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Simulation of Military Logistics Operation in an
Underdeveloped Country

J. E. Walsh and James L. Taylor

22 February 1963

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SIMULATION OF MILITARY LOGISTICS OPERATION IN AN UNDERDEVELOPED COUNTRY

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ABSTRACT

For the situations considered, military forces are located in an underdeveloped country during peacetime. Logistic support of these forces poses problems of many types. The simulation model described in this paper furnishes a method for quantitative investigation of these problems. Procedures are outlined for consideration of the many factors that are involved in a military logistics operation over a stated period of time. To be realistic, the military logistics system is considered to be imbedded in the larger system in which it operates. Some of the inputs and interrelations for this over-all system are controlled by the military forces, by the underdeveloped country, by other countries, etc. A measure of effectiveness is developed to represent the desirability of the over-all system operation from the viewpoint of the military forces and their supporters. This faction attempts to choose the inputs and relationships they control to improve the level of this measure of effectiveness, and there is an opposing faction that attempts to do the opposite. A solution to this situation of conflicting interests involving two factions can be obtained on the basis of simulation results and game theory. This solution furnishes information about optimum operation of the military logistics system in the presence of the many influences to which it is subjected.

INTRODUCTION

The military forces requiring logistics support could belong to the underdeveloped country in which they are located, be from outside this country, or both. In all cases, however, their size is large enough to place substantial demands on the logistics capabilities of the underdeveloped country. Usually, these military forces receive their principal support from one or more other countries.

A number of problems of a logistics nature are posed by the presence of the military forces in the underdeveloped country. The logistic deficiencies of this country may result in a substantial lowering of the potential effectiveness of the military forces. If the existing logistics capabilities are inadequate, determination of preferable ways of raising these capabilities can be important. As time passes, the presence of the military forces has an impact on the economy of the underdeveloped country. This could lead to a strong improvement in the logistic capabilities of this country, to a deterioration of these capabilities, or to something in between.

Investigation of these and many other problems can be performed by the development of a suitable simulation model. However, any realistic representation of the military logistics system is almost necessarily of a very complicated nature. Namely, it should allow for the influences of the over-all system in which it is imbedded. Also, the activities performed in logistics are of a dynamic nature and should be considered under transient conditions. These transients may be due to random circumstances or may be deliberate internal and/or external attempts to interfere with the system operation. Thus, a Monte Carlo type of simulation is needed.

The development of a simulation model that is both realistic and feasible is not an easy task. A huge amount of flexibility is required to quantitatively allow

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for the various inputs, relationships, interactions, types of degradation, types of weapon systems, types of logistics units, tactics and countertactics, geographical effects, economic effects, political effects, etc. that should be included in the model. The complication is greatly magnified by the time-dependent and random nature of the problem. To attain feasibility, a large amount of aggregation of effects must be accomplished without substantial loss of realism.

Although concerned with problems involving a large amount of technical detail, the material of this paper is of a descriptive nature. However, the method outlined is a direct extension of an available simulation model (see ref. [1]) that is expressed in technical terms. Similarity to the available model should often furnish a strong indication of suitable technical representations for the quantities that occur in this extension.

For brevity, and to avoid duplication, the reader is referred to ref. [1] for a discussion of the concepts and considerations involved in logistics operation in a randomly damaged system. The material considered here extends that of [1] in two respects. First, a method is outlined for using stepwise aggregation to ultimately place the simulation model in the form presented in [1]. Second, some effects of a more general nature than were considered in [1] occur here, and the model is generalized to include these effects. Also, some discussion is given about measures of effectiveness.

Additional discussion of the simulation situation is given in the next section. This is followed by an outline of the kinds of quantities that occur in the simulation model. Development of measures of effectiveness is considered next. The stepwise approach used to develop the needed level of aggregation is outlined in the following section. Representation of the situation in a discrete form, and

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the method used to apply the type of simulation model that is developed, are discussed in the next two sections. The final section contains some comments concerning the model presented in [1] and its relation to the model considered in this paper.

DISCUSSION OF PROBLEM

The direct purpose of a military logistics system is to provide the personnel, facilities, materiel, and transportation necessary to the operation of weapons systems. The military logistics system is only a subsystem of the over-all military activities, which in turn are only a part of the over-all national activities. Moreover, there are many interactions and interrelations among the various systems that are involved. In some cases, this imbedding may extend further than the underdeveloped country. For example, situations where the underdeveloped country cooperates in a definite fashion with one or more other countries may arise.

