SIMULATION OF PERSONNEL MOBILIZATION AND COMPLETION SYSTEM AT BRIGADE LEVEL

A THESIS SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL ENGINEERING AND THE INSTITUTE OF ENGINEERING AND SCIENCES OF BILKENT UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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June, 2001

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ABSTRACT

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Turkish Armed Forces maintains the number of personnel in their units at minimum level during peacetime because of some political and economical reasons, but it sustains some activities under the name of "Personnel Mobilization and Completion System" to enable these units to reach their personnel numbers sufficient to combat in war situation. Today, for only a small part of this system Turkish Armed Forces can perform field exercises to see its behavior. There is no study to investigate all aspects of this system, which has a very important role in directly affecting the combat power of the Army. This thesis aims to analyze and, if there is any, to offer some solutions for the problems by using the simulation method. We believe that by using the simulation model of this system a scientific support mechanism for the commanders during the decision process can be provided. Moreover, by using this model, some improper functions can be detected earlier just at peacetime and some probable solutions can be evaluated with the help of studies including alternative system comparisons and optimization of some decision variables.

Keywords: Simulation, Personnel Mobilization, Personnel Completion Plan.

ÖZ

PERSONEL SEFERBERLİK VE BÜTÜNLEME SİSTEMİNİN TUGAY SEVİYESİNDE SİMÜLASYONU

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Türk Silahlı Kuvvetleri, ekonomik ve politik sebeplerden dolayı personel mevcutlarını barış zamanında asgari seviyede tutmakta ancak bir savaş durumunda mevcutlarını sefer kadrosu olarak adlandırılan rakamlara yükseltmek maksadıyla "Personel Seferberlik ve Bütünleme Planı" adı altında birtakım faaliyetler yürütmektedir. Orduların muharebe gücünü doğrudan etkileyen bu planların halihazırda sadece ufak bir kısmına ait bölümü arazi tatbikatları ile denenmekte, bütününe yönelik herhangibir tatbikat ya da araştırma yapılamamaktadır. Simülasyon metodları kullanılarak, seferi koşulların fiziki olarak gerçekleştirilmesinin imkansız olmasından kaynaklanan bu probleme çözüm getirilmesi planlanmaktadır. Bu sisteme ait simülasyon modeli kullanılarak; komutanlara planlama safhasında ve karar verme sürecinde bilimsel bir karar destek mekanizması sağlanabilir. Ayrıca, bu model kullanılarak, mevcut sistemdeki sorunlar henüz barış zamanındayken tespit edilebilir ve tespit edilen sorunlara yönelik olarak, alternatif sistem karşılaştırmaları ve bazı karar değişkenlerinin optimizasyonu gibi çalışmalarla çözümlerin analizleri gerçekleştirilebilir.

Anahtar Sözcükler: Simülasyon, Personel Seferberliği, Personel Bütünleme Planı.

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To my family, I thank them for their sacrifice and patience in every stage of my life.

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GLOSSARY

Administrative Service Team (AST)

This is an unit in the organization of a brigade and has the responsibility to deploy the reserve personnel to the units of the brigade, document the statistics of the reserve personnel, support administrative services and training for reserve personnel and participate in defensive and security missions at the rear zone.

Brigade Acceptance Unit (BAU)

After a mobilization duty call, it is the unit performing the activities containing the receiving, classifying, constituting, equipping, settling and feeding of the reserve personnel.

Cadre

This is the table showing the types and numbers of personnel, animals, weapons and vehicles that must be present in the constitution of the units belong to an organization.

In epoch

The limitations of the age determined by the laws to point out the age that a person can perform military mission.

Mobilization

A situation in which the power, sources and mainly the military forces of the country are prepared, gathered, arranged and used for the needs of a war and in which the rights and liberties are limited partially or wholly.

Mobilized Cadre Personnel

The personnel who have MDO to complete the mobilized cadre of the units and institutions.

Mobilization Duty Call

The call made for mobilization or war situation.

Mobilization Duty Order (MDO)

The document showing the unit that the reserve personnel should join in mobilization and the time that the reserve personnel must join his/her unit and which is given to the personnel at peacetime.

Mobilization Situation

This is the period of time that starts with the time and date of mobilization declaration and ends with the removal of it.

Net Casualty

While predicting the casualties, the numbers of casualties who can return to duty from the hospitals are calculated. If this number is subtracted from the rough casualty, the remaining number of casualty is called as net casualty.

Peacetime

This is the period of time that starts with the removal of war situation and ends with a new war situation declaration.

Personnel Casualty

This is the decrease in the numbers of the personnel existing in the cadre of an organization because of the enemy, illness, accidents and administrative causes.

Personnel Completion Company (PCC)

This is an unit in the organization of an Army Personnel Completion Regiment (APCR) and after finishing its organization has the responsibility of receiving, cleaning, settling, feeding, deploying and training the reserve personnel belong to the brigade to which it is assigned.

Personnel Mobilization

This contains the activities of completing the 100% mobilized cadre of the head quarters, units and institutions, establishing the units to be arranged at mobilization and supplying the needs of armed forces during mobilization as the mobilization is declared and also contains the preparations made by related commandries, institutions, headquarters and units to preserve the mobilized cadre numbers in the mobilization period.

Reserve Personnel Sources

The personnel who had completed his/her active mission and who are in epoch and taken into records of recruiting offices.

Rough Casualty

This is the number of casualties just found after the calculations.

War Situation

This is the period of time that starts with the war declaration and ends with the removal of war situation declaration. During this period of time rights and liberties are limited partially or wholly.

Military Word's Turkish Meanings

Army: Ordu, involves approximately 9 brigades. Its commander is full general.

Corps: Kolordu, involves approximately 3 brigades. Its commander is lieutenant general.

Brigade: Tugay, involves approximately 3 battalion task forces. Its commander is brigadier general.

Battalion: Tabur, involves approximately 3 companies. Its commander is lieutenant colonel.

Company: Bölük, involves approximately 4 platoons, its commander is captain.

Platoon/Team: Takım, involves approximately 50 persons. Its commander is first lieutenant or second lieutenant.

Army Personnel Completion Regiment (APCR): Ordu Personel Bütünleme Alayı, involves 2-6 Personnel Completion Battalions and one stock Battalion.

Personnel Completion Battalion: Personel Bütünleme Taburu, involves 2-6 Personnel Completion Companies (PCC).

Administrative Service Company: İdari Hizmet Bölüğü, involves 2 personnel completion sections. It is constituted in division organization.

Administrative Service Team (AST): İdari Hizmet Takımı, involves 2 personnel completion sections. It is constituted in brigade organization.

Brigade Acceptance Unit (BAU): Tugay Teslim Alma Kurulu, it is constituted in brigade organization.

CHAPTER 1

INTRODUCTION

Turkish Nation is probably the first nation among the others when the numbers of facing with mobilization are considered in her history. Nevertheless, such statistics are not so important today in predicting the possible time that any nation may find itself on the combat field. Because even for the nations that have had no great wars in their history there is no guarantee that they will never have to fight with an enemy. Tensions between countries arise suddenly and improve quickly. Although the frame of today's wars and weapon systems have changed too much especially after World War II, when one consider some of the wars going on the theaters of operation, again it can be recognized that people factor can not be underrated. The anxiety of any possible war that mostly is fed by historical background, explains why almost all of the nations in the world spends too much time and money on the systems related with war.

