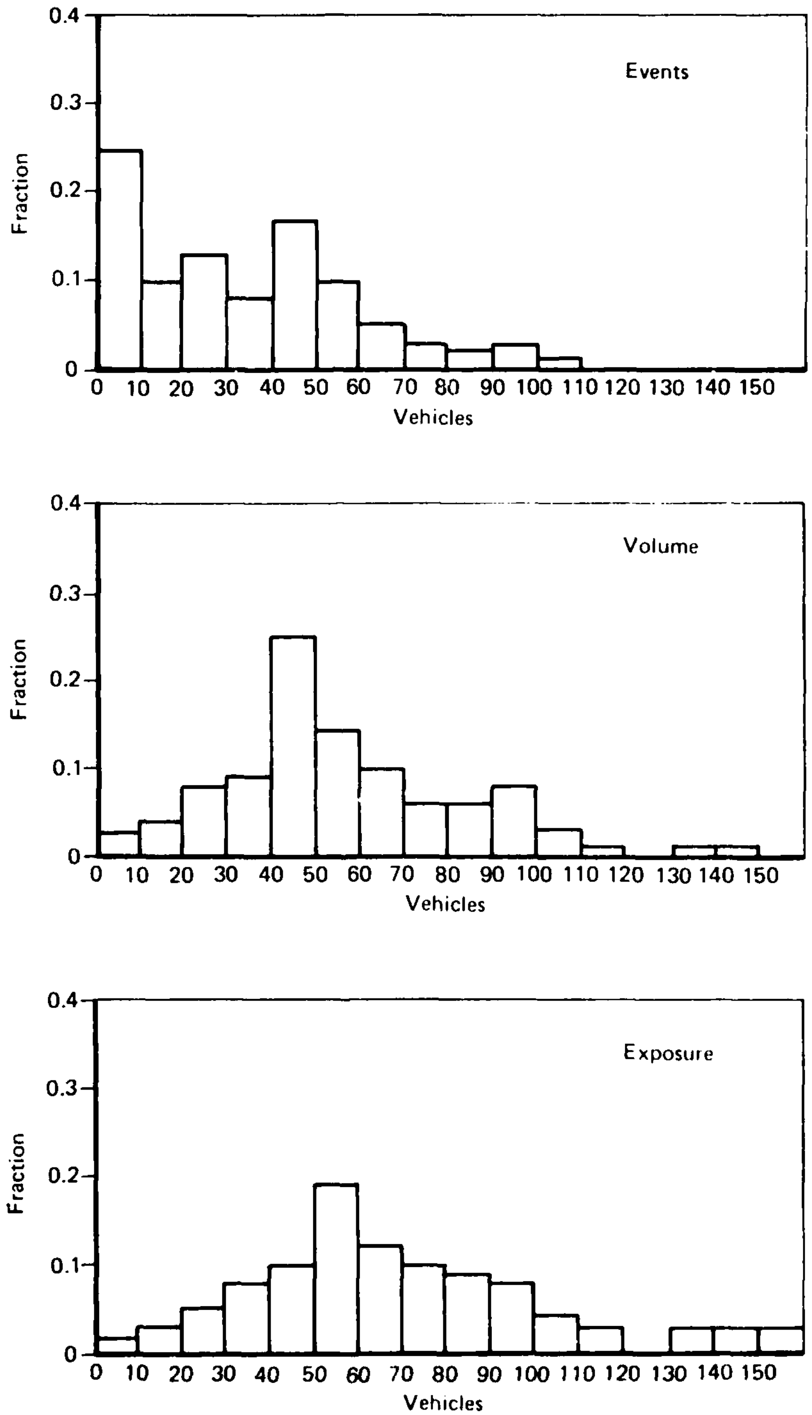


Fig. 17 — Distribution of all activity according to march unit size

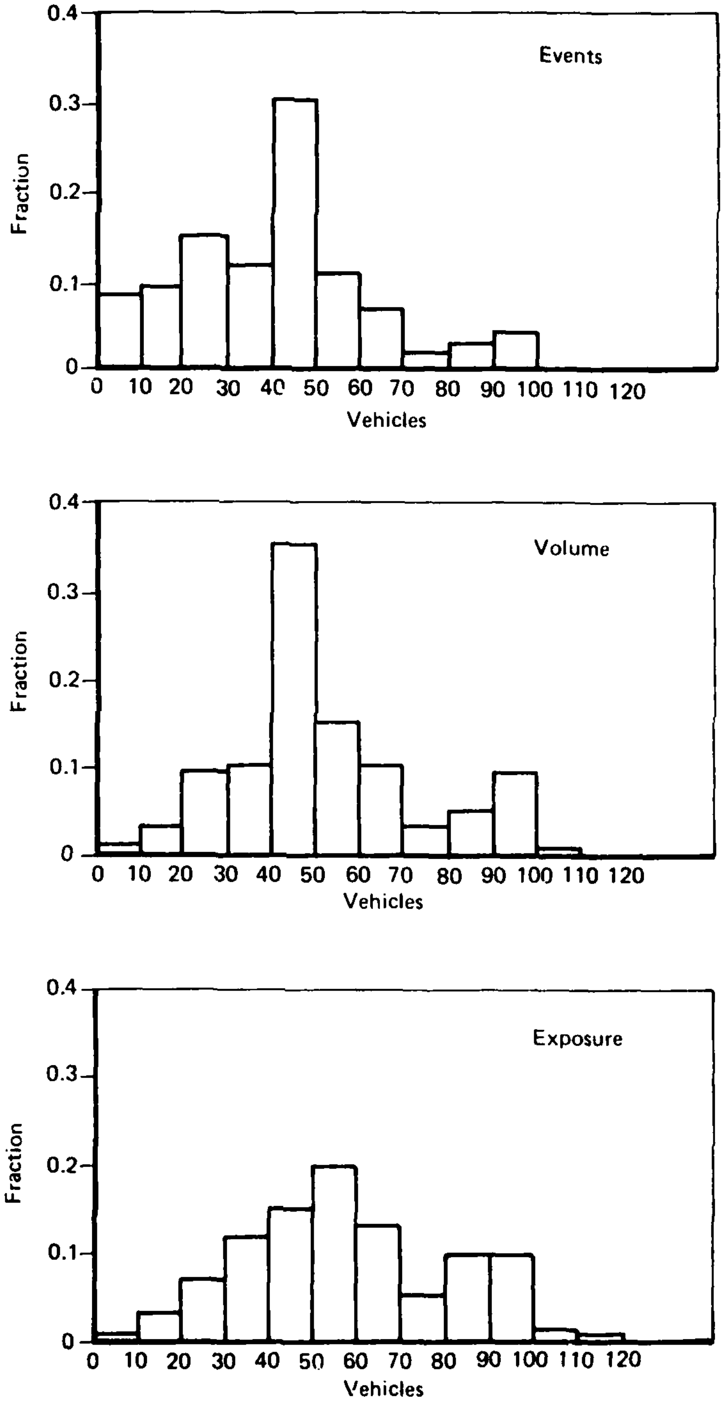


Fig. 18 — Distribution of day activity according to march unit size

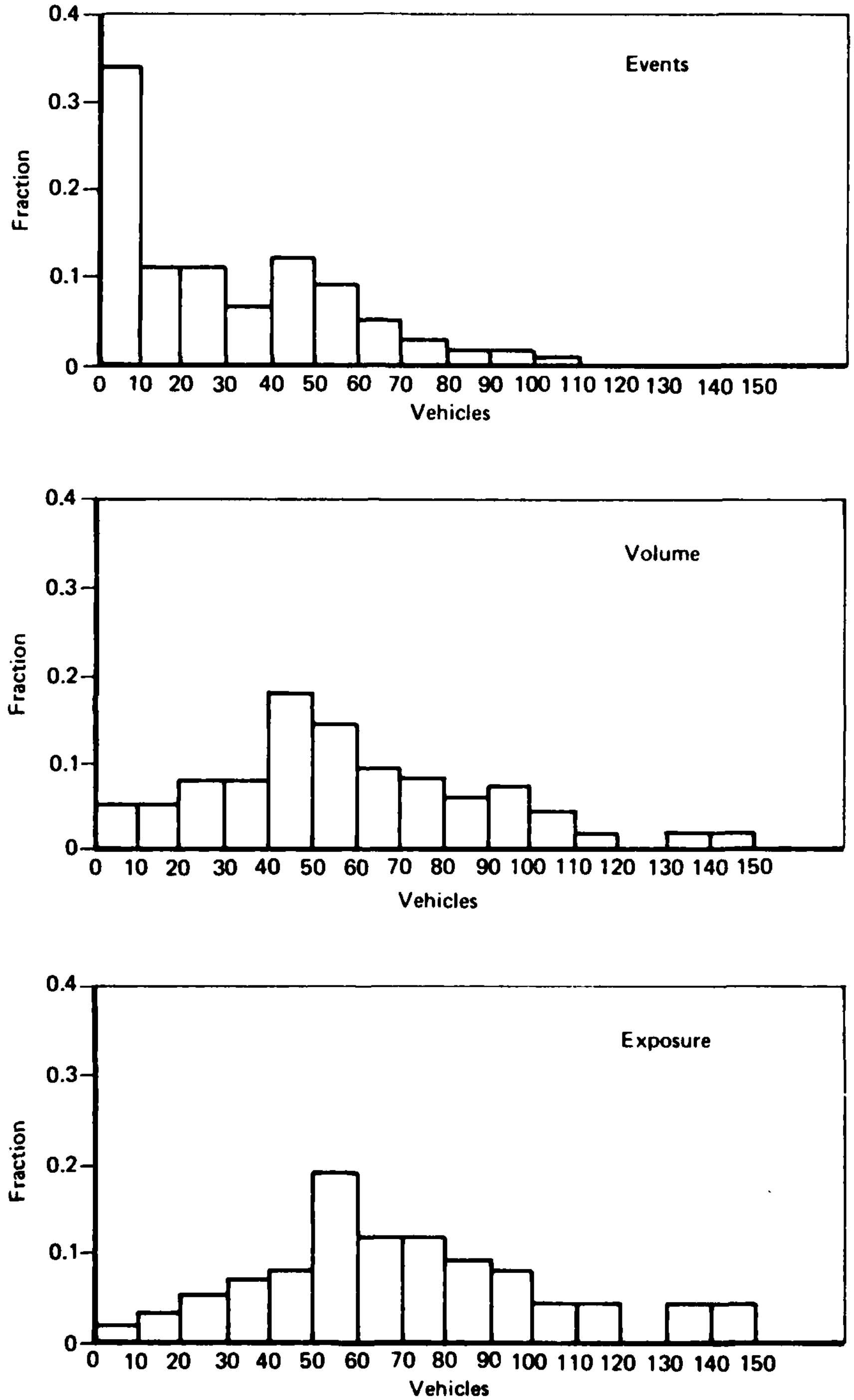


Fig. 19 — Distribution of night activity according to march unit size

These comparisons apply only to highly aggregated perspectives. If one were to examine the distribution of march unit size for, say, those nights when a second echelon division is on the move, it would differ quite markedly from that shown in Fig. 19.

