

**EVALUATION OF MOBILIZATION AND DEPLOYMENT PLAN
OF A TURKISH ARMORED
BATTALION VIA SIMULATION**

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BY

SELİM MÜSLÜM

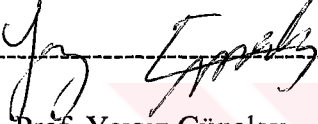
July, 2001

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ABSTRACT

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M.S. in Industrial Engineering

Supervisor: Assoc. Prof. İhsan Sabuncuoğlu

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As being ready for war as soon as possible and with minimum casualties during the crises is the first mission for the troops, the Mobilization and Deployment Plan arises as one of the most important topic for Army. Because this plan includes all the activities that troops have to execute for responding against enemy immediately. In this study, the performance of existing Mobilization and Deployment Plan of a Turkish Armored Battalion is evaluated via simulation. The Mobilization and Deployment simulation model allows military operation planners to build models of Mobilization and Deployment operation of troops early in decision process; perform bottleneck analysis and take necessary measures against the problem areas; and perform risk management of the operations before conducting the real ones.

In this thesis, our objectives are to evaluate the Mobilization and Deployment system of an Armored Battalion, find out the significant factors of enemy threat on the existing system, detect the most hazardous border and the most hazardous factor for each border, and discover the system limits. The output of the model is analysed by experimental design, and ranking and selection procedures. The code of simulation model is written in ARENA simulation program.

Key Words: Military Simulation, War Gaming, Combat Simulation, Force Projection

ÖZET

SİMULASYONLA BİR TÜRK TANK TABURUNUN ALARM PLANININ ANALİZİNİN YAPILMASI

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Kriz anında savaşa en kısa zamanda ve en az hasar ile hazır olmak askeri birliklerin en önemli görevi olduğundan, Alarm Planı Türk Ordusu için en önemli konulardan birisidir. Çünkü bu Alarm Planı askeri birliklerin savaş öncesi yapması gereken bütün faaliyetleri kapsamaktadır. Bu çalışmada, bir tank taburunun alarm planı analiz edilmektedir. Alarm simülasyon modeli, askeri operasyon planlayıcılarına, karar aşamasından önce alarm operasyonunun modelini kurma; plandaki problemlerin tesbit edip bunlara karşı tedbir alma, ve gerçek operasyondan önce risk analizi yapma imkanı sağlar.

Bu tez çalışmasında, Alarm Planının analiz edilmesi, şu an kullanılan sisteme etki eden faktörlerin ve etkilerinin tesbit edilmesi, ve sistem limitlerinin tesbit edilmesi ana amaçlarımızdır. Alarm modelinin sonuçları, deneysel dizayn ve sıralama ve seçme prosedürleri kullanılarak analiz edilmiştir. Modelin kodu ARENA simülasyon programıyla yazılmıştır.

Anahtar Kelimeler: Askeri Simülasyon, Harp Oyunu, Savaş Simülasyonu, Birlik Kaydırma

To my parents and fiancé



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GLOSSARY

AIR ATTACK: Assault with air combat vehicles (warplane, helicopter).

ALERT DISPERSION AREA: Area where the troops spread for minimizing the casualties during an enemy attack.

ALERT AND MOBILIZATION PLAN: The plan that troops execute for being ready for combat as soon as possible.

AMBUSH: An unexpected, trap-type military operation.

ARTILLERY ATTACK: Assault with the artillery guns (cannons).

ASSEMBLY AREA: The area where troops make last preparations for further military operations.

BREAKDOWN: Malfunctioning of the vehicles.

DEPLOYMENT: The strategic relocation and concentration of forces and their support base (manpower and logistics) from barrack into a theater.

MARCH: Travelling of troops under the threat of enemy.

MINEFIELD: An area where the ground mines are positioned.

MOBILIZATION: A process by which the armed forces reach a state of enhanced readiness in preparation for war or other national emergencies.

CHAPTER 1

INTRODUCTION

1.1. MOBILIZATION AND DEPLOYMENT PLAN OF AN ARMORED BATTALION

Mobilization describes a process by which the armed forces reach a state of enhanced readiness in preparation for war or other national emergencies. It includes activating all or part of the reserve component as well as assembling and organizing personnel, supplies, and material prior to deployment. Strategic deployment is the strategic relocation and concentration of forces and their support base (manpower and logistics) from barrack into a theater. Deployments may take the form of a forcible entry for crisis response or unopposed entry for natural disasters or humanitarian (Department of Army, 1996). We do not handle the activities of the reserve components; we deal with the activities of active components of an Armored Battalion.

We model the mobilization and deployment of an Armor Battalion to Assembly Area via simulation. The aim of mobilization and deployment is to be ready for combat with minimum casualties and equipment loss. This activity has to be made as soon as possible, because it occurs under the disturbance of enemy, any lateness can cause many human casualties. Because of that reason evaluation of mobilization and deployment plan has great importance in military.

An armored battalion is formed of four companies. First three companies are identical armored (tank) companies; the other one is Headquarters and Headquarters Company.

As a strategy when there is a sense of danger or threat, Turkish Army starts to

load ammunition, gas and equipment to the vehicles for being totally ready for future operations. So when the alert order is announced, most of equipment and ammunition has already been loaded. Troops only make partial loading after alert order.

Mobilization starts with the alert order, immediately soldiers start to make partial loading of equipment and guns quickly. Without waiting others, each vehicle starts to travel from garages to Alert Dispersion Area individually to minimize the casualties and vehicle losses caused by enemy attacks. The breakdown of vehicles may occur in garage after alert order, the other vehicles pull off the broken vehicles to the Alert Dispersion Area. In daytime at most in *half an hour*, at night in *45 minutes* from the alert order, Armored battalion has to complete its deployment to Alert Spread Area. After an hour from the alert order, reconnaissance group starts to travel to Assembly Area to secure the roads and Assembly Area from enemy. At most after *two hours* from the alert order, main troops have to be ready for travelling to Assembly Area.

In Alert Dispersion Area, Armored Battalion members make preparations for travelling to Assembly Area that is the last place to complete the preparations for combat. During travel, vehicle breakdowns can occur, enemy can make air and artillery assaults, lay ambush and use ground mines to destruct vehicles and kill soldiers. These assaults of enemy cause vehicle destruction and delay that will affect the success of further operations. When a vehicle is shot, its crew moves off the vehicle out of road not to prevent traffic and tries to repair. If the damage is not repairable for the crew, they wait for the maintenance team. Maintenance team arriving shot area immediately begins to repair the vehicle. If vehicle is destructed completely, it is left in a safe region with its crew, and maintenance team continues travelling. In our study, activity ends when the troops reach Assembly Area. We do not deal with the activities in Assembly Area. The

figure 1.2.1 shows the travel plan of Armored Battalion.

We study on the system that starts with the alert order, and ends with the arriving of all vehicles to Assembly Area. We do not cope with the activities before the alert order, and we assume that before the alert order, ammunition and fuel oil loadings are completed, and most of the equipment is loaded to wheeled-trucks. We analyze the system in the name of vehicles; we do not deal with the soldiers individually. Because armored battalions fight with the armored vehicles and wheeled-trucks, soldiers do not get off the vehicles. But for infantry battalion, soldiers should be taken into account instead of vehicles, because infantry soldiers fight by getting off the vehicles.

In this study, we evaluate the performance of existing Mobilization and Deployment Plan of a Turkish Armored Battalion. The objectives of this study are to examine the behavior of existing Mobilization and Deployment Plan of an Armored Battalion in Turkish Army, establish the nature of relationship among one or more significant factor and the system performance, analyze the efficiency of this plan, compare different scenarios and improve system performance. We also try to detect the most hazardous border of Turkey and the most hazardous factor for each border, and discover the system limits. We focus on five factors that are breakdowns of vehicles, air attack, artillery attack, mine fields and ambushes of enemy in our study.

The results that we get during this thesis can be used in different areas of military operation planning and defense planning. We give a brief summary of practice suggestions below. In the situation that the system does not work properly, we try to detect the major problem areas (bottlenecks) of the system by sensitivity analysis, then propose the modifications to make the system work properly. Determining the significant effects of five factors that we state above can be useful information for development of

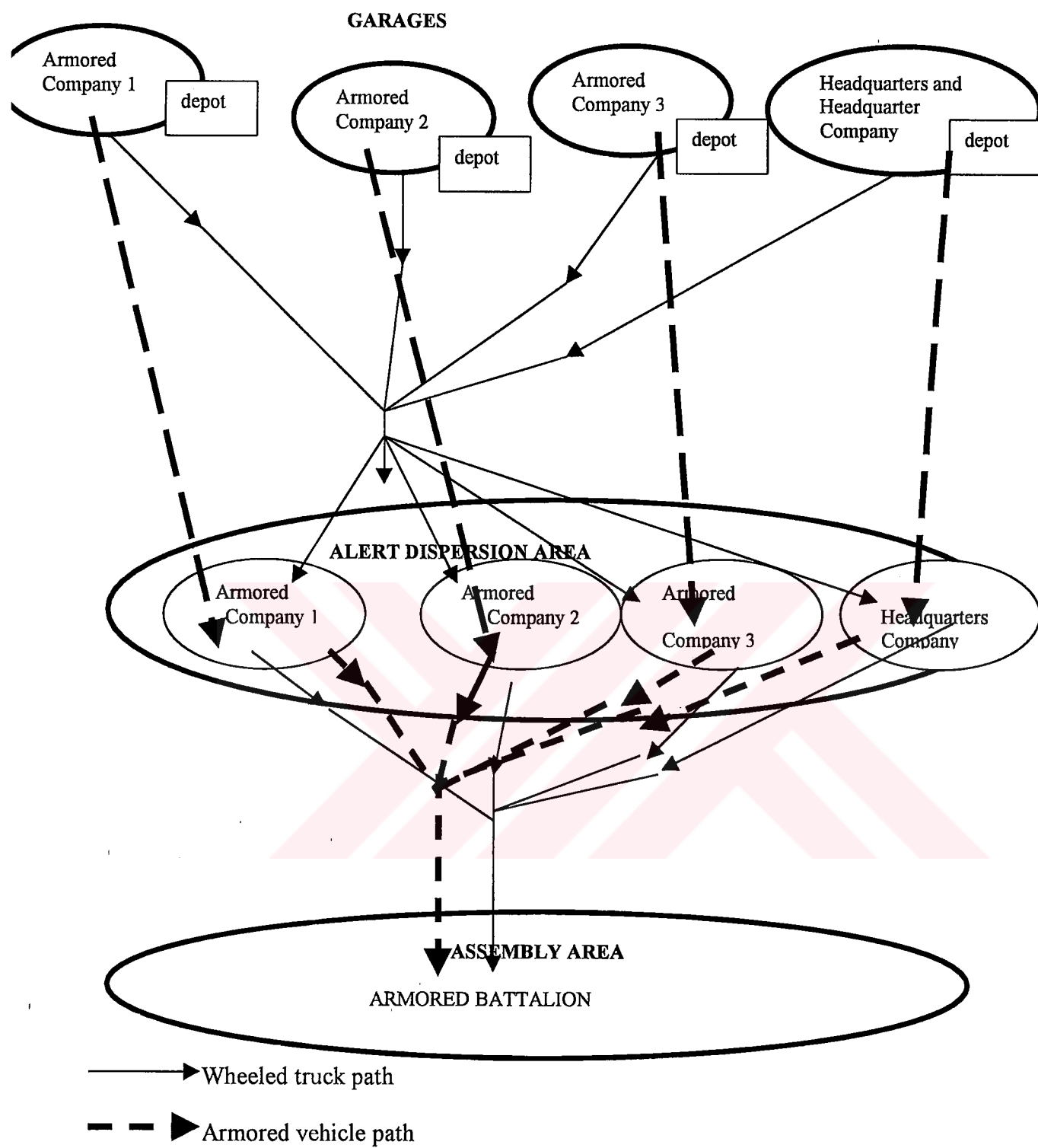


Figure 1.2.1. The march plan of Armored Battalion for wheeled trucks and armored vehicles

the national defense plans.

The defense arrangements may focus on the most significant factors. The most critical border information may also be used for improvement of the national defense plans. Selection of the most hazardous factor and rankings of five factors according to the threat for each border of Turkey may guide the commanders of these armored battalions for deciding which factors they should emphasize on during the planning of the field exercises. Being aware of his Armored Battalion's limits, commanders can make more healthy decisions that may have changed the faith of the war. We know that the importance of performance measures vary depending on the type of the military operations. For attack-type operations time is more important whereas, for defense operations the amount of totally destructed vehicles are more important. Because the assault is a surprise operation that the time is very limited. But for defense operations, the time limitations are more loosed, so the number of totally destructed vehicles measure arises as the most important factors, because totally destructed vehicles can not be repaired, thus they are constant loss. To provide consultation for armored battalion commanders, we collect different types of statistics, some of which are arriving time of last vehicle to Assembly Area, the number of damaged vehicles, the number of totally destructed vehicles.

Chapter organization is as follows. Chapter 2 presents the related literature with the simulation software and methods; the requirements of military simulation modeling; combat modeling and simulation applications that provide useful information for modeling combat activities. Chapter 3 interprets the implementation of simulation model of Mobilization and Deployment Plan of a Turkish Armored Battalion. Chapter 4

presents experimental design of five factors that are breakdown of vehicles, air attack, artillery attack, minefields and ambushes of enemy. We implement the ANOVA procedure to find out the significant factors for three different performance measures in this chapter. Chapter 5 includes the ranking and selection of the most critical region of Turkey out of ten for three different performance measures and we also apply analytic hierarchy process to identify a single most critical region that is valid for all of three performance measures. Chapter 6 interprets the ranking and selection of the most critical factor out of five factors for each of ten regions in Turkey. Chapter 7 presents the limits of an Armored Battalion executing the Mobilization and Deployment Plan. In Chapter 8, we give the conclusions of the research. As a final step, ideas and suggestions for future researches are listed. In Appendices, some figures about the structure of a Turkish Armored Battalion, outputs, a part of computer code and the bibliography are given.

CHAPTER 2

LITERATURE REVIEW

During the literature review, we have not come across any study that is directly related with our topic. We meet some of abstracts of military researches conducted in U.S. but because of the privacy of topic, they are not open to the public use. Thus, we could not obtain detailed information about these military researches. In the next sections, we present the available references in three groups that are the simulation software and methodology, military simulation, and combat simulation (war games). We also provide a table (Table 2.1.) that summarizes the literature.

2.1 SIMULATION SOFTWARE AND METHODOLOGY

We construct the frame of our simulation model, verify and validate it under the light of some of techniques and ideas presented in the papers in this part of literature review.

Throughout our study we use the basic principles, stated in Banks (1998). In that study, the author explains the fundamentals of the modeling methodologies, gives brief information about the use of simulation and then recommends a stepwise logic for all phases of simulation. In our thesis, we use ARENA software for coding system because it is a powerful tool that meets all of our requirements. Takus and Profozich (1997) explain the software and its capabilities in their tutorial.

Sergeant (1998) discusses approaches to verify and validate the simulation models and how model verification and validation relate to the model development process. After defining various validation techniques, he describes conceptual model

validity, model verification, operational validity, and data validity and recommends a procedure.

Kleijnen (1999) explains which statistical techniques can be used to validate simulation models depending on which real-life data are available. He categorizes the situations as the cases of having no data, only output data, both input and output data. To explain these three cases he provides some case study summary.

Alexopoulos and Seila (1998), Kelton (1997), Centeno and Reyes (1998), and Sanchez (1998) all study on the procedures, techniques about the simulation output analysis. We use the techniques determined for the terminating systems.

2.2 MILITARY SIMULATION

The papers in this section discuss the general military issues and necessary techniques for military modeling and simulation. By the help of this literature, we understand the military aspect of simulation and recognize the differences of military simulation. We take the guidance of these papers for overcoming the problems that we encounter during the model development (lack of real data, etc.). We also implement techniques for verification, validation and accreditation of military models mentioned in some of these papers.

Page and Smith (1998) give the overview of military training simulation in the form of an introductory tutorial. They provide basic terminology, and current trends and research focus in the military simulation domain. Also they explain verification, validation and accreditation of military models.

The U.S. Department of Defense (DoD) is currently embracing object-oriented programming as a possible solution to problems that beset current simulation tools in the

paper of Painter (1995). He mentions about the benefits that are object reuse (sharing objects between simulations), data hiding (encapsulation), and code reuse and extension (polymorphism) and also the associated cost as a paradigm. Finally, he states that the immediate need facing the military simulation is to agree on and build a framework for object-oriented simulations.

Smith (1998) identifies and explains essential techniques necessary for modern military training simulations. He provides a brief historical introduction; discussion of system architecture; multiple interactive training simulations; event and time management; distributed simulation; and verification, validation, and accreditation. After all, he discusses the fundamental principles in modeling and specific military modeling domains. While discussing the fundamental principles of modeling, he stresses on the importance of modeling the right problem, complete and accurate understanding, credibility and construction of the model subject to some constraints. Under the heading of physical modeling, he focuses on the importance and usage of physical objects, which include vehicles, people, and machinery involved in the activities of moving, perceiving other objects, and interacting with them in the military simulations. Behavioral, environmental and multi-resolution modelings are the other discussed subjects in his study.

Kang and Roland (1998) discuss the military simulation within the subjects of organizations that deal with classification of military simulation, simulation as a training tool, and applications and their areas of study. They stress the subjects of advanced distributed simulation, distributed interactive simulation, and high-level architecture.

Roland (1998) gives an overview of the panel “The future of military simulation” in which military simulation is categorized as including engineering models, analyses

models and training models. The members army answer the questions about their background; goals and objectives of their involvement in modeling and simulation; HLA studies; major problems in the current state of modeling and simulation development and use; today's major modeling and simulation opportunities and challenges.

Sisti (1996) studies on the topics of interest to researchers in the simulation community and present some of selected Air Force programs. He deals with the wide variety of research issues in simulation science being presented by government, academia and industry, and their application to the military domain.

Hatley (1997) discusses the difficulties, ways and cost of the military simulation model validation and verification. He compares the other simulation models with the military ones in terms of validation, verification and accreditation.

Kathman (1995) summarizes the data collection process in field combat simulation of U.S. Army. He describes four basic types of instrumentation that have been developed to assist data collection in field combat simulation and gives explanations of these four basic types.

2.3 COMBAT MODELING AND SIMULATION (WAR-GAMING)

Our simulation model is an example of combat simulation because it includes the combat activities (air attack, artillery assault, mine fields and ambushes of enemy). Thus, we give some of the applications of war-gaming in that section. Under the light of information that we gained from the papers below, we implement some of war-gaming modeling techniques used in these combat simulation applications for some parts of our model during the model development.

Caldwell, Wood and Pate (1995) summarize a two-year project, called JLINK, which enables the JANUS, Army constructive interactive simulation to be connected to manned land and air combat vehicle simulators, using Distributed Interactive Simulation (DIS) Protocol Data Units (PDU). The JLINK project was one of the firsts to demonstrate that a constructive simulation can be connected to and realistically interact with DIS compliant virtual combat vehicle and aircraft simulators. They discuss how this was accomplished, highlight the major considerations involved, and describe the interface model that was developed to connect JANUS to the DIS world.

Parker (1995) explains a unique approach developed for analyzing force structures of the armed forces of U.S. With this approach, new ways of measuring combat readiness are available to ensure that the armed forces remain ready to fight during the defense draw down of the 1990s. He explains a network representative language Dynamic Simulation that combines the continuous variable features of system dynamics and the discrete event features of conventional simulation techniques.

Mostaglio, Johnson and Peterson (1993) give an overview of a Distributed Interactive Simulations (DIS) training system used by Army, which is called The Close Combat Tactical Trainer (CCTT). They discuss how it will use the DIS standard protocols and semi-automated forces within its architecture, the program's development methodology, and its role in future Army training.

Childs and Lubaczewski (1987) propose a simulation model used for training Brigade and Battalion commanders and their staffs to exercise procedures and decision-making skills. They briefly address the background of command and control training and provide an in-depth discussion of the COMBAT-SIM model.

Parker (1991) gives an overview of combat vehicle reliability assessment

simulation model, which portrays the disposition, or status of vehicles over time. He also suggests using this information to initialize the other combat models in which reliability may not previously have been a consideration.

Allen and Wilson (1988) describe a methodology for developing combat simulations that may be readily tailored to specific study issues, and structured so as to threat both qualitative and quantitative variables using the natural language of military planners. This methodology was developed for the RAND Strategy Assessment System (RSAS) and exploits a new programming language called RAND-ABEL. They also explain in what areas RAND-ABEL language is used.

Blais (1994) gives the description of a computer assisted, two-sided warfare gaming system designed to support training of U.S. Marine Corps commanders and their staffs. He explains development phases and usage areas of this simulation system, which is called The Marine Air Ground Task Force Tactical Warfare Simulation.

Henry (1994) describes The Corps Battle Simulation as a standard tool for training commanders and their staffs in U.S. Army. This simulation model is written in C programming language, and combat is modeled mathematically using Lanchester-type equations as described by Taylor (1981). He also stated the hardware and evolution of The Corps Battle Simulation.

Youngren, Parry, Gaver and Jacobs (1994) give description of a research conducted at the Naval Postgraduate School into new methodologies for joint theater-level combat simulation modeling, emphasizing C31, operational intelligence, decision making under certainty, and aggregated stochastic process modeling. Research outcomes to date as well as a prototype software tool are described in their paper.

Russell and McQuay (1993) give an overview of a system called The Joint

Modeling and Simulation System (J-MASS) whose development standards and software tools support a disciplined approach to the development, configuration, operation, and analysis of digital models and simulations. They explain that J-MASS provides a common modeling architecture with a library of verified and validated software components and models of weapon systems developed by different military communities for Department of Defense.

Oswalt (1995) presents the technologies critical to military simulation, summarizes their status, proposes a concept of what technologies are likely to be applied in the future military simulations, and concludes with a review of two current simulation architectures-SIMOBJECT and J-MASS.

Garrambone (1992) gives an overview of one of the most difficult topics of Operations Research- combat modeling and simulation. He describes a team leader standpoint, the requirements, which drive the modeling process used to support DoD studies. He discusses models, (sources and construction notes), scenarios, data, computer concepts, team composition, and many other important considerations needed to accomplish the analytical study tasks. The reader, novice or seasoned, will find that this approach to the subject contains insights rarely found in manuals, covering topics from defining the study environment, to the techniques for presenting study results.

Garrabrants (1998) proposes “an expansion of simulation systems’ role to support all levels of command and control functioning, especially staff planning after receipt of orders and mission rehearsal” in this study. He explains how Marine Tactical Warfare Simulation (MTWS), an advanced simulation system, is used to model all aspects of combat (air, land, sea, and amphibious ship-to-shore activities) and gives detailed information about its usage. We give summary of related literature in Table 2.1.

Table 2.1. Summary table of related literature

Simulation Software and Methodology	Takush and Profozich (1997) Sargent(1998) Sanchez (1998) Kleijnen (1999) Alexopoulos & Seila (1998) Centeno & Reyes (1998) Kelton (1997)	ARENA software tutorial Verification and validation of simulation models ABC' s of output analysis Statistical techniques and data availability Advanced methods for simulation output analysis Simulation output analysis Statistical analysis of simulation output
Military Simulation	Page & Smith (1998) Painter (1995) Smith (1998) Kang & Roland (1998) Roland (1998) Sisti (1996) Hatley (1997)	Introduction to military training simulation Object oriented military simulation development and application Essential techniques for military modeling and simulation Military simulation The future of military simulation Modeling and simulation technologies for military applications Verification and validation in military simulation
Combat Modeling and Simulation	Caldwell & Wood & Pate (1995) Parker (1995) Mostaglio, et al. (1993) Childs & Lubaczewski (1987) Parker (1991) Allen & Wilson (1988) Blais (1994) Henry (1994) Youngren, et al. (1994) Russel & McQuay (1993) Kathman (1995) Garrambone (1992) Garrabrants (1998)	JLINK-JANUS fast movers Military force structure and realignment “ sharpening the edge” through the dynamic simulation The close combat tactical training program A battalion / brigade training simulation Combat vehicle reliability assessment simulation model Modeling qualitative issues in military simulations with the RAND-ABEL language. Marine air ground task force tactical warfare simulation The corps battle simulation The future theater-level model The joint modeling and simulation Data collection in field combat simulation An overview of air land combat modeling and simulation Simulation as a mission planning

CHAPTER3

THE SIMULATION MODEL

3.1 FORMULATION OF THE PROBLEM AND PLANNING THE STUDY

The objectives of this study are to examine the behavior of existing Mobilization and Deployment Plan of an Armored Battalion in Turkish Army, establish the nature of relationship among significant factors and the system performance, analyze the efficiency of Mobilization and Deployment plan of an Armored Battalion, compare different scenarios and improve system performance. In the case where the system does not work properly, we try to detect the major problem areas of the system, and then propose the modifications to make the system work properly.

For the solution of the problem, we decided to use simulation instead of probabilistic methods (probability tree), because all vehicles of Armored Battalion travel together, which causes interactions among the vehicles for maximum and average time in system measures. As an example of interactions, the vehicles must travel all together, and obey the leading vehicle's speed as a military strategy. We cannot deal with this type of interactions by the probability tree. By the probability trees, we compute the expected value of number of damaged vehicles and number of totally destructed vehicles, which are 30.75 and 7.87 vehicles, respectively. During the validation, we see that the outputs of simulation model are 32.6 damaged vehicles and 7.6 totally destructed vehicles under the same conditions with the probabilities. The outputs are very close to expected values which also confirms the accuracy of simulation model. The other difficulty is complex structure of the system. We have 167 vehicles to deal with, which make the probability tree very complex and huge. We give the probability tree of the model for only one

vehicle in Appendix E. And also, we need a dynamic model to run the different scenarios with slight modifications. When we use probability tree, we have to draw different tree for each scenario that will take more time and effort. Simulation handles all these difficulties easily. Because of that reason for the solution of our problem, we use simulation.

Specifically, we will attempt to answer the following research questions:

- Is the existing plan efficient?
- After alert order, can whole battalion reach to Alert Dispersion Area in *30 minutes* in daytime, *45 minutes* at night (NATO standards)?
- After alert order, can reconnaissance force at most in *one hour*, main force in *two hours* be ready for moving to the Assembly Area?
- Where does the bottleneck occur in the system?
- How does air attack, artillery assault, mine fields and ambush of enemy affect the system performance?
- Which region of Turkey is most vulnerable against enemy attack?
- Which factor (breakdown of vehicles, air attack, artillery assault, mine fields and ambush of enemy) is the most hazardous for each region of Turkey?
- What are the limits of an Armored Battalion executing Mobilization and Deployment Plan?
- Can I suggest a better alternative plan?