Besides holding these truths on mind, governments have to manage people who are not interested in spending much money for this purpose. That is to say, they have to find solutions, which can satisfy both the probability of any war and the people who do not believe in these truths. One way for these solutions might be to keep the military forces small in numbers but ready for any crisis. Therefore, the governments should take action to increase the ability to mobilize their resources and to enhance their capability to respond with military measures to wide-ranging geographical contingencies using the lessons learned from the studies and exercises.

Now, although it is prudent to prepare for a long war, come-as-you-are crisis-response operations are the most likely actions the military will be required to undertake. These operations are envisioned to be joint service actions. They will most likely be combined operations with allied or coalition forces that project the

power to end the crisis quickly and decisively. More than ever the massing of such power will have to rely on the Army's ability to mobilize and deploy.

In light of these truths, Turkish Armed Forces enforces “Personnel Mobilization and Completion System” that aims to deploy existing units with the personnel needed for mobilized cadre and the replacement personnel for the casualties that may occur on the battlefield as quick as possible.

We develop a simulation model of this system that has not been studied before in Turkish Land Forces. The greatest motivation was the system’s importance such that its function plays a great role during a war situation and if there is something wrong with the system it is too late to fix it when that day comes out. There are several purposes in constructing such a simulation model. Firstly, we aim to construct a sufficiently valid model that represents the real system in order to analyze the existing system and to find the possible problems if there are any. Second, we aim to perform comparisons among some alternatives of the existing system and finally for the case in which the alternatives are not affordable, we aim to solve these problems by considering reserve personnel requirement plans that are prepared in peacetime.

The basic reason in choosing simulation as a tool in this study is the impossibility of experimenting the system by field exercises. This study shows simulation is really an applicable method for such systems of which physical representations are impossible. This study also presents the attitude of simulation studies in solving problems. In fact simulation is better suited for understanding the problem and generating an environment for a systematic debate for the decision makers. “Simulation is used to describe and analyze the behavior of a system, ask what-if questions about the real system, and aid in the design of real systems.” (Banks, Handbook of Simulation, 1998). If one looks into the conclusions of the study, it can be realized that they are statistical issues for what-if questions of problem owners rather than direct and absolute solutions for the problems. In other words, at the end of a simulation study what we get is an objective result to give the right decision instead of the solution itself. This aspect of the simulation makes it a more powerful and useful tool among the others. This also explains why each new day simulation appreciates the interest of more people especially for the military studies.

ARENA 3.0 Software Package is used while constructing the simulation model of Personnel Mobilization and Completion System. The analyses are performed only for the first ten days of a combat. Because the nature of today's wars shows us that they are intended to end in a few days, moreover the first days of a combat is the most violent period of a battle and casualties are the most during this early stage. Additionally, the application of this system for the preceding days does not have rigid rules to enable a logical model building. The system under consideration is a terminating system since the starting and ending conditions are well defined. The starting condition is the beginning of combat and declaration of mobilization and the ending condition is the end of this ten-day period.

In Chapter 2, we present a literature review. In Chapter 3, we give the problem definition and a brief description of the real system. The conceptual model and the verification and validation issues are explained in Chapter 4. In Chapter 5, we give the details of simulation experiments and analyses of results including the primary analysis of the existing system, comparisons among some alternatives and the optimization study focusing on the reserve personnel assignments. Finally in Chapter 6, concluding remarks and future research directions are given.

CHAPTER 2

LITERATURE REVIEW

In the literature, there is no study considering all aspects of the Personnel Mobilization and Completion System. To the best of our knowledge, ours is the first study that evaluates such a system with its all components. However, it may be beneficial to review some other studies, which deals with subjects close to this area such as manpower planning systems in Armed Forces. We constructed this section in a way that one can find useful background of our study under these subtitles:

- Simulation software and methodology
- Military simulation
- Modeling&Simulation of Personnel Mobilization in Military

The summary list for the literature survey can be found in Table 2.1.

2.1. Simulation Software and Methodology

While building the simulation model of the Personnel Mobilization and Completion System and while performing some of the analyses of the outputs, we used Arena 3.0 and its Output Analyzer, which is a product of Systems Modeling Corporation. Banks (1998) points out that "It provides a complete simulation environment that supports all steps in a simulation study. Arena combines the modeling power and flexibility of the SIMAN simulation language, while offering the ease of use of the Microsoft Windows and Microsoft NT environment". Takus and Profozich (1997) explain the software and its capabilities in their tutorial.

Table 2.1: Summary table of related literature

CLASS	PUBLICATION	SUBJECT
Simulation Software and Methodology	Balci (1998)	V&V of simulation models
	Takus and Profozich (1997)	ARENA software tutorial
	Law and Kelton (1991)	Statistical analysis of simulation output
	Sargent (1988)	V&V of simulation models
	Kleijnen (1999)	V&V and data availability
	Alexopoulos and Seila (1998)	Advanced methods for output analysis
	Dudewicz and Dalal (1975)	Selecting the best of k systems
	Saaty (1988)	AHP in multiple objective problems
	Tecle and Duckstein (1990)	A procedure for selecting MCDM methods
	Tekin and Sabuncuoglu (1998)	Techniques for simulation optimization
	Friedman and Savage (1947)	Single factor method
Military Simulation	Kang and Roland (1998)	Military simulation
	Sisti (1996)	M&S technologies for military applications
	Pace (1993)	VV&A in naval M&S
	Hatley (1997)	V&V in military simulations
	Smith (1998)	Essential techniques for military M&S
	Garrabbrants (1998)	Simulation as a mission planning and rehearsal tool
Modeling and Simulation of Personnel Mobilization in Military	Collins, Gass and Rosendahl (1983)	The Accession Supply Costing and Requirements Model (ASCAR) for evaluating military manpower policy
	Parker (1995)	Military force structure and realignment through dynamic simulation
	Gass, Collins, Meinhardt, Lemon and Gillette (1988)	OR practice about the Army manpower long-range planning system MLRPS
	Bres, Burns, Charnes and Cooper (1980)	Goal-programming model for planning officer accessions

We also used trial version of Expert Choice, which is the product of Expert Choice Inc. in implementing the Analytic Hierarchy Process (AHP).

Balci (1998) explains how to create sufficiently valid models, principles of verification and validation and over 75 methods to use in these activities.

Law and Kelton (1991) explain the timing and relationships of validation, verification and establishing credibility, and discuss guidelines for determining the level of model detail and some techniques for verification and validation.

Sargent (1988) explains various verification and validation techniques and discusses conceptual model validity, model verification, operational validity, 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 distinguishes this availability as (i) no data, (ii) only output data and, (iii) both input and output data and discusses some methods depending on these levels of data availability.

Alexopoulos and Seila (1998) and Law and Kelton (1991) explain techniques and procedures dealing with output data analysis, moreover they discuss statistical analysis for terminating simulations.

Law and Kelton (1991) explain some comparison techniques and describe ranking and selection procedures, which enables us to select the best of k systems.

Dudewicz and Dalal (1975) discuss a two-stage procedure that protects us against selecting a system with mean that is more than "indifference amount" worse than that of the best system.