The minimum, average, median, and maximum group sizes are shown in Table 12, for day events, for night events, and for the aggregate of all events.

Table 12

NUMBER OF VEHICLES COMPRISING AN EVENT

	Day Events	Night Events	All Events
Minimum	2	1	1
Average	42	32	36
Median	48	24	31
Maximum	114	142	142

As noted earlier, when each march unit was defined, a maximum size of 100 vehicles was adopted as a goal. In the end, however, some march units proved to be somewhat larger than the desired maximum. It is of some cogency, therefore, to note that only a very small fraction of the activity was generated by these excessively large march units, as seen in Table 13.

Because combat vehicles, when present, are almost always in the company of non-combat vehicles, characterizing combat vehicle activity in terms of group size is a somewhat elusive goal. One way of getting at the information is to examine the ratios of combat vehicles to all vehicles, for each event in the history. Figure 20 gives these data for all 2088 events, in the form of a cumulative frequency distribution.

Table 13

FRACTION OF ACTIVITY GENERATED
BY OUTSIZE MARCH UNITS

Metric	Fraction
Events	.02
Volume	.06
Exposure	.14

Where combat vehicles are concerned, the ratio between vehicles of high value and the total number of vehicles in an event is not nearly as high--at least in MOVER--as is often supposed. Fewer than 1 percent of the events are composed entirely of combat vehicles, while 51 percent contain no combat vehicles at all. The ratio of combat vehicles to others in the event is 1 to 1 or greater in only 4 percent of the cases.

HOW DOES THE AMOUNT OF TRAFFIC ON THE ROADS COMPARE WITH THE CAPACITY OF THE AVAILABLE ROAD NET?

In our analysis we wished to test the hypothesis, among others, that the amount of rear area activity associated with a doctrinaire Soviet offensive in Central Europe would produce highly congested traffic conditions. The MOVER activity model coupled with a close analysis of the road net in the area of the scenario gives some insight concerning this issue, even if it does not address all of the factors that might lead to the kind of congestion some see as a potential Achilles' heel of Soviet operations.

The road net capacity data that will be used in the present comparison are taken from an extensive study made in an earlier phase of the research. One of the techniques used in that analysis involved a division of the geographical region into 10 kilometer bands oriented generally perpendicular to the

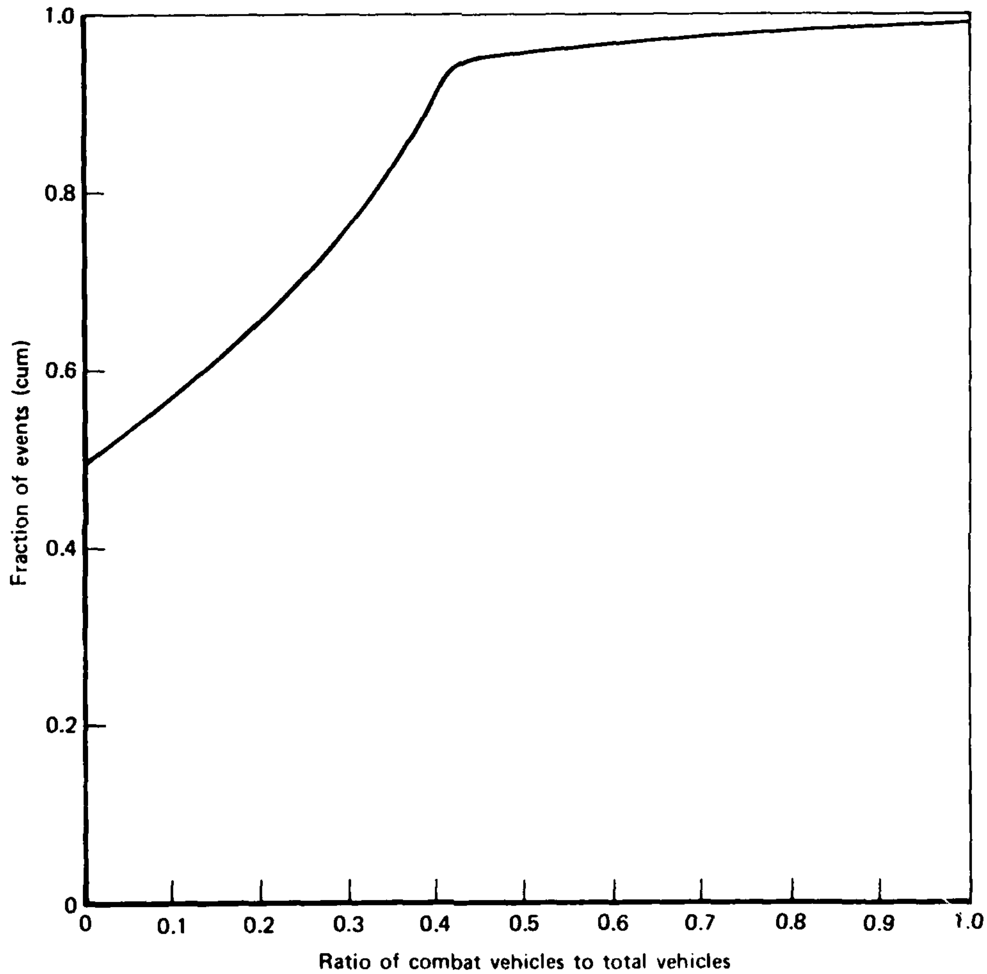


Fig. 20 — Ratio of combat vehicles to all vehicles – all events

direction of the Soviet advance, as shown in Fig. 21. The availability of roads was then defined, band by band, by the number of mutually exclusive paths leading from one side of the band to the other, i.e., in an east-west direction. The path count obtained from this method is given in the lower portion of the figure.

An Index of Traffic Density

The comparison of traffic volume with road capacity will be made by constructing a simple density index, in which the number of vehicles arriving at a particular 10 kilometer band during a given hour is taken as the numerator; and the theoretical throughput capacity of the road net in the band--based on appropriate assumptions about vehicle speed and spacing--is the denominator. The vehicle speeds used will be those specified for tracked vehicles, as given in Appendix A. Spacing will be as appropriate for the prevailing light condition, also given in Appendix A.

Since there are 22 10-kilometer zones covered by the array and 120 hours in the scenario, a full comparison would involve the calculation of 2640 separate values of the density index. But since our purpose here is to evaluate the upper bounds of traffic density, we shall confine ourselves to a much smaller set of illustrative calculations. Specifically, we shall evaluate the density in Zone 2 (10 to 20 kilometers) and Zone 3 (20 to 30 kilometers) for each hour of the scenario, since one or the other of these zones experiences the heaviest volume of traffic of any zone, in 9 of the 10 scenario periods.

Having made the necessary calculations, we next focus on the most taxing hour within each period, i.e., the hour in which the greatest number of vehicles intruded on the zone. The results are displayed in Table 14.

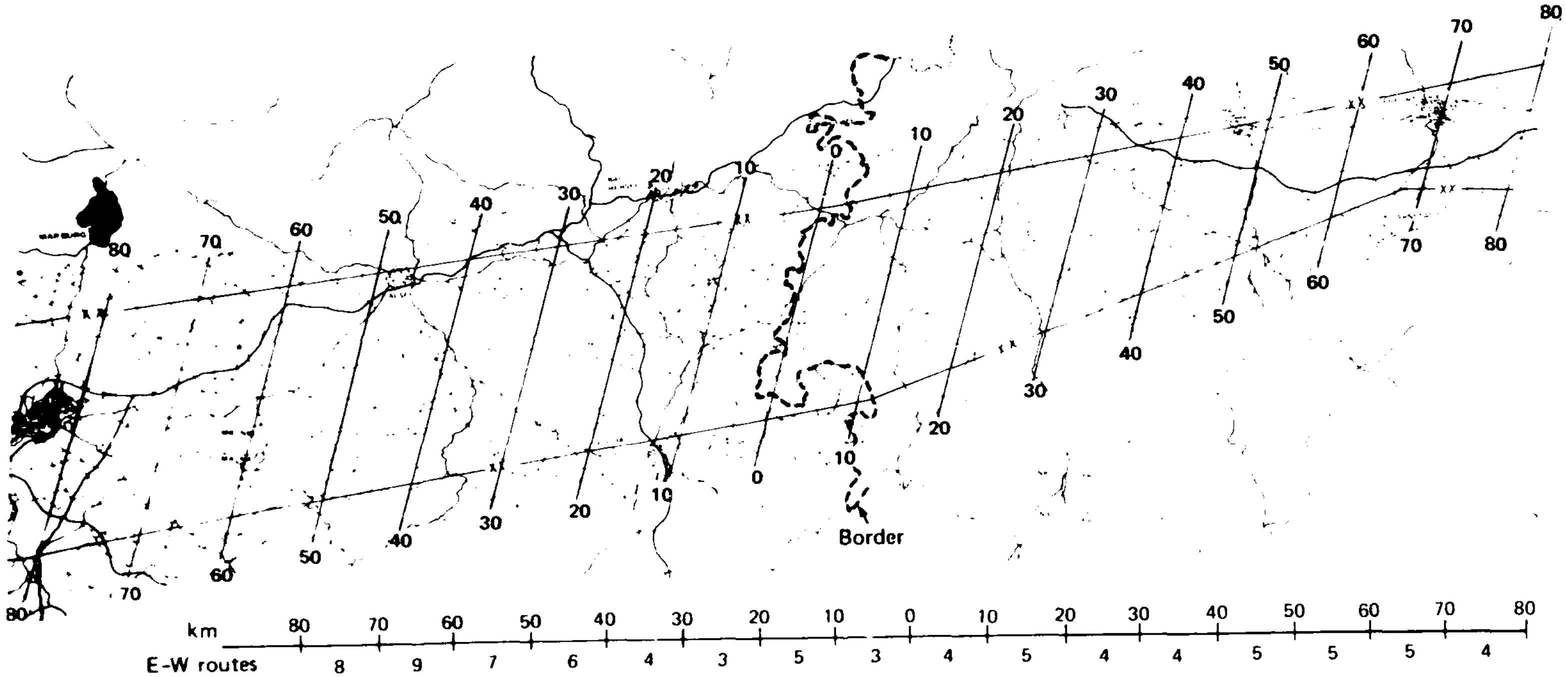


Fig. 21 — Route inventory in the MOVER area of interest

Table 14

TRAFFIC DENSITY IN ZONES 2 AND 3
FOR THE MOST ACTIVE HOUR
IN EACH PERIOD

Period	Zone 2 (10-20 km)	Zone 3 (20-30 km)
1	1.73	0.98
2	0.37	0.38
3	0.86	0.62
4	0.48	1.03
5	1.59	0.32
6	1.15	1.26
7	0.85	0.40
8	0.62	0.36
9	0.50	0.35
10	0.34	0.37