The performance measures under consideration are:

- Average time in system measure of last vehicle reaching the assembly area

- Average time in system measure of vehicles
- Number of damaged vehicles
- Number of totally destructed vehicles

Since the mobilization and deployment are a part of combat, the data requirements are hard to provide. The data requirements of our simulation model are:

- Loading time data
- Velocities of tanks and wheeled trucks
- Repairing time distributions of damaged vehicles by breakdowns, air attack, artillery attack, mine and ambush

This study helps to see how the Mobilization and Deployment Plan works, how the behavior of system changes under the certain conditions and different scenarios. The end user of this study is Armored Battalion Commanders of Turkish Army. We model the system by using the following assumptions, assumptions about the enemy threat are determined according to the inquiry that we give the Armored Battalion commanders:

- 1 Armored Company has 9 wheeled-truck and 14 armored vehicles
- Headquarters Company has 75 wheeled-truck and 22 armored vehicles
- Elementary unit is company
- The construction of Armored Battalion is in Appendix A and it is taken from the Turkish Military Logistics Procedure (1994).
- Velocity of armored vehicles is 29 km/h (taken from the Turkish Military Logistics Procedure (1994))
- Velocity of wheeled trucks is 40 km/h
- Ambush guns are 4 LAWs

- Artillery guns are 4 155mm. Cannons
- Air attack gun is 1 F-16 war plane
- Mine density on the path of vehicles is 6 anti-tank mines in a 8*8 mine field

3.2. MODEL DEVELOPMENT

We start with the forming the conceptual model to develop our simulation model. During this phase, we consulted the Armored Battalion, Armored Company and Team commanders who are the main actors of Mobilization and Deployment Plan. We also interview with the staff officers who are the experts of planning of military operations to build the logical model. Then we write the code of model by using ARENA software. Figure 3.1 gives the schematic view of model development.

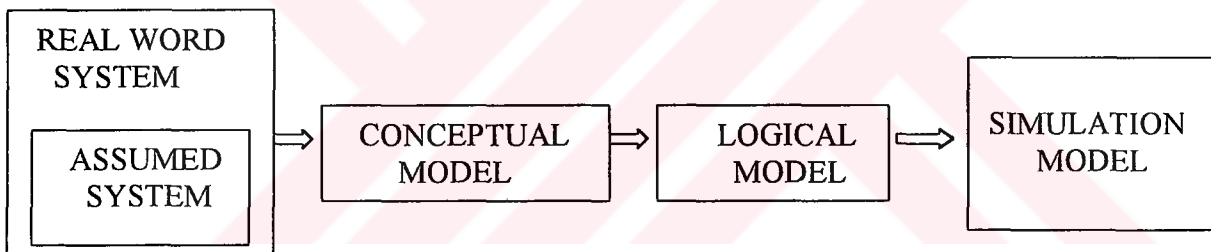


Figure 3.1. Schematic view of model development

3.2.1 CONCEPTUAL MODEL

We form a conceptual model of Mobilization and Deployment Plan of Armored Brigade to convert the real system into a simple system to examine the structure and components, which should be included. The Mobilization and Deployment Plan is used by all troops in Turkish Army. The frame of plan is the same for all kinds of troops (armored, artillery, infantry etc.). Only minor differences are made to plan

according to the positioning and structure of the troop, the mission type etc. During conceptualization, we interviewed with armored battalion, company, team commanders and staff officers. The basic elements of the simulation model is given below:

Events:

Events are instantaneous occurrences that change the state of the system. The list of events that occur in our simulation model is:

- Announcement of alert order event: The alert order is given to battalion by the intelligence service. Soldiers take their personal equipments and guns, and then make partial loading of equipment to the wheeled trucks.
- Departure of vehicles from garages event: After the completion of loading and preparation, vehicles start to travel to Alert Dispersion Area independent of others.
- Arrival of vehicles to Alert Dispersion Area event.
- Departure of reconnaissance force from Alert Dispersion Area event: The reconnaissance force starts to travel to Assembly Area for securing the roads and Assembly Area.
- Breakdown of vehicles during march from Alert Dispersion Area to Assembly Area event: The broken vehicle is moved off the road not to prevent traffic flow and wait for repairing by maintenance team.
- Air attack of enemy during march event: The damaged vehicle is moved off the road not to prevent traffic flow and wait for repair by maintenance team. If the vehicle is totally destructed, it is left in a safe area. The same procedure is also valid for in the situation of artillery assault, ambush and mine fields.
- Artillery assault of enemy during march event.

- Hitting ground mines of enemy during march event.
- Ambush of enemy event.
- Failure of vehicles because of air and artillery attack, breakdowns, ground mines and ambushes.
- Completion of repair of damaged and broken vehicles event.
- Departure of damaged and broken vehicles from the repair areas event.
- Arrival of totally destructed vehicles to a safe area.
- Arrival of vehicles to Assembly Area event.

Entities:

Entities are the objects of the interest in the system that requires an explicit representation in the system. There is only one type of entity in our system and it is vehicles of Armored Battalion.

Attributes:

Attributes are the characteristics of the entities. In our model, we have the following attributes:

- The beginning time of Mobilization activity
- Company identification numbers
- Vehicle identification numbers
- Type of damage that the vehicle takes
- Air attack identification numbers (helicopter or plane attack)

Activities:

Activity represents a time period of specified length. Some of activities are:

- Equipment loading in garages
- March of vehicles from garages to Alert Dispersion Area
- Preparation of main troops of Armored Battalion in Alert Dispersion Area for march to Assembly Area
- March of Armored Battalion from Alert Dispersion Area to Assembly Area

Exogenous Variables (Input Variables):

We have two types of input variables: decision variables (controllable variables) and parameters (uncontrollable variables).

Decision Variables:

- Velocity of vehicles

Parameters

- Time that we spent for partial loading of equipment and preparation for march to Alert Dispersion Area (most of the equipment (ammunition, guns etc.) is loaded before the alarm order according to the intelligence report, only the equipment that is essential for soldiers to continue their daily activities in barracks is left unloaded.)
- Readiness time of reconnaissance force for march to Assembly Area from Alert Dispersion Area
- Readiness time of main force (Armored Battalion) for march to Assembly Area from Alert Dispersion Area
- Repair time of vehicles broken by breakdowns
- Repair time of vehicles damaged by enemy attacks

Endogenous Variables (Output Variables):

We classify the endogenous variables as state variables and performance

measures.

State Variables:

- Number of vehicles waiting in the repair queues
- Number of vehicles that are not damaged or broken in the convoy
- State of repair units (busy or idle)

Performance Measures

- Average time in system measure of last vehicle reaching the assembly area
- Average time in system measure of vehicles
- Number of damaged wheeled trucks because of breakdowns
- Number of damaged wheeled trucks because of air attack
- Number of damaged wheeled trucks because of artillery assault
- Number of damaged wheeled trucks because of ground mines
- Number of damaged wheeled trucks because of ambush
- Number of damaged armored vehicles because of breakdowns
- Number of damaged armored vehicles because of air attack
- Number of damaged armored vehicles because of artillery assault
- Number of damaged armored vehicles because of ground mines
- Number of damaged armored vehicles because of ambush
- Number of totally destructed wheeled trucks because of breakdowns
- Number of totally destructed wheeled trucks because of air attack
- Number of totally destructed wheeled trucks because of artillery assault
- Number of totally destructed wheeled trucks because of ground mines
- Number of totally destructed wheeled trucks because of ambush

- Number of totally destructed armored vehicles because of breakdowns
- Number of totally destructed armored vehicles because of air attack
- Number of totally destructed armored vehicles because of artillery assault
- Number of totally destructed armored vehicles because of ground mines
- Number of totally destructed armored vehicles because of ambush
- Total number of damaged vehicles
- Total number of totally destructed vehicles

3.2.2 LOGICAL MODEL

Logical model shows the relationships among the elements of the model. We construct the logical model of Mobilization and Deployment Plan of a Turkish Armored Battalion. Our model starts with the receiving of alert order and ends with the occupation of Assembly Area by the Armored Battalion. The main events that our model includes are the partial loading of the wheeled-trucks, march of Armored Battalion from garages to Alert Dispersion Area, march from Alert Dispersion Area to Assembly Area, and attacks of enemy against the Armored Battalion during this march. During the construction of logical model, we took the consultancy of Armored Battalion and Company commanders who are the executers of the Mobilization and Deployment Plan. We present the relationship among the elements of the Mobilization and Deployment Plan of an Armored Battalion in Figure 3.2 as flow charts.

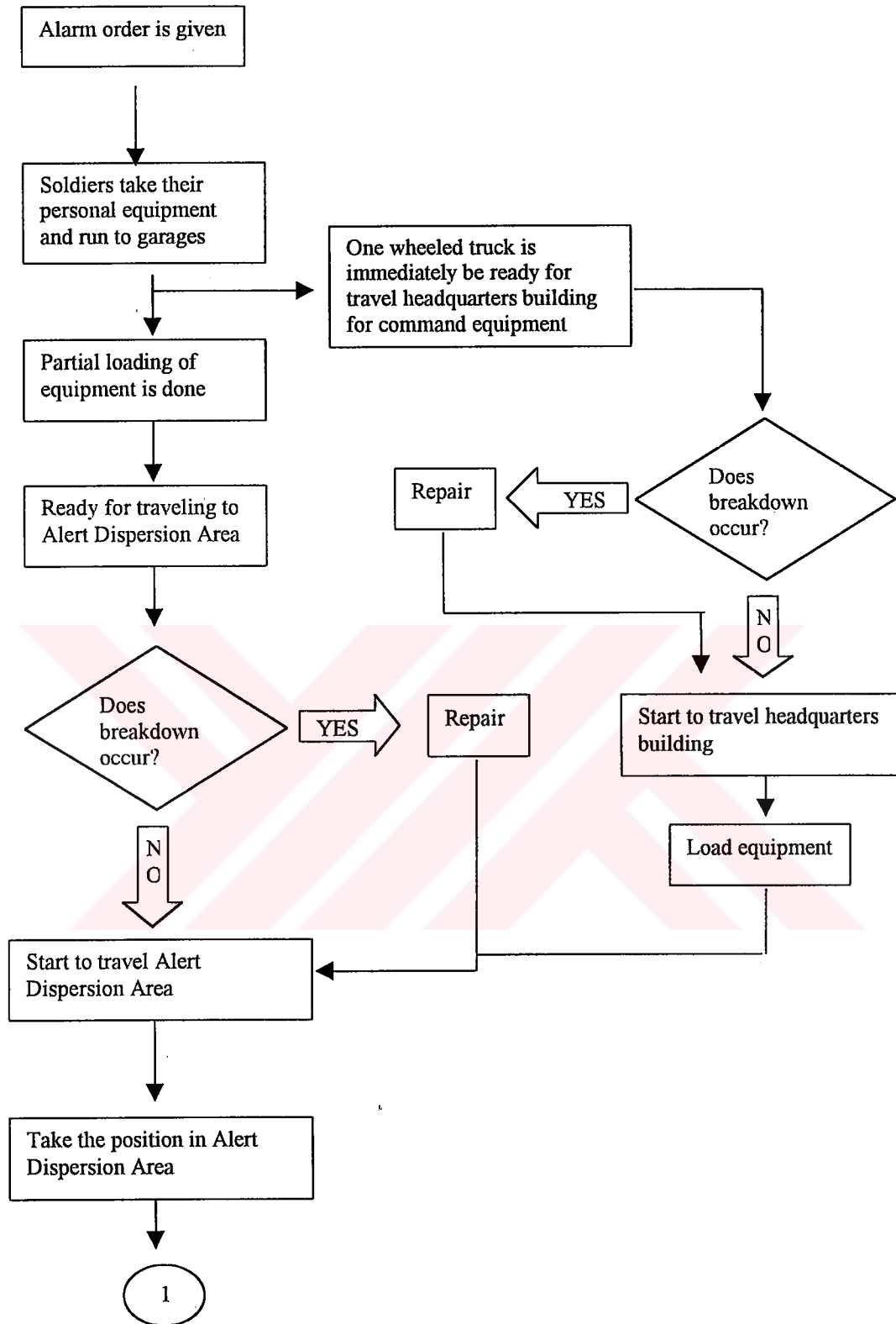


Figure 3.2. Flow chart of Mobilization and Deployment of Armored Battalion (con't)

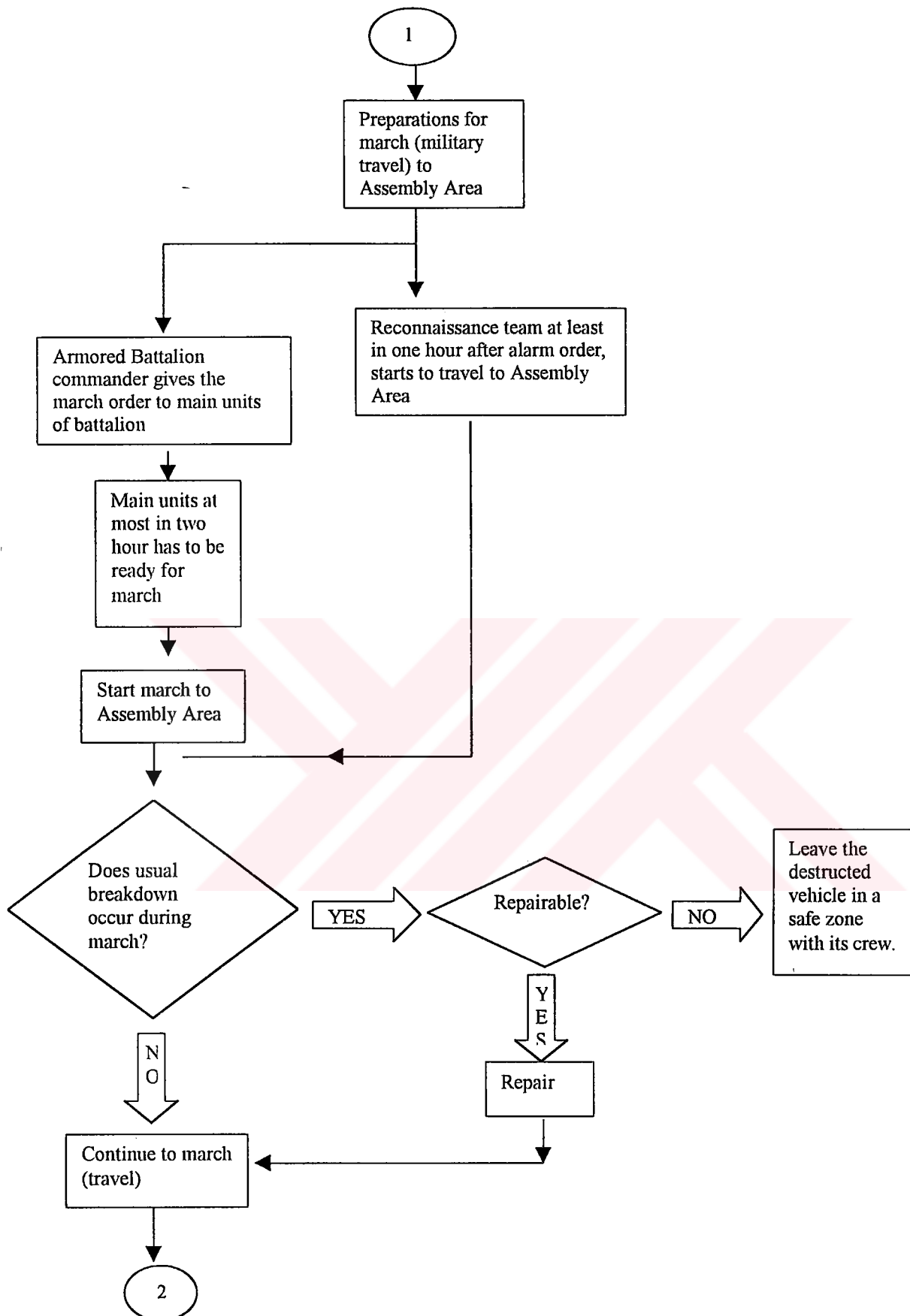


Figure 3.2. Flow chart of Mobilization and Deployment of Armored Battalion (con't)

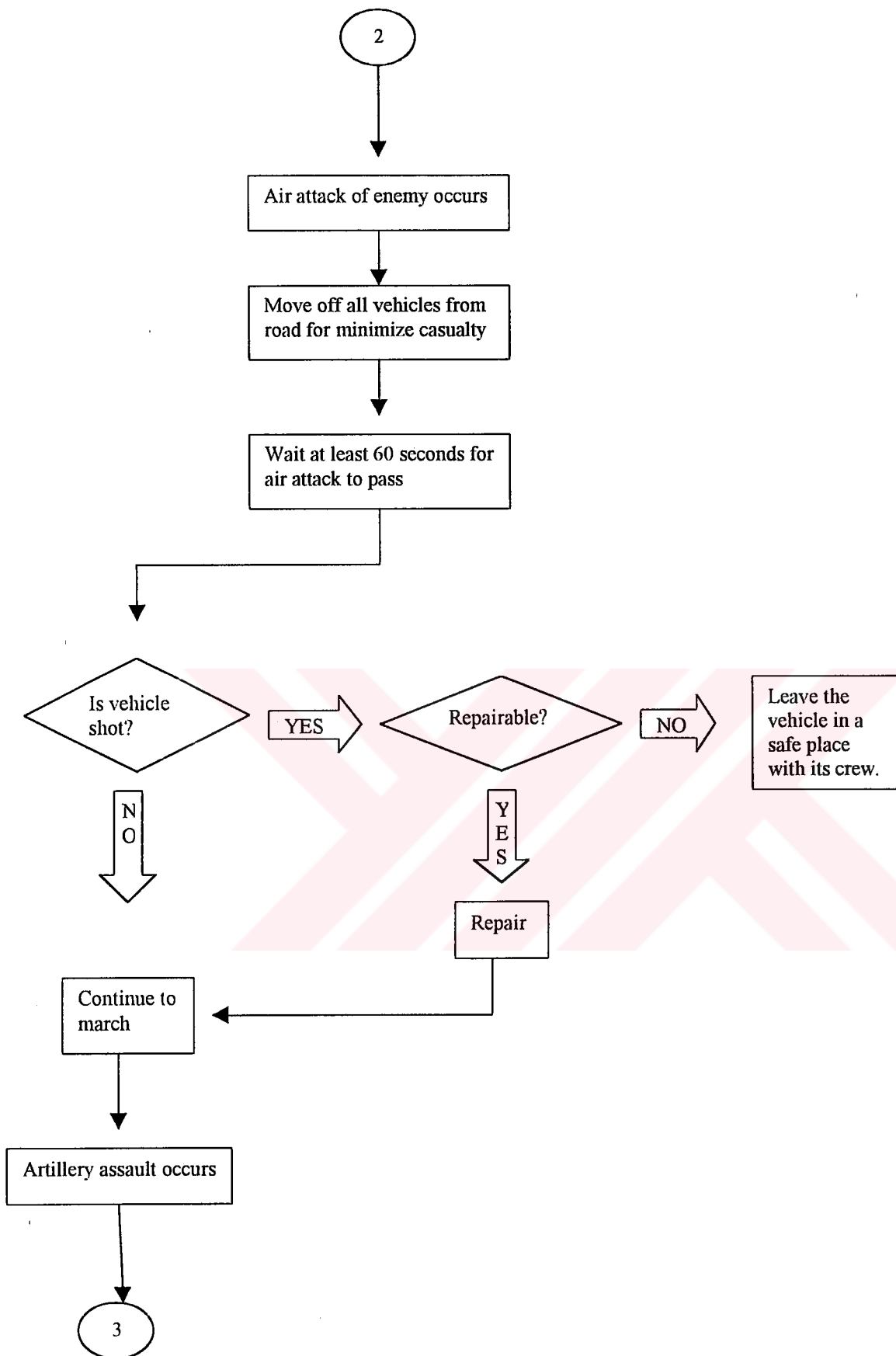


Figure 3.2. Flow chart of Mobilization and Deployment of Armored Battalion (con't)

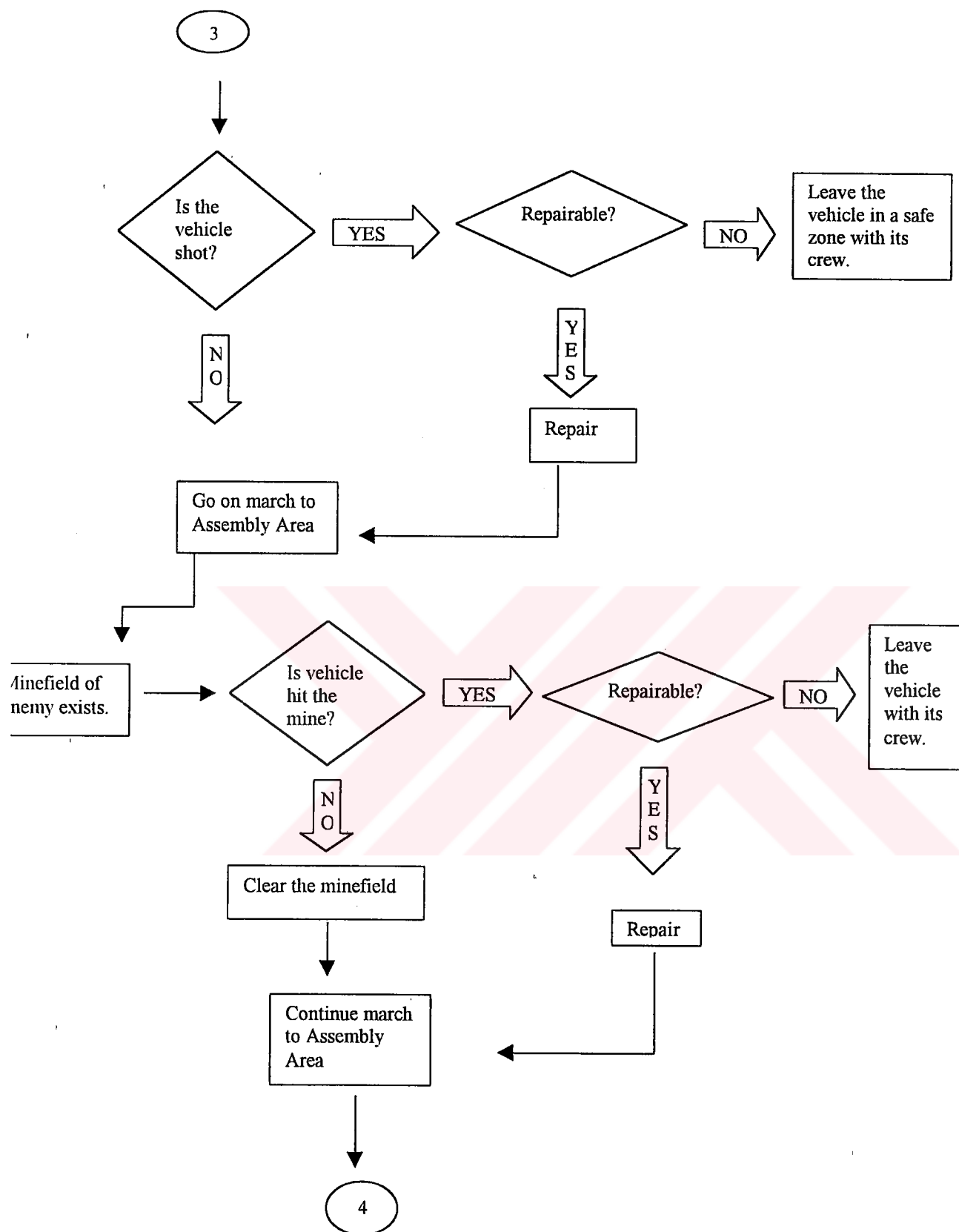


Figure 3.2. Flow chart of Mobilization and Deployment of Armored Battalion (con't)

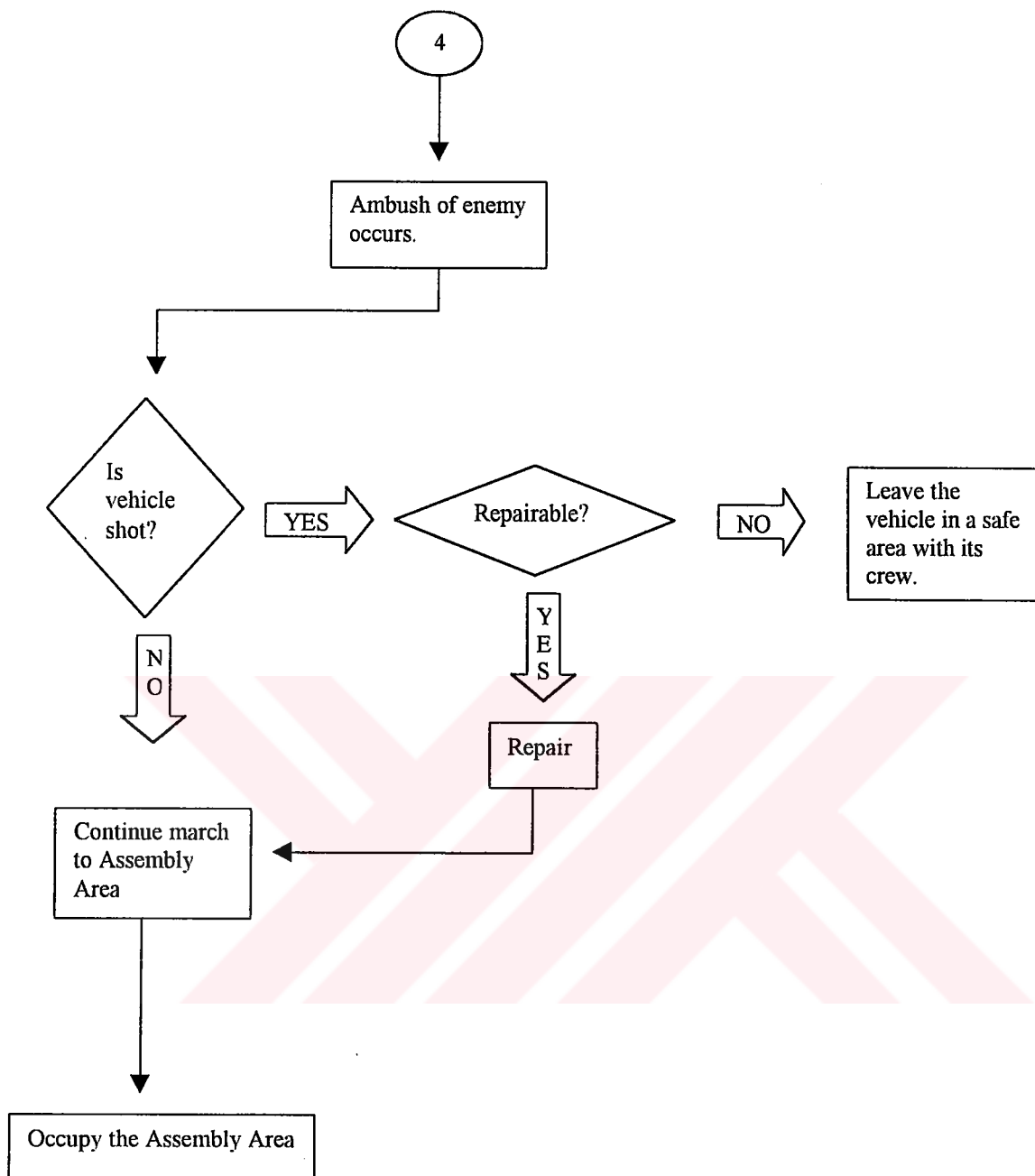


Figure 3.2. Flow chart of Mobilization and Deployment of Armored Battalion (con't)

3.2.3 SIMULATION MODEL (COMPUTER CODE)

Although our simulation model can be described as a combat simulation, we use ARENA software, which is not a combat simulation package. Because we need a detailed evaluation of Mobilization and Deployment Plan. The Mobilization and Deployment Plan include the activities just before the war. In other words, it organizes the combat preparation and alert activities. It is a detailed plan, and every detail is too important because the objective of plan is to prepare the troops for combat as soon as possible after alert. As time so important, to model the details is also important. The currently available combat simulation packages in Turkish Army do not support such kind of detailed modeling. The most available combat simulation package in Turkish Army for our subject is JANUS software. But it is especially used for modeling the combat area activities. The Mobilization and Deployment Plan organizes the combat preparation and alert activities, not the combat. The details that JANUS cannot model are stated below:

- 1) The preparation period which soldiers take their equipment and guns.
- 2) Loading equipment to the lorries.
- 3) The details of modeling the transportation of soldiers and equipment with vehicles.