Saaty (1988) presents Analytic Hierarchy Process (AHP), which works by developing priorities for alternatives and the criteria used to judge the alternatives. AHP provides a powerful tool that can be used to make decisions in situations involving multiple objectives. We chose AHP among more than 70 multicriterion decision making methods (MCDM) because of its simplicity in both application and interaction with the decision makers. Tecle and Duckstein present a procedure to select a proper MCDM technique. They apply this procedure to the well known ones including Analytic Hierarchy Process (AHP), Composite Programming (CTP), Compromise Programming (CP), Cooperative Game Theory (CGT), Displaced Ideal (DISID), ELECTRE, Evaluation and Sensitivity Analysis Program (ESAP), Goal Programming (GP), Multiattribute Utility Theory (MAUT), Multicriterion Q-

Analysis (MCQA), Probabilistic Tradeoff Development Method (PROTRADE), Zionts-Wallenius (Z-W), Step Method (STEM), Surrogate Worth Trade-off (SWT) and PROMETHEE (PRM).

Law and Kelton (1991) consider how simulation can be used to design a system to yield optimal expected performance and explain optimum seeking procedures and optimum-seeking packages interfaced with simulation software.

Tekin and Sabuncuoglu (1998) present a comprehensive survey on the techniques for simulation optimization and classify the techniques according to the characteristics of the problems such as objective functions, parameter spaces and shape of the response surface.

Friedman and Savage (1947) discuss Single Factor Method (SFM), which involves coordinated movement of one factor while all other factors are held constant.

2.2. Military Simulation

Kang and Roland (1998) stress on the differences of military simulation and classify the military simulation models in their study. Moreover, their study includes a well-organized history of simulation in military. They provide some explanations about simulation as a training tool and also mention a war-gaming model of joint theater-level simulation. A brief explanation about verification, validation and accreditation (VV&A) of military simulation models is also included in their study.

Sisti (1996) deals with a wide variety of research issues in simulation science being presented by government, academia, industry and their application to the military domain; especially, to the problems of intelligence analyst.

Pace (1993) discusses naval modeling and simulation verification, validation and accreditation. He reviews VV&A processes developed as interim policy guidance for Navy managed models and simulations. The conceptual foundation and basic paradigm for these VV&A processes are examined as is VV&A for distributed simulations. Relationships of Navy interim policy guidance VV&A processed to other VV&A activities with Department of Defense and elsewhere are discussed.

Hartley (1997) stresses on the difficulties, methods and cost of the military simulation studies mainly and presents the comparison of military simulation studies with others in terms of verification, validation and accreditation.

Smith (1998) provides a brief historical introduction and goes on with essential methods necessary for modern military training simulations in his study. He stresses on the importance of modeling the right problem, complete and accurate understanding and credibility while mentioning the fundamental principles of military modeling. He explains the importance of physical objects including vehicles, people and machinery involved in the activities of moving, perceiving other objects and interacting with them in military simulations.

Garrabbrants (1998) explains how Marine Tactical Warfare Simulation (MTWS), an advanced simulation system, is used to model all aspects of combat and gives detailed information about its usage. He discusses the importance of simulation in support of the all levels of command and control functioning, especially stuff planning after receipt of orders and mission rehearsal.

2.3. Modeling&Simulation of Personnel Mobilization in Military

Collins, Gass and Rosendahl (1983) propose the Accession Supply Costing and Requirements Model (ASCAR) for evaluating military manpower policy. The ASCAR model uses goal programming to evaluate the accession needs of the all volunteer armed forces to reach or maintain a given strength and optimize the qualitative mix of new recruits. The ASCAR model analyses historical data to develop specific rates and factors and to establish starting personnel levels for the simulation period. Then it uses these levels to simulate the first one-year period of personnel actions to determine what new recruits are required as a result of losses to the starting force and changes in the desired end strength or in man-year requirements.

Parker (1995) presents a study including military force structure and realignment through dynamic simulation. With the approach he developed, 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. “As part of the approach, a symbolic network representative language was developed which combines the continuous variable features of system dynamics and the discrete event features of conventional simulations techniques. This network representative language, referred to as Dynamic Simulation (DYNASIM), is built with the network SLAMSYSTEM environment. The contribution of this research is a prescribed method for the strategic analyst to develop an influence diagram which can be used to analyze force structures within the combat logistics domain.”

Gass, Collins, Meinhardt, Lemon and Gillette (1988) present an OR practice about the Army manpower long-range planning system MLRPS. “MLRPS provides the analytical capability to project the strength of active U.S. Army for 20 years, thus allowing for the development of long-range manpower plans. The system’s models simulate the interaction of gains, losses, promotions and reclassifications to enable analyst to determine the impact of existing policies over the long term, and to determine changes that might be required to reach a desired force.”

Bres, Burns, Charnes and Cooper (1980) present a goal-programming model for planning officer accessions. “A goal programming model for planning officer accessions to the U.S Navy from various commissioning sources is developed and described. Present and future requirements for different career specialty areas in the Navy are considered in terms of years of commissioned service and reacted to various choke points where inventories fall short of requirements in officer force structure. An illustration of the use of this model is provided which involves assessments of the effects of phasing out one commissioning source. Other uses and possible further extensions are also indicated for this model, which now forms a part of the Navy’s manpower planning procedures.”

CHAPTER 3

THE PROBLEM DEFINITION AND SYSTEM DESCRIPTION

3.1. General

In this study, we developed a model for the Turkish Army Personnel Mobilization and Completion System for the first ten days of a combat. This system enables the units of army to maintain their numbers of personnel during any combat situation. One must provide convenient reserve personnel at any needed time and place to maintain the numbers of personnel assigned to any unit of the Army. This system consists of personnel completion units. At the facilities of these units, reserve personnel is accepted, sheltered, categorized, trained, assigned and transported to the units in need. The responsibility of this system is to support combat power of the units of the Army.

To execute this mission the branches and ranks of probable casualties of any unit during a combat should be determined, the demand satisfaction capabilities of the reserve personnel resources should be inspected and a well-organized training mechanism for these reserve personnel should be conducted. Demand and completion means should be determined and transportation should be satisfied for these reserve personnel.

3.2. Casualty Evaluations

One of the most important factors in maintaining the personnel numbers is to estimate the number of casualties as correctly as possible. Casualty is any decrease in personnel numbers assigned to a unit. During the early stages of a combat, the number of casualties is best estimated by using the experiences, which belong to the previous wars. We have some documents to use in the study of casualty estimation, but it is not recommended to use these information exactly, because they may lead to some incorrect conclusions. They should be used for the early stages of combat and for further stages. For the subsequent days, the way that the battle goes on should be studied and then new casualty numbers, which are derived from this study, should be used.

3.2.1 Casualty Categories and Evaluation Criteria

There are two types of casualty: 1) Battle casualty and 2) Administrative casualty. Specifically, these are:

(1) Battle Casualty

a. Personnel died on battlefield.
b. Personnel died because of the injuries occurred on battlefield.
c. Personnel injured on battlefield.
d. Missed and prisoned personnel.
e. Personnel injured or died because of the causes other than the enemy factors.
f. Personnel with physical and mental unfitness.

(2) Administrative Casualty

a. Assignments to other units.
b. Personnel sent to discipline courts.
c. Deserter personnel.
d. Retired and rebranched personnel.
e. Personnel who changed his/her armed forces.

Casualty evaluation is made in two ways: Short-term and long-term. The short-term evaluation is made for ten and less than ten days' casualties. It is basically performed at army, corps, division and brigade level. The long-term evaluation made for more than ten days' casualties. It is performed at Land Forces, army and corps level.