Critical Densities and Their Implications

In the density index, as we have constructed it, any value greater than 1.00 implies that the traffic placed on the roads by our various scheduling algorithms exceeds the capacity of the road net at that particular place and time. Five such instances are plainly evident in Table 14, and a sixth--for which a value of .98 was obtained--should be regarded as signifying an extremely marginal condition. But before conclusions may be drawn about the degree of congestion implied by these findings, it is necessary to take into account several ameliorating factors.

First, the density index tends to overstate the amount of traffic that must be accommodated in each zone, since it treats every event as though the event traverses the entire zone. In actuality, some of the events originate within the zone, and others terminate at points part way through the zone.

Second, the method of calculating the index tends to understate the capacity of the road net, because it uses the slowest speed of travel--i.e., the rate for tracked vehicles--as though all of the traffic will be proceeding at that speed. The history, however, contains a number of events that consist entirely of wheeled vehicles, and these events might be expected to proceed at a faster rate than was used in the calculation. The net effect would be to increase the computed capacity of the road net by some small amount.

Third, no allowance is made for the possibility of two way traffic on the roads. Since almost all of the rearward traffic in the history takes place at night, this factor might operate to ease the criticalities observed in Periods 4 and 6. However, since only 8 percent of the volume, generally, is moving away from the FEBA, the effect on capacity vs. demand is apt to be small.

Finally, in devising the scheduling algorithms used to construct the synthetic history of movement, no attempt was made to match the loading of the road net precisely to the available capacity. But in the real world, we should expect that any reasonably efficient movement management system would be able to adjust and enforce schedules in such a way as to reduce the risk of congestion. We should even expect that pragmatism would prevail over doctrine in those cases where the Soviets might see congestion as a problem.

Adjusting Movement to Reduce Congestion

Regarding this last caveat, the data produced in the density computations give some insight concerning the degree to which the movement schedules in the history might be adjusted to reduce congestion without doing violence to the scenario or to the operational concepts and principles that gave rise to the movement in the first place. As an extreme excursion we may examine the traffic density that results from distributing all of the movement occuring during a period uniformly over the entire 12 hours of the period. Doing so yields density index values for each period and zone as shown in Table 15. As might be expected, the prospect of congestion is virtually eliminated except for Zone 2 during Period 1. In this one exceptional instance, it does indeed appear that the Soviets would have to resort to extraordinary measures in order to ensure an acceptably smooth flow of traffic.

Table 15

AVERAGE TRAFFIC DENSITY IN ZONES 2 AND 3 FOR EACH SCENARIO PERIOD

Period	Zone 2 (10-20 km)	Zone 3 (20-30 km)
1	1.04	0.33
2	0.19	0.19
3	0.22	0.13
4	0.21	0.41
5	0.53	0.13
6	0.33	0.28
7	0.28	0.13
8	0.32	0.11
9	0.18	0.16
10	0.17	0.18

Distributing the activity over the entire period, as shown in Table 15, represents the maximum latitude available for adapting the movement schedule to the constraining influences of the road net. It is instructive, therefore, to examine a more modest degree of adjustment in attempting to preserve the basic pattern of movement incorporated in the original scheduling algorithms. To do this we shall evaluate a scheme in which the averaging process is confined to the 3 hours that bracket the most intense hour in each period. To illustrate, the critical hour in Period 1 for Zone 2 was found to be Hour 8; in the computation to be made now, the total volume of traffic in Hours 7, 8, and 9 will be distributed uniformly over all three hours. The resulting density index values for the six critical instances observed in Table 14 are displayed in Table 16.

Table 16

ADJUSTMENT OF TRAFFIC DENSITY IN ZONES 2 AND 3 FOR SIX CRITICAL CASES

Zone	Period	Index from Original Schedule	Index from Adjusted Schedule
2	1	1.73	1.42
2	5	1.59	0.93
2	6	1.15	0.49
3	1	0.98	0.89
3	4	1.03	0.71
3	6	1.26	0.49

Table 16 seems to suggest that displacing certain movements in time by as little as an hour from the original schedule would all but eliminate the overloading of the road net observed earlier; only Zone 2 in Period 1 remains as an example of a clearly super-saturated condition.

However, this line of argument should not be taken to mean that the Soviet force will have an easy time of it in the management of movement over a limited road net. Despite the fact that the Soviet army appears to devote substantial resources to the traffic and movement control function, Tables 14 and 16 both suggest that these resources may be severely taxed.

The larger issue of potential congestion shall remain moot, since congestion is usually the product of a number of factors besides traffic volume and theoretical road capacity. These other factors include march discipline, mechanical failures, system failures and operational failures, to say nothing of the effects of hostile action, none of which are reflected in the data shown here. Moreover, the density index does not account for the tendency of vehicular traffic to become massed at critical nodes in the logistics system and at key road intersections and defiles.

What the density index does provide, however, is insight concerning the extent to which these other factors might be tolerated in this scenario before catastrophic congestion begins to appear.

INTERPRETING THE DATA IN MOVER

The data presented and discussed above were selected in order to give a more or less comprehensive overview of vehicular activity in the Soviet rear area, as represented in MOVER according to an explicit set of assumptions. Differing assumptions will, of course, lead to other images, especially about the particulars of the activity.

At the same time, there is reason to believe that other models of activity constructed within the broader framework of the MOVER scenario would exhibit more similarities than differences, at least in their significant characteristics. An advance from the inter-German border to the Rhine River involves an amount of vehicular movement which--for a force of given composition--is essentially inelastic. The need to preserve a certain proximity among the elements of the force will dictate the frequency with which units will move and the distances they will move at each bound. And a preference for moving at night rather than in daylight--whether imposed by the threat of attack or by some other consideration--will largely determine the division of activity between the two light conditions.

There are, however, several aspects of the MOVER representation of which the reader should be especially mindful when evaluating this particular model.

Definition of Day and Night Periods

The first of these concerns the arbitrary selection of equal hours of daylight and darkness. For a scenario set in the winter months, it should be expected that a moderately larger fraction of the activity would be covered by darkness. On the other hand, it is not so clear that a scenario set in summer would have the opposite effect. The evidence compiled during the construction of MOVER suggests that most of the movement scheduled in our 12 hour periods of darkness could be accomplished as well during the shorter nights of summer.

Absence of Deeper Combat Echelons

The second point has to do with the apparent dearth of activity, as seen in MOVER, at depths greater than about 50 kilometers. We believe that this is due in great part to the expected behavior of the tank army's rear elements, but it also reflects the fact that combat echelons behind the tank army are not included in the model. Had an army of the second echelon been represented, it is likely that at least one of its divisions plus some number of non-divisional units would have made an appearance somewhere in the MOVER time-space continuum. This would have the effect of increasing the amount of vehicular activity at depths of 100 kilometers and greater.

Partitioning [illegible] Movement

The third [illegible] the partitioning of TO&E units of the Soviet [illegible] units. The literature on this issue is sparse, but we have relied extensively on the logic governing U.S. practice in the matter. The numbers of movement events, their sizes, and their composition would all be affected by changes in our assumptions. At the same time, however, there should be little or no change in either the volume of traffic or the vehicle exposure seen in the model.

Determinants of Logistics Activity

The fourth aspect relates to the amount of logistics activity, i.e., the movement of replacement and resupply vehicles, which has been incorporated in MOVER. This part of the data depends not only upon the scenario, but upon detailed assumptions about the rates of consumption, expenditure, and attrition imputed to the Soviet force and about the presumed workings of the Soviet logistics system. While we have relied on the most authoritative information available to us in framing these assumptions, this part of the synthetic history is probably more open to challenge than any other.

Influence of Interdiction on Subsequent Rear Area Activity

The model represents rear area activity as though it were completely undisturbed by hostile action. If one were to assume that the activity in, say, Period 2 is attacked with some nontrivial degree of success, then the model's representation of activity in all subsequent periods would have to be altered accordingly. Therefore, MOVER is not well suited to the analysis of an interdiction program that extends over several periods in the scenario. The value of a model that extends through ten periods lies in the comparisons it offers among different operational phases of a campaign.

Appendix A

THE BASIS OF THE HISTORY

The model of vehicular activity constructed in this research results from following the expected movement of the constituent elements of a Soviet force as they conform to their doctrinal roles in a given scenario. As the scenario unfolds, the attacking echelon makes progress over the ground against a defense of stipulated character; the attacker's supporting artillery, engineers, air defenses, chemical units, and other supporting troops advance by bounds so as to be able to provide continous support to the attacking maneuver units; at the appropriate time maneuver forces of the second echelon are brought forward to join the battle; and there develops a more or less predictable flow of supplies and replacements from rear supply bases to the engaged forces.

All of this movement occurs at times and places that can be predicted within certain tolerances, according to major points of Soviet doctrine, the basic framework of the scenario, and the influence of the terrain and road net over which the campaign is presumed to be waged.

If a record is made of this hypothetical movement, in the form of a time-ordered series of discrete events, each involving a stipulated complement of vehicles, the result will be a synthetic history of the vehicle activity generated by the Soviet force during the prosecution of the campaign. In the present case, we have given this history the name MOVER.

This appendix describes the scenario that underlies the MOVER model of activity, gives the composition of the enemy force, and discusses the various doctrinal and procedural stimuli that give rise to the movement represented in the model.