These activities cannot be modeled with JANUS. Thus, we use ARENA software for modeling The Alert, Mobilization and Deployment Plan of an Armored Battalion in Turkish Army. ARENA software is a flexible and powerful tool that allows modeling all the activities of mobilization and deployment plan of Armored Battalions. It also provides creating animated models and offers reasonably good simulation input and output process. We have only one animated model. The computer codes of model occupy 4.68 MB and one run takes approximately 3 minutes. We give a small part of the code of

our simulation model in Appendix D.

3.3 INPUT DATA ANALYSIS

As our simulation model is a combat simulation model, we face with a lacking of real data problem. To overcome this problem, we use triangular distributions as recommended by Banks (1998). We interviewed with the armored battalion, armored company and the armored team commanders who are the real executers of Mobilization and Deployment Plan to determine the triangular distributions of activities. We also take some of data from the Army Field Manuals that are written according to the combat experiences. We convert these types of raw data into the triangular distributions via consulting the experts. We take hit and kill probabilities of guns, and vulnerability of combat vehicles from the databases of JANUS software. We give the lists of random variables of our simulation model, distribution fuctions, and their parameters in Table 3.3.1-Table 3.3.3.

3.4 MODEL VERIFICATION AND VALIDATION

We perform the Verification and Validation (V&V) techniques stated in the Army Pamphlet 5-11 published by Department of Army (1999) and Balci (1998) for all steps of our simulation model.

3.4.1 VERIFICATION

- “ Verification of a M&S is the process of determining that an M&S accurately represents the developer’s conceptual description and specifications” (Army Pamphlet 5-11, 1999). We applied some of techniques that are stated in Army

Table 3.3.1 Readiness and pull-off times of vehicles

	readiness time after alert order	pull of time of broken vehicle in garage
wheeled-truck	tria (8,10,12)	tria (8,12,16)
armored vehicles	tria (10,12,16)	tria (13,15,17)

Table 3.3.2 Repair times of vehicles

type of damage			
	1	2	3
wheeled trucks			
breakdown	tria(15,20,25)	tria(30,35,40)	tria(45,50,55)
air attack	tria(35,40,45)	tria(40,45,50)	tria(55,60,65)
artillery	tria(25,30,35)	tria(40,45,50)	tria(55,60,65)
minefields	tria(25,30,35)	tria(45,60,75)	tria(70,80,90)
ambush	tria(25,30,35)	tria(40,45,50)	tria(55,60,65)
armored vehicles			
breakdown	tria(15,20,25)	tria(30,35,40)	tria(45,50,55)
air attack	tria(25,30,35)	tria(40,45,50)	tria(55,60,65)
artillery	tria(25,30,35)	tria(40,45,50)	tria(55,60,65)
minefields	tria(25,30,35)	tria(45,60,75)	tria(70,80,90)
ambush	tria(25,30,35)	tria(40,45,50)	tria(55,60,65)

Table 3.3.3 Hit and kill probabilities of guns used in our model

	for wheeled trucks		for armored vehicles	
	hit	kill	hit	kill
30 mm cannon (F-16)	0.1	0.65	0.1	0.55
155 mm cannon	0.08	0.5	0.12	0.35
anti-tank mine	0.02	0.72	0.04	0.27
LAW (ambush gun)	0.04	0.8	0.06	0.55

Pamphlet 5-11 (1999) for verification of our model.

As logical verification:

- **Design Walk-Through:** We perform design walk-through with the Armored Battalion and Company commanders who are the execution experts of Mobilization and Deployment Plan to verify the design of our model.

As code verification:

Sensitivity Analysis: We apply sensitivity analyses to check the algorithms and code to ensure that our model is reacting in expected manner.

- **Code Walk-Through:** We put into practice code walk-through with the simulation men from our department to ensure the efficiency, correctness, consistency and completeness in the implementation.
- **Automated Test Tool:** We use ARENA debugger function as an automated test tool to check whether the activities in Mobilization and Deployment Plan occur properly or not.
- **Unit Checks:** We also put into use unit checks to ensure that the proper units of measure results from equations used in algorithms and code of our model (km/h etc.).
- **Additional Statistics:** We also check the properness of system performance by using additional output statistics that are verifying our performance measures (total time in system etc.).

3.4.2 VALIDATION

“Validation is the rigorous and structured process of determining the extent to which an M&S accurately represents the intended real world phenomena from the perspective of the intended use of M&S” (Army Pamphlet 5-11, 1999).

As procedural approaches:

- **Peer Review:** We realized peer reviews, which are the detailed examination of input data, key parameters and resulting output with the personnel who are knowledgeable about modeling the functional areas represented in our model. For this method, we took the consultancy of the military personnel from I.E. department.
- **Independent Review:** We implemented review with the people independent of our model development for validation of our model.

As technical methods:

- **Face Validation:** We put into service face validation to check if our model seems reasonable to personnel who are knowledgeable about the Mobilization and Deployment Plan of Armored Battalion. For this purpose, we took the consultancy of Armored Battalion and Company commanders that are the executors of plan, staff officers that are the experts of military operation planning. With little modifications towards their comments, we got reasonable and satisfactory result.
- **Animation:** We check the behavior of our system through time by the

animation, especially the movements of vehicles of Armored Battalion. We give a sight from our simulation model in Figure 3.4.2. We also compare the results of our model with the expected values of the probability tree, and observe that the expected values are very close to the outputs.

3.4.2.2 VALIDATION OF MODEL ASSUMPTIONS

We discussed the structural and data assumptions of our model with two Armored Battalion and Company commanders and one staff officer from Turkish Armor School. They found these assumptions reasonable for our objectives. We could not perform statistical validation of output because we do not have actual combat data to compare.

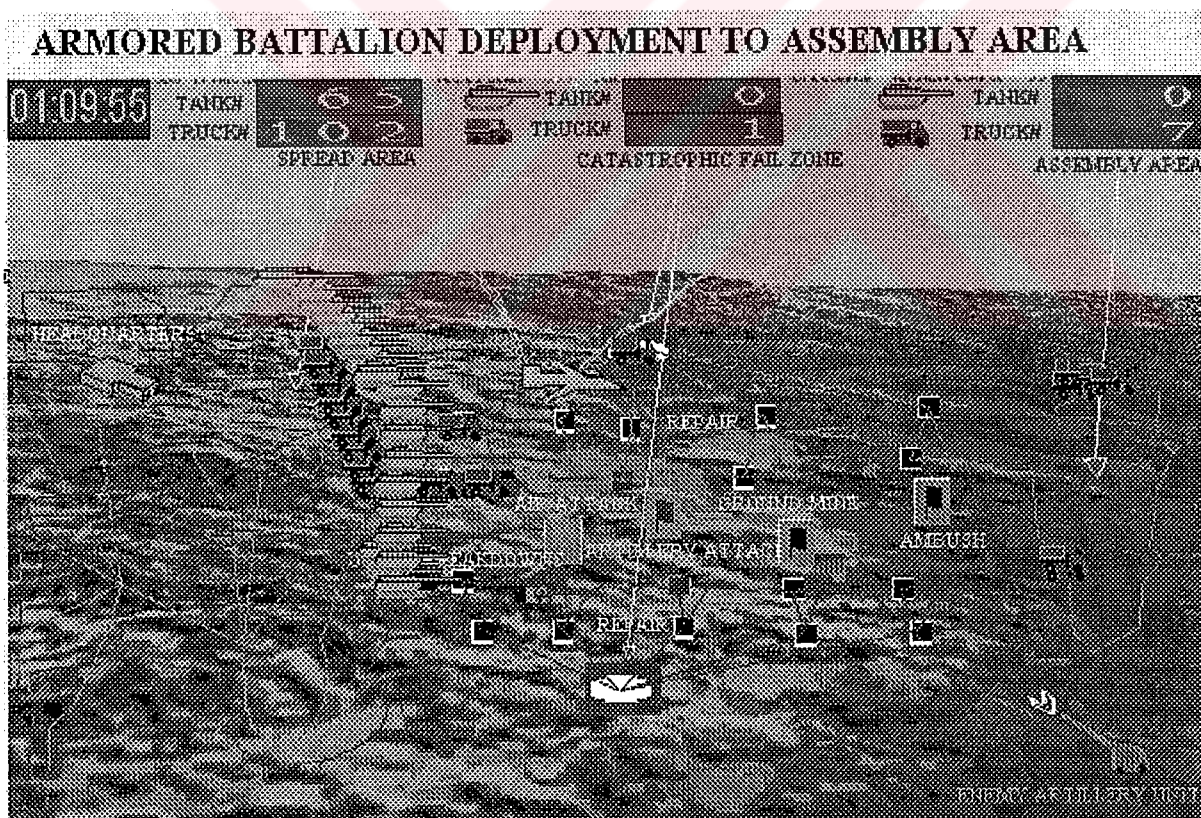


Figure 3.4.2. A sight of our simulation model

CHAPTER 4

DESIGN AND ANALYSIS OF EXPERIMENTS

Experiments are carried out by investors in all fields of science either to discover something about a particular process or to compare the effect of several factors on some phenomena (Montgomery, 1984). For this part of our study, we look for the answers of questions:

- After alert order, can whole battalion reach to Alert Dispersion Area in *30 minutes* in daytime, *45 minutes* at night?
- After alert order, can reconnaissance force at most in *one hour*, main force in *two hours* be ready for moving to the Assembly Area?
- Where does the bottleneck occur in the system?
- Is the existing plan efficient?
- How do air attack, artillery assault, mine fields and ambush of enemy affect the system performance?

We run our simulation model and construct one-sided confidence intervals to check whether the Mobilization and Deployment Plan satisfies the specifications stated in the first and second questions. After constructing the confidence intervals, we see that the existing system meets all the necessary measures. We discuss this procedure in detail in Section 4.2. To answer the fourth and fifth questions, we just run the simulation model and check whether the Mobilization and Deployment Plan satisfies the specifications. We encounter bottlenecks in the repair units of Armored Battalion, because of the longer waiting queues in front of them. By the sensitivity analysis, we find the optimal number of repair units for the Armored Battalion. We also implement 2^k factorial design for five

factors which are breakdowns of vehicles, air attack, artillery attack, mine fields and ambushes of enemy to find out an answer for the last question. The factors and their levels are presented in Table 4.1. Our aim is to discover the effects and interactions of these five factors on system response. Our performance measures are maximum time in system (time in system of last vehicle reaching Assembly Area), number of damaged vehicles, and number of totally destructed vehicles. As we have five factors, we have 32 design points. To satisfy the normality assumption, we make twenty replications for each design point. Because the maximum time in system measure is one of our performance measures, we should take more replications to satisfy normality. We conduct experiments for each design point with the 20 replications and calculate the effect of each factor and their interactions with each other. We implement analysis of variance (ANOVA) to find out which factor or factors have a significant effect on system performance and by effect diagrams we explain the main effects and interactions of factors. We also check normality of data by normal probability plots of residuals and the homogeneity of variances with scatter diagrams and Bartlett's test, in Section 4.1.1 and Section 4.1.2 respectively. To ensure the independence, we assign different random number generator for each random activity in our simulation model.

We give a name to each design point; names and the roles of factors for each design point are stated in Table 4 in Appendix B. The expressions "run xyz" in result tables means the replication that the factors x, y and z are at highest levels whereas the others are at lowest levels. Our performance measures are maximum time in system (time in system of last vehicle reaching Assembly Area), number of damaged vehicles, and number of totally destructed vehicles and we have five factors, we implement the procedure below for each performance measure.

Table 4.1. The factor names and levels

	factor description	Lower level (occurrence probability)	Upper level (occurrence probability)
1	breakdown	0.01	0.06
2	air attack	0	1
3	artillery attack	0	1
4	minefield	0	1
5	ambush	0	1

4.1. CONFIRMATION OF DATA ASSUMPTIONS

Throughout this chapter we assume that (1) data is independent, (2) variances are homogeny, and (3) the usual normality assumptions are satisfied. To reach correct results, we need to ensure that all the three assumptions hold for our data. For data independency, we assign different random number generators for each random event. We check the normality assumption in Section 4.1.1, homogeneity of variances assumption in Section 4.1.2.

4.1.1 NORMALITY OF DATA

To ensure the normality of data for three performance measures that we use in experimental design, we compute the residuals and draw the normal probability plots of residuals. As all the residual plots in Figure 4.1.1.1 - Figure 4.1.1.3 lie reasonably close to a straight line; we can say that the data of three performance measures are normally distributed.

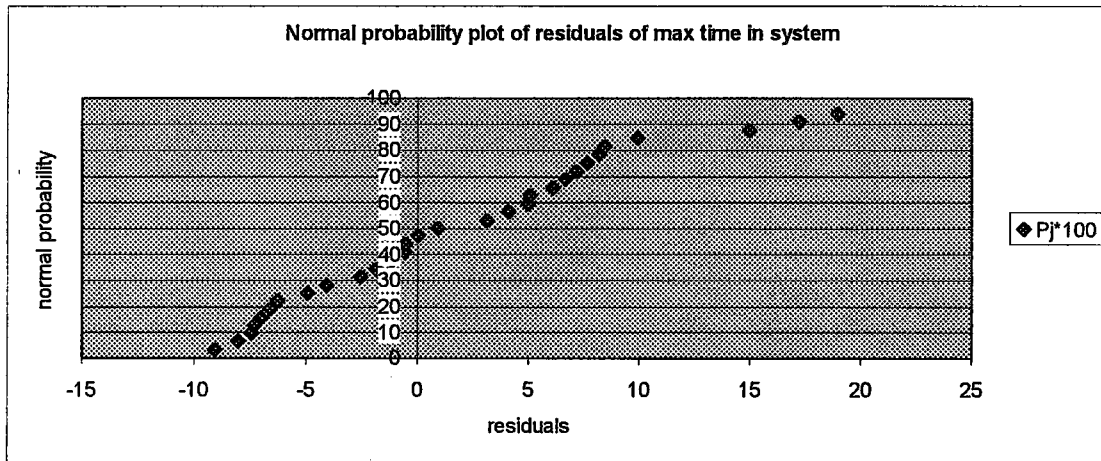


Figure 4.1.1.1 Normal probability plot of residuals of maximum time in system

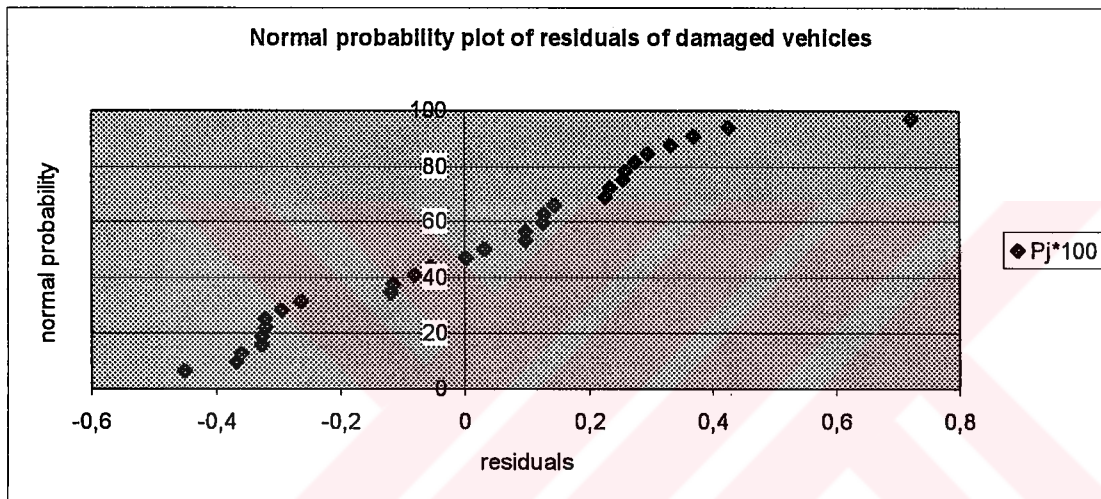


Figure 4.1.1.2 Normal probability plot of residuals of number of damaged vehicles

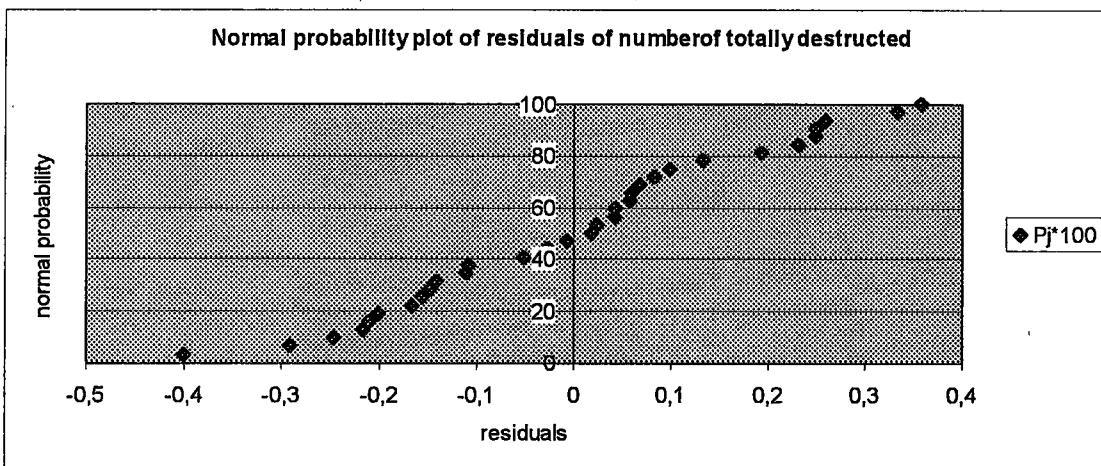


Figure 4.1.1.3 Normal probability plot of residuals of number of totally destroyed Vehicles

4.1.2 DEPARTURES FROM THE ASSUMPTIONS IN ANALYSIS OF VARIANCES

The assumptions of homogeneity of variances may cause serious problems in ANOVA test if it does not satisfied. To check the homogeneity of variances, we draw scatter diagrams of variances of three performance measures. There is no evidence of correlation of variances in scatter diagrams (Figure 4.1.2.1-4.1.2.3), to be sure the homogeneity, we also implement Bartlett's test. Bartlett's tests give that the variances of three performance measures are homogeneity. The test results are given in Table 4.1.1. Thus, we can conclude that the homogeneity assumption of variances holds for our data.

Table 4.1.1 Bartlett's test results for variance homogeneity

	time in system	# of broken vehicles	# of totally destructed
grand variance	4134.68	12.91	2.1
q	11.71	18.92	14.8
c	1.02	1.02	1.0
Xo*Xo	26.5	42.79	33.6
chi square(0.05, 31)	44.97	44.97	44.9
test result	pass	pass	pass

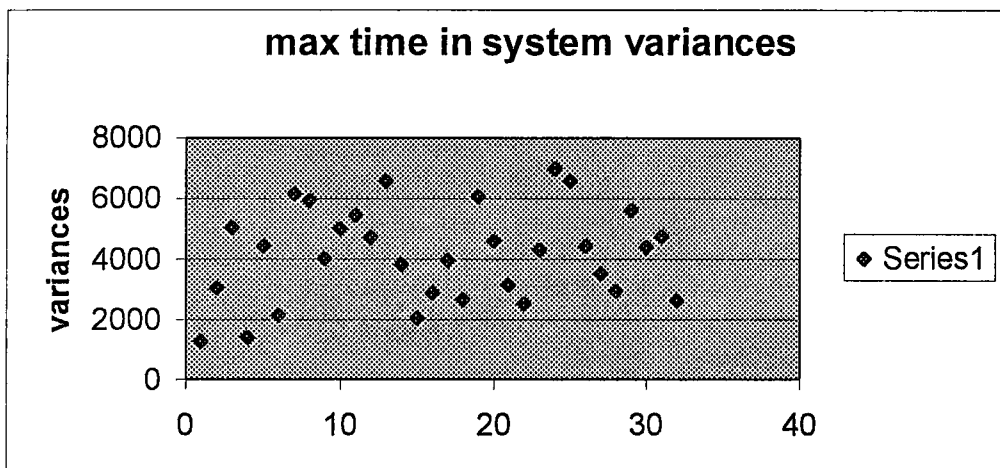


Figure 4.1.2.1 Scatter diagram of variances of maximum time in system measure

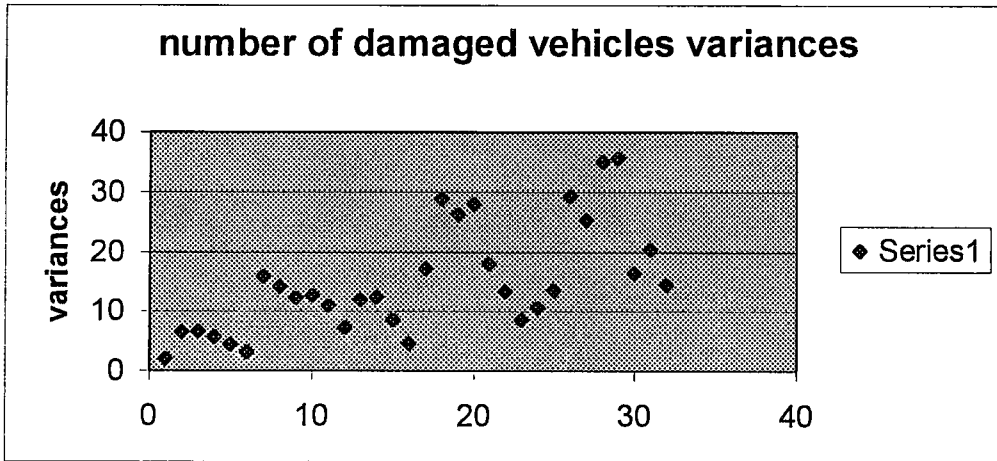


Figure 4.1.2.2 Scatter diagram of variances of number of damaged vehicles measure

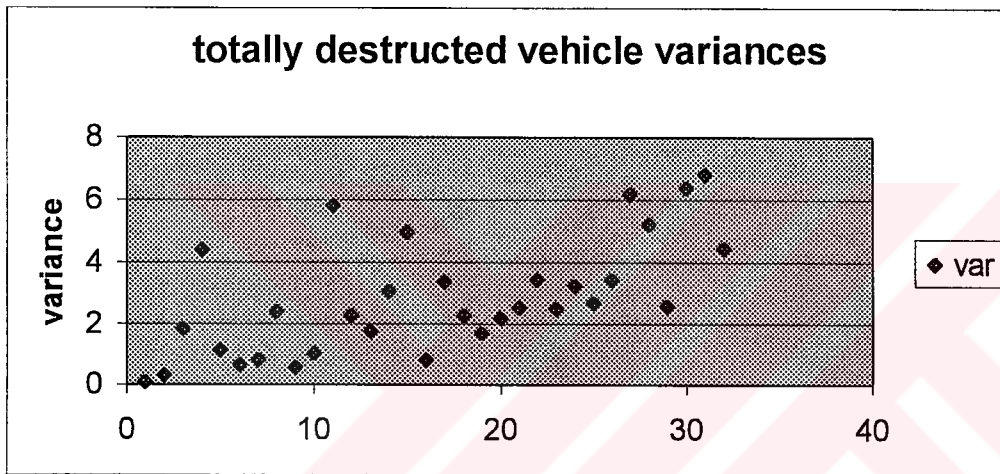


Figure 4.1.2.3 Scatter diagram of variances of number of totally destructed vehicles measure

4.2 EFFICIENCY CHECK OF MOBILIZATION AND DEPLOYMENT PLAN

For the efficiency of the Mobilization and Deployment Plan, we check whether any bottleneck occurs during the execution of the Mobilization and Deployment Plan and whether the Armored Battalion satisfies the Turkish Army time standards or not. For the bottleneck checking, we implement sensitivity analysis. For the control of the time specifications, we construct confidence intervals.