3.2.2 Factors Affecting Personnel Casualties

There are too many factors that may affect the number of casualties of a unit. Moreover, on battlefield no two situation looks like each other. So, while determining casualty rates, one may use the factors below. These factors do not affect casualty factors always the same in every war situation; moreover since they have some effects on each other, they should not be handled separately. These are:

(1) Type of the combat to be executed
(2) Geographical position
(3) Field
(4) Properties of the enemy
(5) Whether conditions
(6) Level of training and mental fitness of the troops
(7) The time passed during combat
(8) Quality of medical measures

3.3. Sources of Reserve Personnel

There are two types of personnel when the reserve sources are considered. These are *Personnel Inside the Country* who come to the battlefield after their training is completed and they are assigned to the units according to their branches and training and *Personnel Provided from the Battlefield* who are already present on battlefield and can be assigned again. Second group consists of these personnel below:

a. Personnel whose injuries and illnesses have treated.
b. Extra personnel caused by abolishment and cancelled permits.
c. Personnel who are present because of designation or draft.

d. Personnel returning from prison, captivity or miss.

3.4. Organization and Allocation of Personnel Completion Units

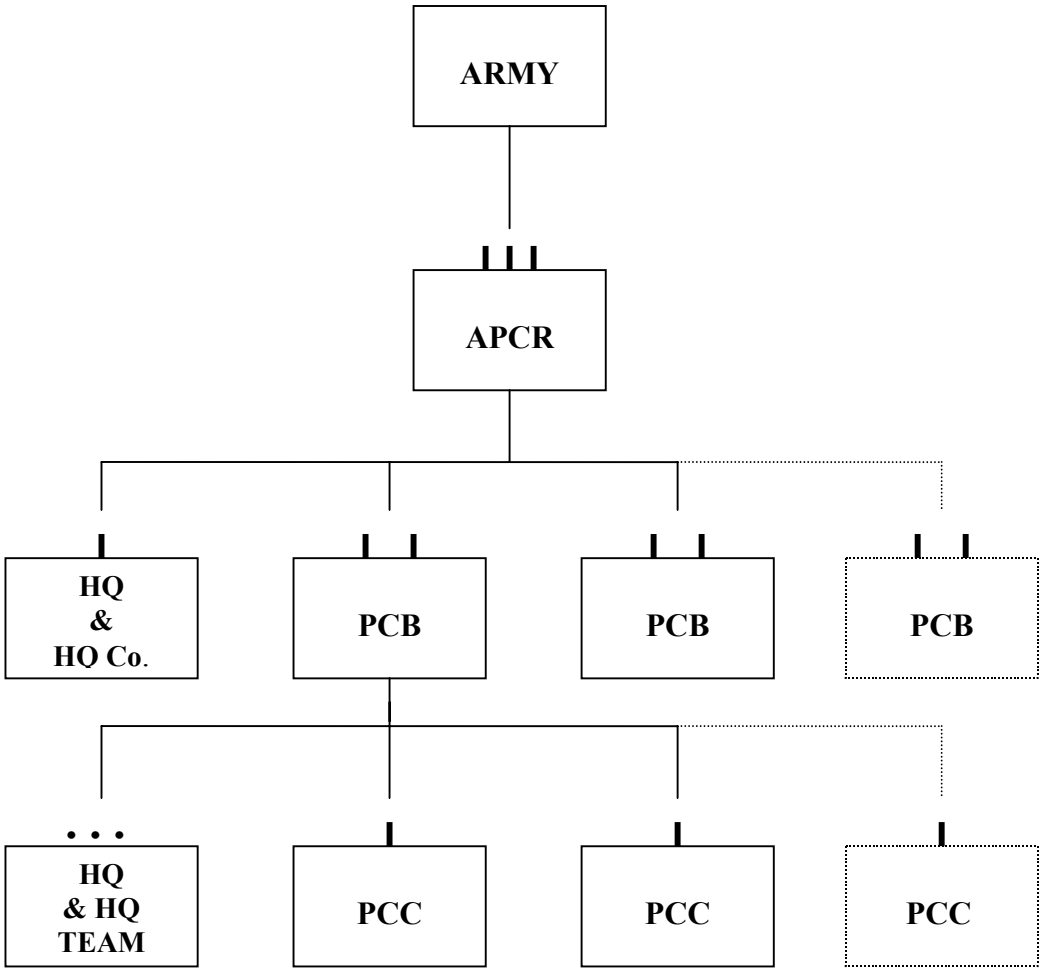
Personnel completion units have the capacity to supply ten days' casualties of the units which they support at Temporary Completion Stage and have the capacity to supply thirty days' casualties for enlisted (E) and fifteen days' casualties for noncommissioned officers (NCO) and officers (O) of the units which they support at Normal Completion Stage.

3.4.1. Constitution and Allocation

For the personnel completion system, there exist 1-2 Personnel Completion Regiment (APCR) in the organization of the Army, one Personnel Completion Regiment (APCR)/Battalion (APCB) in the organization of independent corps or commandant of logistics, one Administrative Service Company (ASC) in the organization of division and one Administrative Service Team (AST) in the organization of brigade. All these units are established at mobilization time.

3.4.2. Organization

Personnel completion regiments consist of a headquarters company and 2-7 personnel completion battalions. Personnel completion battalions consist of a headquarters team and 2-7 personnel completion companies. Each battalion has two companies for an army, one company for corps, two companies for division and one company for brigade to support these units. Personnel completion companies are capable of training, sheltering and supplying administrative services for 400-600 reserve personnel. Administrative service companies/teams support the first two days' casualties of division/brigade and supply administrative service for the completion personnel for the preceding days of the combat. Their capacities are 100-200 personnel but they can be increased with additional precautions. Organization of the personnel completion units can be observed in Figure 3.1.



APCR : Army Personnel Completion Regiment
PCB : Personnel Completion Battalion
PCC : Personnel Completion Company
Note : Dashed lines are used to point out that the number of subunits is not constant.

Figure 3.1: Organization of the personnel completion units.

3.5. Stages and Types of the Personnel Completion System

From the beginning of the mobilization, the personnel completion activities are performed in two stages: 1) The personnel mobilization plan and 2) The personnel completion plan.

3.5.1. The Personnel Mobilization Plan

With this plan that begins as the mobilization is declared, to increase the present numbers of personnel to the 100% cadre numbers;

(1) The mobilized cadre shortages of the constituted units are completed.

(2) The units to be constituted at mobilization are established and the numbers of personnel completion units are increased to their mobilized cadre numbers.

(3) The completion personnel of administrative service companies/teams join directly these units to supply the first two days' casualties.

(4) The first group of the temporary completion plan is sent directly to the personnel completion units.

(5) The first group of the normal completion plan is sent to the branch schools and to the training centers.

3.5.2. The Personnel Completion Plan

This plan is conducted to complete the decreases in the mobilized cadre numbers and has the stages described below:

(1) Firstly, the number of personnel that will be sent to the personnel completion units and training centers is determined.

(2) Then, according to these studies, the cadre and the organizations of the units are determined.

(3) The location of the completion units is determined according to the units, which they are assigned to support.

(4) Finally the displacement of these completion personnel from completion units to the units in need is regulated. This regulation is performed by the help of personnel completion plans described below.

The Temporary Personnel Completion Plan

Until the time that the Normal Personnel Completion Plan begins to be applied (until the time that the reserve personnel training in the branch schools and the training centers are completed their training and joined to the units), this plan is conducted to supply the needed personnel for the first days of the mobilization. In this plan, the reserve personnel, who are young and whose training is fresh are sent directly to the completion units from the recruiting offices. The personnel included in this plan are in the form of groups each of which are gathered to support ten days' casualties of the units in need. This activity is planned for thirty days for E and forty days for NCO and O. The first group is sent to completion units as soon as the mobilization is declared. Other groups are sent by order. This plan takes place at the most violent period of the combat and when the amount of casualties is much.