THE SCENARIO

The underlying scenario selected for MOVER is a short-warning scenario in which the Warsaw Pact is assumed to attack a semi-prepared NATO; the attacking forces reach their initial objectives on the Rhine River in five days.

In the zone of action covered by MOVER, a reinforced Soviet tank division, as part of a Soviet tank army, leads the attack in the first echelon. This division is followed initially by a second tank division, which has the mission of completing and exploiting the breakthrough begun by the first echelon division.

The scenario was originally developed in terms of alternating 12 hour periods of daylight and darkness. The 10 periods needed to define the 5 day scenario were characterized as shown in Table A-1. The rate of advance of the FEBA given in the table is of special importance, because it has a major influence on the amount and pace of activity generated in the Soviet rear area.

The campaign portrayed in the scenario passes through several operational phases, each of which might be expected to produce a different pattern of vehicular activity in the rear area. As an aid in capturing these differences, the history was divided into the following four phases:

Phase I	Driving in the Covering Force and closure with the MBA	Periods 1 & 2
Phase II	Breaching the MBA	Periods 3 - 6
Phase III	Initial exploitation of the breakthrough	Periods 7 - 9
Phase IV	Final pursuit	Period 10

Table A-1

OUTLINE OF THE SCENARIO

Period Number	Time Span	Principal Activity
1	0600 - 1800 D-Day	Leading regiments cross the border and attack the defender's covering force, driving it in by the end of the period. Distance advanced: 25 km
2	1800 D-Day to 0600 D+1	The first echelon division probes the defender's MBA and prepares to launch a coordinated breakthrough attack. The second echelon division moves forward and occupies the assembly area that was vacated at H-Hour by the leading division. Distance advanced: 0
3	0600 - 1800 D+1	The first echelon assaults the MBA, penetrating to a depth of approximately 10 kilometers. Distance advanced: 10 km
4	1800 D+1 to 0600 D+2	The first echelon consolidates its gains, probes the defense, and prepares to continue the attack on D+2. During the last part of the period the second echelon division moves forward to attack positions in readiness for commitment on D+2. Distance advanced: 0
5	0600 - 1800 D+2	Both divisions attack in concert to complete the breakthrough. Distance advanced: 10 km
6	1800 D+2 to 0600 D+3	The fresh division continues the attack against a weakening defense fought from hastily prepared positions. The original

Table A-1 (cont.)

		first echelon division reduces by-passed defenders and prepares to be refurbished. Distance advanced: 8 km
7	0600 - 1800 D+3	The leading division, still exploiting the breakthrough, is involved in a meeting engagement with light but fresh defending forces. Distance advanced: 18 km
8	1800 D+3 to 0600 D+4	The leading division, having overcome the defender's forces in the meeting engagement, now launches a pursuit to the west. Distance advanced: 27 km
9	0600 - 1800 D+4	The leading division closes with the a hasty defensive position representing the last organized resistance east of the Rhine. The trailing tank division--now refurbished--moves forward in preparation for the final pursuit to the Rhine.* Distance advanced: 5 km
10	1800 D+4 to 0600 D+5	The fresh division passes through the engaged division and pursues retreating NATO forces to the Rhine. The engaged division continues to reduce the defensive positions encountered in the previous period. Distance advanced: 95 km

*The notion that a division might be refurbished and re-committed to battle this early in the operation does not agree well with most views of Soviet practice. This feature of the scenario was adopted as a matter of convenience at a point in the research where it appeared not to make a material difference. A better representation would substitute a new division --perhaps from a second echelon army--for the refurbished division seen here.

COMPOSITION OF THE SOVIET FORCE

The forces depicted in MOVER comprise a troop slice taken through the depth of the tank army. The major troop components are 2 tank divisions, an independent tank regiment, an army artillery brigade, a regiment of front artillery, a front supply base section (FSBS) supporting the army, and that portion of the non-divisional army troops expected to be operating along the central axis of the tank army. The complete list of units represented in the history is given in Table A-2.

The level of organization reflected in Table A-2 is much too highly aggregated to allow the degree of spatial and time resolution we wish to capture in the synthetic history. Regiments--to say nothing of divisions--rarely take the road as single movement entities. They are much more likely to be divided, along logical organizational lines, into march units of manageable size.* And while these march units may have a common point of departure and a common destination, they are not likely to depart and arrive at the same time, nor is it necessary that they follow a common route.

The concept of a march unit has special significance here since it determines the size and composition of the clusters of vehicles that are followed as entities in MOVER. A march unit, quite simply, is a group of 1 or more vehicles, which move as an entity from a common starting point over a common route at a common speed to a common destination. The vehicles making up the march unit are under the control of a single commander. In dividing the troop organizations of

*The term "march unit" employed here is borrowed from U.S. Army usage, and we have not found a corresponding term in the Soviet lexicon. However, the concept is an important one in planning and conducting military motor movements, especially where a large number of such movements are to be carefully ordered in space and time over a road net of finite proportions. We believe therefore that it is reasonable to suppose that the Soviet Army will employ some such notion, despite our failure to find specific reference to it in the literature.

Table A-2

SOVIET ARMY UNITS REPRESENTED IN MOVER

Front Units

Artillery Regiment, Artillery Division (5 battalions)
Supply Element, Artillery Division
Ordnance Maintenance Company, Artillery Division
FSBS Command Element
Armament Maintenance Repair Shop
Armor Maintenance Repair Shop
Motor Maintenance Repair Shop
2 x Motor Transport Battalion

Army Units

Army Headquarters
Chemical Battalion
Signal Regiment
Signal Battalion (Composite)
Engineer Ponton Bridge Regiment
Engineer Construction Battalion
Artillery Brigade
SA-4 Brigade Headquarters and Service Battery
3 x SA-4 Battalion Headquarters
3 x SA-4 Battery
SA-6 Regiment Headquarters and Service Battery
3 x SA-6 Battery
(1/2) Army Rear Services
Army Hospital
Armament Maintenance Unit
Armor Maintenance Unit
Engineer Maintenance Unit
Motor Transport Repair Unit
Signal Repair Unit
Motor Transport Regiment

Divisions

2 x Tank Division

Table A-2 into march units, care was taken to conform as closely as possible to the following guidelines:

- The partitioning must allow the elements of the force to operate in the ways specified in Soviet doctrine.

- The size of a march unit should not exceed 100 vehicles.
- The partitioning should group vehicles that have a common operational mission or functional relationship.
- Mixtures of tracked and wheeled vehicles should be avoided, except in tactical formations.

The partitioning of the force along these lines created a total of 177 march units whose identities and compositions were preserved throughout the history. They are identified and described in Annex 1 to Appendix A, March Units. The organization displayed in Annex 1 also reflects cross attachments of tanks and infantry, as well as other ad hoc groupings that appear to be appropriate to the scenario; e.g., the attachment of amphibians and bridging to the leading tank regiments.

In addition to the 177 march units into which the TO&E elements of the force were divided, the logistical traffic portrayed in the model was also treated as though organized into march units. In these cases, commonality of source and destination provided the principal basis for the grouping. Unlike the TO&E march units, each logistical march unit was formed for a particular movement event and dissolved at the conclusion of that event. The constraints as to size and as to comingling of tracked and wheeled vehicles, noted above, were observed here as well. Logistical activity resulted in the creation of another 875 ad hoc march units.

DETERMINANTS OF VEHICLE ACTIVITY

Station-Keeping Activity

Each element of the attacking force has a function to perform and a role to play in making the offensive operation successful. And, in each instance, these functions and roles imply a set of spatial relationships among the elements of the force. If the offensive is indeed successful, i.e., if the attacking maneuver units in the present case advance the 200 kilometers to their objectives on the Rhine River in 5 days, as stipulated in the scenario, then by implication the majority--if not all--of those units whose functional place is in the rear area must also advance a corresponding distance, if they are to continue to support the battle to best effect. But whereas forward movement is an important concomitant of success for the engaged forces, it can have serious drawbacks for units in the rear, for either of two reasons.

Reserves and other maneuver units not in the engaged echelon must keep pace with the advance so that they will be readily available for commitment at the desired time and place. But these units, at normal march speeds, are able to move forward at a much faster pace than can the engaged forces; therefore they will soon overtake the latter and become prematurely involved in the battle unless they follow a policy of making short moves--sometimes referred to as "bounds"--interspersed with periods of inactivity. Properly timed, this technique keeps the trailing echelons within acceptable proximity to the battle. At the same time, it allows them to seek concealment off the roads when they are not required to be moving, and it frees the roads for other traffic.

Another set of units is also constrained to intersperse their movements forward with periodic halts, for the simple reason that they cannot function on the move. This set of units includes repair shops, hospitals, certain signal units, artillery units, air defense units, and even some headquarters units. These units, therefore, also make their way forward by bounds.

Supply units--which at the FSBS and all lower echelons consist of loaded supply trucks and trailers--likewise move by bounds, for much the same reason as do second echelon maneuver forces, i.e., their normal rate of march is much faster than is the progress of the engaged forces, yet they must avoid becoming embroiled in the fighting.

Movement of the kind just described has been referred to earlier as "station-keeping." Here we must note that the proper "station" for any unit is necessarily defined within rather broad tolerances. In other words, a given unit should not come closer to the FEBA than some minimum distance and should not allow the FEBA to draw away from it by a distance greater than some maximum. Fortunately for present purposes, military doctrine provides reliable and readily interpreted guidelines for determining nominal minimum and maximum station-keeping distances to be maintained by virtually all units.

The nominal distances observed in the construction of MOVER are given in Annex 2 to this appendix, Rules for the Positioning and Movement of Units. In applying these values to the scenario at hand it was necessary, of course, to adapt them to the particular terrain and road net in the area of operations. Thus, for example, an ammunition train that should be positioned 25 kilometers behind the FEBA as the doctrinal minimum might in fact have been put down 20 kilometers from the FEBA in order to take advantage of the concealment afforded by a wood.

Frequency of Station-Keeping Moves

Even a cursory comparison of the FEBA progress shown in Table A-1 with the "trigger" distances given in Annex 2 will show that many units must make more than one move per 12 hour period, in one or more of the scenario periods; by the same token, certain other units will have to move much less frequently. The frequency spread actually experienced in the construction of the history ranged from 22 moves (by an artillery battalion) to a single move in the entire 5 days (in the case of the FSBS). In those cases that required multiple moves by a unit during a single period, it has been assumed that the FEBA advances at a uniform rate during the period, and the moves required of a given unit have been spaced more or less uniformly over the 12 hours. These assumptions allow the history to be defined on a minute-by-minute basis, and thus provide a more detailed representation of the expected duration of movement events, the numbers of moves taking place, and the duration of the periods of inactivity between successive moves.