4.2.1 TEST WHETHER THE MOBILIZATION AND DEPLOYMENT PLAN MEETS TIME SPECIFICATIONS

There are some time specifications that a Turkish Armored Battalion has to obey while executing the Mobilization and Deployment Plan. First one that we will check is that whole battalion has to reach Alert Dispersion Area in *30 minutes* in daytime, *45 minutes* at night. Second one is that reconnaissance force at most in *one hour*; main force in *two hours* has to be ready for moving to the Assembly Area. In this section, we check whether these specifications are satisfied or not, by constructing one-sided confidence intervals with 0.95 confidence level. Confidence intervals are one-sided because we only have an upper time limit to compare for these activities. We run our model for 20 replications; compute averages, variances and confidence intervals. The results are given in Table 4.2.1.

Table 4.2.1 Results and one-sided confidence intervals for time specifications

	time of last vehicle reaching Alert Dispersion Area		readiness time for movement
	daytime	night	
average	26.8	37.84	53.51
variance	6.067	5.94	8.35
confidence interval	29.13	40.12	56.71
standard	30	45	60/120

As seen in Table 4.2.1, the confidence intervals reveal that an Armored Battalion can complete the traveling from garages to the Alert Dispersion Area under the time standards 30 minutes at daytime, 45 minutes at night. It also gets ready for traveling to Assembly Area in 53.51 minutes with both reconnaissance and main forces that means it satisfies the time specifications 60 minutes for reconnaissance force, 120 minutes for the

main force. Thus, the existing system satisfies all necessary time standards of Turkish Army.

4.2.2 BOTTLENECK ANALYSIS

During the experiments, we observe that there occur sudden queues in front of the repair units of breakdown of vehicle, air attack, artillery attack, minefield and ambush. In our model, we assume that the armored battalion has 5 repair units. We conduct sensitivity analysis by changing the number of repair units to find out the optimum number of repair unit for the armored battalion. We conduct these experiments when all the occurrence probabilities of five factors are 1 (worst case), and observe that the last vehicle arrives the Assembly Area in 361 minutes when there are 5 repair units. As a result of sensitivity analysis, we see that the maximum time in system statistic does not change for the 11 and more repair units. Then we can conclude that 11 repair units are the optimal quantity for the Armored Battalion. For 14 repair units, the maximum time in system statistic is 216 minutes. Increasing the number of repair units from 5 to 11 provides a %40 decrease in maximum time in system statistic. The behavior of the maximum time in system statistic depending on the number of repair units is given in Figure 4.2.2.

Thus, as results of Section 4.2.1 and Section 4.2.2, we can conclude that except the bottleneck in repair units existing Mobilization and Deployment Plan of a Turkish Armored Battalion is efficient. The bottleneck can be fixed by increasing the number of repair units 11 for the armored battalion. But this number is computed when the armored battalion is exposed to worst enemy threat and the highest vehicle breakdown rate which means enemy makes air attack, artillery attack, position minefield, lay an ambush and breakdown rate of vehicle is at highest level during the march to Assembly Area.

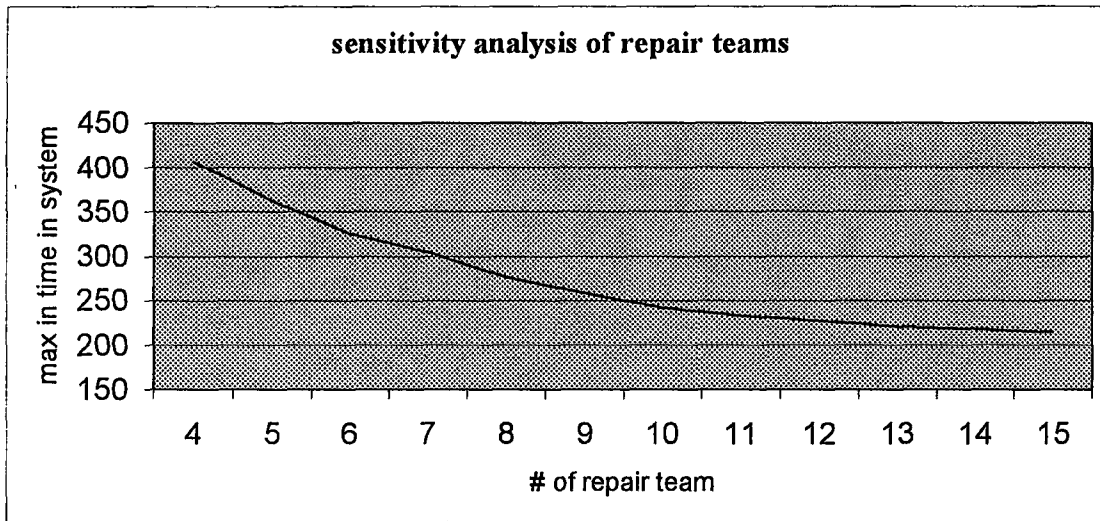


Figure 4.2.2. Sensitivity analysis of repair teams

4.3 2^5 FACTORIAL DESIGN FOR MAXIMUM TIME IN SYSTEM MEASURE

Maximum time in system measure is very important for the Turkish Army because this measure gives us the time that all the parts of battalion except the totally destructed ones reach the target and be ready for the further military operations. Because of that reason, we choose maximum time in system measure as one of our performance measure. We conduct the thirty-two experiments with twenty replications and give the results of these replications, with their averages and variances for every design point in Table 4.3.1- Table 4.3.4 in Appendix B. We compute the effects at every design point according to the procedure in Montgomery's book (1984) and give the results in Table 4.3.5 in Appendix B.

To be able to give a statistical explanation, we implement analysis of variances (ANOVA) procedure. By ANOVA, we can state which factors have a significant effect on maximum time in measure. During the implementation of ANOVA, we compute contrasts and variances of design points and use the F- test to find out which factor has

significant effect on system response. The analysis of variances is also summarized in Table 4.3.5 in Appendix B. We have eight main significant factors and interactions on maximum time in system measure. The main significant factors are breakdowns of vehicles (65.68 min.), air attack (71.91 min.), minefields (12.99 min.) and ambushes (17.3 min.) of enemy as factors, and they all have positive effects. Air attack has the most positive greatest effect on this performance measure. As seen only artillery attack does not have a significant effect because its totally destruction rate is very high. Most of the vehicles affected by artillery attack is totally destructed and does not cause a delay in maximum time in measure because the totally destructed vehicles are left in a safe place without repair. The significant interactions are breakdown- air attack (-28.21 min.), breakdown- mine fields (-12.62 min.), breakdown-ambush (-13.2 min.) and air attack-artillery attack (-11.62 min.). All the significant interactions have negative effects on maximum time in measure. We explain the significant factors and interactions in Section 4.3.1 via effect diagrams.

4.3.1 INTERPRETATION OF MAIN EFFECTS AND INTERACTIONS

We analyze these significant main effects and interactions by using effect diagrams below. We only give the effect diagrams of significant factors and interactions. We first discuss the effects of main factors. We draw all the significant main effects on a single figure to compare and also give the minimum and maximum values of each effect inside the figure. As seen in Figure 4.3.1.1, the dotted lines of factors breakdowns of vehicles and air attack of enemy have steeper increase than the lines of other factors, because number of broken vehicles and number of damaged vehicles by air attack in average are 10.15 and 7.35 vehicles at maximum levels of these two factors respectively.

Repairing them takes much time and this causes maximum time in system measure to increase.

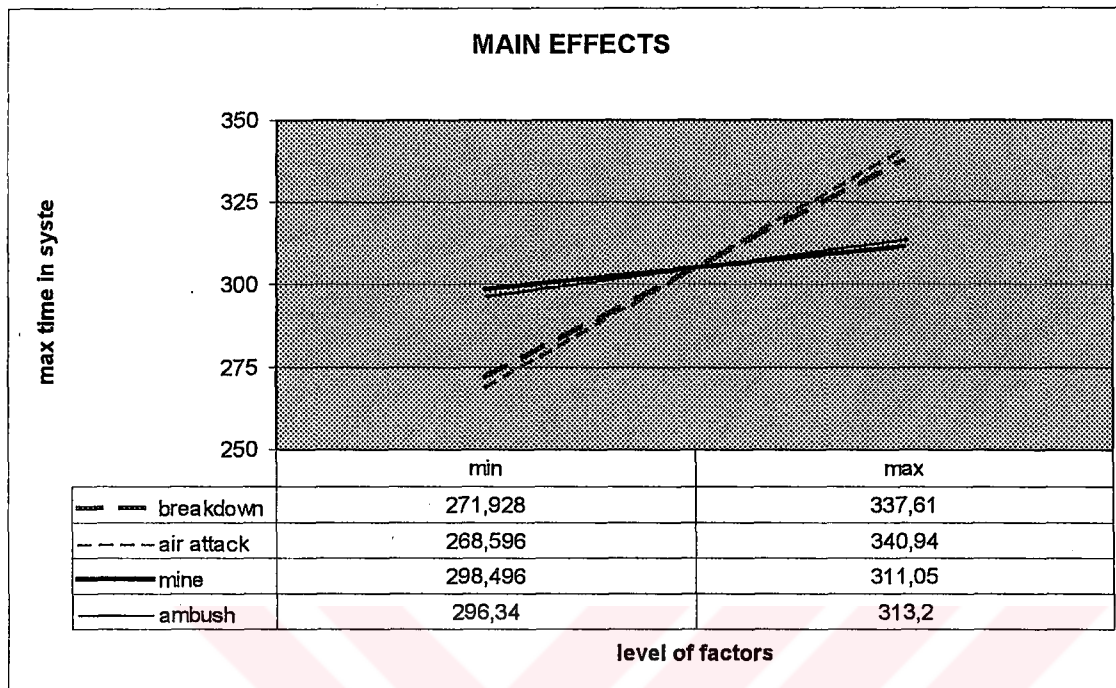


Figure 4.3.1.1 Main effect diagram of significant factors

Although average number of damaged vehicles by air attack is smaller than the average number of broken vehicles, the line of air attack of enemy is steeper. Because the mean of repairing time of a vehicle, which is damaged in air attack, is larger than the mean of repairing time of broken vehicle. The factors mine fields and ambushes of enemy cause less increase on maximum time in measure. Because number of damaged vehicles by mine fields and the number of damaged vehicles by ambushes of enemy in average are 4.15 and 6.4 vehicles. These values are smaller than the values of air attack and breakdowns. And also the totally destruction rate of ambushes and mine fields are very high. When a vehicle is totally destructured, it is left in a safe area, and this does not cause any time loss. Because of lower number of damaged vehicles and higher number

of totally destructed vehicles, lines (permanent) of number of damaged vehicles by mine fields and the number of damaged vehicles by ambushes have less steep increase.

We also look at the interactions between the factors. We start with the breakdown-air attack interaction given in Figure 4.3.1.2. The permanent line shows the change in time in system measure while breakdown probability is at lowest level 0.01 and air attack probability is shifting from 0 to 1. The dotted line shows the change in time in system measure while breakdown probability is at highest level 0.06 and air attack probability is shifting from 0 to 1. As seen in the figure, there is a steeper increase in time in system measure when the breakdown probability is at low level. Because when the breakdown probability is at high level, in average approximately 10 vehicles are blocked in breakdown station for repair. When air attack occurs, all vehicles in convoy are affected at the same time. This causes a sudden queue at that time in front of the air attack repair unit. If the breakdown probability is at high level, more vehicles will be allocated in breakdown station for repair. Less vehicles will be damaged in air attack station at that time, so repair queue will be shorter, which means shorter waiting time in queue and also less steeper increase in maximum time in measure.

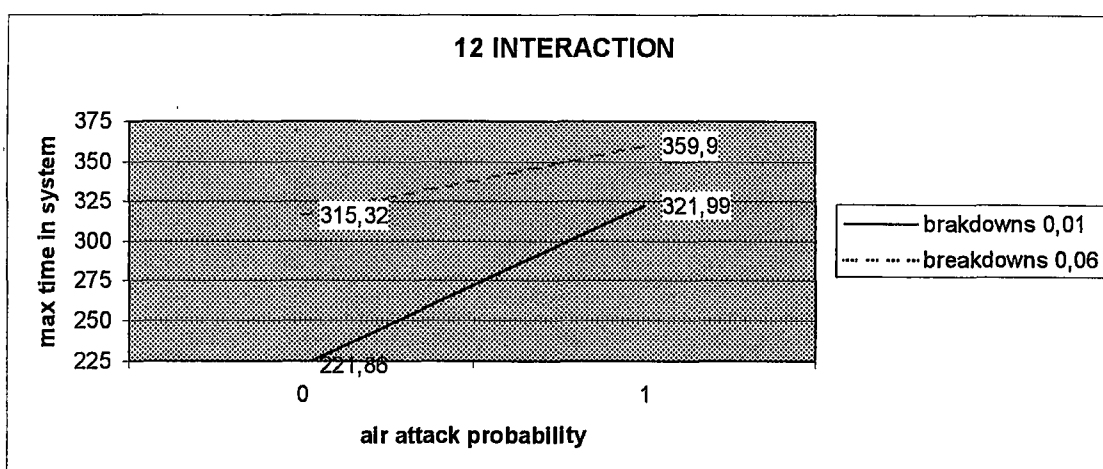


Figure 4.3.1.2 Interaction between breakdown of vehicles and air attack of enemy

The interaction between breakdown and mine fields is given graphically in Figure 4.3.1.3. Again, the dotted line represent the behavior of maximum time in system measure while mine existing probability shifting from probability 0 to 1 and breakdown probability is constant at highest level. The continuous line shows the same relation while breakdown probability is constant at lowest level. The same reasoning explained in former interaction for the less steeper increase in dotted line is also valid for this case. In addition, when we compare the interaction of breakdown and air attack with the interaction of breakdown and minefield, we see that the increase in maximum time in measure for former interaction is steeper than the other when the breakdown probability is at high level. Because in our model, the time between occurrence of breakdowns and air attack is shorter than the time between breakdowns and mine fields. As the time between breakdown and air attack area is shorter, the queue length of air attack repair queue will be longer than the queue length of minefield repair queue, because longer time between occurrences means meeting with less vehicles in repair queue of reached station. This naturally decreases waiting time in queue and causes less steep increase.

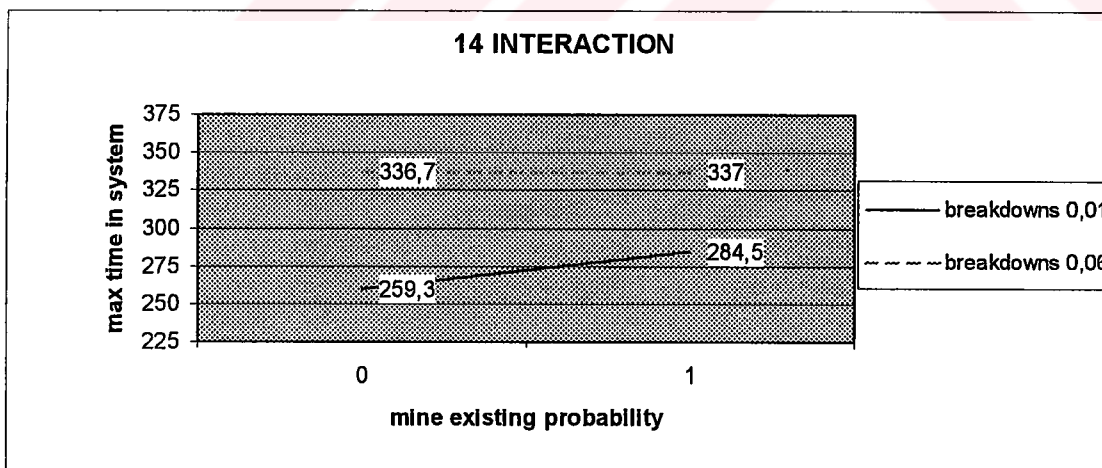


Figure 4.3.1.3 Interaction between the breakdown of vehicles and minefield of enemy

We give the effect diagram of breakdown-ambush interaction in Figure 4.3.1.4.

The interaction between breakdown and ambush of enemy is similar with the breakdown-minefield interaction. Thus, the previous comments and explanations that we make in former case are also valid for this case.

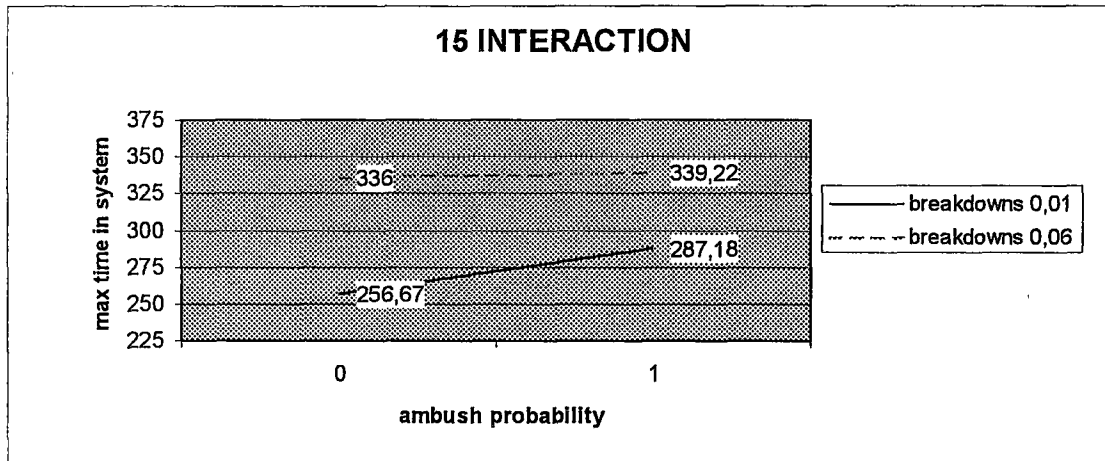


Figure 4.3.1.4 Interaction between the breakdown of vehicles and ambush of enemy

As last significant interaction, air attack-ambush interaction is given in Figure 4.3.1.5. The dotted line shows the change in time in system measure while air attack

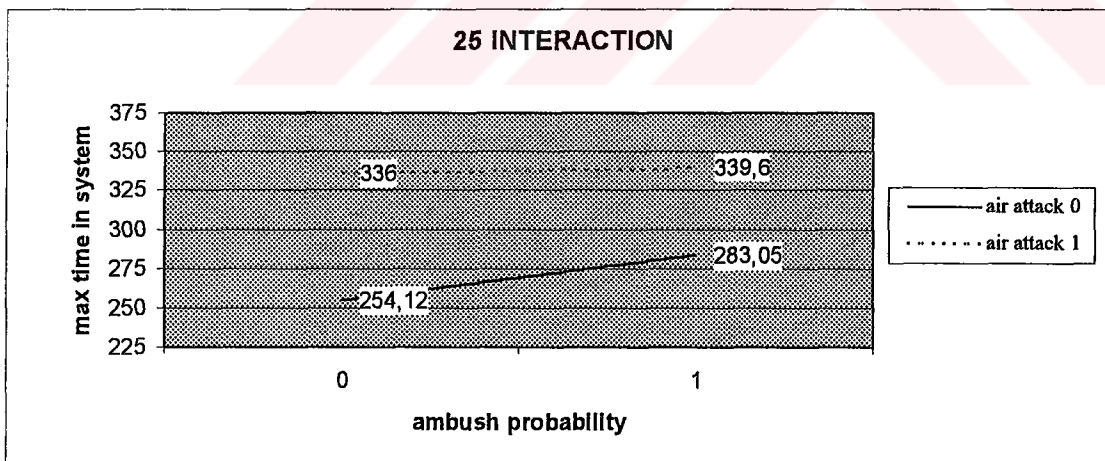


Figure 4.3.1.5. Interaction between air attack and ambush of enemy
probability is at highest level 1 and ambush probability is shifting from 0 to 1. The continuous line represents the behavior when air attack probability is lowest level. We

can say that air attack-ambush interaction resembles the behaviors of the interactions that we explain above. So the interpretations that we make for two former cases are also suitable for air attack-ambush interaction.

4.4 2⁵ FACTORIAL DESIGN FOR NUMBER OF DAMAGED VEHICLES MEASURE

We also collect the number of damaged vehicles measure because it gives the critical damage information about the attacks of enemy and about the breakdown of vehicles. The measure in that category also includes the totally destructed vehicles measure. This measure is also directly related with the maximum time in system measure, there is a positive correlation between them. An increase in the number of damaged vehicles measure causes increase in the maximum time in system measure. Thus, this relation can be useful for the interpretations of some results that we obtain for the maximum time in system measure. By that type of information, commanders can obtain ideas about the enemy attacks and breakdown of vehicle, and can take necessary measures to minimize the damage. We conduct the thirty-two experiments with twenty replications for the number of damaged vehicles measure and give the results of these replications, with their averages and variances for every design point in Table 4.4.1-Table 4.4.4 in Appendix B. We compute the effects of factors and to be able to reach a conclusion about the significant effects, we apply ANOVA procedure. We present the effects and results of ANOVA in Table 4.4.5 in Appendix B.

We have five significant factors and no interactions for number of damaged vehicles measure. All the factors have significant main effects. The significant factors are breakdowns of vehicles, air attack, artillery attack; mine fields and ambushes of

enemy and their effects are 8.615, 7.765, 6.997, 2.728 and 4.959 damaged vehicles respectively. Breakdown of vehicles has the greatest effect on this performance measure. To lessen the effect of this factor, the Armored Battalion Commanders should focus on the maintenance activities of vehicles. We give details of significant factors in Section 4.4.1.

4.4.1 INTERPRETATION OF MAIN EFFECTS

For the number of damaged vehicles measure all five factors have positive significant main effects, but there is no significant interaction. To be able to compare the effects of factors on the number of damaged vehicles measure, we draw all the effects on a single graph. The values of number of damaged vehicles are given at both minimum and maximum levels of factors in Figure 4.4.1.1. As seen the dotted thin line belonging to

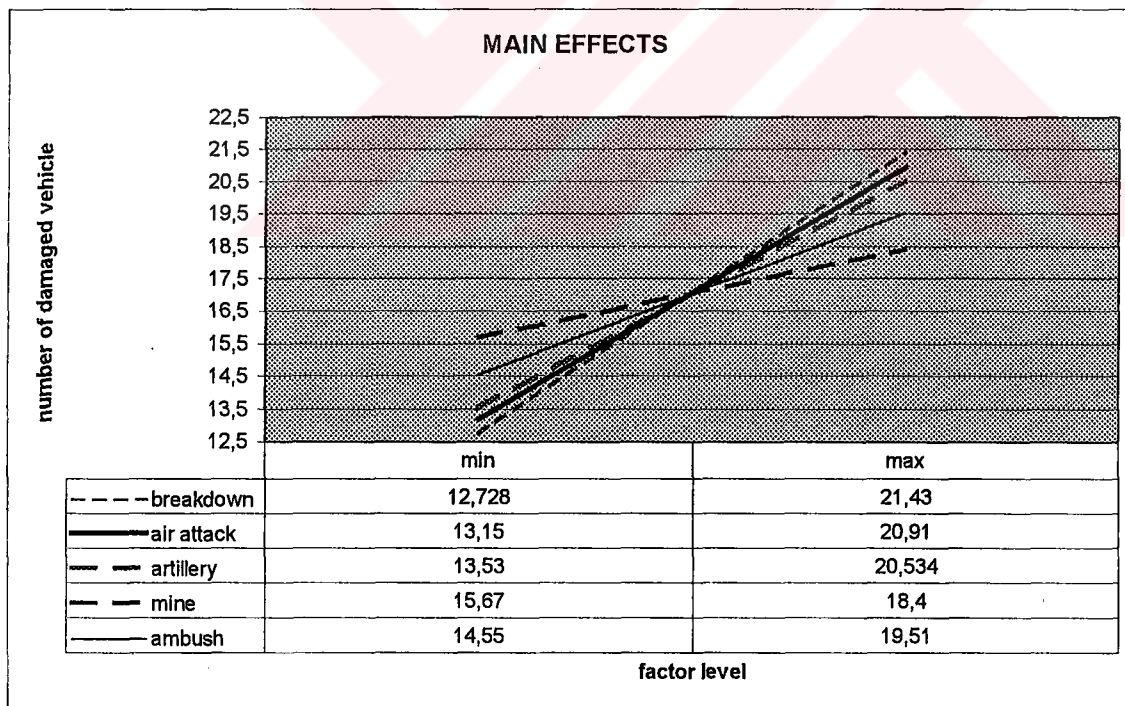


Figure 4.4.1.1. Main effect of diagram of significant factors

factor breakdown shows steepest increase for number of damaged vehicles measure whereas the minefield line (thick dotted) represents the smoothest increase. The reason for smallest effect for mine fields is that when any vehicles hit the mines all vehicles stop and soldiers began to mine clearing activity. After clearing they begin to travel. Thus that few vehicles hit the mines and damaged.

4.5. 2⁵ FACTORIAL DESIGN FOR NUMBER OF TOTALLY DESTROYED VEHICLES MEASURE

The number of damaged vehicle measure provides battalion commander to be aware of his military units that have ability to fight, by presenting the number of totally destroyed units. For that reason, it is an important measure that may change the faith of war. It also gives information about the total destruction rate of enemy attack and breakdown of vehicles. We implement the same experimental design procedure that we mention at the beginning of Chapter 4 for this performance measure. We conduct the thirty-two experiments with twenty replications for the number of totally destroyed vehicles measure and give the results of these replications, with their averages and variances for every design point in Table 4.5.1 - Table 4.5.4 in Appendix B. The effects of factors and results of ANOVA are given in Table 4.5.5 in Appendix B. We observe that air attack, artillery attack, minefield and ambush of enemy have positive significant main effects and there is no significant interaction between factors. The effects of significant factors air attack, artillery attack, minefield and ambush of enemy are 1.234, 4.19, 0.959, 0.99 totally destroyed vehicles, respectively. The effect of artillery attack is the greatest because the total destruction rate of artillery guns for vehicles are very higher from others. The other three significant factors have approximately one totally

destroyed vehicle. The main factor breakdown (0.128 totally destroyed vehicles) has no significant effect on number of totally destroyed vehicles measure, which is logical because the totally destruction rate of breakdown is too low. We give detailed explanation of the significant factors via the effect diagram in Section 4.5.1.