The Normal Personnel Completion Plan

By the help of this plan, the reserve NCO and O are trained in branch schools, the reserve E are trained in training centers and then they are sent to the completion units. Since the training level of the personnel included in this plan is less fresh than that of the other plan, NCO and O are trained for thirty days and E are trained for fifteen days. NCO and O are formed in two groups and enlisted are formed in four groups to be sent in a period of two months.

3.6. Personnel Completion System at Brigade Level

Since all aspects of this system can be observed and this is the most general case when the usage of this system is considered, we construct a simulation model of

this system at brigade level. Therefore, the real life system at brigade level will be explained in more detail in this part.

3.6.1. The Personnel Completion on Battlefield at Brigade Level

From the very beginning of the mobilization, the activities performed in brigade are described below. For simplicity, they are explained step by step.

(1) As the mobilization is declared, reserve personnel who were ordered to join their planned units makes any necessary preparations and leaves home at most in six hours.

(2) These personnel include the personnel, who will complete the mobilized cadre of the brigade, the personnel of AST that will support the first two days casualties of the brigade and the personnel of PCC that is assigned to the brigade to support the brigade for further days.

(2) These personnel must join the Brigade Acceptance Unit (BAU) of the brigade in at most 48 hours.

(3) Arriving personnel are sheltered and equipped in BAU. Then they are transported to their units (AST, Brigade or PCC). After this period, reserve personnel is ready to be sent to brigade according to the demand reports.

If brigade is in a combat during or after the mobilization declaration, the steps that are described below (also depicted in Figure 3.1) are performed:

(1) Starting at the team level, the numbers and types of casualties are reported to the battalion command.

(2) The casualties, who are controlled by battalion commander and battalion headquarters, are reported to the brigade rear command area.

(3) The central office administrator at the brigade rear area examines the number of casualties according to the numbers in AST and sends a draft plan to the personnel office administrator.

(4) The personnel office administrator examines these numbers and cooperate with G3 and G4, offers the assignment plan to the chief of the staff and then makes the brigade commander endorse the assignment plan. The endorsed plan is sent to the central office administrator.

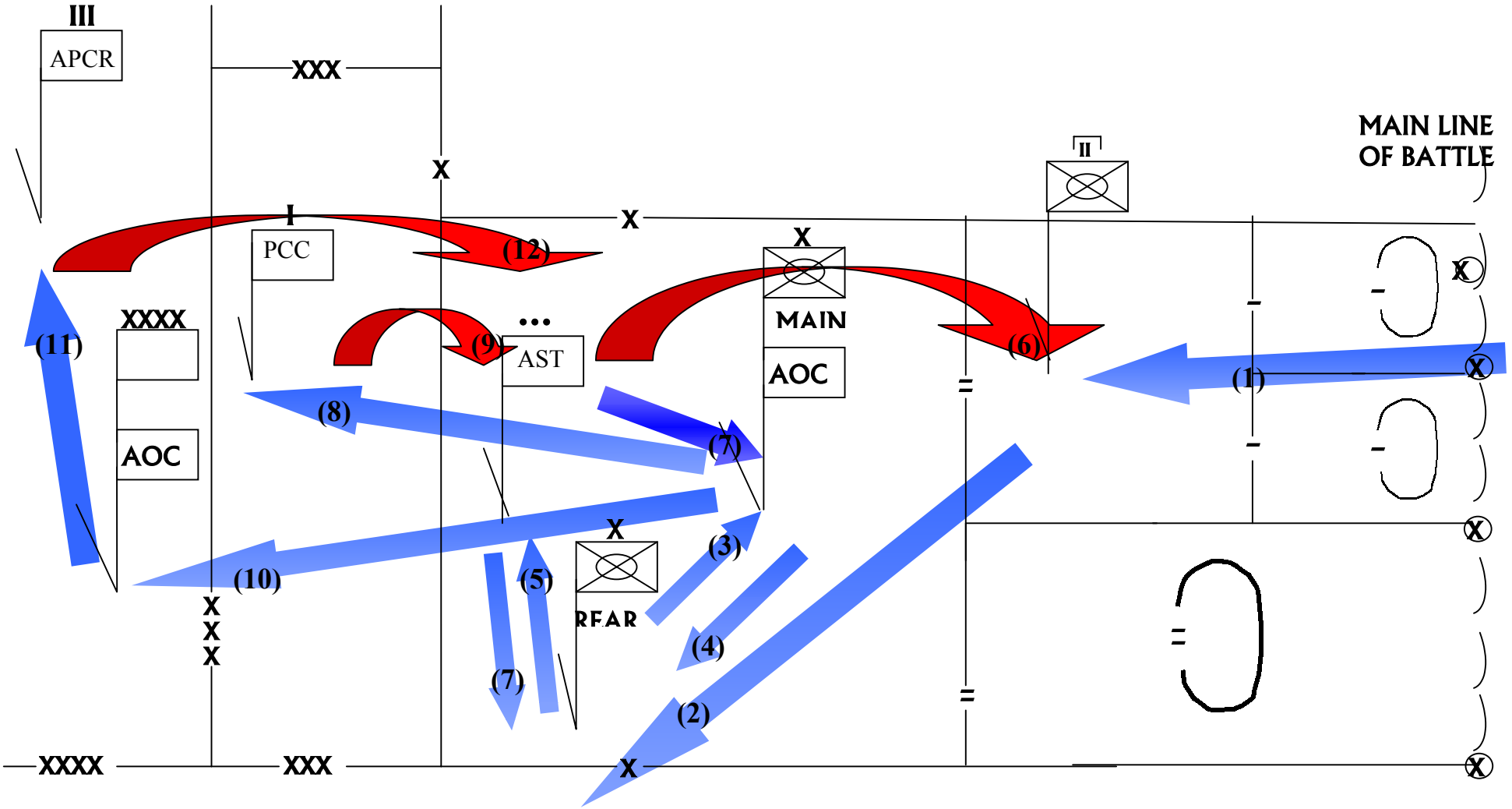


Figure 3.2: Steps of personnel completion activities on battlefield.

(5) The central office administrator orders AST to supply the assigned reserve personnel.

(6) AST sends these personnel to the units in need.

(7) AST informs both the central office and personnel office administrators about the execution.

(8) The personnel office administrator reports the decrease in the number of reserve personnel of AST to PCC.

(9) The demanded personnel are sent to AST by PCC.

(10) The personnel office administrator cooperates the probable number of casualties with the brigade headquarters and after the endorsement of the brigade commander, he sends a personnel demand report to the army command.

(11) The army chieftaincy of the personnel examines the personnel demand report and cooperates with the army headquarters. Then he offers the assignment plan to the chief of staff. After making the army commander endorse the assignment, he orders APCR to supply the demanded reserve personnel.

(12) APCR sends the demanded reserve personnel to PCC that is supporting the related brigade.

3.7. A Marginal Approach to the Personnel Mobilization and Completion System

This section presents a marginal approach to the system under consideration. Since this approach will be used as an alternative system for the existing system and there will be some comparisons including this alternative system, we will explain it in this section.