Any realistic representation of the military logistic system should take these interactions and relationships into consideration. That is, suitable allowance should be made for the influences of the larger system on the military logistics system, also for the effects of the military logistics operation on the over-all system. In fact, the measure of effectiveness would ordinarily seem to be mainly concerned with the effects of the military logistics operation on some of the important parts of the over-all system in which it is imbedded.

The military aspects of the situation, combined with the existence of an opposing faction, indicate that deliberate attempts may be made to degrade the system operation. Allowance should be made for the use of such tactics, of counter-tactics, etc.

Even with as much aggregation as can be obtained without substantial loss of realism, the simulation model will undoubtedly be of a massive nature. This implies that a single simulation run will require at least a moderate amount of time, even on the most advanced digital computers, and will be expensive. Thus, there will be

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practical limitations on the allowable number of simulation runs. Consequently, it is desirable to have special statistical methods for utilizing the outputs of simulation runs. The linearized nonlinear regression method introduced in ref. [2] would seem to be useful in this respect.

INGREDIENTS OF MODEL

The ingredients of the simulation model can be classified under the headings of inputs and relationships. The initial conditions, and quantities that are introduced from external sources during the simulation, represent the inputs. The various interactions and interrelations, which can be deliberately changed (perhaps in an evolutionary manner) during the course of the simulation, are the relationships. Every part of the model is an input and/or a relationship in some sense.

The parts of the model that are considered to be subject to deliberate change are referred to as strategies. As used here, the word "strategy" does not refer to military strategy. Instead, its meaning is like that for game theory. In a sense, all parts of the simulation model represent potential strategies. However, the possibility of changes is considered only for the more promising of these parts. The faction consisting of the military forces and their supporters (the first faction) attempts to use its available strategies in a manner that is most effective for the accomplishment of its goals (improvement of the level of the measure of effectiveness). However, the second faction controls some of the strategies. Thus, determination of a preferable course of action for the first faction involves the resolution of a conflict of interests.

Since there are only two factions, and they have directly opposing interests, a type of game theory (two-person, fixed-sum) can be used to obtain a meaningful solution. This is accomplished by development of a measure of effectiveness that is a satisfactory representation of the goals of the first faction.

A measure of effectiveness is constructed so that it is one-dimensional and so that increasing values represent closer attainment of these goals. The first faction attempts to choose its strategies, perhaps subject to budget limitations, so as to maximize the measure of effectiveness. The second faction is considered to choose its strategies so as to minimize the measure of effectiveness. The solution to this game theory situation furnishes the resolution of this conflict of interests and determines the "optimum" course of action for the first faction.

MEASURES OF EFFECTIVENESS

The various happenings during the course of a simulation, over the period of time considered, are the outputs from a simulation run. Usually, the situation at the completion of the simulation furnishes the most important outputs. A measure of effectiveness is a function of the outputs of a simulation. However, since the outputs of a simulation are random quantities, the measure of effectiveness is taken to be some suitable average value of the function of these outputs that is of interest. That is, consider the probability distribution of this function of outputs; the measure of effectiveness is some "average" value of this distribution (for example, its mean or its median). In practice, this "average" value is estimated on the basis of simulation runs. The material of [2] should be useful for obtaining estimates of this nature.

Several considerations are involved in the development of a suitable function of the outputs for use as the measure of effectiveness. In general, the measure of effectiveness will represent a compromise between realism and feasibility. It must furnish a reasonably accurate measure of the goals that the first faction desires to attain through use of the military logistics system, with increasing values representing closer attainment of these goals. Simultaneously, decreasing

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values should represent increasingly desirable situations from the viewpoint of the second faction.

To some extent, the broad properties that a measure of effectiveness should possess can be identified from general considerations. However, specific knowledge of the simulation model is needed for the development of a detailed measure of effectiveness. Also, even the broad properties are, to at least a moderate extent, based on the general behavior of the over-all system. Prior to the development and computer-programming of the simulation model, this behavior can only be roughly anticipated. When the simulation model is in operation, it can be used, in a probing sense, to obtain a more definite idea of the over-all system behavior.

DEVELOPMENTAL STEPS

An important part of the approach used in developing the simulation model is the construction of a fundamental unit that is of an extremely flexible nature. This unit must be capable of handling the systems that occur at the various levels of aggregation that are used in developing the final form of the model. That is, at any level, the system considered must be realistically expressible as a combination of these fundamental units, including a specification of their interrelationships.