4.5.1 INTERPRETATION OF MAIN EFFECTS

We will give details of the significant factors by the help of a single effect diagram in Figure 4.5.1.1. The factors (permanent lines) air attack, minefields and ambush of enemy has similar and smoother effect on number of totally destroyed vehicles measure whereas the factor artillery attack (the thick dotted line) has the greatest

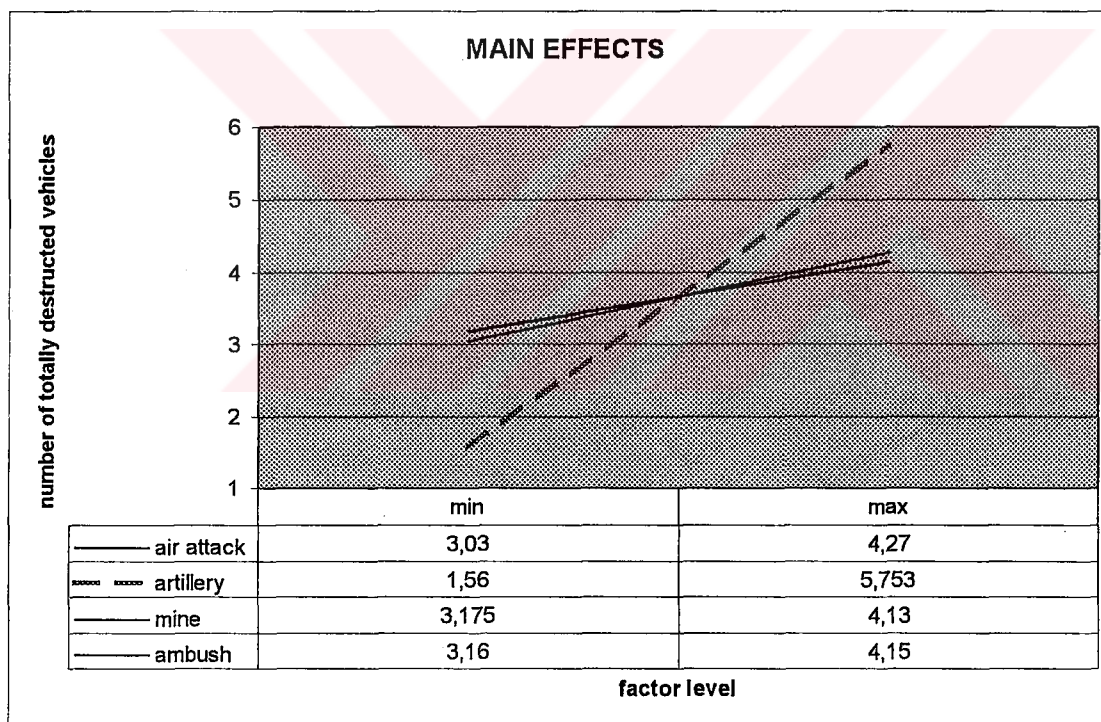


Figure 4.5.1.1. Main effect diagram of significant factors

and keen effect on this performance measure, because the total destruction rate of artillery guns is highest. So we can conclude that as the artillery guns (155mm cannon)

has the greatest effect in this performance measure, the necessary precautions against the artillery attacks of enemy should be taken to minimize the number of totally destructed vehicles.

4.6. CONCLUSIONS

As a summary of the results that we have obtained from Chapter 4 is below:

- We observe that the Armored Battalion executing the existing Mobilization and Deployment Plan satisfies all the time standards determined by Turkish Army. As a result of experiments, we detect that the Mobilization and Deployment Plan has a bottleneck in repair units. By sensitivity analysis, we find out that 11 repair units are the optimal quantity for the Armored Battalion under the worst conditions.
- For the performance measure maximum time in system measure, there are four significant main effects and four significant interactions. The main effects are breakdowns, air attack, minefield and ambush of enemy. The most significant main effect is air attack of enemy and breakdown of vehicles follows it. The significant interactions are breakdown of vehicles - air attack, breakdown - mine fields, breakdown - ambush and air attack - ambush. The interaction with the most negative effect is breakdowns - air attack interaction. The main effects have positive whereas interactions have negative effect on maximum time in measure.
- For the performance measure number of damaged vehicles by breakdowns, air attack, artillery attack, mine fields and ambush of enemy, there are five main effects and no interaction among factors. The main effects are breakdowns, air attack, artillery attack, minefield and ambush of enemy. The most significant main effect is breakdown of vehicles and air attack of enemy follows it. All these factors have

positive effect on number of damaged vehicles measure.

- For the performance measure number of totally destructed vehicles by breakdowns, air attack, artillery attack, mine fields and ambush of enemy, there are four main effects and no interaction among factors. The main effects are air attack, artillery attack, minefield and ambush of enemy. The most significant main effect is artillery assault of enemy and air attack of enemy follows it. All these factors have positive effect on number of damaged vehicles measure.
- In Chapter 4, we get general information about the attacks of enemy and breakdown of vehicles for three different performance measures. This broad-spectrum information can be evaluated in two ways. First one is using it for planning of national defense by focusing on the necessary measures against the strongest factors. The other one is usage of information for planning of military operations by the Armored Battalion commanders. The significant factors are different for each performance measure. For an Armored Battalion commander, the importance of performance measures is changeable according to the type of military operation. If the operation is an ambush-type operation, time is more important. If the operation is a defense-type operation, then the number of totally destructed vehicles measure arises as the most important statistic. So commanders may use the proper information for his battalion to plan the military operations and take necessary precautions against the significant factors. We give the summary table of significant factors and interactions in Table 4.6.1.

Table 4.6.1. Summary table of significant factors and interactions

factors	maximum time in system(min.)	number damaged vehicles	number of totally destruced vehicles
breakdown	65.68	8.61	----
air attack	71.91	7.76	1.23
artillery attack	----	6.99	4.19
minefield	12.99	2.72	0.95
ambush	17.3	4.95	0.99
breakdown-air	-28.21	----	----
breakdown-mine	-12.62	----	----
breakdown-ambush	-13.2	----	----
air-ambush	-11.62	----	----

CHAPTER 5

5. SELECTING THE MOST CRITICAL REGION OF TURKEY

As a strategy, Turkish Army gives more importance to the troops in critical regions.

We can describe the regions in Turkey in three categories according to the enemy threat.

- 1) Eastern and South Eastern regions as most critical
- 2) Aegean, Black Sea, Marmara, and Mediterranean as critical region
- 3) Inside of Anatolia as least critical regions

The occurrence probabilities of enemy attacks and breakdown of vehicles are different for each region. The troops in most critical regions have priority of having new equipments and vehicles. The breakdown probabilities are determined according to the condition of vehicles. Thus, the troops inside the Anatolia have higher breakdown probabilities for breakdown station. Air attack, artillery attack, mine existing and ambush probabilities are determined according to the power of neighbor country's army, border range with Turkey and the distance between that country and Turkey. The harm that the enemy can cause depends on the power of its army. Border range is also an important effect for combat. When the border is long, controlling the border will be hard. For that reason, the probability of enemy penetrations, which can cause artillery assault, minefields and ambush will increase. The distance between neighbor country and Turkey also affects the condensation of artillery attack, minefield and ambush. For example, between Russia and Turkey, the distance is very long because of Black Sea. For that reason, artillery attack, mine existing and ambush probabilities are very low. Number of totally destructed vehicles is higher in artillery attack, minefields and ambush than in air attack and breakdown, because of the properties of guns and ground mines.

We compare the results of different regions according to the four performance measures which are time in system of last vehicle arriving assembly area (maximum time in system), average time in system, number of broken vehicles and number of totally destructed vehicles. To be able to compare, we implement ranking and selection of Rinott (1978) for selecting the most critique region among the ten regions of Turkey from most to least critique according to the four performance measures. We prefer Rinott's procedure because it is more sensitive from others. It is used for the ranking and selection of closer alternatives, because it needs more additional replications than the other methods, and also needs less computation effort. We see that the rankings are different from each other. To get a single ranking, we implement Saaty's analytic hierarchy process (AHP) (Winston, 1994). The Rinott's ranking and selection process can be implemented to the independent and normally distributed data. Our data is normally distributed and independent. We check the normality of data in Chapter 4 and use different random number generators for each random activity in our model to get independent data. The steps of Rinott's procedure are as follows:

Rinott's Procedure:

STAGE 1:

- We run 20 independent replications for each region.
- We calculate average and variance of these replications for each region.
- We find the sufficient number of replication for each region by the formula:

$$N_i = \max \{n_0, (h \cdot S_i / d)^2\}$$

STAGE 2:

- We take $N_i - n_0$ additional replications.

- We calculate the average of N_i replications for each region.
- Finally, we select the largest region as the most critique region among ten alternatives.

Our h value is 3.875 (from Table 8.3 (Rinott, 1978)) and desired probability of correct selection is 0.95 for each performance measure whereas indifference amount differs.

5.1. SELECTING THE MOST CRITICAL REGION OF TURKEY ACCORDING TO THE MAXIMUM TIME IN SYSTEM MEASURE

We implement the process above for the maximum time in measure of ten regions. Our indifference amount d is 15 minutes for this performance measure. We determine this d value by means inquiry that we give to the Armored Battalion and Company commanders. The general opinion of commanders about the indifference amount d is that the value depends on the type of operation and situation. We assume that the Armored Battalion will execute a defense-type operation. Thus, the 15 minutes indifference zone amount is reasonable for that type of operation. The results of twenty replications, averages, variances and the sufficient replication number for Rinott's procedure are given in Table 5.1 – 5.2 in Appendix C.

After computing needed replication numbers, we take additional replications of each region, and compute final averages of maximum time in measure for each region. The final values (averages) are given in Table 5.1.1. We see that the average of the results belonging to interior regions of Anatolia is lower than the others. It is logical because the defense systems are more effective inner parts of Turkey. The most critical

regions are the Greece borders (Aegean and Trakya), and Southern East Region (Syria, Iran and Iraq) borders follow them.

Table 5.1.1. Final averages of regions

no	region	average
1	Trakya Greece	329.35
2	Aegean	302.8
3	Syria	294.75
4	Iran	293.24
5	Iraq	292.06
6	Eastern Black Sea	278.61
7	Bulgaria	266.99
8	Middle Black Sea	233.06
9	Mediterranean	230.97
10	Middle Anatolia	223.12

The Greece border in Trakya is most critical because Greece Air Force is the strongest one among other neighbors, and artillery units are very effective because of the short distance between Turkey and Greece. Thus, these two strong factors cause more damaged vehicles, which also increase the maximum time in measure.

5.2. SELECTING THE MOST CRITIQUE REGION OF TURKEY ACCORDING TO THE AVERAGE TIME IN SYSTEM MEASURE

We apply the same process above for the average time in system measure of ten regions. From the view of Armored Battalion commander, this performance measure does not mean too much because, the important thing is when and with how many vehicles Armored Battalion is ready in Assembly Area for combat. Thus, this performance measure does not give necessary information about combat readiness. We include this performance measure for only checking the average performance of our system. Our indifference amount d is 15 minutes for this performance measure. The

reasoning in previous case for the determination of d value is also valid for this performance measure. The results of twenty replications, averages, variances and the sufficient replication number for Rinott's procedure are given in Table 5.3 – 5.4 in Appendix C. There is no need for additional replications indicated by the Rinott's procedure because the variances are so small. We can make a selection of the most critique region by depending on averages of twenty replications. We give the summary of averages in Table 5.2.1.

Table 5.2.1 Final averages of regions

no	region	average
1	Aegean	92.01
2	Trakya Greek	91.49
3	Iran	91.3
4	Syria	91
5	Iraq	90.4
6	Eastern Black Sea	89.7
7	Bulgaria	89.14
8	Mediterranean	82.97
9	Middle Black Sea	82.38
10	Middle Anatolia	80.04

We observe that the average of the results belonging to Middle of Anatolia is lowest and Greece border in Aegean is the greatest. But there are very slight differences between first seven regions in Table 5.2.1. Our indifference value d is 15 minutes for average time in system measure, so we do not care about the selecting the most critique system because the alternatives are too close to each other. We can say that the average time in system measure does not give us necessary information about selecting the most critique region. For that reason we do not include average time in system measure in analytic hierarchy process (AHP) to find the most critique region among ten.

5.3. SELECTING THE MOST CRITICAL REGION OF TURKEY ACCORDING TO THE NUMBER OF DAMAGED VEHICLES MEASURE

We determine indifference zone amount d from the inquiry as in previous case. For the number of damaged vehicles our indifference amount d is 3 vehicles. We again assume that operation is a defense-type operation. Three damaged vehicles can be accepted as a reasonable value for a defense-type operation because the Armored Battalion will occupy the predetermined position and wait for the enemy. Thus, there may be enough time for repairing three vehicles before combat. We give the results of twenty replications; averages, variances and the sufficient replication number for Rinott's procedure for the number of damaged vehicles measure are given in Table 5.5 – 5.6 in Appendix C. After taking additional replications needed, we present the final averages in Table 5.3.1.

Table 5.3.1. Final averages of regions

no	region	average
1	Trakya Greek	25.45
2	Iraq	22.27
3	Bulgaria	22
4	Iran	21.9
5	Aegean	21.818
6	Eastern Black Sea	21.7
7	Syria	21.45
8	Mediterranean	12.27
9	Middle Black Sea	12.05
10	Middle Anatolia	9.75

The Greece border in Trakya is most dangerous and Middle Anatolia is the least critical borders for this performance measure as in maximum time in system measure case. The reasoning explained for that result in Section 5.1 is also valid. When number of damaged vehicles increases, the maximum time in system measure naturally increases

because of the repairing times of damaged vehicles. We can say that there is a positive correlation between these two performance measures. This relation is consistent with results; the most and least critical regions for these two performance measures are the same.

5.4 SELECTING THE MOST CRITICAL REGION OF TURKEY ACCORDING TO THE NUMBER OF TOTALLY DESTROYED VEHICLES MEASURE

We put into practice the same ranking and selection procedure for number of totally destroyed vehicles measure, and give the results in Table 5.7 –5.8 in Appendix C. Our indifference amount d takes the minimum value 1 vehicle. Because total destruction of a vehicle means it cannot be used anymore, this is an important loss. After taking additional replications needed, we give the final averages in Table 5.4.1.

Table 5.4.1 Final averages of regions

no	region	average
1	Iran	6.45
2	Syria	6.06
3	Trakya Greek	6.04
4	Bulgaria	5.626
5	Eastern Black Sea	5.59
6	Iraq	5.56
7	Aegean	5.3
8	Mediterranean	1.33
9	Middle Black Sea	1.21
10	Middle Anatolia	0.78

The Iran border is most critical because the Iran border is more suitable for minefields; ambush and artillery assault whose total destruction rates are the highest. These three strong factors cause more totally destroyed vehicles, which also increase the maximum time in measure. When a vehicle is totally destroyed by the enemy, it is left in

a safe zone and this does not cause time loss. So we can say that there is no a direct relation between maximum time in system and number of totally destructed vehicles measure. The results that we obtain for these two are logical because results are different as expected.

5.5. THE ANALYTIC HIERARCHY PROCESS

When we implement the ranking and selection process, we see that the rankings of regions are different for each performance measure. For a decision maker, these three performance measures are important. We have faced problem with a multiple objectives. Thomas Saaty's analytic hierarchy process (AHP) provides a powerful tool that can be used to make decisions in situations involving multiple objectives (Winston, 1994). We use AHP to make a single ranking of ten regions of Turkey according to the criteria of criticism.

We describe an objective matrix of three performance measures by consulting the military experts. The matrix is in Table 5.5.1.

Table 5.5.1 Objective matrix of three performance measures

objective matrix	max time in	# of damaged	# of totally
max time in	1	1.45	1.2
# of damaged	0.67	1	0.6
# of totally	0.83	1.67	1

And then by computing the normalized matrix of objective matrix, we get the weights of each performance measures (Table 5.5.2).

Table 5.5.2 Normalized objective matrix and weights of performance measures

Norm(objective)	max time in	# of damaged	# of totally	weights
max time in	0.4	0.351941748	0.428571	0.393504
# of damaged	0.268	0.242718447	0.214286	0.241668
# of totally	0.332	0.405339806	0.357143	0.364828

CONSISTENCY CHECK OF OBJECTIVE MATRIX

To check the consistency of our objective matrix, we implement the following procedure (Winston, 1994):

Procedure:

Step1. We multiply the objective matrix with the transpose of the weights of performance measures.

$$A * w^T$$

Step 2. We compute

$$1/n * \sum (\text{ith entry of } A * w^T / \text{ith entry of } w^T) = 3.000419$$

Step 3. We compute the consistency index (CI) as:

$$CI = ((\text{Step 2 results}) - n) / (n - 1) = 0.000209$$

Step 4. Finally, we compare the result with the theoric value (RI=0.58) in Table 23 of Winston's book (1994). For a perfectly consistent decision makers are probably consistent enough to give useful estimates of weights for his objective function. We need to check if $CI/RI < 0.10$. If $CI/RI < 0.10$, then we can say that the our objective matrix is consistent. In our case,

$$CI/RI = 0.000209/0.58 = 0.000362 < 0.10$$

So we can say that our objective matrix is consistent, and we can continue implementing AHP. We construct a 10*10 (10 regions) pair wise comparison matrix for each performance measure by using the final results of ranking and selection procedure

for that performance measure. We compute the weights for each matrix. The results and weights are in Table 5.5.3.

Table 5.5.3 The results and weights of regions

regions	max time in output	# of damaged output	# of totally output	max time in weights	#of damaged weights	#of totally weights
Middle Anatolia	223.12	9.75	0.78	0.081284	0.051408324	0.017749056
Greece Trakya	329.35	24.45	6.04	0.119984	0.12891626	0.137441405
Bulgaria	266.99	22	5.626	0.097266	0.115998271	0.128020753
Aegean	302.8	21.818	5.3	0.110312	0.115038649	0.120602558
Middle Black Sea	233.06	12.05	1.21	0.084905	0.063535416	0.027533791
Eastern Black Sea	278.61	21.7	5.59	0.101499	0.114416476	0.127201566
Iran	293.24	21.9	6.45	0.106829	0.115471006	0.146771037
Iraq	292.06	22.27	5.56	0.106399	0.117421886	0.12651891
Syria	294.75	21.45	6.06	0.107379	0.113098314	0.137896509
Mediterranean	230.97	12.27	1.33	0.084144	0.064695399	0.030264415

Finally we compute the scores of regions according to the procedure in Winston's book (1994) and rank them from most to least critique and give the results in Table 5.5.4.

Table 5.5.4 Final scores of regions via AHP

	region	scores
1	Greece Trakya	0.128512
2	Iran	0.123489
3	Syria	0.119895
4	Iraq	0.116403
5	Aegean	0.115208
6	Eastern Black Sea	0.113998
7	Bulgaria	0.113013
8	Mediterranean	0.059787
9	Middle Black Sea	0.05881
10	Middle Anatolia	0.050885

As a result of AHP, we observe that Greece border in Trakya is the most critical frontier for three performance measures.

5.6 THE DETAILED RESULTS OF NUMBER OF DAMAGED VEHICLES AND NUMBER OF TOTALLY DESTRUCTED VEHICLES MEASURE

We give the detailed results of the number of damaged and totally destructed vehicles measure by partitioning them as the number of damaged vehicles by breakdown of vehicles, the number of damaged vehicles by air attack, the number of damaged vehicles by artillery attack, the number of damaged vehicles by minefields and the number of damaged vehicles by ambush of enemy. These results are given to see how many damaged vehicles or how much time delay do the factors cause for every scenario separately. This type of information would be useful for the Armored Battalion Commanders of regions that we inspect. Commanders can use this information for effective planning of field exercises by focusing on the important factors. These statistics are computed from the initial twenty replications only as information; we do not implement any statistical procedure to make a comparison. We give the statistics of wheeled trucks of Armored Battalion in Table 5.6.1-5.6.2, the number of damaged armored vehicles measure in Table 5.6.3-5.6.4, the number of totally destructed wheeled trucks measure in Table 5.7.1-5.7.2 and the number of totally destructed armored vehicles measure in Table 5.7.3-5.7.4 in Appendix C.

5.7. CONCLUSIONS

In this chapter, we run our simulation model for armored battalions from ten different regions of Turkey according to the four performance measures which are maximum time in system, average time in system, number of damaged vehicles and number of totally destructed vehicles. We implement Rinott's ranking and selection procedure (Rinott, 1978) to find out the most critical region for each performance

measure. For maximum time in system and number of damaged vehicles measures Greece border in Trakya is the most critical whereas for the number of totally destructed vehicle measure Iran, for the average time in system measure Aegean border of Greece is the highest one. But we do not care about selecting the most critique system for that performance measure because the alternatives are too close to each other.

For an Armored Battalion commander the number of totally destructed vehicles, number of damaged vehicles and maximum time in system measures are very important. However the average time in system measure does not imply a significant importance for the military operations, because average time in system measure does not give sufficient information about the whole battalion whereas maximum time in system points out the readiness time of battalion for the combat. Except average time in system measure, we implement analytic hierarchy process (AHP) to find out which region is the most critique for the three performance measures. After implementation of AHP, we conclude that Greece border in Trakya is the most critical region among ten regions of Turkey.

The information that we obtain in Chapter 5 may be used for planning of national defense. According to our results, the defense planners should give the most importance to Greece border in Trakya. For Iran border necessary precautions should be taken to lessen the number of totally destructed vehicles, which is affected deeply from the artillery guns, minefields, and ambushes of enemy.

CHAPTER 6

6. SELECTING THE MOST CRITICAL FACTOR FOR EACH REGION OF TURKEY ACCORDING TO THE NUMBER OF TOTALLY DESTROYED VEHICLES MEASURE

In Chapter 5, we implemented the ranking and selection procedure of Rinott (1978) to find out which region of Turkey is most critical. In this chapter, we try to discover which factor out of five is the most critical for each region. Again, we will use the Rinott's procedure only for number of totally destroyed vehicles measure. The information that other measures such as the maximum, average time in system measure and number of damaged vehicles measures provide, is subjective, the indifference zone amount for them may change depending on the type of military operation whereas the indifference zone amount is always accepted as minimum number (1 vehicle) independent of the type of military operation. At that point, the number of totally destroyed vehicles measure arises as an objective measure. Thus, we cannot reach general conclusions for these three performance measures by performing ranking and selection procedure while totally destroyed vehicles measure can help us to reach exact results for the degrees of criticism of five factors in the name of total destruction. Our five factors are:

- Breakdowns of vehicles
- Air attack of enemy
- Artillery assault of enemy
- Mine field of enemy
- Ambush of enemy.

In the experiments, we use the following assumptions in attacks of enemy:

- 40 mm cannon on war plane (air attack)
- 155 mm artillery cannon (artillery attack)
- Ground mine for vehicles (mine fields)
- LAW as ambush gun (ambush)

We apply the Rinott's ranking and selection procedure to find the most critical factor for each region. In first stage, we take 15 replications for each region and then the additional runs to reach a solution. We give the final results and ranks below for each region separately.

6.1 RANKINGS OF FACTORS FOR REGIONS

We give the final results and ranks below for each region separately. For seven regions out of ten, artillery assault is the most critical and dangerous factor for number of totally destructed vehicles measure, because the total destruction capability of ambush guns is the highest (artillery gun has the biggest diameter, 155mm cannon). For most of the regions the breakdown of vehicles is the least critical factor since the total destruction rate of a vehicle because of breakdown is too low. The summary tables of averages, variations and number of needed replications for Rinott's procedure of seven regions for which the artillery assault is the most hazardous factor are given above. The rest three regions that have different results are presented separately after the seven regions.

Table 6.1.1 Rankings of factors for Eastern Black Sea (Armenia) Border

	factor	average	variance	# of replication for Rinott
1	artillery assault	1.76	4.4	66
2	mine-air attack	0.8	0.88-0.88	15
3	ambush	0.7	0.45	15
4	breakdown	0.1333	0.123	15
5				

Table 6.1.2 Rankings of factors for Iran border

	factor	average	variance	# of replication for Rinott
1	artillery assault	2.1	4.4	66
2	air attack	0.8	0.88-0.88	15
3	mine	0.7	0.45	15
4	ambush	0.1333	0.123	15
5	breakdown	0	0	15

Table 6.1.3 Rankings of factors for Iraq border

	factor	average	variance	# of replication for Rinott
1	artillery assault	1.68	3.73	42
2	air attack-ambush	1.2	0.6-0.622	15
3	mine	0.733	0.352	15
4	breakdown	0.0667	0.0667	15
5				

Table 6.1.4 Rankings of factors for Syria border

	factor	average	variance	# of replication for Rinott
1	artillery assault	1.77	4.6	69
2	mine	1.2	1.028	15
3	air attack	0.8	0.6	15
4	ambush	0.5	0.5	15
5	breakdown	0	0	15

Table 6.1.5 Rankings of factors for Greece border in Trakya

	factor	average	variance	# of replication for Rinott
1	artillery attack	1.81	4.266	65
2	air attack	0.933	1.49	23
3	ambush	0.8	0.844	15
4	mine	0.6	0.4	15
5	breakdown	0	0	15

Table 6.1.6 Rankings of factors for Bulgaria border

	factor	average	variance	# of replication for Rinott
1	artillery attack	1.65	3.83	58
2	air attack	1.066	1.209	18
3	ambush	0.6	0.711	15
4	mine	0.533	0.69	15
5	usual break	0.0667	0.0667	15

Table 6.1.7 Rankings of factors for Greece border in Aegean

	factor	average	variance	# of replication for Rinoff
1	artillery attack	1.58	4.12	62
2	air attack-mine	0.866	1.12-0.98	17-15
3	ambush	0.4	0.488	15
4	usual break	0	0	15
5				

The ranking of factors for Mediterranean border is given in Table 6.1.8. Minefield is the most, breakdown and artillery attack are least critical factors for this border. Because of Mediterranean Sea the artillery attack probability is very low whereas the minefield existing probabilities are higher because of guerilla activities of enemy and total destruction rates of mines are very high. Thus, artillery attack and breakdown of vehicles are the least risky factors for that region.

Table 6.1.8 Rankings of factors for Mediterranean border

	factor	average	variance	# of replication for Rinoff
1	mine	0.6	0.54	15
2	air attack	0.33	0.238	15
3	ambush	0.3	0.45	15
4	breakdown-artillery	0	0	15
5				

We give the average and variances of factors for Middle Anatolia in Table 6.1.9. Air attack is the most critical factor because the most effective combat weapons for the inner sides of countries are warplanes. The occurrence probabilities of other enemy attacks are very low because defense is very effective for interior regions. The artillery attack is the least critique because it is very hard even impossible for enemy to carry the artillery guns inside the Anatolia to make an artillery assault against the interior sides.