First of all, this approach is marginal, because the proposed change affects not only the personnel mobilization and completion system but also almost all systems in Army. In fact, some of the studies that will conducted in Chapter 5 can be thought as the impact of this marginal change on personnel mobilization and completion system. Basically this approach recommends that units of Army at all levels should have only one type of cadre to be used in both peacetime and wartime. If the impact of proposal is examined for the personnel mobilization and completion

system only, one may face with some advantages and disadvantages. But, if the spirit of present wars is thought those disadvantages are not so important with respect to its advantages.

Today, almost all nations have a tendency to keep their armies small but mobilized so that they keep up with the speed of present wars. Since the governments do not approve a war unless they have to and they have a tendency to end a war situation as quick as possible, they need mobile and brisk armies. Therefore, units of which number of personnel is the same in both peacetime and wartime have too many advantages. Such units would need less reserve personnel during mobilization. Because they would need reserve personnel for only the casualties that may occur on battlefield instead of a huge number of reserve personnel that must join their units in a very short period of time. This change also makes units be able to get rid of the adaptation problem of the new personnel on battlefield. Moreover, it minimizes the risk that Army takes on while expecting that all reserve personnel that Mobilization Department of the Ministry of National Defense has planned would join their units at the time of mobilization. These are only the most visible part of the advantages.

On the other side, keeping Army always ready to fight and at a constant number may be seen as a problem for governments because of some economical and social reasons. But the solution exists in the change itself. Having a small but brisk army enables governments achieve the mission with the same cost. Instead of having tremendous numbers of units waiting their mobilized cadre personnel on battlefield, decreasing the numbers of units to enable them to be small and brisk would also be a solution to the cost problem. Although the cost of such a change will not be examined in our studies, we found it critical to mention about such a solution briefly to show that this change is indeed an alternative.

The only difference between the existing system and the proposed one is that in the proposed one, brigade will have reserve personnel in BAU for only supplying completion personnel for the casualties occurred on battlefield. There will be no personnel assigned to complete mobilized cadre of brigade since the brigade already has this cadre needed for any warfare.

3.8. Possible Modifications on the System

Besides such a marginal approach which effects not only the personnel completion and mobilization system but almost all systems and plans in Army, we tried to find some small modifications on the existing system so that the new system may achieve a better work without the problem of reducing cost and personal rejections that may occur against such marginal changes. We have mentioned that the marginal approach is not proposed for only personnel mobilization and completion system but it can be thought as the impact of this marginal change on personnel mobilization and completion system. Because of this reason, we explored an alternative system for our existing one that is only a modified version of it. In this way, if the modified version works better, it would have no additional cost for the existing system.

This modification is proposed just after we modeled the system and while we were performing primary analyses of the model that will be explained in more detail in Chapter 5. With this modification, we propose a change that reserve O and NCO who are assigned to PCC would join directly AST. Because, we observed that the number of O and NCO who were to join PCC is not a big number so that there remains no O and NCO after the first few days of the battle. Their directly joining AST would not make additional problems for AST, but this change might cause some positive affects such as the reduction of shortages of AST.

Since these positive and negative affects are just assumptions at this early stage, we will conduct some statistical studies in succeeding chapters to see whether these changes do really work better or not.

CHAPTER 4

SIMULATION MODEL OF PERSONNEL MOBILIZATION AND COMPLETION SYSTEM AT BRIGADE LEVEL

4.1. Why Simulation?

We model the system and analyze its behavior by using simulation method because of the reasons summarized below:

- The exact numbers of personnel planned to be assigned as reserve personnel to a brigade cannot always be assigned by the Mobilization Department of the Ministry of National Defense because of some shortages in reserve personnel resources.
- Some of the personnel who are assigned as reserve personnel may not know their mission.
- Some of those who know their mission may not join their units during mobilization for some reasons.
- The number of personnel in a brigade is not a constant number during peacetime. So, a brigade enters in a battle with uncertain numbers.
- The plans depend on the past experiences about the casualty types and numbers, but these experiences may not be valid for the next war that the brigade will have a role in.
- The transportation utilities and related times may differ from time to time during the mobilization time from that of the peacetime when all plans are prepared.

- The personnel assignment plans are generally prepared based on defense operations, but the kind of operation of which the brigade takes responsibility may be different on battlefield. Therefore, the number of casualties may be different than the planned numbers.
- Because of the reasons some of which we explained above, the system under investigation has too many randomness. (e.g., the rates of casualties, the rate of reserve personnel who can be assigned by the Mobilization Department of Ministry of Defense, the rate of the reserve personnel who knows his mission and join the unit to which they are assigned).
- During the peacetime, only a small sub model of the real system can be exercised on field exercises. Whole real system cannot be exercised or experimented during the peacetime because of physical, political and economical reasons.
- Simulation enables us to study on such systems that does not exist at the present time and has too much randomness.
- We also propose alternative system designs and compare them. Simulation quantifies the difference between the alternative systems and helps to see their advantages or disadvantages.

To conduct the simulation study for the personnel mobilization and completion system, we use ARENA 3.0 Simulation Software Package to model the system. The model represents the flow of this system for the first ten days of a war. Because the first days of a combat is the most violent period of times of a battle and casualties are the most during this early stage. Moreover the application of this system for the succeeding days has not rigid rules. ARENA 3.0 is used because of its ability to provide an object-oriented environment where transporters and environments can be represented at the same time and its ability to supply animation for the model with which we could build a valid model. The system under consideration is a terminating system. Because it has well defined starting and ending events. For this system, declaration of the mobilization is the starting event and the end of the ten day-period is the ending event. The model is built in terms of hours where all statistics can be collected in terms of hours. Below is some technical information about the model.

- Maximum run speed (with animation) : 4.05 minutes
- Maximum run speed (without animation) : 0.03 minutes
- Number of blocks in model file : 340 blocks
- Number of attributes : 11 attributes
- Number of variables : 80 variables
- Total number of lines : 980 lines
- Size of the model : 8.52 MB

In Appendix A, there exists the model file of the code written by using Arena 3.0. In Appendix B, there exists the experimental file of the same code and in Appendix C, there exists an output file (for only one replication) belong to this code written for the existing system.

4.2. Conceptual Model of the System

"The construction of a model is probably as much art as science. The art of modeling is enhanced by an ability to abstract the essential features of the problem, to select and modify basic assumptions that characterize the system, and then to enrich and elaborate the model until a useful approximation results." (Banks, Carson and Nelson, 1996). We adopted this principle while conceptualizing the Personnel Mobilization and Completion System. Because, trying to develop a model, which is a one to one representation of the real system only causes additional costs. In the following sections, we present the conceptualization process for our system step by step.

4.2.1. Events

Event is an instantaneous occurrence that changes the state of the system. The events of the system under consideration are

- Decision of mobilization. This is the starting event at the same time.
- Arrival of the reserve personnel in Brigade Acceptance Unit (BAU).
- Arrival of the reserve personnel in Administrative Service Team (AST).

- Arrival of the reserve personnel in Personnel Completion Company (PCC).
- Arrival of the reserve personnel in Army Personnel Completion Regiment (APCR).
- Casualty occurrence.
- Personnel demand from AST.
- Personnel demand from PCC.
- Personnel demand from APCR.
- Arrival of the demanded personnel in brigade.
- Arrival of the demanded personnel in AST.
- Daily casualty report arrival.
- Returning of treated personnel to duty.
- Transportation vehicle demand.

4.2.2. Entities

Entity is an object of interest in the system, which requires an explicit representation in the system. The entities of the system under consideration are

- Reserve officers (O), noncommissioned officers (NCO) and enlisted men (E).
- Casualty report.
- Casualties.