In many instances the missions or other functional relationships existing among two or more march units have a bearing on the times at which these units move with respect to one another. The partitioning of major headquarters into "main" and "alternate" command posts provides a clear example. In the case, say, of the Army headquarters it is clearly undesirable to have both command posts on the road simultaneously. Consequently, when the FEBA has advanced far enough to require displacement of the headquarters care must be taken to ensure that one of the command posts remains in place until the other has completed its move and become operational.

Logistical Activity

Another set of interesting and important timing relationships devolves from the nature of the Soviet Army supply system. In that system, supplies are delivered forward on demand, from one echelon to the next; e.g., replenishment ammunition is delivered from division to regiment on divisional trucks and is transferred to regimental trucks at the regimental supply point. The empty divisional trucks then return to the division supply point where they are in turn replenished by trucks that have their turn, are replenished by yet another contingent that has moved forward from the FSBS.*

The generation of logistics movement events according to this scheme is illustrated in Fig. A-1.

The resupply and replacement traffic incorporated in MOVER was based on a rather extensive simulation of the Soviet logistics system that was undertaken in another phase of the research. This simulation--called the MECA program--took into account the attrition and expenditure of consumables experienced by each element of the Soviet force during each period; the status of equipment and supplies on hand in each unit during each period; the status of replenishment supplies and replacements at each node in the logistics system every 12 hours; and the priorities for logistic support dictated by the tactical situation. It then calculated the amount of logistics traffic presumed to flow through the support system each period as the system sought to meet the demands of the consuming units. In adapting the results of this simulation to the synthesis of the MOVER model, it was necessary to adopt rules specifying the precise times within each 12 hour period when particular implied or derivative events were presumed to occur. These times are given in Annex 2. It was also necessary to extrapolate from the regimental level of aggregation used in MECA to the march unit level used in MOVER.

Preference for Night Movement

One final dictum--which may be regarded either as a point of doctrine or as simple prudence--had a major influence on the way events were scheduled in MOVER. This was a rule specifying that after the operational demands of the scenario

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*Soviet doctrine also allows for an emergency supply procedure in which supplies moving forward may by-pass one echelon and make delivery to the next lower echelon. This alternative was not represented in MOVER.

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A MODEL OF VEHICLE ACTIVITY IN THE WARSAW PACT TACTICAL REAR DU--ETC(U)

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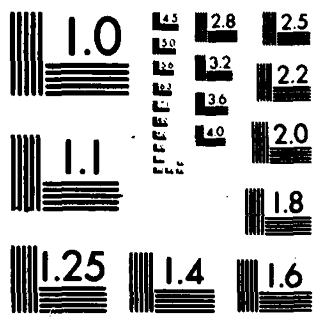


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

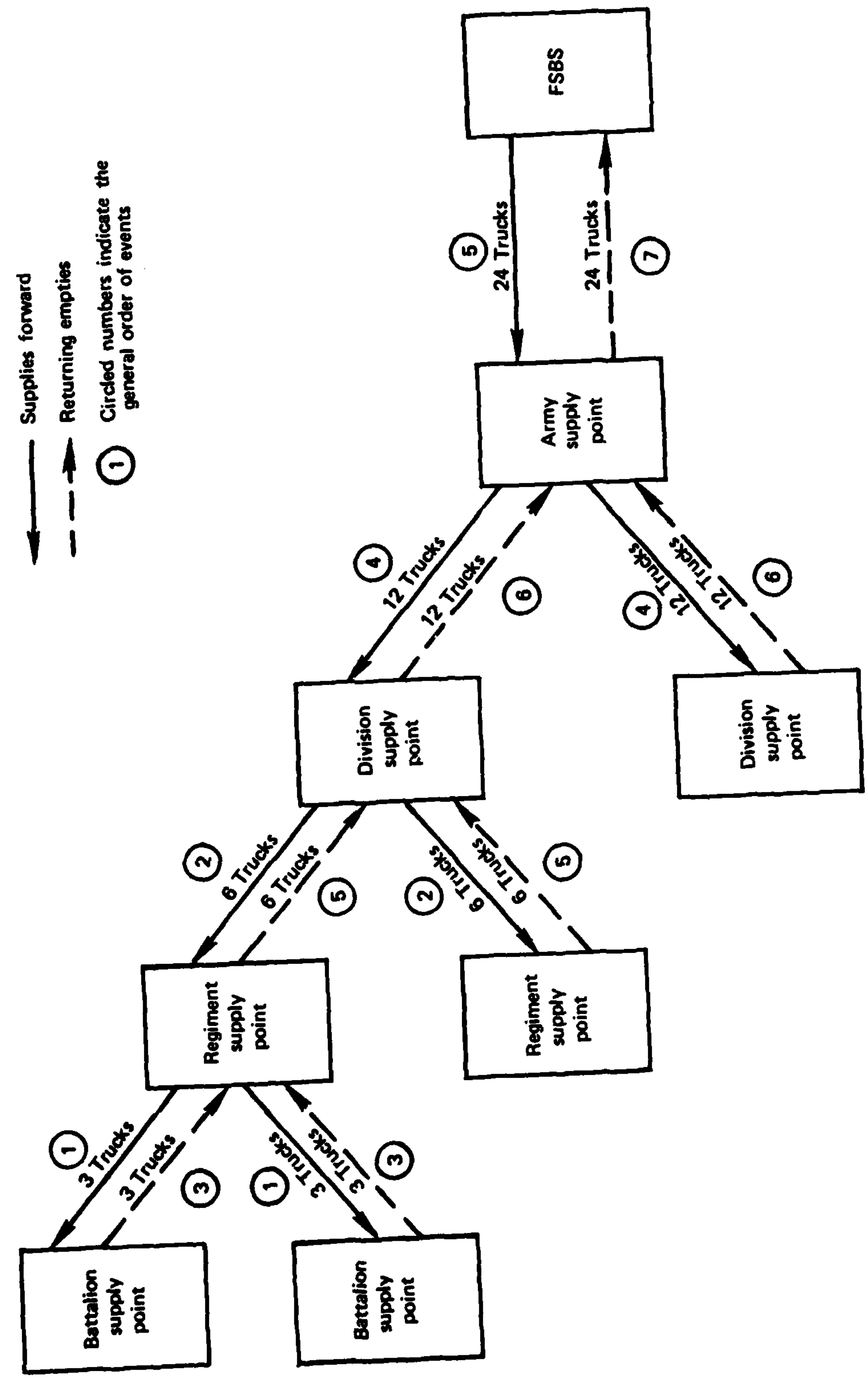


Fig. A-1 — Vehicular activity generated in the typical resupply process

<u>and all other points of doctrine are satisfied, movement in the rear area will be confined to the hours of darkness.</u>

Many other minor points of Soviet doctrine and procedure were instrumental in defining the vehicular activity incorporated in MOVER. Clearly the specifics of the synthetic history described here depend on the many interpretations of doctrine and military behavior attributed to the Soviet force in this scenario by the authors. In one sense, then, the view given by MOVER is but one among many possible--and equally plausible--views.

At the same time, many of the more important descriptors of vehicle activity--populations, frequency of movement, and transit times, for example--are established rather firmly by major features of the scenario, major points of doctrine, and a certain ineluctability attributable to the nature of modern battle. These factors, interpreted with an appropriate sense of military prudence, are apt to produce models that are more notable for their similarities than for the differences among them.

Annex 1 to Appendix A

MARCH UNIT COMPOSITION

The following paragraphs identify the 177 march units into which the organizations in Table A-2 were ultimately converted. A 6-digit march unit identifier has been assigned to each one to facilitate creation of the computer version of the history, as described in Appendix B.

Front Units.	
Artillery Regiment	
Artillery Battalion	910401
Artillery Battalion	910402
Artillery Battalion	910403
Artillery Battalion	910404
Artillery Battalion	910405
Headquarters and Service	910406
Artillery Division Supply Unit	910800
Artillery Division Maintenance Unit	911000
FSBS Control Element	930100
Armament Maintenance Repair Shop	
First Section	930201
Second Section	930202
Motor Maintenance Repair Shop	930400
Supply and Transportation Units	
Ammunition Supply Unit	930601
Ammunition Supply Unit	930602
Ammunition Supply Unit	930603
POL Supply Unit	930604
POL Supply Unit	930605
POL Supply Unit	930606
Army Units.	
Army Headquarters	
Main Command Post	110101
Alternate Command Post	110102
Chemical Defense Battalion	
Company	110103
Company	110104
Signal Regiment	
Main Command Post Group	110401
Alternate Command Post Group	110402
Composite Signal Battalion	110501

  - Independent Tank Regiment
    - Reconnaissance Platoon — 110301
    - Tank Battalion — 110302
    - Tank Battalion — 110303
    - Tank Battalion — 110304
    - Headquarters & Combat Support — 110305
    - Motor Transport Company — 110306
    - Other Service Support — 110307
  - Artillery Brigade
    - Artillery Battalion — 111001
    - Artillery Battalion — 111002
    - Artillery Battalion — 111003
    - Headquarters & Service — 111004
  - Engineer Ponton Bridge Regiment (-) — 110600
  - SA-4 Brigade (Selected Elements)
    - Headquarters Battery — 111102
    - Service Battery — 111101
    - Battalion Headquarters and 1 AD Battery — 111300
    - Battalion Headquarters and 1 AD Battery — 111600
    - Battalion Headquarters and 1 AD Battery — 111900
  - SA-6 Regiment (Selected Elements)
    - Headquarters & Service — 113100
    - AD Battery — 113300
    - AD Battery — 113500
    - AD Battery — 113600
  - Army Rear Services
    - First Section — 120101
    - Second Section — 120102
  - Army Hospital
    - First Section — 120201
    - Second Section — 120202
  - Armor Maintenance Unit — 120400
  - Armament Maintenance Unit — 120500
  - Motor Transport Repair Unit — 120600
  - Signal Repair Unit — 120700
  - Engineer Repair Unit — 120800
  - Engineer Construction Battalion
    - Company (+) — 120901
    - Company (+) — 120902
  - Motor Transport Regiment
    - Company (Ammunition Supply) — 121101
    - Company (Ammunition Supply) — 121102
    - Company (POL Supply) — 121103
    - Company (POL Supply) — 121104
- Tank Division (Reinforced)
  - Headquarters Group
    - Signal Battalion (-) — 140101
    - Alternate Command Post — 140102
    - Main Command Post — 140103