Table 6.1.9 Rankings of factors for Middle Anatolia

	factor	average	variance	# of replication for Rinott
1	air attack	0.4	0.4	15
2	ambush	0.3	0.233	15
3	mine	0.266	0.209	15
4	usual break	0.133	0.123	15
5	artillery attack	0	0	15

For the Middle Black Sea region, ambush is the most critical factor, artillery assault and breakdown is the least critical factors for this region. The ambush probability is highest because of guerilla activities of enemy; the artillery assault is the lowest because of the Black sea. The results for this region are presented in Table 6.1.10.

Table 6.1.10. Rankings of factors for Middle Black Sea border

	factor	average	variance	# of replication for Rinott
1	ambush	0.6	0.933	15
2	air attack-mine	0.466	0.4-0.55	15
3	artillery-usual	0	0	15
4				
5				

6.2 CONCLUSIONS

For most of the regions, the artillery assault is the most critical factor (other factors also have critical effect) because the total destruction rates of artillery guns are very higher than others (artillery gun has the biggest diameter that causes more totally destructed vehicles). For most of the regions, the breakdown is the least critical factor, because the total destruction rate of a broken vehicle is very low. Armored Battalion commanders can use results related to his battalion to minimize the number of totally destructed vehicles by giving more importance to the field exercises of the most critical factors and taking necessary safety measures for the significant factors.

CHAPTER 7

7. LIMITS OF MOBILIZATION AND DEPLOYMENT PLAN

To find out when our system collapse, we run the model under the worst enemy threat. Up to now, our assumptions about the enemy forces were:

- 1 F-16 with 40 mm cannon on it
- 1 artillery platoon (4 155 mm artillery cannon)
- 6 ground mines for vehicles in an 8*8 mine field
- 4 LAW as ambush guns

We run our model for two scenarios. The assumptions and results for the worst two scenarios are stated below.

7.1 SCENARIO 1

Mobilization and Deployment Plan of a Turkish Armored Battalion is executed in Turkish Land. Thus, the density of enemy threat that an Armored Battalion encounters will be less than the threat in enemy land. The assumptions that we make up to this Chapter 7 are reasonable for an operation in Turkish Land. As a military strategy, for an armored battalion generally, one artillery platoon (4 cannons), for an ambush 4 LAWs, for an 8*8 minefield 4 mines are assigned for assaulting against. To test the system under worst conditions, we increase the density of enemy attack as much as possible. For enemy it is unlikely to attack an armored battalion with 8 F-16 warplanes, one artillery company, 8 LAWs in an ambush and a more condensed minefield. And also the probability that all these enemy activities will occur together is very low. As our aim is

to find the system limits, we run our model under these worst conditions. The assumptions are:

- 8 F-16 with 40 mm cannon on it
- 1 artillery company (8 155 mm artillery cannon)
- 12 ground mines for vehicles in 8*8 mine field
- 8 LAW as ambush guns

The results and variances of 20 replications are given in Table 7.1.1. For the Scenario 1, the average time in system statistic is 504.3 and maximum time in system statistic is 2009 minutes. Although there is no specific rule for the time delay of any military operation, these measures are not reasonable for all kind of military operations. When we look at the number of damaged vehicles, we see that 36 armored vehicles and 70-wheeled trucks are damaged. These are also huge numbers for an armored battalion. Also 5 armored vehicles and 15-wheeled trucks are totally destructed by the enemy. Thus, we can say that the Armored battalion in that condition cannot give proper reaction to orders.

7.2 SCENARIO 2

For armored troops, the Apache helicopters are accepted as the most dangerous enemy. Because they have hell-fire missiles that can hit a tank from 8000 meters with 0.55 shot probability. For the scenario 2, we just replace the F-16 warplanes with Apache helicopters to observe the system performance. We make following assumptions for Scenario 2:

- 8 Apache helicopters with hell-fire missile on it
- 1 artillery company (8 155 mm artillery cannon)

- 12 ground mines for vehicles in an 8*8 mine field
- 8 LAW as ambush guns

We present the results of Scenario 2 in Table 7.2.1. The average and maximum time in system statistics are 868.34 and 2558 minutes respectively. The number of damaged armored vehicles and wheeled-trucks are 46 and 81 respectively. When we take a look at the number of totally destructed vehicles, 17 wheeled-trucks and 6 armored vehicles are totally destructed. The hell-fire missiles are more effective against armored forces; their hit probabilities are very high. So as expected all the performance measures in Scenario 2 is higher than the ones in Scenario1.

Table 7.1.1 Results of Limit Scenario 1

8 F-16 (40 mm cannon), 8-155 mm cannons, 12 mines, 8 LAWs

	average time in	max time in	damaged			totally destructed		
			tank	vehicle	total	tank	vehicle	total
1	322.98	1545.64	40	55	95	2	11	13
2	502.04	1976.11	38	72	110	6	13	19
3	502.78	1920.16	39	70	109	5	12	17
4	456.91	1893.76	38	75	113	4	19	23
5	545.11	2341.43	33	75	108	4	14	18
6	295.56	1368.21	33	55	88	3	17	20
7	657.52	2620.02	32	75	107	3	12	15
8	779.55	2743.89	45	83	128	10	15	25
9	645.26	2629.47	28	79	107	5	14	19
10	431.31	1218.98	39	52	91	3	16	19
11	382.20	1704.73	35	60	95	2	15	17
12	403.04	1800.74	28	61	89	5	14	19
13	478.64	1744.60	42	63	105	9	15	24
14	629.08	2291	30	81	111	4	12	16
15	413.54	1897.56	39	73	112	8	20	28
16	479.93	2108.37	36	71	107	12	15	27
17	467.62	1915.66	34	67	101	3	13	16
18	600.12	2083.24	38	67	105	5	15	20
19	643.30	2337.15	41	78	119	2	20	22
20	450.95	2052.43	31	76	107	6	16	22
average	504.37	2009.66	35.95	69.4	105.35	5.05	14.9	19.95
variance	15143.0	163791.8	22.36	82.88	99.71	7.73	6.62	15.94

Table 7.2.1 Results of Limit Scenario 2

8 helicopter (hellfire). 8-155 mm cannons. 12 mines. 8 LAWs

	average time in	max time in	damaged			totally destructed		
			tank	vehicle	total	tank	vehicle	total
1	805.25	2460.06	50	78	128	12	18	30
2	1049.49	3112.88	44	93	137	6	14	20
3	929.40	2328.77	48	82	130	8	17	25
4	747.32	2105.57	51	73	124	4	16	20
5	833.65	1970.91	55	72	127	4	17	21
6	703.59	1717.28	43	58	101	3	16	19
7	821.06	2697.45	47	86	133	9	20	29
8	1004.76	3277.37	44	89	133	6	15	21
9	580.93	1800.67	44	64	108	6	15	21
10	1154.16	3364.48	52	102	154	6	18	24
11	749.42	1921.96	44	75	119	6	15	21
12	784.93	1976.90	39	64	103	5	15	20
13	1026.14	3300.79	49	88	137	9	14	23
14	1015.85	3123.13	45	94	139	6	18	24
15	619.36	1835.61	46	58	104	5	15	20
16	1026.52	3075.41	53	97	150	10	19	29
17	1013.91	3148.11	44	95	139	5	19	24
18	590.12	1627	43	58	101	3	16	19
19	946.28	3107.04	41	93	134	1	18	19
20	964.71	3209.29	40	90	130	4	13	17
average	868.34	2558.03	46.1	80.45	126.55	5.9	16.4	22.3
variance	28283.96	406874.2	19.46	206.26	251.20	6.93	3.72	13.37

7.3. CONCLUSIONS

Comparing the results of Scenario 2 with the Scenario 1 as seen in Table 7.3.1., the performance measures of Scenario 2 are all greater than the measures of Scenario 1. We also give the increase rates of performance measures for two scenarios in Table 7.3.2.

Table 7.3.1. Summary table of results of limit scenarios

	average	max	damaged			totally destructed		
scenario	time in	time in	tank	vehicle	total	tank	vehicle	total
scenario 1	504.37	2009.66	35.95	69.4	105.35	5.05	14.9	19.95
scenario 2	868.34	2558.03	46.1	80.45	126.55	5.9	16.4	22.3

The maximum time in system statistic increase 13 times for Scenario1, whereas 17 times for Scenario 2. There is a % 63 increase in Scenario 1, %75 increase in Scenario 2 for the number of damaged vehicles measure. The increase rate in totally destructed vehicles measure is %12 for Scenario 1 and % 13 for Scenario 2.

Table 7.3.2. Increase rates of performance measures

	average	max	damaged			totally destructed		
scenario	time in (%)	time in (%)	tank (%)	vehicle (%)	total (%)	tank (%)	vehicle (%)	total (%)
scenario 1	522	1366	55	68	63	7	14	12
scenario 2	899	1738	71	79	75	9	16	13

As all the measures of Scenario 2 are greater, the enemy forces in Scenario 2 can be accepted as limits that will put the Armored Battalion executing Mobilization and Deployment Plan into a catastrophic situation. In other words, if enemy attacks an Armored Battalion executing the Mobilization and Deployment Plan with 8 Apache helicopters, one artillery company, lays an ambush with 8 LAW guns and positions a minefield with density 12 anti-tank mines in a $8 \times 8 \text{ m}^2$, the Armored Battalion will get into a mortal situation.

CHAPTER 8

CONCLUSIONS

8.1. GENERAL

In this study, we developed a simulation model of Mobilization and Deployment of a Turkish Armored Battalion from garages to Assembly Area. We construct a flexible model that can be also used for the Artillery and Infantry Battalion with slight modifications. It can also be adapted to brigade-level Army Forces.

The objectives of our study are:

- To understand the behavior of existing Mobilization and Deployment Plan of an Armored Battalion
- To find out the effects of enemy attacks on Armored Battalion
- To detect the bottlenecks of system if exist, and to develop solutions for overcoming these problems

With our simulation model, we can test the system with different factors such as the velocity of vehicles, the distance between garages and Alert Dispersion Area, the distance between Alert Dispersion Area and Assembly Area, probability of breakdown of vehicles, probability of air attack, probability of artillery assault, mine field existing probability, ambush occurrence probability of enemy, the size of enemy forces (platoon, company etc.).

In our study, we analyze the existing Mobilization and Deployment Plan of a Turkish Armored Battalion; examine the effects of enemy attacks and breakdowns of vehicles, select the most critical region out of ten region of Turkey, select the most critical factor for each region according to the performance measures, maximum time in system,

select the most critical region out of ten region of Turkey, select the most critical factor for each region according to the performance measures, maximum time in system, number of damaged vehicles and number of totally destructed vehicles by five factors. And finally find out limits of system for an Armored Battalion by running the model at extreme conditions.

8.2. DESIGN AND ANALYSIS OF EXPERIMENTS

We test out the efficiency of the Mobilization and Deployment Plan of a Turkish Armored Battalion by checking whether it satisfies time specifications of Turkish Army, whether it has problem areas (bottlenecks). We also apply 2^k factorial for observing the effects of breakdown of vehicles, air attack, artillery assault, minefield, and ambush of enemy according to the performance measures, maximum time in system, number of damaged vehicles and number of totally destructed vehicles by five factors. We obtain the results:

- As a result of experiments, we observe that the Armored Battalion executing the existing Mobilization and Deployment Plan satisfies the all the time standards determined by Turkish Army. But we discover that the Mobilization and Deployment Plan has a bottleneck in number of repair units. 11 repair units are the optimal quantity that minimizes the waiting time in queue statistic for the Armored Battalion. Increasing the number of repair units from 5 to 11 in the structure of the Armored Battalion will fix the bottleneck but may bring additional cost.
- For the performance measure maximum time in system measure, the significant effects are breakdowns of vehicles; air attack, minefield and ambush are 65.68,

interactions of breakdowns- air attack, breakdowns- ambush, breakdowns- minefields and air attack-ambush are -28.21, -13.2, -12.62 and -11.62 minutes, respectively. Air attack has the greatest positive effect.

- For the number of damaged vehicles, there is no significant interaction among factors. The significant effects of breakdowns of vehicles, air attack, artillery assault, mine field and ambush are 8.6, 7.7, 6.99, 2.72, 4.96 vehicles respectively. Breakdown of vehicles has the greatest effect.
- For the number of totally destructed vehicles, there is not a significant interaction among factors either. There are four significant main effects. The significant effects of air attack, artillery assault, minefield and ambush are 1.23, 4.19, 3.96, and 0.99 vehicles respectively. Artillery assault has the greatest effect on this performance measure.

The significant factors are different for each performance measure. For an Armored Battalion commander, the importance of performance measures varies according to the type of military operation. If the operation is an ambush-type operation, maximum time in system measure is more important. If the operation is a defense-type operation, then the number of totally destructed vehicles measure arises as the most important measure. The information gained above can be also used for the Turkish national defense planning: our study shows that the air attacks of enemy cause great delay for forward military operation. To prevent this, the air defense system should be stronger. And also breakdowns of vehicles are important factor for the maximum time in system measure and number of damaged vehicle measure, which alert us to renew the vehicles for decreasing reaction time of Armored Battalion for combat. We have to implement

preventative measures against the artillery assault of enemy to decrease the catastrophic vehicle losses of Armored Battalion.

8.3. SELECTING THE MOST CRITICAL REGION OF TURKEY

We perform ranking and selection procedure for three performance measures. We get different results for each performance measure. To find the most critical for three of them we implement the analytic hierarchy process (AHP). The results are:

- The Greece border in Trakya is the most critical region for the performance measure maximum time in system measure and number of damaged vehicles whereas Iran is the most critical region for the performance measure number of totally destructed vehicles.
- The result of AHP shows that the Greece border in Trakya is the most critical region for three performance measures.
- Results reached in this chapter are high-level information that exceeds the responsibilities of Armored Battalion commanders. This type of information can be useful for the people who have the responsibility of planning the whole defense system of Turkey. They should focus on Greece border in Trakya. For Iran border necessary precautions should be taken to lessen the number of totally destructed vehicles, which is affected intensely from the artillery guns, minefields, and ambushes of enemy.

8.4. SELECTING THE MOST CRITICAL FACTOR FOR EACH REGIONS OF TURKEY ACCORDING TO THE NUMBER OF TOTALLY DESTROYED VEHICLES MEASURE

We execute ranking and selection procedure to select the most critical factor for each region. For this purpose, we only use the number of totally destroyed vehicles measure to reach a general conclusion. The results are:

For most of the regions, artillery assault of enemy is the most critical factor and breakdown arises as the least critical factor for the number of totally destroyed vehicles measure.

- This type of information can be used by the Armored Battalion commanders for taking necessary precautions and the planning of field exercises against these five factors. The commander should give more emphasis to the training against the most critical factor for his region.

8.5. LIMITS OF MOBILIZATION AND DEPLOYMENT PLAN OF ARMORED BATTALION

To find out when our system fails, we run the model under the worst enemy threat. We observe after experiments that, if enemy attacks an Armored Battalion executing the Mobilization and Deployment Plan with 8 Apache helicopters, one artillery company, lays an ambush with 8 LAW guns and positions a minefield with density 12 anti-tank mines in a $8 \times 8 \text{ m}^2$, the Armored Battalion will get into a mortal situation. We can conclude that when the enemy attacks to an Armored Battalion with the force that we

stated below, enemy will cause the dead of battalion before getting into the battlefield. Thus, the enemy forces mentioned below are the limits of the system.

8.6. CONCLUDING REMARKS

We draw following conclusions from our study:

- The existing Mobilization and Deployment Plan of Armored Battalion does not have a serious problem during the movement from garages to Alert Dispersion Area. Under the assumption that the vehicles are loaded before the alert order, it satisfies the time limitations. But it needs a modification for the number of repair units in structure of Armored Battalion.
- During the march from Alert Dispersion Area to Assembly Area there are five significant factors that affect the performance of the Armored Battalion. The factors are breakdowns of vehicles, air attack of enemy, artillery attack, mine fields and ambushes of enemy. Only the breakdown of vehicles is the controllable factor for Turkish Army. As it is a significant factor, the renewing of vehicle or giving more emphasis on maintenance activities can decrease the effect of it. For the other factors that are not controllable, the national defense system can be strengthened to lessen the effects of them.

8.7. FUTURE RESEARCH TOPICS

Combat modeling is the most important issue in military. It is the modeling of actions that may cause many casualties. By combat modeling, the military systems can be examined with no losses and less cost. Simulation arises as one of the main tools of combat modeling because terrain factors that the military operations continue and the

structure changes in military units can be the only issue to be handled by the simulation to triumph over the problems.

We do not deal with the activities that are loading of ammunition and equipment to wheeled trucks from depots and fuel oil filling of vehicles. These are also very important factors that must be done before the alert order. A further study, including these activities can be executed.

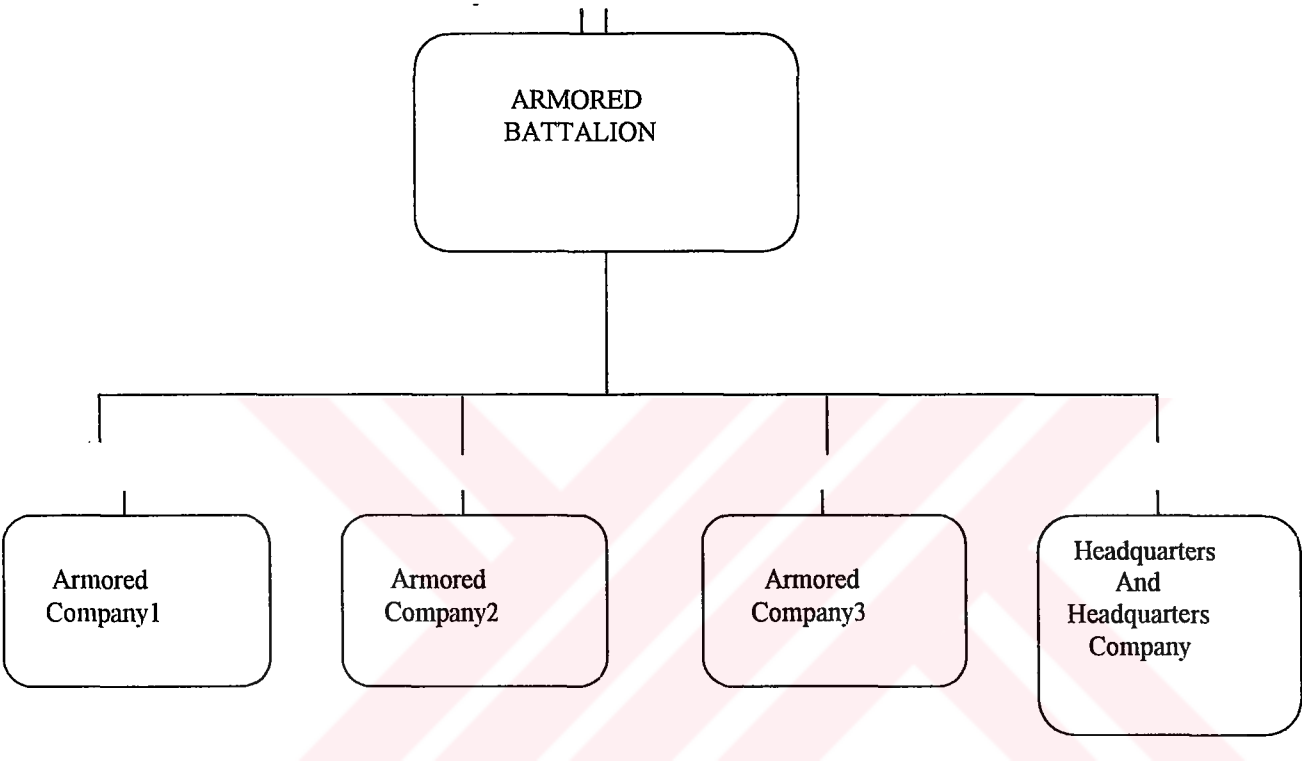
In our study, we make assumptions about the enemy forces and guns that are the minor part of the whole alternatives. Thus, different types alternative scenarios can be modeled for the Mobilization and Deployment Plan for future studies. And also we do not deal with the terrain factors, the future studies may undertaken the terrain factors.

Our study considers the Mobilization and Deployment Plan of an Armored Battalion. Future studies may consider the other types of battalions (infantry, artillery, etc.) or the military units from different levels (brigade, company, etc.).

We take the vehicles of Armored Battalion as entities, so we only deal with the vehicles in our study and evaluate the system in the name of vehicles. A more detailed study that takes soldiers as entities may be conducted. We do not take care of the cost in our study; this factor can be included in future studies.

APPENDIX A

STRUCTURE OF A TURKISH ARMORED BATTALION



APPENDIX B

RESULTS OF 20 REPLICATIONS FOR EXPERIMENTAL DESIGN



Table 4.1. Factor names and roles of factors for design points

	Break(0.01-0.06)	air(0-1)	artillery(0-1)	mine(0-1)	ambush(0-1)	design points
1	-	-	-	-	-	run
2	+	-	-	-	-	run1
3	-	+	-	-	-	run2
4	-	-	+	-	-	run3
5	-	-	-	+	-	run4
6	-	-	-	-	+	run5
7	+	+	-	-	-	run12
8	+	-	+	-	-	run13
9	+	-	-	+	-	run14
10	+	-	-	-	+	run15
11	-	+	+	-	-	run23
12	-	+	-	+	-	run24
13	-	+	-	-	+	run25
14	-	-	+	+	-	run34
15	-	-	+	-	+	run35
16	-	-	-	+	+	run45
17	+	+	+	-	-	run123
18	+	+	-	+	-	run124
19	+	+	-	-	+	run125
20	+	-	+	+	-	run134
21	+	-	+	-	+	run135
22	+	-	-	+	+	run145
23	-	+	+	+	-	run234
24	-	+	+	-	+	run235
25	-	+	-	+	+	run245
26	-	-	-	+	+	run345
27	+	+	+	+	-	run1234
28	+	+	+	-	+	run1235
29	+	+	-	+	+	run1245
30	+	-	+	+	+	run1345
31	-	+	+	+	+	run2345
32	+	-	+	+	+	run12345

Table 4.3.1. Results. averages and variances of 20 replications for maximum time in

	run 0	run1	run2	run3	run4	run5	run12	run13
1	159	418	351.5	201.98	347.16	222.27	379	372
2	149	286	280.24	157.15	162.69	225.27	284	272
3	145	277	209.38	163.35	254.36	229.31	327	313
4	161	365	373.88	180.32	231.04	256.67	301	309
5	115	227	315.76	186.15	223.58	351.82	233	263
6	103	335	347.2	213.32	368.11	237.07	302	450
7	147	198	325.32	207.91	162.81	178.2	421	170
8	111	330	225.94	158.4	147.99	203.5	458	478
9	137	297	366.09	185.59	199.49	207.07	452	300
10	164	299	351.37	189.08	166.13	236.87	427	390
11	177	302	326.39	191.72	191.79	192.65	326	341
12	199	327	402.6	280.17	204.78	183.1	390	215
13	141	343	188.64	154.19	217.45	235.38	303	353
14	104	246	198.72	290.45	194.74	271.92	283	259
15	179	280	222.7	157.49	144.34	253.54	264	331
16	105	206	211.22	201.39	250.63	160.28	442	270
17	225	259	245.78	192.63	184.79	246.66	293	220
18	102	353	287.07	210.75	194.94	279.58	288	257
19	128	334	393.55	224.5	352.56	316.27	487	345
20	191	319	355.93	163.41	180	254.64	446	261
average	147.1	300.05	298.964	195.4975	218.969	237.1035	17.85	16.45
variance	1246.095	3025.418	5001.383	1386.733	4412.529	2116.553	6126.747	5915.524

Table 4.3.2. Results. averages and variances of 20 replications for maximum time in

	run14	run15	run23	run 24	run25	run34	run35	run45
1	366	399.59	390.98	314.43	355.56	261.36	164.39	348.68
2	265	234.45	323.37	331.32	307.77	199.8	225.3	261.03
3	313	297.16	239.82	247.51	222	258.37	258.59	216.62
4	338	360.62	262.86	350.66	240.53	169.96	174.44	185.29
5	247	365.25	338.86	265.98	343.05	244.54	368.35	308.69
6	380	434.94	279.91	376.19	328.89	362.79	183.65	357.14
7	238	209.01	262.28	408.86	308.26	207.41	278.56	159.64
8	382	459.87	309.83	380.43	307.96	219.03	214.49	252.05
9	338	333.18	486.13	364.73	435.16	173.04	242.43	236.85
10	308	283.25	445.13	468.4	450.8	227.71	193.08	210.2
11	305	302.2	309.61	219.59	348.81	247.36	213.3	192.18
12	282	249.74	397.65	338.86	325.78	273.26	247.49	203.25
13	384	414.41	298.32	293.87	304.95	270.83	228.35	227.49
14	250	268.07	307.53	238.38	239.4	206.99	189.28	256.6
15	401	336.89	212.81	247.97	207.62	163.74	204.44	206.96
16	335	297.58	208.68	250.5	208.87	177.88	235.25	237.89
17	218	230.75	278.1	277.77	349.56	286.91	264.42	275.12
18	300	365.52	359.14	260.81	289.29	151.71	218.78	253.35
19	453	314.29	367.01	392.44	479.81	372.1	236.64	320.36
20	253	270.61	257.51	375.4	449.07	173.95	206.52	220.09
average	317.8	321.369	316.7765	320.205	325.157	232.437	17.85	16.45
variance	3990.274	4979.673	5433.551	4705.497	6560.31	3794.19	2017.493	2859.336