4.2.3. Attributes

Attribute is the characteristics of an entity. The attributes of the system under consideration are

- Type of reserve personnel (officer, NCO or enlisted men).
- Unit of the reserve personnel (Brigade, AST or PCC).
- Type of casualty (Dead, injured, mortal injured or prisoner).
- Arrival time of the reserve personnel in BAU.
- Arrival time of the reserve personnel in AST.
- Arrival time of the reserve personnel in brigade.
- Arrival time of the reserve personnel in PCC.

4.2.4. Exogenous Variables (Input Variables)

These variables are input variables and have two subgroups as controllable variables (decision variables) and uncontrollable variables (parameters).

(1) Decision Variables

- Number and capacity of transportation vehicles assigned to AST, BAU, PCC and APCR.
- Mobilized cadre of the brigade.
- Distances between brigade, AST, BAU, APCR, PCC.
- Reserve personnel demands from the completion units, which are not depending on casualty reports but predictions.

(2) Parameters

- Number of casualties.
- Number of reserve personnel in AST, BAU and PCC.
- Initial number of personnel just at the decision of mobilization.
- The time needed for reporting and demand determination activities.
- Arrival time of reserve personnel to completion units.
- The equipage time needed for the reserve personnel to come from their home.
- Transportation times.
- Amount of demand from completion units and the rate of O, NCO and E numbers in these demands.

4.2.5. Endogenous Variables (Output Variables)

These variables are output variables. They are internal to the model and are function of the exogenous variables and the model structure. The endogenous variables of the system under consideration are:

(1) State Variables

- State of transportation vehicles (busy or idle).
- State of personnel completion units (Enough personnel exist or do not exist).

- Number of reserve personnel in BAU.
- Number of reserve personnel in AST.
- Number of reserve personnel in PCC.
- Number of current personnel in brigade.
- Number of unsatisfied demand from the completion units.
- Number and type of casualties.
- Status of the casualty (Return to duty or can not return to duty).

(2) Performance Measures

- O number percentage via mobilized cadre of the brigade.
- NCO number percentage via mobilized cadre of the brigade.
- E number percentage via mobilized cadre of the brigade.
- Total number of O demanded from APCR.
- Total number of NCO demanded from APCR.
- Total number of E demanded from APCR.
- Average number of O demanded from AST.
- Average number of NCO demanded from AST.
- Average number of E demanded from AST.
- Average number of O demanded from PCC.
- Average number of NCO demanded from PCC.
- Average number of E demanded from PCC.
- O shortages of AST.
- NCO shortages of AST.
- E shortages of AST.
- Time spent in PCC.
- Time spent in AST.
- Time spent in BAU for brigade personnel.
- Time spent in BAU for PCC personnel.
- Time spent in BAU for AST personnel.
- Time spent for O between the entrance in BAU and arrival in brigade.
- Time spent for NCO between the entrance in BAU and arrival in brigade.

- Time spent for E between the entrance in BAU and arrival in brigade.
- Average number of reserve personnel in BAU.
- Average number of reserve personnel in AST.
- Average number of reserve personnel in PCC.
- Minimum and maximum number of O in brigade.
- Minimum and maximum number of NCO in brigade.
- Minimum and maximum number of E in brigade.
- Utilizations of transportation vehicles.
- Average equipage time for the reserve personnel arriving in BAU.
- Average time spent during the transportations.
- Average time spent for the procedures.
- Total number of O casualties.
- Total number of NCO casualties.
- Total number of E casualties.
- Total number of personnel died during the battle.
- Total number of injured personnel.
- Total number of injured personnel who cannot return to duty.
- Total number of prisoner of war (POW).

4.2.6. Assumptions of Simulation Model

Since we need only the essence of the real system, we made the following assumptions in constructing the model. Most of the assumptions are made to simplify the model construction providing that they do not affect the results of analyses to be made.

- In this study, the personnel mobilization and completion system is modeled at brigade level and a Personnel Completion Company (PCC) of the Army Personnel Completion Regiment (APCR) is assigned to this brigade to support it. Although there are too many different levels of units that this system is planned for, we assume that this model is sufficient to evaluate the system under consideration. Because, the other levels can be thought as extraordinary positions and the system can be observed with its all

components at brigade level. Moreover, this is the most general situation that one may come across in Turkish Army.

- The time that combat begins for the brigade and the time that mobilization decision is declared take place at the same time. Again we thought this situation as the most general case, because the other cases have less possibility to happen. For instance, declaration of the mobilization decision may happen many days before a combat begins and this makes the system under consideration work better, but this is not a wanted case since the governments do not want to increase tension unless they are obliged to.
- System is modeled for the first ten days of a combat. Because the first days of a combat is the most violent period of a battle and casualties are the most during this early stage. Moreover the application of this system for the succeeding days has not rigid rules to be modeled.
- Second groups of reserve personnel are supposed to join their units at the planned time (tenth day) since calling these personnel earlier is a hard precaution to order during mobilization. Moreover, their arrival would be probably late so that the precaution would not effect the flow of the system in a better way.
- Instead of calling the next groups earlier, it is assumed that the shortages occurred during this first ten day period will be handled with the ability of APCR to supply the brigade by its jurisdiction to exchange reserve personnel among the personnel completion companies.
- Personnel completion activities have no restriction by the time; i.e. these activities can take place during daylight as well as during night.
- Casualty reports are sent to the upper command echelon at 20:00 o'clock and only once a day.
- It is assumed that the reserve personnel in completion units fit the demanded personnel by the means of military arms. They differ only in types (O, NCO, E).
- All personnel completion units have the capacity to equipage and train all reserve personnel by means of additional procurement if needed.

- During peacetime, the personnel assignment plans are prepared according to a defense operation.
- Combat starts at 08:00 o'clock in the morning.
- On the third day, besides casualties, the personnel, who was expected to complete mobilized cadre but unable to do because of shortages are demanded from the completion units.
- The predictions about the next day's casualties are made according to the exact numbers mentioned in the documents of Army.
- The casualties that are able to return to duty are assumed to join directly AST after the needed duration.
- It is assumed that on the first day, brigade cannot demand reserve personnel from the completion units except AST. Because the flow of reserve personnel continues during the first 48 hours of the mobilization.

4.2.7. Limitations

Because of the Army's security rule we cannot write down the exact organization and location of the units of brigade. A brigade of which mobilized cadre is 7000 personnel in total is used in modeling. Again the calculations for determining the numbers of reserve personnel units and the names of the troops on which some of the statistical data depend are omitted for this purpose. However, it is provided that these omitations do not affect the accuracy and conformity of the studies performed.

4.3. Flowchart of the Model

A flowchart is a pictorial summary of the flows and decisions that comprise a process. It has too many advantages in constructing the model such as functioning as a communication and planning tool, providing an overview of the system, defining roles, demonstrating interrelationships and promoting logical accuracy. The flow of Personnel Mobilization and Completion activities that starts at 8 o'clock in the morning and ends at the end of the ten-day period is presented in the flowchart in Figure 4.1.