Tank Regiment (Reinforced)	
Reconnaissance Company	140201
Tank Battalion (Reinforced)	140202
Tank Battalion (Reinforced)	140203
Tank Battalion (Reinforced)	140204
Regimental Headquarters, Signal Company & AD Battery (-)	140205
Motorized Rifle Battalion (-) and Amphibious Carrier Company	140206
Rear Services	140207
Engineer Company, Chemical Defense Company & AD Section	140208
Motor Transport Company	140209
Tank Regiment (Reinforced)	
Reconnaissance Company	140301
Tank Battalion (Reinforced)	140302
Tank Battalion (Reinforced)	140303
Tank Battalion (Reinforced)	140304
Regimental Headquarters, Signal Company & AD Battery (-)	140305
Motorized Rifle Battalion (-) and Amphibious Carrier Company	140306
Rear Services	140307
Engineer Company, Chemical Defense Company & AD Section	140308
Motor Transport Company	140309
Tank Regiment (Reinforced)	
Reconnaissance Company	140401
Tank Battalion (Reinforced)	140402
Tank Battalion (Reinforced)	140403
Tank Battalion (Reinforced)	140404
Regimental Headquarters, Signal Company & AD Battery (-)	140405
Motorized Rifle Battalion (-) and Amphibious Carrier Company	140406
Rear Services	140407
Engineer Company, Chemical Defense Company & AD Section	140408
Motor Transport Company	140409
Motorized Rifle Regiment (-)	
Reconnaissance Company	140501
Tank Battalion, Howitzer Battery, AD Section, AT Battery	140502
Regimental Headquarters, Signal Company & AD Battery (-)	140503
Rear Services	140504
Engineer Company, Chemical Defense Company & AD Section	140505
Motor Transport Company	140506

- Artillery Regiment (+)
  - Artillery Battalion 140601
  - Artillery Battalion 140602
  - Artillery Battalion 140603
  - Headquarters & Service 140604
  - FROG Battalion Headquarters and 1 Battery 140605
  - FROG Battery 140606
  - MRL Battalion Headquarters and Service 140607
  - MRL Battery 140608
  - MRL Battery 140609
  - MRL Battery 140610
- Engineer Assault Crossing Company and Ponton Bridge Company 140701
- Engineer Battalion (-) 140702
- Ponton Bridge Battalion (-) 140703
- Chemical Defense Battalion 140704
- Reconnaissance Battalion 140800
- Rear Services Headquarters 140900
- Supply and Transport Battalion (+)
  - Truck Company (Ammunition) 141001
  - Truck Company (Ammunition) 141002
  - Truck Company (POL) 141002
  - Battalion Headquarters (+) 141004
- Medical Unit 141100
- Maintenance Unit 141200

Tank Division (Reinforced)

- Headquarters Group
  - Signal Battalion (-) 150101
  - Alternate Command Post 150102
  - Main Command Post 150103
- Tank Regiment (Reinforced)
  - Reconnaissance Company 150201
  - Tank Battalion (Reinforced) 150202
  - Tank Battalion (Reinforced) 150203
  - Tank Battalion (Reinforced) 150204
  - Regimental Headquarters, Signal Company & AD Battery (-) 150205
  - Motorized Rifle Battalion (-) and Amphibious Carrier Company 150206
  - Rear Services 150207
  - Engineer Company, Chemical Defense Company & AD Section 150208
  - Motor Transport Company 150209
- Tank Regiment (Reinforced)
  - Reconnaissance Company 150301
  - Tank Battalion (Reinforced) 150302
  - Tank Battalion (Reinforced) 150303
  - Tank Battalion (Reinforced) 150304
  - Regimental Headquarters, Signal Company & AD Battery (-) 150305

Motorized Rifle Battalion (-) and Amphibious Carrier Company	150306
Rear Services	150307
Engineer Company, Chemical Defense Company & AD Section	150308
Motor Transport Company	150309
Tank Regiment (Reinforced)	
Reconnaissance Company	150401
Tank Battalion (Reinforced)	150402
Tank Battalion (Reinforced)	150403
Tank Battalion (Reinforced)	150404
Regimental Headquarters, Signal Company & AD Battery (-)	150405
Motorized Rifle Battalion (-) and Amphibious Carrier Company	150406
Rear Services	150407
Engineer Company, Chemical Defense Company & AD Section	150408
Motor Transport Company	150409
Motorized Rifle Regiment (-)	
Reconnaissance Company	150501
Tank Battalion, Howitzer Battery, AD Section, AT Battery	150502
Regimental Headquarters, Signal Company & AD Battery (-)	150503
Rear Services	150504
Engineer Company, Chemical Defense Company & AD Section	150505
Motor Transport Company	150506
Artillery Regiment (+)	
Artillery Battalion	150601
Artillery Battalion	150602
Artillery Battalion	150603
Headquarters & Service	150604
FROG Battalion Headquarters and 1 Battery	150605
FROG Battery	150606
MRL Battalion Headquarters and Service	150607
MRL Battery	150608
MRL Battery	150609
MRL Battery	150610
Engineer Assault Crossing Company and Ponton Bridge Company	150701

Engineer Battalion (-)	150702
Ponton Bridge Battalion (-)	150703
Chemical Defense Battalion	150704
Reconnaissance Battalion	150800
Rear Services Headquarters	150900
Supply and Transport Battalion (+)	
Truck Company (Ammunition)	151001
Truck Company (Ammunition)	151002
Truck Company (POL)	151002
Battalion Headquarters (+)	151004
Medical Unit	151100
Maintenance Unit	151200

Annex 2 to Appendix A

RULES FOR POSITIONING AND MOVING UNITS

The synthetic history of vehicle activity named "MOVER," which is described in this Note, is based on a particular battle scenario covering the initial 5 days of a Soviet attack against the U.S. V Corps in Central Germany. The original scenario was constructed by the following procedure.

- The assumed objectives and progress of the attack and the corresponding nature of the U.S. opposition were first defined in terms of a sequence of 12 hour periods of operations.
- The attacking force was then defined in terms of standard Soviet combat, combat support, and service support organizations, the general level of definition being the regiment.
- Next, the presumed progress and activity of each organizational element was developed and recorded, through the medium of a map exercise.
- Finally, the location and activity records derived from the map exercise were submitted to a computer program (called MECA), which calculated the amount of logistical activity needed to support the combat operations depicted in the scenario.

Detailed descriptions of the map exercise and of MECA may be found in Lewis et al. (1978).

The degree of aggregation inherent in this procedure masks many of the details of vehicle activity that ought to be represented in a target model like MOVER. For example, the map exercise record fails to show the occurrence of intra-period movement in those cases where a force element makes more than one move in a 12 hour period. It also omits the logistic activity that takes place below the regimental level. It does not account for the rearward movement of empty supply vehicles following the delivery of supplies. It depicts some movement as taking place in implausibly large aggregations of vehicles. And, finally, it fails to show the precise time within the 12 hour period when each movement event is presumed to take place.

The additional detail wanted for MOVER but missing from MECA was supplied by resorting to a set of rules devised for the purpose. Like the basic scenario itself, these rules were based on Soviet doctrinal writings, interpreted in the context of the scenario, and a reading of the terrain as presented in 1:100,000-scale maps.

The rules followed in developing this additional level of detail are given below.*

INITIAL DISPOSITION OF FORCES

The history commences at the moment that Soviet forces cross the border in the sector of the U.S. V Corps. In order to position the elements of the force properly for this moment in the scenario, it was necessary to construct their pre-H-Hour dispositions and activities with some care, even though the movements prior to H-Hour were not to be included in the model.

The initial dispositions of the force were based on a doctrinaire deployment and progression of events, in which the first echelon division and its attachments occupied forward assembly areas during the hours of darkness preceding H-Hour. These assembly areas were located approximately 25 kilometers to the east of the border, which meant that a substantial fraction of the division was presumed to be on the road in march column as the history opened.

*These ruless are based on the unclassified material given in the U.S. Army Field Manual, FM 30-102, Opposing Forces Europe, November 1977.

The four artillery regiments in the force were all deployed initially in firing positions behind the first cover to the east of the border.

GENERAL RULES GOVERNING DEPTH OF ORIGIN

In the original map exercise on which the synthetic history of vehicle activity is based, each TO&E unit was relocated (displaced) as frequently as necessary to keep it within certain limits of proximity to the advancing FEBA. This process of "station-keeping" dictated the frequency with which each unit moved and the approximate distance of each such move. The limits in each case consist of a maximum and a minimum. The maximum is to be regarded as a "trigger" distance that determines the time at which the unit must displace. The minimum, in a similar way, determines how far the unit will move. The proximity limits used here are:

Unit Category	Proximity to the FEBA (km)
Front Organizations	
FSBS	120-160
Front Artillery Regiment	
Gun/Howitzer Battalions	5-10
Regimental Hq and Service	10-15
Army Organizations	
Army Hq and Combat Support	30-60
Army Supply Base	60-100
Army Artillery Brigade	
Gun/Howitzer Battalions	5-10
Regimental Hq and Service	10-15
Independent Tank Regiment	
Regimental Hq	8-12
Combat Support	8-12
Rear Services	12-15
Uncommitted Maneuver Battalions	6-10
Divisions in the First Echelon	
Division Hq and Combat Support	10-15
Division Rear Services	25-35
Division Artillery Regiment	
Regimental Hq and Service	10-15
FROG Battalion	20-35
Howitzer/MRL Battalions	5-10

First Echelon Regiments	
Regimental Hq	8-12
Combat Support	8-12
Rear Services	12-15
Uncommitted Maneuver Battalions	6-10

In the scenario the leading elements of the first echelon division cross the inter-German border at H-Hour, marking the beginning of the synthetic history. This implies that at time 0 some elements of the force are on the road in approach march formation and that others are still in their initial assembly areas inside East Germany. The depth of origin for the initial moves by many of these units therefore differs somewhat from the proximity norms given above.