Table 4.3.3. Results. averages and variances of 20 replications for maximum time in

	run123	run124	run125	run134	run135	run145	run 234	run235
1	372.76	407.89	364.05	412.94	356.68	355.01	324.14	303.17
2	334.19	342.28	327.38	330.75	343.49	369.19	363.18	281.15
3	480.29	309.04	374.44	298.22	244.12	368.77	320.18	219.33
4	419.17	394.93	420.66	338.89	353.85	324.65	219.88	321.01
5	305.91	390.29	412.16	306.79	312.89	367.36	250.79	352.56
6	381.64	331.01	321.77	470.57	378.16	347.44	355.1	321.99
7	331.51	361.76	385.23	200.57	256.33	231.43	339.45	405.24
8	347.41	361.91	337.58	366.31	422.87	267.48	366.19	288.78
9	329.67	372.79	404.04	306.21	317.11	276.47	362.41	389.42
10	545.24	375.18	530.3	241	262.55	296.69	443.79	561.14
11	306.65	318.81	320.91	285.58	320.87	296.06	326	259.39
12	410.33	311.51	383.37	396.45	417.33	205.61	419.75	373.01
13	376.54	347.68	389.42	380.62	407.93	373.23	360.05	287.63
14	370.85	259.98	260.25	266.44	263.66	319.96	252.04	237.54
15	350.08	448.74	294.07	230.92	368.36	380.55	275.18	267.21
16	352.24	286.46	215.16	298.77	320.94	257.69	202.92	263.6
17	288.94	354.04	241.5	261.84	327.52	333.48	263.56	349.56
18	302.46	333.32	278.83	295.22	271.2	312.07	281.86	286.56
19	420.03	412.11	363.33	328.94	346.33	354.14	398.93	481.58
20	384.63	463.46	482.75	240.93	254.49	303.42	356.49	287.16
average	370.527	359.1595	355.36	312.898	327.334	317.035	17.85	16.45
variance	3930.591	2643.283	6038.194	4555.176	3118.174	2506.963	4281.769	6986.258

Table 4.3.4. Results. averages and variances of 20 replications for maximum time in

	run245	run345	run1234	run1235	run1245	run1345	run2345	run12345
1	341.75	401.15	437.2	381.4	448.66	431.66	34	361.53
2	278.8	272.86	342.54	342.9	377.49	340.17	333.8	387.12
3	219.44	278.78	307	370.1	219.85	357.08	224.1	359.32
4	338.16	297.17	383.9	344.5	478.6	345.62	318.3	411.48
5	436.04	348.32	400.1	367.4	473.63	414.13	442.1	396.59
6	342.24	313.46	398.57	322.4	370.13	336.09	320.7	356.06
7	279.53	214.58	344.21	384.0	419.55	270.85	381.0	337.71
8	302.66	328.17	406.14	382.1	321.14	269.47	270.5	443.96
9	386.46	216.71	393.91	432.2	414.03	302.41	304.7	454.58
10	529.93	270.38	409.77	470.0	439.46	324.06	484.7	434.83
11	271.05	200.13	315.25	325.6	296.58	323.58	244.8	347.05
12	466.72	231.34	356.9	328.9	316.96	266.3	417.8	350.33
13	358.59	288.86	374.87	397.6	378.01	390.73	343.	384.32
14	282.56	195.04	277.44	235.4	271.79	227.3	233.5	307.5
15	253.15	159.89	321.22	267.3	274.2	233.39	249.5	279.44
16	229.22	192.36	212.93	310.5	311.41	193.85	287.3	295.33
17	351.51	316.38	336.94	298.1	295.65	282.45	344.2	335.89
18	271.54	338.47	267.87	360.8	278.48	263.14	321.9	284.85
19	387.77	347.61	433.54	383.4	403.1	393.54	371.6	380.09
20	393.24	198.46	398.12	381.	387.88	380.88	335.2	316.36
average	336.018	270.506	355.921	354.36	358.83	317.335	17.8	16.45
variance	6562.572	4411.6	3498.781	2909.29	5593.41	4360.184	4730.74	2611.693

Table 4.3.5. Effects and Results of Analysis of Variance for maximum time in system statistic

source of variation	average	effect	SSx	df	MSx	Fo	
1	300.5	65.68275	690275.7836	1	690275.78	167.940	significant
2	298.96	71.91	827367.696	1	827367.7	201.294	significant
3	195.48	7.259	8430.89296	1	8430.893	2.05119	insignificant
4	218.5	12.99	26998.416	1	26998.416	6.56856	significant
5	237.1	17.3	47886.4	1	47886.4	11.650	significant
12	355.39	-28.21	127328.656	1	127328.66	30.9783	significant
13	308.43	-4.24	2876.416	1	2876.416	0.69981	insignificant
14	317.8	-12.62	25482.304	1	25482.304	6.19970	significant
15	321.36	-13.2	27878.4	1	27878.4	6.78266	significant
23	316.76	-3.47	1926.544	1	1926.544	0.46871	insignificant
24	320.2	-8.024	10301.53216	1	10301.532	2.50630	insignificant
25	325.08	-11.62	21603.904	1	21603.904	5.25611	significant
34	232.38	-3.64	2119.936	1	2119.936	0.51576	insignificant
35	227.37	-5.14	4227.136	1	4227.136	1.02843	insignificant
45	246.47	-5.401	4667.32816	1	4667.3282	1.13553	insignificant
123	371.014	4.16	2768.896	1	2768.896	0.67365	insignificant
124	359.15	6.99	7817.616	1	7817.616	1.90198	insignificant
125	355.36	4.861	3780.69136	1	3780.6914	0.91982	insignificant
134	312.87	-0.59	55.696	1	55.696	0.01355	insignificant
135	327.36	4.31	2972.176	1	2972.176	0.72311	insignificant
145	317	3.611	2086.29136	1	2086.2914	0.50758	insignificant
234	324.01	-1.231	242.45776	1	242.45776	0.05898	insignificant
235	326.83	0.433	29.99824	1	29.99824	0.00729	insignificant
245	336	6.09	5934.096	1	5934.096	1.44373	insignificant
345	270.5	6.389	6531.09136	1	6531.0914	1.58897	insignificant
1234	355.89	1.631	425.62576	1	425.62576	0.10355	insignificant
1235	354.8	-2.09	698.896	1	698.896	0.17003	insignificant
1245	358.81	1.15	211.6	1	211.6	0.05148	insignificant
1345	317.33	-2.686	1154.33536	1	1154.3354	0.28084	insignificant
2345	328.1	-3.04	1478.656	1	1478.656	0.35974	insignificant
12345	361.8	4.947	3915.64944	1	3915.6494	0.95265	insignificant
error			2499028.882	608	4110.2449		
total			4368504	639			

Table 4.4.1. Results. averages and variances of 20 replications for number of damaged vehicles

	run0	run1	run2	run3	run4	run5	run12	run13
1	2	13	8	10	6	6	16	21
2	2	11	6	6	3	4	17	16
3	3	11	5	12	8	9	14	20
4	2	9	10	9	6	8	16	18
5	1	8	5	6	3	9	17	13
6	0	13	8	13	5	7	20	23
7	1	4	9	8	3	6	14	11
8	1	13	7	7	4	8	25	21
9	1	9	10	6	4	5	22	16
10	2	12	12	9	3	6	24	20
11	2	10	7	9	3	4	20	19
12	2	10	8	10	2	4	18	13
13	2	13	10	12	8	5	23	19
14	0	10	5	6	1	8	11	14
15	4	9	6	7	2	6	14	13
16	0	6	2	6	3	4	16	13
17	5	7	6	11	4	6	13	15
18	0	10	4	5	6	7	16	11
19	1	13	10	9	7	7	23	20
20	4	12	10	9	2	9	18	13
average	1.75	10.15	7.4	8.5	4.15	6.4	17.85	16.45
variance	1.986842	6.45	6.463158	5.526316	4.239474	2.989474	15.71316	13.94474

Table 4.4.2. Results. averages and variances of 20 replications for number of damaged vehicles

	run14	run15	run23	run24	run25	run34	run35	run45
1	17	17	19	15	15	14	13	10
2	14	14	12	10	11	8	11	7
3	14	14	17	12	12	18	19	12
4	16	19	19	13	17	13	13	9
5	12	20	11	10	16	9	15	12
6	19	22	19	13	13	17	17	8
7	7	10	20	12	16	10	13	6
8	15	22	17	10	15	11	15	11
9	13	18	18	14	16	9	11	8
10	12	14	20	16	18	10	12	8
11	12	14	17	12	12	10	11	7
12	10	11	18	15	16	10	15	8
13	18	16	17	15	12	14	13	10
14	10	14	13	6	12	8	11	9
15	14	15	11	10	10	7	7	5
16	12	11	12	11	10	6	12	8
17	9	11	22	12	22	16	19	12
18	13	17	14	12	15	7	11	12
19	20	18	19	17	17	15	15	10
20	9	14	18	16	22	11	12	11
average	13.3	15.55	16.65	12.55	14.85	11.15	13.25	9.15
variance	12.11579	12.57632	10.87105	7.207895	11.81842	12.34474	8.513158	4.45

Table 4.4.3. Results. averages and variances of 20 replications for number of damaged vehicles

	run123	run124	run125	run134	run135	run145	run234	run235
1	31	27	27	25	24	21	23	22
2	22	21	25	21	21	19	17	20
3	26	19	20	25	22	21	22	24
4	31	26	28	26	25	23	19	23
5	20	22	25	19	24	21	14	19
6	33	20	23	30	29	21	21	22
7	24	15	19	12	17	10	18	23
8	26	22	25	21	28	17	18	26
9	30	27	25	19	23	17	20	22
10	24	20	23	16	18	13	21	23
11	26	20	15	20	21	14	17	19
12	29	13	16	19	24	10	23	23
13	34	31	31	29	29	24	21	22
14	25	14	18	17	20	20	18	18
15	24	22	21	12	19	16	14	18
16	20	12	12	14	18	11	12	15
17	24	15	18	23	26	18	24	25
18	22	18	21	14	18	15	13	19
19	30	29	30	23	25	21	23	25
20	25	21	27	16	19	18	22	25
average	26.3	20.7	22.45	20.05	22.5	17.5	19	21.65
variance	17.06316	28.64211	26.15526	27.94474	14.36842	17.84211	13.15789	8.45

Table 4.4.4. Results. averages and variances of 20 replications for number of damaged vehicles

	run245	run345	run1234	run1235	run1245	run1345	run2345	run12345
1	19	18	35	34	31	28	26	38
2	14	13	25	29	28	25	20	33
3	17	24	30	28	23	31	26	37
4	18	16	32	40	35	31	23	37
5	17	18	27	26	33	35	22	36
6	15	17	32	30	25	28	24	33
7	12	14	24	28	19	19	22	30
8	22	19	22	29	26	23	27	36
9	18	13	26	30	30	22	23	35
10	16	14	26	33	26	23	22	31
11	16	14	25	26	20	20	22	29
12	15	20	23	29	18	17	26	29
13	21	17	35	35	33	33	28	35
14	14	15	23	25	19	20	21	30
15	14	10	24	18	22	17	17	27
16	12	12	16	21	16	15	17	23
17	15	23	31	33	25	23	31	30
18	20	15	18	28	24	18	23	28
19	23	21	34	34	36	32	33	42
20	21	15	31	25	29	24	24	33
average	16.95	16.4	26.95	29.05	25.9	24.2	23.85	32.6
variance	10.47105	13.41053	29.20789	25.20789	34.83158	35.53684	16.23947	20.25263

Table 4.4.5. Effects and Results of Analysis of Variance for number of damaged vehicles statistic

source of variation	average	effect	SSx	df	MSx	Fo	
1	10.15	8.615	11874.916	1	11874.916	839.9884	significant
2	7.4	7.765	9647.236	1	9647.236	682.41041	significant
3	8.5	6.997	7833.2814	1	7833.28144	554.09786	significant
4	4.15	2.728	1190.7174	1	1190.71744	84.227024	significant
5	6.4	4.959	3934.669	1	3934.66896	278.32418	significant
12	17.85	-0.003	0.00144	1	0.00144	0.0001019	insignificant
13	16.45	-0.159	4.04496	1	4.04496	0.2861258	insignificant
14	13.3	-0.115	2.116	1	2.116	0.1496781	insignificant
15	15.55	-0.209	6.98896	1	6.98896	0.4943736	insignificant
23	16.65	0.178	5.06944	1	5.06944	0.3585938	insignificant
24	12.55	0.059	0.55696	1	0.55696	0.0393973	insignificant
25	14.85	0.028	0.12544	1	0.12544	0.0088732	insignificant
34	11.15	-0.247	9.76144	1	9.76144	0.6904888	insignificant
35	13.25	-0.153	3.74544	1	3.74544	0.2649388	insignificant
45	9.15	-0.121	2.34256	1	2.34256	0.1657042	insignificant
123	26.3	-0.015	0.036	1	0.036	0.0025465	insignificant
124	20.7	-0.046	0.33856	1	0.33856	0.0239485	insignificant
125	22.45	-0.228	8.31744	1	8.31744	0.5883455	insignificant
134	20.05	0.0093	0.0138384	1	0.0138384	0.0009789	insignificant
135	22.5	0.0531	0.4511376	1	0.4511376	0.0319118	insignificant
145	17.5	0.171	4.67856	1	4.67856	0.3309443	insignificant
234	19	-0.353	19.93744	1	19.93744	1.410302	insignificant
235	21.65	-0.271	11.75056	1	11.75056	0.8311919	insignificant
245	16.95	0.159	4.04496	1	4.04496	0.2861258	insignificant
345	16.4	0.29	13.456	1	13.456	0.9518285	insignificant
1234	26.95	0.065	0.676	1	0.676	0.0478178	insignificant
1235	29.05	0.021	0.07056	1	0.07056	0.0049912	insignificant
1245	25.9	0.665	19.54	1	19.54	1.4230022	insignificant
1345	24.2	-0.09	1.296	1	1.296	0.0916743	insignificant
2345	23.85	0.359	20.62096	1	20.62096	1.4586518	insignificant
12345	32.6	0.015	0.036	1	0.036	0.0025465	insignificant
error			7850.676	608	12.26682		
total			42471.512	639			

Table 4.5.1. Results. averages and variances of 20 replications for number of totally destructed vehicles

	run0	run1	run2	run3	run4	run5	run12	run13
1	1	0	0	7	2	3	1	5
2	0	0	1	3	1	0	2	3
3	0	0	1	8	2	1	1	4
4	0	0	1	4	3	1	1	7
5	0	1	0	2	0	2	0	2
6	0	0	0	7	0	2	1	3
7	0	0	1	4	0	1	2	5
8	0	2	4	5	2	2	1	5
9	0	0	3	3	0	1	3	3
10	0	0	3	5	0	1	2	4
11	0	1	0	4	0	1	1	3
12	0	0	1	4	1	1	1	6
13	0	0	4	8	2	0	3	4
14	0	0	1	1	0	1	0	3
15	0	0	0	3	1	0	0	3
16	0	0	0	2	0	1	1	3
17	0	0	2	5	1	1	0	8
18	0	0	0	1	3	0	1	3
19	0	0	2	3	1	0	1	4
20	0	0	2	5	0	1	1	3
average	0.05	0.2	1.3	4.2	0.95	1	1.15	4.05
variance	0.05	0.273684	1.8	4.378947	1.102632	0.631579	0.765789	2.365789

Table 4.5.2. Results. averages and variances of 20 replications for number of totally destructed vehicles

	run14	run15	run23	run24	run25	run34	run35	run45
1	1	1	6	1	0	8	10	2
2	1	3	3	1	2	3	3	1
3	2	0	8	3	2	8	3	2
4	2	2	5	3	5	7	4	3
5	1	1	2	2	2	3	5	4
6	0	1	10	1	1	6	10	2
7	0	0	7	0	2	3	4	1
8	2	1	5	0	4	6	4	3
9	1	1	5	3	4	4	4	3
10	0	1	4	1	2	3	6	2
11	1	2	1	1	2	3	3	1
12	1	0	6	3	2	5	5	1
13	1	2	6	3	1	5	4	3
14	1	3	1	1	2	3	7	2
15	0	0	4	1	3	5	2	2
16	2	0	3	0	0	3	3	2
17	0	0	7	2	2	7	6	1
18	1	1	4	5	2	5	5	3
19	0	0	7	5	0	6	7	1
20	1	0	8	3	3	5	3	2
average	0.9	0.95	5.1	1.95	2.05	4.9	4.9	2.05
variance	0.515789	0.997368	5.778947	2.260526	1.734211	3.042105	4.936842	0.786842

Table 4.5.3. Results. averages and variances of 20 replications for number of totally destructed vehicles

	run123	run124	run125	run134	run135	run145	run234	run235
1	6	1	1	7	5	2	7	6
2	4	2	1	5	3	1	5	6
3	3	2	2	7	8	4	6	9
4	7	3	4	6	5	1	7	4
5	5	0	2	6	4	4	3	7
6	7	2	1	7	7	1	7	9
7	7	0	2	5	5	0	4	8
8	4	2	2	5	4	5	5	8
9	5	3	4	3	4	2	7	7
10	3	3	2	5	3	3	7	5
11	8	1	0	6	3	0	4	4
12	8	3	2	5	6	0	9	8
13	8	6	3	9	10	4	6	5
14	9	3	3	5	5	2	7	6
15	4	3	1	5	3	0	4	6
16	4	1	1	5	3	0	3	6
17	7	0	5	6	9	2	8	4
18	4	3	3	2	6	2	4	6
19	6	3	4	5	3	2	7	6
20	6	0	2	5	4	0	9	8
average	5.75	2.05	2.25	5.45	5	1.75	5.95	6.4
variance	3.355263	2.260526	1.671053	2.155263	4.421053	2.513158	3.418421	2.463158

Table 4.5.4. Results. averages and variances of 20 replications for number of totally destructed vehicles

	run245	run345	run1234	run1235	run1245	run1345	run2345	run12345
1	1	6	6	5	3	9	6	6
2	5	4	3	5	1	4	4	4
3	3	10	9	4	9	8	7	13
4	6	6	7	10	4	6	8	9
5	3	7	8	4	6	7	7	7
6	0	6	5	7	0	6	11	8
7	3	5	7	5	1	4	7	8
8	4	8	4	7	2	6	9	8
9	3	6	6	10	6	7	10	11
10	0	5	7	4	3	4	5	5
11	4	6	8	5	2	6	8	6
12	2	8	11	8	3	5	11	10
13	1	5	7	6	4	6	4	8
14	4	7	6	12	1	6	10	7
15	3	5	7	2	5	4	2	4
16	2	6	5	6	1	8	6	5
17	2	10	7	9	2	8	8	10
18	3	6	7	5	4	4	8	5
19	7	5	4	7	6	7	11	6
20	3	5	8	8	5	4	6	12
average	2.95	6.3	6.6	6.45	3.4	5.95	7.4	7.6
variance	3.207895	2.642105	3.410526	6.155263	5.2	2.576316	6.357895	6.778947

4.5.5. Effects and Analysis of Variance for number of totally destructed vehicles statistic

source of variation	averages	effect	SSx	df	MSx	Fo	
1	0.2	0.128	2.62144	1	2.62144	0.93115	insignificant
2	1.3	1.234	243.641	1	243.641	86.5431	significant
3	4.2	4.19	2808.976	1	2808.976	997.769	significant
4	0.95	0.959	147.149	1	147.149	52.2684	significant
5	1	0.99	156.816	1	156.816	55.7022	significant
12	1.15	0.14	3.136	1	3.136	1.11393	insignificant
13	4.05	0.084	1.12896	1	1.12896	0.40101	insignificant
14	0.9	0.028	0.12544	1	0.12544	0.04456	insignificant
15	0.95	-0.09	1.296	1	1.296	0.46035	insignificant
23	5.1	0.078	0.97344	1	0.97344	0.34577	insignificant
24	1.95	-0.028	0.12544	1	0.12544	0.04456	insignificant
25	2.05	0.09	1.296	1	1.296	0.46035	insignificant
34	4.9	0.078	0.97344	1	0.97344	0.34577	insignificant
35	4.9	0.009	0.01296	1	0.01296	0.0046	insignificant
45	2.05	0.0906	1.313338	1	1.313338	0.46651	insignificant
123	5.75	0.0343	0.188238	1	0.188238	0.06686	insignificant
124	2.05	0.053	0.44944	1	0.44944	0.15964	insignificant
125	2.25	0.0468	0.350438	1	0.350438	0.12448	insignificant
134	5.45	0.021	0.07056	1	0.07056	0.02506	insignificant
135	5	-0.121	2.34256	1	2.34256	0.83209	insignificant
145	1.75	-0.065	0.676	1	0.676	0.24012	insignificant
234	5.95	-0.046	0.33856	1	0.33856	0.12026	insignificant
235	6.4	0.021	0.07056	1	0.07056	0.02506	insignificant
245	2.95	0.0281	0.126338	1	0.126338	0.04488	insignificant
345	6.3	-0.0031	0.001538	1	0.001538	0.00055	insignificant
1234	6.6	-0.065	0.676	1	0.676	0.24012	insignificant
1235	6.45	-0.096	1.47456	1	1.47456	0.52377	insignificant
1245	3.4	0.084	1.12896	1	1.12896	0.40101	insignificant
1345	5.95	-0.059	0.55696	1	0.55696	0.19784	insignificant
2345	7.4	-0.0031	0.001538	1	0.001538	0.00055	insignificant
12345	7.6	0.078	0.97344	1	0.97344	0.34577	insignificant
error			2356.698	608	3.876148		
total			5735.708	639			

APPENDIX C

RESULTS BELONGING TO CHAPTER 5



Table 5.1. Results of 20 replications for maximum time in statistic for scenarios

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
1	339.53	363.25	286	285.75	274.21
2	199.73	322.78	200.52	269.73	244.23
3	178.6	198.22	229.65	292.25	237.37
4	244.86	324.65	186.88	318.45	247.33
5	352.92	290.32	310.85	178.01	159.38
6	237.49	314.1	243.2	367.27	209.29
7	139.77	289.35	331.25	326.54	303.62
8	171.53	331.99	213.27	339.21	241.39
9	258.72	449.59	230.44	206.64	277.8
10	217.34	410.52	234.64	325.62	184.78
11	232.74	231.99	311.01	383.8	196.6
12	206.1	413.3	486.43	199.51	275.92
13	284.68	382.63	317.17	370.2	257.27
14	164.83	253.03	259.07	237.4	238.04
15	261.03	236.52	249.39	389.88	219.99
16	149.19	254.4	240.84	305.14	294.29
17	170.42	269.3	221.25	242.22	223.73
18	214.15	282.8	217.74	239.33	200.65
19	238.76	381.58	227.29	309.89	168.96
20	247.97	406.42	237.82	228.78	263.27
average	225.518	320.337	261.7355	290.781	235.906
variance	3294.440238	5003.137106	4449.33223	4058.046094	1637.309183
Rinott Ni	54.96453244	83.47247846	74.2327825	67.70455375	27.31691189

Table 5.2. Results of 20 replications for maximum time in statistic for scenarios

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
1	344.18	366.12	328.15	258.89	233.43
2	253.62	244.39	270.15	237.76	174.82
3	243.66	225.86	222.01	205.78	197.28
4	306.13	335.28	208.25	302.18	202.68
5	224.13	192.84	306.24	236.82	190.57
6	231.58	278.96	266.86	280.96	181.78
7	192.44	310.44	223.51	256.93	264.48
8	242.49	370.56	336.6	414.03	202.32
9	357.48	247.02	286.27	255.97	227.91
10	276.13	277.91	288.67	260.66	249.17
11	273.25	512.64	228.7	369.02	251.49
12	401.57	294.52	317.55	206.55	257.95
13	265.91	361.79	315.45	370.61	277.23
14	498.64	299.62	370.98	168.27	140.25
15	218.97	300.8	249.7	257.53	373.06
16	310.84	245.23	212.47	243.82	270.72
17	254.66	228.69	233.99	359.25	219.9
18	227.16	328.92	269.14	229.53	194.71
19	234.23	201.98	295.66	305.01	242.55
20	240.95	239.66	208.13	171.91	239.54
average	279.901	293.1615	271.924	269.574	229.592
variance	5364.870304	5516.505561	2299.56893	4438.600531	2438.210533
Rinott Ni	89.50764518	92.03753201	38.3660719	74.05373455	40.67917225

Table 5.3. Results of 20 replications for average time in system statistic

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
1	80.97969188	100.872583	92.27901	94.27061	83.41522293
2	82.02723975	89.4062411	85.18545	88.28968	85.39079871
3	76.88376915	89.6083513	91.19765	98.742	80.182875
4	79.33338448	90.1038799	88.64506	101.1501	77.201603
5	87.63261752	102.082391	106.3033	89.03896	86.21215776
6	78.86401267	101.723678	90.65045	94.03939	83.05114389
7	73.9106841	88.6757203	89.74868	87.0491	84.10305264
8	73.56329869	85.4268795	80.1824	88.62605	88.70803504
9	76.89963944	91.6523764	91.24092	102.295	90.76777083
10	76.05082778	96.4123143	97.89529	83.66058	72.17620735
11	81.72448488	84.7323616	86.539	93.82302	83.19288733
12	79.8454944	93.2741559	90.97685	88.77911	81.32661025
13	85.89101681	92.2939882	83.78412	88.0226	82.84849592
14	77.94628028	82.0991347	85.02793	82.55445	83.04311478
15	83.19618894	84.7303087	86.92281	98.81348	81.26057781
16	77.44192688	85.8461963	86.61373	90.93258	78.69133597
17	82.8882067	94.5546577	91.52622	91.79029	79.15458657
18	83.78477465	79.8133169	82.45468	85.01472	84.63971246
19	83.65184643	105.867818	92.24365	104.6742	78.24190245
20	78.41796854	90.7872289	83.50415	88.76423	84.05990886
average	80.0466677	91.4981791	89.14607	92.01651	82.38339998
variance	14.5069266	50.0990387	34.06967	39.93122	17.21815359
Rinott Ni	0.968135865	3.34341502	2.273677	2.664854	1.149072611

Table 5.4. Results of 20 replications for average time in system statistic

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
1	93.92485199	96.4879889	96.42521	94.53191	85.02941152
2	83.1296402	84.5402687	82.23703	83.67647	87.53527572
3	91.42104598	93.8571639	89.76464	90.88702	83.13701968
4	96.11387647	96.3849096	102.8433	106.0004	77.61937909
5	96.22798587	94.6913511	100.0834	95.82335	84.21989386
6	90.72177704	94.932558	89.62466	89.9347	84.54347748
7	84.44564339	85.420581	83.85871	88.15933	84.69647935
8	85.28552189	89.9264388	100.0857	100.3957	84.31712413
9	103.8642825	100.152622	85.00068	91.98402	83.78469215
10	81.35469549	90.4184085	81.44329	81.10124	75.22573959
11	90.77225706	98.5832717	86.82369	89.54946	82.76989203
12	88.33294707	80.4241469	85.86559	79.92388	85.06494801
13	79.15233588	90.2513462	86.08216	92.75932	88.93285408
14	96.58219002	88.4006925	87.55966	86.07345	75.8040312
15	87.08993901	92.2718568	92.34716	93.22029	97.79619633
16	84.1836153	86.4158398	80.728	87.03398	80.21231251
17	93.3827979	93.3584601	97.17999	99.6095	81.94807691
18	89.80909723	85.039228	88.90276	85.98646	75.84595077
19	93.44286441	96.682057	106.8818	103.9923	85.38767446
20	84.85616162	87.7932449	84.27349	79.47082	75.59595331
average	89.70467632	91.3016217	90.40055	91.00568	82.97331911
variance	37.6878864	28.1913389	58.59577	57.0855	29.15711658
Rinott Ni	2.515142975	1.88138032	3.910454	3.809665	1.945832572