Developmentally, the model can be considered to consist of several levels. Except for the final (highest) level, the principal purpose of the results for a given level is to furnish information for use in developing the next higher level. The highest level consists of the simulation model that is used to investigate the over-all system behavior, and is a representation of the over-all system in the final stage of aggregation. The lower levels are representations of parts of the over-all system. Their purpose is to furnish a basis for the

aggregation that occurs at the final level. The lowest level consists of a large number of relatively small parts and considers each of these parts in at least moderate detail.

Thus, the problem of obtaining sufficient aggregation without substantial loss of realism is handled in a stepwise fashion. The flexibility required of the fundamental unit is emphasized by the fact that this unit must be able to satisfactorily represent systems that range from small detailed parts of a country to entire countries.

Satisfactory construction of a fundamental unit, including interrelations among units, requires great care and substantial ingenuity. Allowance must be made for the largest number of different types of items that might reasonably be encountered. The large number of possible interrelations and interactions among these items as they are used in a large number of possible ways must also receive consideration. In addition, allowance should be made for a number of different types and levels of aggregation. Fortunately, for simulations on advanced high-speed computers, this situation can often be satisfactorily handled by use of suitable functional forms that depend on one or more variables and one or more parameters. By suitable specification of the parameter values, a function can allow for a very broad class of possibilities. Moreover, programming of a function of this nature on a high-speed computer is not overly difficult. Of course, the suitable choice of a function for representing a given class of interactions, interrelations, etc., requires a large amount of insight and experience. In particular, the expense for a simulation run can be greatly increased by using functions that are more complicated than is necessary.

A motivation for use of the fundamental-unit method is that the required computer programming is not overwhelming. Nearly all that needs to be programmed

is the fundamental unit and its interrelations with other fundamental units (all of which are represented by this programmed unit).

USE OF DISCRETE REPRESENTATION

A somewhat different form of aggregation that occurs in the type of simulation model considered is a conversion of the continuous situation for the over-all system and its parts to a workable discrete form. This conversion is discussed in some detail in ref. [1] and only the basic considerations are mentioned here. First, only the situations at a specified finite set of times are considered. However, if the consecutive times are not too far apart, this conversion from a continuous-time basis should not result in much loss of realism. An important practical problem is to maintain realism without using too large a number of times, since the computational expense is roughly proportional to the number of times used.

A second type of conversion to discrete form occurs with respect to subdivision of systems. Each system being simulated (perhaps some part of the over-all system) is divided into appropriate subsystems. This subdivision can be based on operational, geographical, economic, political, etc., considerations. The choice of the subsystems represents a compromise between feasibility and realism. Here, each subsystem should be representable by the fundamental unit and there should not be an overly large number of subsystems.

METHOD OF APPLICATION

As for ref. [1], time is used as the basis for coordination among subsystems. All important effects are considered to occur at one of the times of the finite set that is used. That is, each of these times represents a time interval and the effects associated with a given time are the effects that occurred during the corresponding time interval. Starting with the initial conditions, the simulation

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is performed over all subsystems for the first time interval. On the basis of the initial conditions, any inputs from outside the system, and the results for the first time interval, the simulation is then conducted for the second time interval. This procedure is continued until the final time considered is reached.

Several runs for the same simulation situation can be used to obtain an indication of the effects of statistical variation on the system behavior. If the method of ref. [2] is used, runs for different simulation situations can be combined to obtain an estimate of the measure of effectiveness, and information about the accuracy of this estimate. The procedure outlined in [2] for determination of strategies that optimize a measure of effectiveness should be directly applicable to this case and can be computer programmed for efficient use.

AVAILABLE MODEL — REMARKS

The over-all system considered in ref. [1] is of a restricted nature. The probability distributions for induced attrition are influenced only by occurrences within the system. Also, no direct allowance is made for effects of an economic or political nature.

One interest is in the economic effects, on the underdeveloped country, of the presence of the military forces and of the operation of its logistics system. Consequently, the over-all system in which the logistics operation is imbedded needs to be of a much more extensive nature than that used in [1]. Also, some new concepts need to be introduced for the handling of political effects.

REFERENCES

- [1] John E. Walsh, "General simulation model for logistics operation in a randomly damaged system," Naval Research Logistics Quarterly, Vol. 7, no. 4, December, 1960, pp. 453-470.
- [2] John E. Walsh, "Use of linearized nonlinear regression for simulations involving Monte Carlo," Operations Research, Vol. 11, no. 1, January-February, 1963.

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