RATES OF TRAVEL AND VEHICLE SPACING

All movement in the synthetic history is presumed to take place on roads at the following rates:

Tracked vehicles, day	24 kph
Tracked vehicles, night	16 kph
Wheeled vehicles, day	36 kph
Wheeled vehicles, night	18 kph

Mixed columns travel at the rate for tracked vehicles. (Where doctrine and operational exigencies allowed, moves of mixed columns were avoided in constructing the history.)

The spacing between vehicles (front bumper to front bumper) is assumed to be as follows:

Day	100 meters
Night	50 meters

RULES FOR LOGISTICS BELOW REGIMENT

The moves to be included are forward moves terminating at battalion and rearward moves originating at battalion.

The total number of vehicles assumed to go forward from a regiment is the same as the number reported as arriving at the regiment, during the same period, in MECA.

The vehicles going forward from regiment are divided evenly among the subordinate battalions.

The regimental service and support units are treated collectively as a battalion.

During night periods, vehicles going forward from regiment are dispatched at the 60th minute in the period.

During day periods, vehicles going forward from regiment are dispatched at the 540th minute in the period.

Ninety minutes are allowed for turnaround at the battalion, after which empty supply and personnel replacement trucks are dispatched on their rearward move to regiment. (Vehicles that are replacements for lost equipment do not return.)

The depth of origin for forward movements is taken from MECA. If the source unit is to move during the period, the resupply cycle is completed before the source unit displaces.

The straight line distances moved in each direction between battalion and regiment are distributed uniformly in the range 7-10 kilometers.

Resupply and replacement activity does not take place concurrently with the displacement of the source or destination units. That is, the displacement of logistics units is assumed to involve the full complement of unit vehicles.

RULES FOR LOGISTICS ABOVE REGIMENT

Forward movements during night periods are dispatched at the following times:

From division:	at the 240th minute in the period
From army:	at the 360th minute in the period

From FSBS: at the 420th minute in the period

Forward movements during day periods are dispatched at the 540th minute in the period.

Ninety minutes are allowed for turnaround at the destination, after which empty supply and personnel replacement trucks are dispatched rearward to the unit of origin. (Vehicles that are replacements for lost equipment do not return to the source unit.)

Resupply and replacement activity does not take place concurrently with the displacement of the source or destination units. That is, the displacement of logistics units is assumed to involve the full complement of unit vehicles.

The depth of origin for forward movements is taken from MECA. If the source unit is to move during the period, both the forward and return logistics moves take place before the source unit displaces.

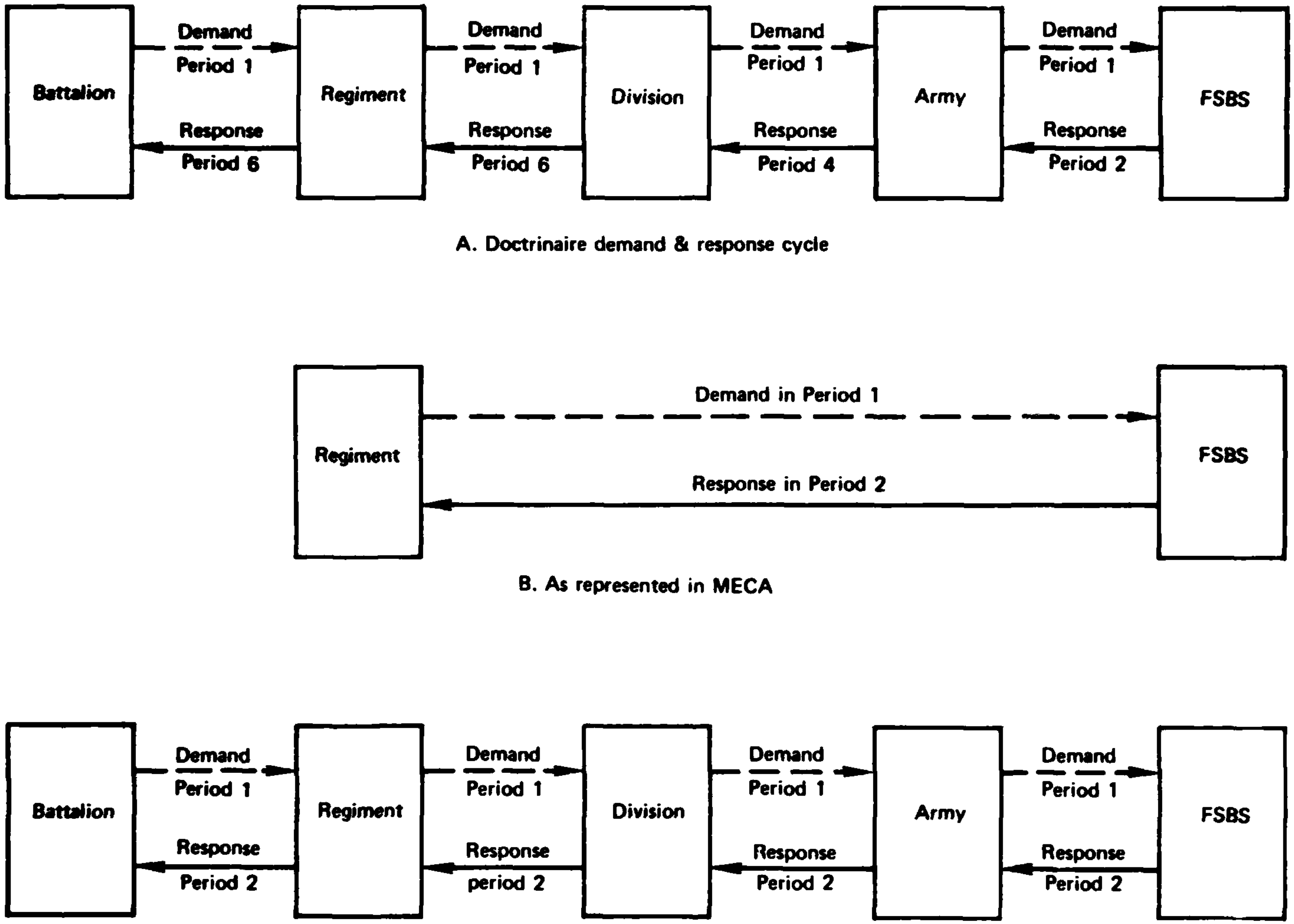
The straight line distance moved in each event is as recorded in MECA.

MOVEMENT OF REPLACEMENT VEHICLES

Our sources of information on the Soviet equipment replacement system are silent on the detailed procedure followed in delivering replacement vehicles from the FSBS to, say, a regiment that is several echelons removed in the logistics system. A doctrinaire view of Soviet logistics organization and procedure suggests a replacement process something like that shown in the upper portion of Fig. A-2.

In MECA, each delivery of replacements was treated as a single cohort; and it was further assumed that each delivery would be made in a direct bound from FSBS to the receiving regiment, the entire move being completed in a single period. This notion is represented in the center diagram in Fig. A-2.

It is not clear that the MECA representation is entirely feasible, either from the standpoint of the time and space factors involved or with respect to the detailed functioning



A. Doctrinaire demand & response cycle

B. As represented in MECA

C. As represented in MOVER

Fig. A-2 — Operation of the replacement demand and response cycle -- 3 interpretations of the Soviet replacement system. Whereas these uncertainties could be safely ignored in MECA, they promised to introduce some avoidable distortions in MOVER.

The flow of replacement vehicles in MOVER follows the pattern seen in the lower portion of Fig. A-2. This pattern is, we believe, somewhat more faithful to the requirements of real-world logistics systems, in that it partitions the delivery stream according to the several echelons in Soviet logistical organization. The consequences are that (1) MOVER contains more replacement events than does MECA, (2) replacement events in MOVER tend to cover shorter distances than those in MECA, and (3) many of the MOVER events, taken individually, have populations unlike any seen in MECA.

The minor distortion that remains in MOVER is that the flow of replacement vehicles is still treated as though the delivery from FSBS to battalion is completed during a single 12 hour period, when in fact two or more periods might well be required. We regard this distortion as minor because the volume of replacement activity varies but little from night to night.

Appendix B

THE VARIABLES IN MOVER

Since MOVER is basically a history, albeit a synthetic one, its substance is contained in the descriptions of a series of events. In its present form, the model consists of 2,088 records, each of which describes a separate movement event. This appendix enumerates and defines the terms used to describe the events. In doing so it provides the reader with an appreciation of the level of detail to be found in the model and hence with an insight concerning its utility.

There are nominally 247 variables or attributes in the structure of the model; each event is described in terms of these variables. (We say, nominally, because the number is expanded from time to time as new research applications are undertaken.) While this may seem to be an inordinately large number of attributes to ascribe to a movement event, almost all of the variables can be placed in the classical Who, What, Where, When classification favored by the practitioners of military combat intelligence. As will be seen below, most of the inflation comes about as a result of defining these four basic variables in a variety of ways, particularly those having to do with the Where and the When of events.

In the discussion to follow, the variables will be grouped under these four main headings; a fifth heading covers some special variables used to define the character of the inter-move pauses subsumed by the record of events.

Neither the creation nor the utilization of such a large number of descriptors would have been practical without the aid of the computer. Consequently MOVER was constructed as a computer file, configured for use with a standard program called Statistical Program for the Social Sciences, or simply

SPSS. This program is supported at a number of computer installations around the country, as well as at Rand.

VARIABLES DESCRIBING THE "WHO" OF EACH EVENT

March Unit Identification Number

Each event involves a single march unit. March units, which consist of TO&E units moving as such, retain the same number throughout the scenario. These numbers, of which there are 177, are given in Appendix A together with the consist of the march units to which they are appended.

Events made up of resupply and replacement traffic are given march unit numbers applicable to a single resupply or replacement cycle. These numbers are not repeated in the history, following completion of the cycle.

Because the numbering scheme for TO&E units, which was inherited from an earlier research task, was a 6-digit scheme, an abreviated 3-digit march unit identifier was added to the record to achieve economies in computer processing.