Table 5.5. Results of 20 replications for number of damaged vehicles statistic

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
1	13	26	27	25	13
2	14	22	21	21	15
3	8	21	22	29	10
4	11	28	27	29	11
5	8	21	20	21	7
6	10	29	26	21	14
7	6	28	20	17	13
8	12	18	18	27	19
9	12	26	25	17	13
10	5	35	23	28	10
11	10	17	19	20	11
12	9	19	22	12	12
13	13	31	20	26	14
14	5	13	21	20	11
15	12	21	22	27	9
16	7	25	24	25	9
17	7	21	19	15	9
18	9	16	22	19	12
19	13	34	21	28	11
20	11	24	21	19	18
average	9.75	23.75	22	22.3	12.05
variance	7.881578947	35.25	6.842105	25.27368	8.892105263
Rinott Ni	11.85305491	53.01224	10.2898	38.00893	13.37277881

Table 5.6. Results of 20 replications for number of damaged vehicles statistic

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
1	26	26	25	25	12
2	18	21	17	20	14
3	27	26	25	26	12
4	24	22	21	20	9
5	22	19	22	23	13
6	18	26	19	23	12
7	19	16	16	17	16
8	20	22	32	22	14
9	19	17	13	20	14
10	23	24	19	20	11
11	19	23	18	21	9
12	21	17	13	19	13
13	20	24	24	31	15
14	26	23	21	17	6
15	22	22	25	22	23
16	19	24	21	23	15
17	22	22	26	26	10
18	22	17	17	16	7
19	23	22	20	26	11
20	24	25	20	14	12
average	21.7	21.9	20.7	21.55	12.4
variance	7.484210526	10.09474	21.37895	16.47105	13.2
Rinott Ni	12.48667763	16.84209	35.6687	27.48035	22.02291667

Table 5.7. Results of 20 replications for number of totally destructed vehicles statistic

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
1	0	6	8	8	1
2	1	1	3	2	1
3	1	5	5	7	0
4	0	6	9	4	2
5	2	8	9	7	0
6	1	9	7	4	0
7	1	10	9	6	5
8	0	4	4	12	2
9	1	8	8	2	4
10	0	6	5	7	1
11	0	3	6	9	2
12	0	6	6	4	1
13	1	9	3	2	0
14	1	6	9	5	1
15	1	3	4	8	1
16	2	6	8	3	1
17	1	5	4	2	0
18	1	2	4	4	2
19	3	4	5	5	1
20	1	4	4	6	1
average	0.93	6.16	6.26	5.72	1.46
variance	0.621052632	5.839474	4.736842	7.292105	1.694736842
Rinott Ni	9.325493421	87.68335	71.12664	109.4955	25.44753289

Table 5.8. Results of 20 replications for number of totally destructed vehicles statistic

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
1	5	6	6	7	0
2	2	5	6	4	2
3	6	11	6	6	0
4	7	5	6	9	0
5	10	7	7	5	1
6	1	9	4	6	4
7	8	5	6	7	5
8	8	3	14	6	1
9	5	7	5	7	1
10	5	6	7	8	1
11	5	5	8	5	1
12	7	8	3	9	0
13	8	6	6	6	0
14	7	7	5	6	2
15	11	4	7	6	2
16	6	5	8	6	2
17	5	7	12	3	1
18	6	2	2	6	1
19	5	9	5	7	1
20	9	6	7	7	0
average	5.79	6.32	6.69	6.59	1.16
variance	5.8	4.45	7.315789	2.115789	1.776315789
Rinott Ni	87.090625	66.81953	109.8512	31.7699	26.67249178

Table 5.6.1. Number of damaged wheeled trucks by five factors

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
usual break	3.766	2.433	2.933	2.56	3.4
air attack	1.5	5.566	4.2	4.8	2.83
artillery	0	4.133	4.066	3.7	0
mine	0.3	1.2	1.13	1.466	0.8
ambush	0.4	1.866	1.933	1.933	0.933
total	5.966	15.198	14.262	14.459	7.963

Table 5.6.2. Number of damaged wheeled trucks by five factors

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
usual break	2.66	1.66	1.66	1.4	2.93
air attack	4.4	4.8	4.8	4.8	2.53
artillery	3.66	4.4	3.733	4.13	0
mine	1.466	1.46	1.6	1.6	0.933
ambush	1.66	1.66	2.066	2.066	1.2
total	13.846	13.98	13.859	13.996	7.593

Table 5.6.3. Number of damaged armored vehicles by five factors

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
usual break	2.8	2.133	2.133	2.133	2.133
air attack	0.55	2.2	1.4	1.866	1
artillery	0	2.33	2.33	1.966	0
mine	0.266	0.66	0.6	0.733	0.533
ambush	0.2	1.3	1.3	1.3	0.33
total	3.816	8.623	7.763	7.998	3.996

Table 5.6.4. Number of damaged armored vehicles by five factors

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
usual break	2.233	1.533	1.533	1.533	2.133
air attack	1.33	1.8	1.6	1.53	0.8
artillery	2.2	2.66	2	2.33	0
mine	0.733	0.733	0.766	0.766	0.533
ambush	1.3	1.3	1.4	1.4	0.8
total	7.796	8.026	7.299	7.559	4.266

Table 5.7.1. Number of totally destructed wheeled trucks by five factors

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
usual break	0.166	0	0.066	0	0
air attack	0.3	1	1	0.666	0.333
artillery	0	2.766	2.8	2.4	0
mine	0.166	0.4	0.533	0.866	0.466
ambush	0.066	0.4	0.266	0.266	0.33
total	0.698	4.466	4.665	4.198	1.129

Table 5.7.2. Number of totally destructed wheeled trucks by five factors

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
usual break	0.133	0	0.066	0	0
air attack	0.666	0.866	1	0.66	0.33
artillery	2.2	2.53	2.466	2.8	0
mine	0.8	0.8	0.733	1.2	0.6
ambush	0.333	0.133	0.466	0.2	0.133
total	4.132	4.329	4.731	4.86	1.063

Table 5.7.3. Number of totally destructed armored vehicles by five factors

	Middle Anatolia	Trakya Greece	Bulgaria	Aegean	Middle Black sea
usual break	0.066	0	0	0	0
air attack	0.066	0.266	0.066	0.2	0.133
artillery	0	1.13	1.33	1.13	0
mine	0	0	0	0	0
ambush	0.1	0.2	0.2	0.2	0.2
total	0.232	1.596	1.596	1.53	0.333

Table 5.7.4. Number of totally destructed armored vehicles by five factors

	Eastern Black sea	Iran	Iraq	Syria	Mediterranean
usual break	0	0	0	0	0
air attack	0.133	0.133	0.2	0.133	0
artillery	1.33	1.46	1.266	1.4	0
mine	0	0	0	0	0
ambush	0.2	0.4	0.5	0.2	0.1
total	1.663	1.993	1.966	1.733	0.1

APPENDIX D

A PART OF CODE OF THE SIMULATION MODEL (MODEL FRAME)

```

0$      BEGIN,      Yes,headquarters wheel;
1$      CREATE,      75:,1;
2$      ASSIGN:      VSayac4=VSayac4+1:
                Truckno4=VSayac4:
                company#=4;
3$      STATION,      Enter4;
17$     BRANCH,      1:
                If,Truckno4<2,muh,Yes:
                Else,ORD,Yes;
muh     ASSIGN:      VBROKE20=DISC(0.02,0,1,1,36);
232$    BRANCH,      1:
                If,VBROKE20==0,pull42,Yes:
                Else,yukle42,Yes;
pull42  COUNT:      garagebreak42,1;
5$      DELAY:      TRIA(8,12,16);                take on vehicle
yukle42 QUEUE,      Vehicle42Q;
4$      REQUEST,      1:Vehicle42(SDS),430,Enter4;
6$      TRANSPORT:      Vehicle42,AMMO,430;
ORD     ASSIGN:      VBROKE21=DISC(0.02,0,1,1,36);
230$    BRANCH,      1:
                If,VBROKE21==0,pull41,Yes:
                Else,yukle41,Yes;
pull41  COUNT:      garagebreak41,1;
231$    DELAY:      TRIA(8,12,16);
yukle41 DELAY:      TRIA(8,10,12);                Garage storage loading
7$      QUEUE,      Vehicle41Q;
8$      REQUEST,      1:Vehicle41(SDS),430;
9$      TRANSPORT:      Vehicle41,sayac,430;
14$     STATION,      AITB4;
15$     DELAY:      0;
16$     TALLY:      time in system4,INT(VArrTime1),1;
bak     BRANCH,      1:
                If,maingroup==102,dev,Yes:
                Else,vdur,Yes;
dev     BRANCH,      1:
                If,Vtruck1#==3,emir2,Yes:
                If,Vtruck2#==3,emir3,Yes:
                If,Vtruck3#==3,emir4,Yes:
                If,Vtruck4#==3,emir5,Yes:
                Else,vscenario,Yes;
emir2   DELAY:      30;                harekat emri
59$     DELAY:      0;                take on

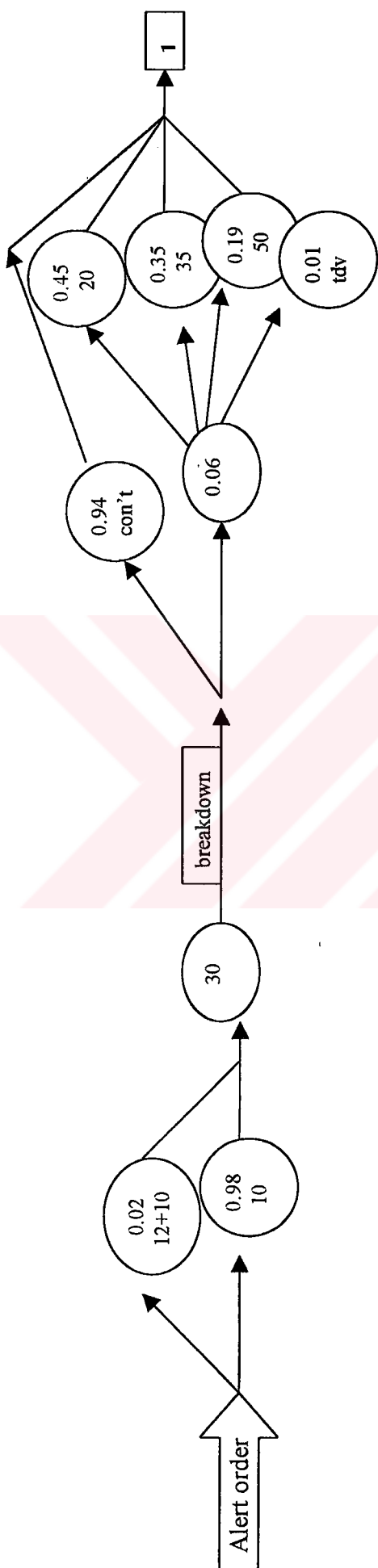
```

111\$ ASSIGN: left=left+1;
247\$ TALLY: check,INT(VArrTime1),1;
110\$ SIGNAL: 102,102;
vscenario TRANSPORT: ,Vcheck1,430;
emir3 DELAY: 33:NEXT(59\$);

emir4 DELAY: 36:NEXT(59\$);
emir5 DELAY: 39:NEXT(59\$);
vdur WAIT: 75,102:NEXT(dev);
18\$ STATION, Gaitb4;
19\$ TALLY: VGiris4,INT(VArrTime1),1;
33\$ ASSIGN: Vsayac5=Vsayac5+1;
Vtruck4#=Vsayac5;
20\$ TRANSPORT: ,AITB4,430;
22\$ CREATE, 9:,1:MARK(VArrTime1); tank company
wheel
107\$ ASSIGN: company#=1;
23\$ STATION, Enter1;
234\$ BRANCH, 1:
With,0.02,pull1,Yes:
Else,yukle1,Yes;
pull1 COUNT: garagebreak1,1;
233\$ DELAY: TRIA(8,12,16);
yukle1 DELAY: TRIA(8,10,12); garage depot loading
24\$ QUEUE, Vehicle1Q;
25\$ REQUEST, 1:Vehicle1(SDS),430,Enter1;
26\$ TRANSPORT: Vehicle1,sayac,430;
27\$ STATION, AITB1;
28\$ DELAY: 0; get off
29\$ TALLY: Time in system1,INT(VArrTime1),1;
34\$ ASSIGN: varisno1=varisno1+1;
Vtruck1#=varisno1:NEXT(bak);
30\$ STATION, GAITB1;
31\$ TALLY: VGiris1,INT(VArrTime1),1;
32\$ TRANSPORT: Vehicle1,AITB1,430;
35\$ STATION, AMMO:MARK(ammo1);
10\$ DELAY: UNIFORM(0.5,1); take off
11\$ DELAY: TRIA(8,10,12); loading
12\$ DELAY: UNIFORM(2,3); take on
36\$ TALLY: loadertime,INT(ammo1),1;
13\$ TRANSPORT: Vehicle42,sayac,430;
37\$ CREATE, 9:,1; tank company wheel2
108\$ ASSIGN: company#=2;
START2 STATION, Enter2;
235\$ BRANCH, 1:
With,0.02,pull2,Yes:
Else,yukle2,Yes;
pull2 COUNT: garagebreak2,1;

APPENDIX E

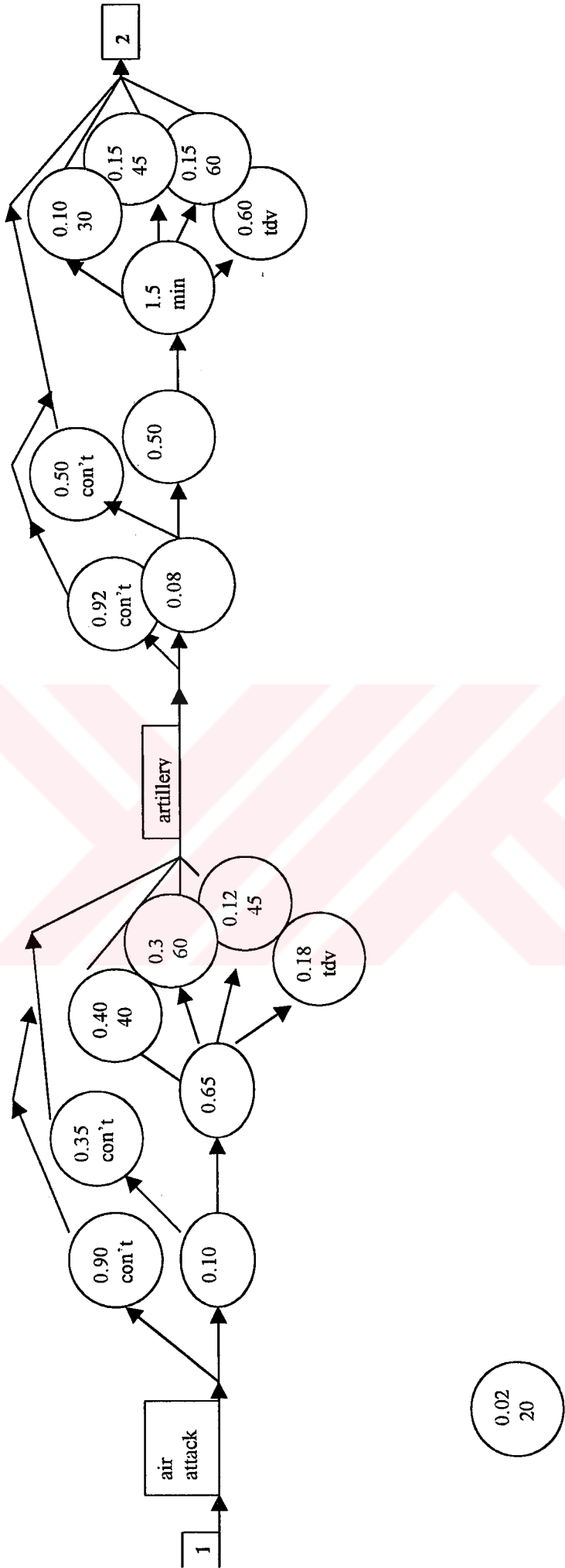
PROBABILITY TREE OF WHEELED-TRUCKS



0.02
20

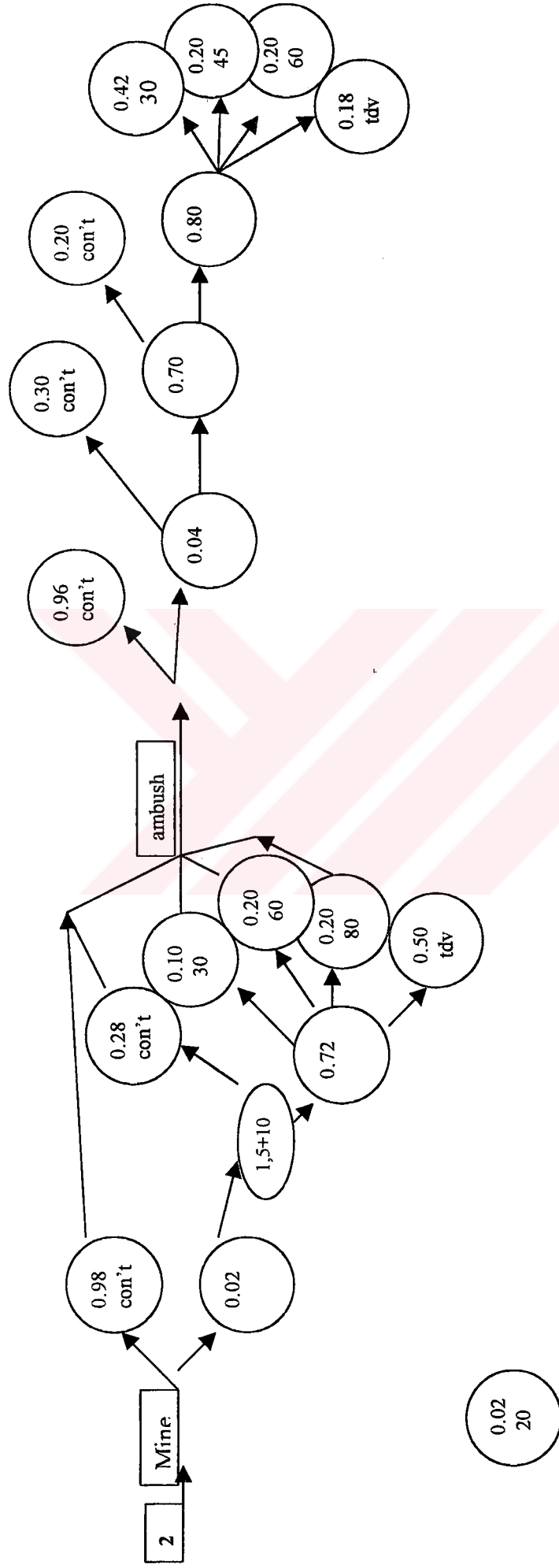
With 0.02 probability 20 minutes
tdv : totally destructed vehicle

PROBABILITY TREE OF WHEELED-TRUCKS (cont'd)



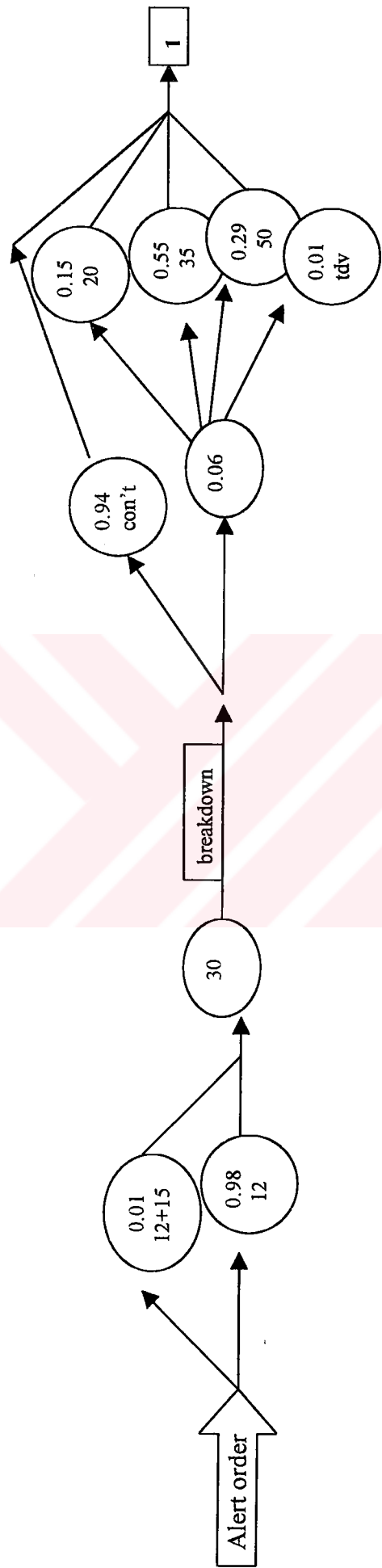
With 0.02 probability 20 minutes
tdv : totally destructed vehicle

PROBABILITY TREE OF WHEELED-TRUCKS (cont'd)



With 0.02 probability 20 minutes
tdv : totally destructed vehicle

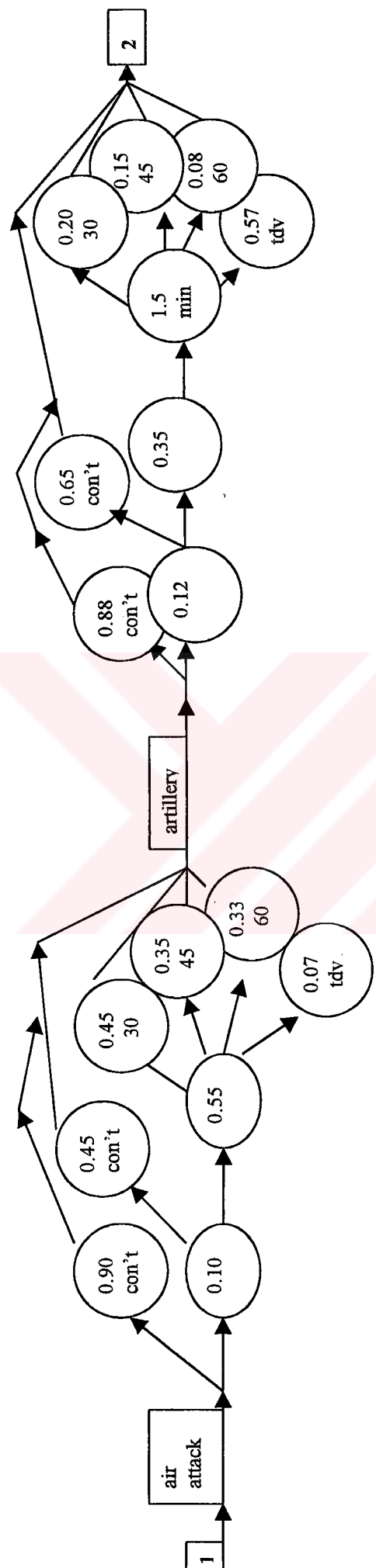
PROBABILITY TREE OF ARMORED VEHICLES



0.02
20

With 0.02 probability 20 minutes
tdv : totally destructed vehicle

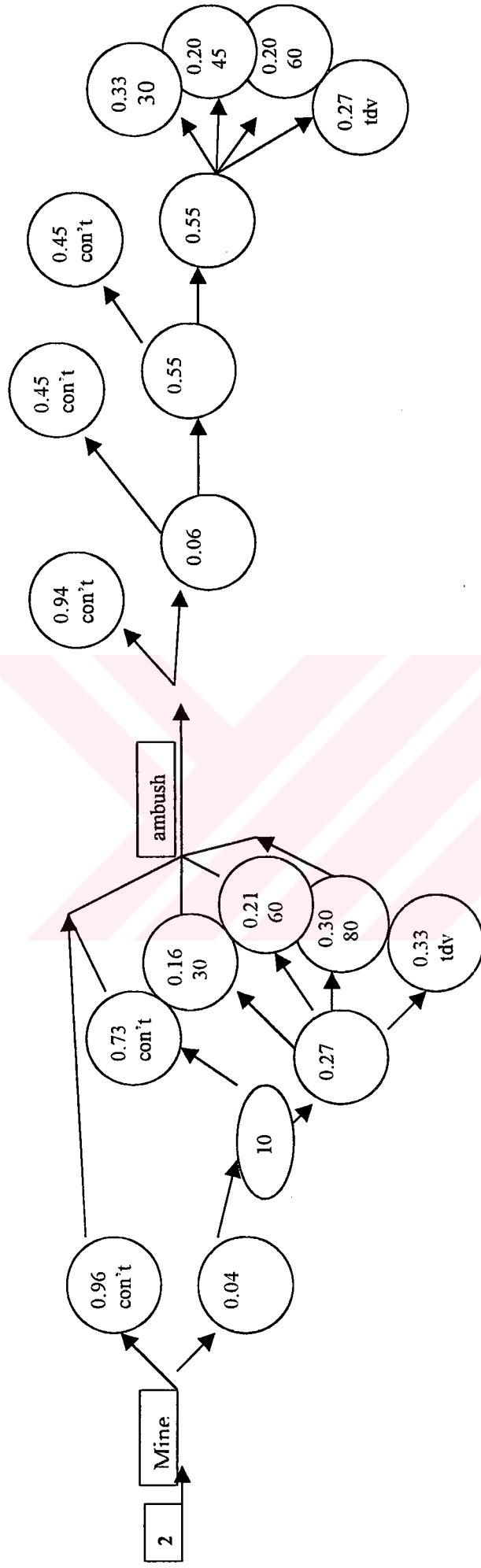
PROBABILITY TREE OF ARMORED VEHICLES (cont'd)



0.02
20

With 0.02 probability 20 minutes
tdv : totally destructed vehicle

PROBABILITY TREE OF ARMORED VEHICLES (cont'd)



0.02
20

With 0.02 probability 20 minutes
tdv : totally destructed vehicle

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