Vehicle Populations

The numbers and types of self-propelled vehicles participating in each event are recorded in a set of 15 variables, according to the following classification:

- Ammunition Resupply Trucks
- POL Resupply Trucks
- Other Resupply Trucks
- Replacement Tanks
- Replacement APCs
- Replacement Artillery Pieces (SP)
- Replacement Air Defense Weapons (SP)
- Other Replacement Vehicles
- Tanks in TO&E Units
- APCs in TO&E Units
- Artillery Pieces in TO&E Units
- Air Defense Weapons in TO&E Units
- Ammunition Trucks in TO&E Units
- POL Trucks in TO&E Units
- Other Trucks in TO&E Units

In addition to this primary classification data, 11 more variables were added to the file to represent the following aggregations across primary class lines:

Combat Vehicles in TO&E Units
Non-Combat Vehicles in TO&E Units
All Vehicles in TO&E Units
All Replacement Combat Vehicles
All Trucks Active in Resupply or Replacement
All Resupply Trucks
All Resupply and Replacement Vehicles
All Replacement Vehicles
All Combat Vehicles
All Non-Combat Vehicles
All Vehicles

The ratio of combat vehicles to total vehicle population was also calculated and recorded in the history as a separate variable.

Unit Function

Each march unit was classified according to one of the following military functions:

Maneuver
Fire Support
Air Defense
Command and Control
Engineer
Supply
Other

On the basis of this classification, each event was more broadly characterized as being either a combat or a support activity.

VARIABLES DESCRIBING THE "WHAT" OF EACH EVENT

Event Identifier

Each event was assigned a unique serial number as an aid in constructing the history. It has no significance in the interpretation of the history.

Each move by a TO&E unit was further identified by a sequence number that placed that event among all events involving that unit. This variable is also a construction aid with no interpretive significance.

The Direction of Progress

The direction of movement is specified for each event, as being simply forward (toward the FEBA) or rearward (away from the FEBA). The only rearward activity included in the history covers the return of empty resupply trucks to their parent supply points following a delivery.

Vehicle Spacing and Column Length

The spacing between vehicles was specified for each event, dependent upon light conditions; the two values allowed are 100 meters for daylight moves and 50 meters for night moves.

The road space occupied by the march unit in each event was calculated as a separate variable.

Distance Traveled During the Event

Two of the variables in each record serve to define the distance traveled. The first is a construction variable that gives the straight line map distance, in kilometers, between the point of origin and the destination of the march unit engaged in the event.

The second is a calculated value purporting to give the road distance covered in the move. It was obtained by multiplying the straight line distance by a factor of 1.2.*

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*The factor was developed by making a series of sample measurements on maps of Central Germany at a scale of 1:500,000. Other researchers have suggested that the factor for this geography should be closer to 1.3. One of the advantages of the computer-based model is that the analyst can readily substitute any factor of his choice, relying thereafter upon the computer to calculate new values for such derivative variables as movement time, arrival time, and exposure time.

Rate of Travel for the Event

A single variable gives the speed at which the march unit is presumed to proceed. The value assigned is dependent on the consist of the march unit and the light conditions prevailing at the time of departure, according to the following:

Wheeled vehicles, daylight	36 kph
Wheeled vehicles, night	18 kph
Tracked vehicles, daylight	24 kph
Tracked vehicles, night	16 kph

In the case of mixed columns, the event was assigned the rate of march for tracked vehicles.

Time Length of the Column

The time required for the march unit to pass a given point was calculated from the speed and road space variables and entered in the record as a separate variable.

Duration of the Event

Five of the variables in the record speak to the issue of duration.

The first of these simply gives the transit time, in minutes, for an individual vehicle to complete the move. The second is a derivative of the first in which the data are classified in intervals of 30 minutes.

The third and fourth divide the transit time, in minutes, into its day and night components, respectively.

The fifth variable in this category is the sum of the time length of the column and the transit time for a single vehicle. It thus defines the total amount of time during which any part of the march unit is moving.

Vehicle Exposure Generated by the Event

There is a strong presumption in our research that the opportunities for attacking vehicles in the hostile rear area are greater, by far, when the vehicles are on the road and moving than when they are at rest between moves. An index useful for measuring these opportunities can be created by multiplying the number of vehicles in an event by the transit time for each vehicle. The metric used here is "vehicle-minutes" of exposure.

Each event record contains eleven variables in this category, one for each of the eleven aggregated vehicle classes listed earlier.

VARIABLES DESCRIBING THE "WHEN" OF EACH EVENT

One of the most important attributes sought in constructing the synthetic history was a definition of the clock time during which each event is in progress. In our research it was found useful to define this time span in a number of ways, using the same basic raw information--the time at which the event begins and the time at which it ends. Ultimately, a total of 142 variables were constructed for recording various aspects and derivatives of these basic data.

In the process of constructing these variables the scenario was divided into a number of scales or clocks, as follows:

Tactical Phase of the Offensive (4)
12 Hour Period Within the Scenario (10)
Hour Within the Period (12)
Minute Within the Hour (60)
Hour Within the Scenario (120)
Minute Within the Scenario (7200)

The starting time and completion time for each event are given in the history on each of these scales.

It was also found useful to characterize each event in terms of the scenario hours during which the event was in progress. Of the 142 variables mentioned above, 120--one for each hour of the scenario--are devoted to this purpose. For each of these variables the event is described as either impinging or not impinging on the hour represented by the variable.

A similar set of 12 variables was included in order to show the hours within the 12 hour period when each event was active.

Lastly, it was found to be especially important to distinguish between activity occurring at night and that occurring in the daytime. To facilitate access to this information, a separate variable was defined that identifies the event as taking place either:

Entirely in daylight
Entirely in darkness
Beginning in daylight, ending in darkness
Beginning in darkness, ending in daylight

VARIABLES DESCRIBING THE "WHERE" OF EACH EVENT

The method used to define the spatial character of events is quite similar to that just described for defining the chronology. That is, two basic data items--the point of departure and the destination--were first defined. Additional classifications of these basic data were then added as necessary.

Point of Departure and Destination

These two variables give the point of origin and the destination, respectively, as a straight line distance measured normal to the general trace of the FEBA. The distance is given in kilometers.

Zones of Departure and Destination

The basic origin and destination data are also classified on two scales--one in intervals of 10 kilometers, the other in intervals of 30 kilometers.

A set of 22 variables, each representing a 10 kilometer zone drawn parallel to the FEBA, was also defined. These were used to characterize each event in terms of the territory traversed during its course; for each zone, the event either did or did not intrude.

Closest Approach to the FEBA

Since the penetration of hostile airspace is a matter of some concern, a special variable was calculated that gives the 10 kilometer zone nearest the FEBA which is entered during the event.

VARIABLES THAT CHARACTERIZE INTER-MOVE PAUSES

Some 20 variables--many of them construction variables--were used in characterizing the period of inactivity that follows each move by a march unit. The significant datum is the length of the pause; it is given both in minutes and in hours.

A set of 11 variables gives the number of "vehicle-minutes" at rest following the event, for comparison with the "vehicle-minutes-of-exposure" index described earlier.

ADDING VARIABLES TO THE HISTORY

As was suggested earlier, it has proven desirable from time to time to create additional variables in connection with a particular research topic or objective. Without the use of a computer program such as SPSS it would not have been practical to develop the large number of attributes discussed above, let alone create additional variables for a transient analytic purpose.

With SPSS, however, it is a relatively easy matter to calculate new variables from the data already in the history. Very often these consist of simple flag variables that serve to identify a particular subset of the events in the file. It is also possible, for example, to calculate such information as the number of sorties required to engage a specified portion of the target array presented by the history, based of course on exogenous criteria supplied by the analyst.

Some of the data thus created will prove to be of such a highly specialized application that it would be improvident to append them permanently to the history. In other cases, however, the newly generated variables will appear to be sufficiently general in interest to warrant adding them to the file permanently. Consequently, the list of attributes that provided the basis for this appendix should be expected to change from time to time.

The ability to expand and manipulate the model in this fashion and to gain access to various statistical representations of the data with comparative ease and economy is an important feature of MOVER.

A brief overview of SPSS is given in the annex to this appendix.*

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*A complete description of the program and its use will be found in N. H. Nie et al., Statistical Package for the Social Sciences, 2nd ed., McGraw Hill, 1975.

Annex to Appendix B

AN OVERVIEW OF THE STATISTICAL PROGRAM, SPSS

SPSS was designed to accommodate very large data bases, far larger, in fact, than the MOVER file. It can also produce many forms of statistical information that are useful for the interpretation of MOVER. In addition to such common statistical measures as mean, standard deviation, variance, and range, among others, SPSS will also provide one-way frequency distributions and two-way to n-way joint frequency distributions.

An SPSS file consists of a number of "cases," each of which is defined in terms of a number of "variables" selected by the analyst. Thus, in SPSS each MOVER event becomes a case and the attributes describing the events become variables.

The computational routines in SPSS enable the analyst to create new variables, either by mathematical manipulation of existing variables or by simple additions to the file. If variables A and B exist in the file, any logical relationship between them can be added to the file as variable C. To illustrate, if the rate of travel and the distance to be covered in a MOVER event are present in the file, SPSS can compute the travel time for the event and store the newly computed data as an additional variable. Similarly, knowing the types of vehicles associated with an event (as stored variables) SPSS can assign differential rates of movement across the entire history to reflect, say, different speeds for wheeled vehicles and tracked vehicles. Moreover, SPSS will perform these operations for all events simultaneously or for a selected subset of the file.

SPSS uses sort routines to enable the analyst to modify the file selectively or to extract statistical information for a selected subset of the cases in the file. For example, the analyst may wish statistics on those events involving the movement of tanks, and then to compare these with events that do not include tanks; such comparisons are readily made by the sort routines in SPSS.

The file may also be given a permanent substructure, in which case the subfiles may be analyzed independently or in groups as specified by the analyst. This allows for a certain amount of computational efficiency and analytic convenience beyond that afforded by the sort routines alone. However, this feature has not as yet been exploited in the case of MOVER.

Another important feature of SPSS is the weighting function, which allows each event to be given a weighted value in the statistical returns produced by the program. The weighting factor may be an external value assigned by the analyst or it may be the value taken by an existing variable. This function was found to be especially useful in computing the three activity metrics described in Sec. II, viz., "Events," "Volume," and "Exposure." A statistical report of the unweighted file is event-based; weighting each case by the number of vehicles in the event yields a volume-based report; and weighting by the value of the vehicle-minutes parameter gives an exposure-based set of statistics.

Finally, it is possible with SPSS to create different versions of the history by varying the assumptions used in the calculation of some of the variables. For example, one might wish to examine the effects of changing the road speed assumptions used in the calculation of event duration.

The reader who wishes to know more about SPSS should consult Nie et al. (1975).