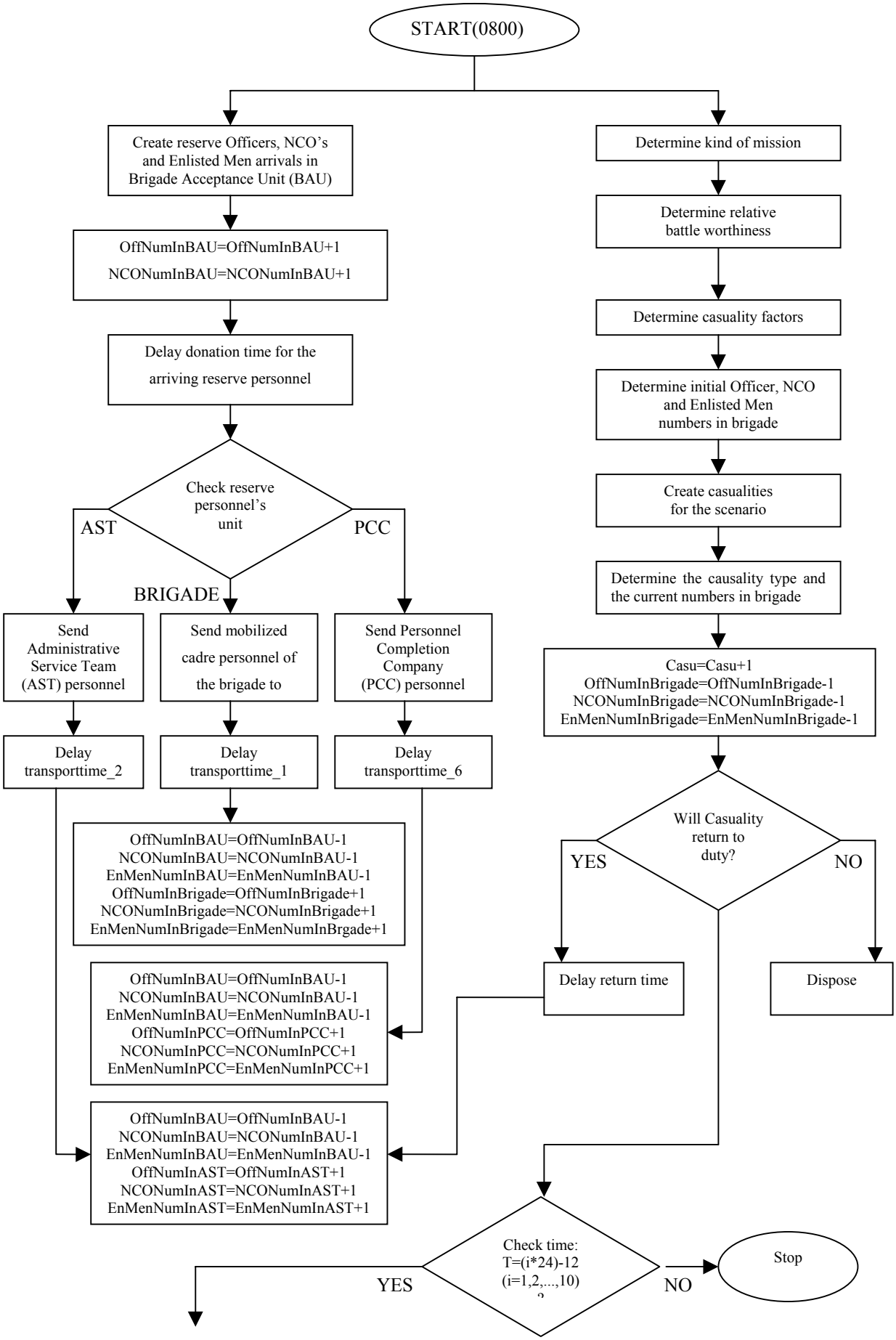


Figure 4.1: Flowchart of the model.

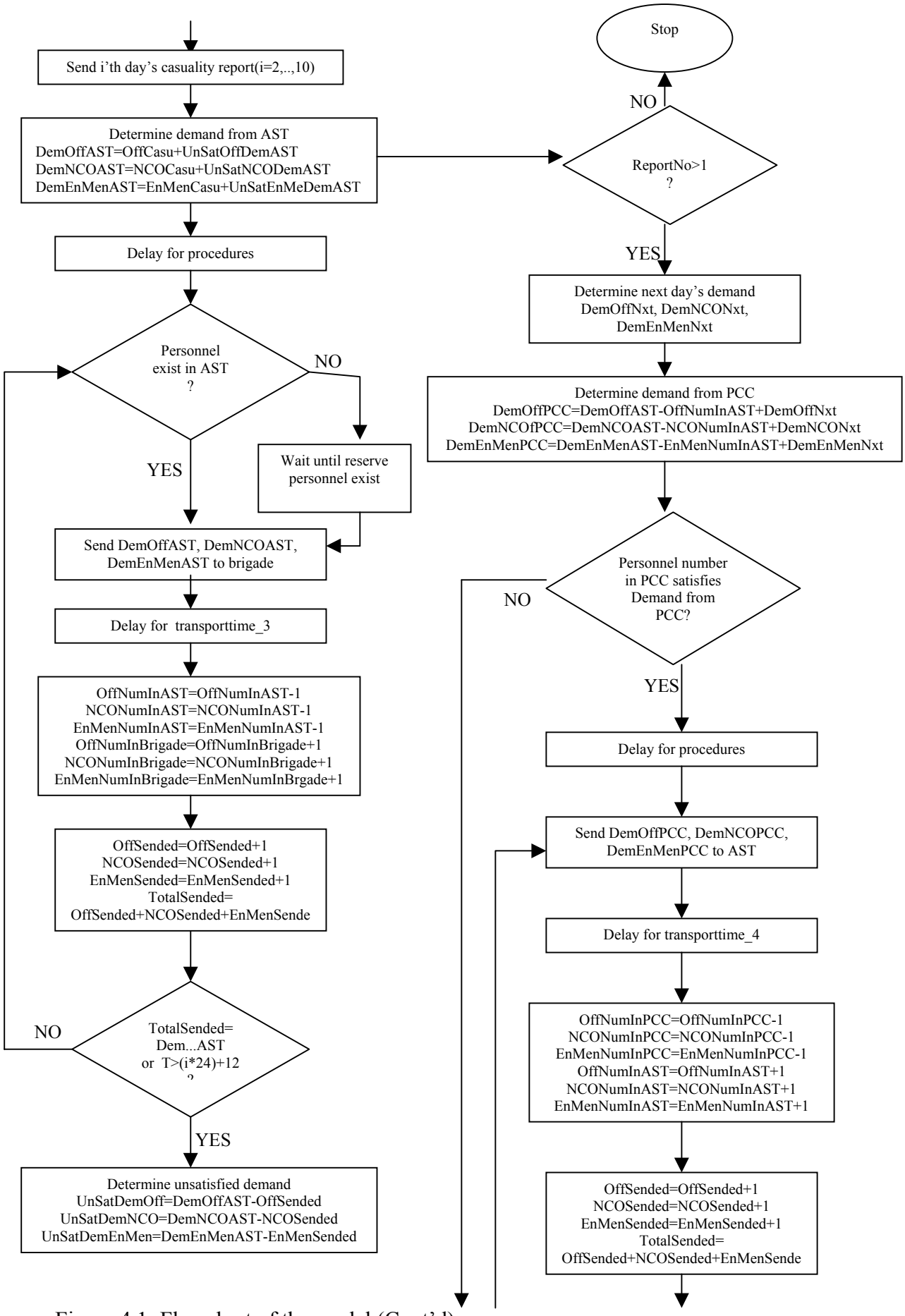


Figure 4.1: Flowchart of the model (Cont'd).

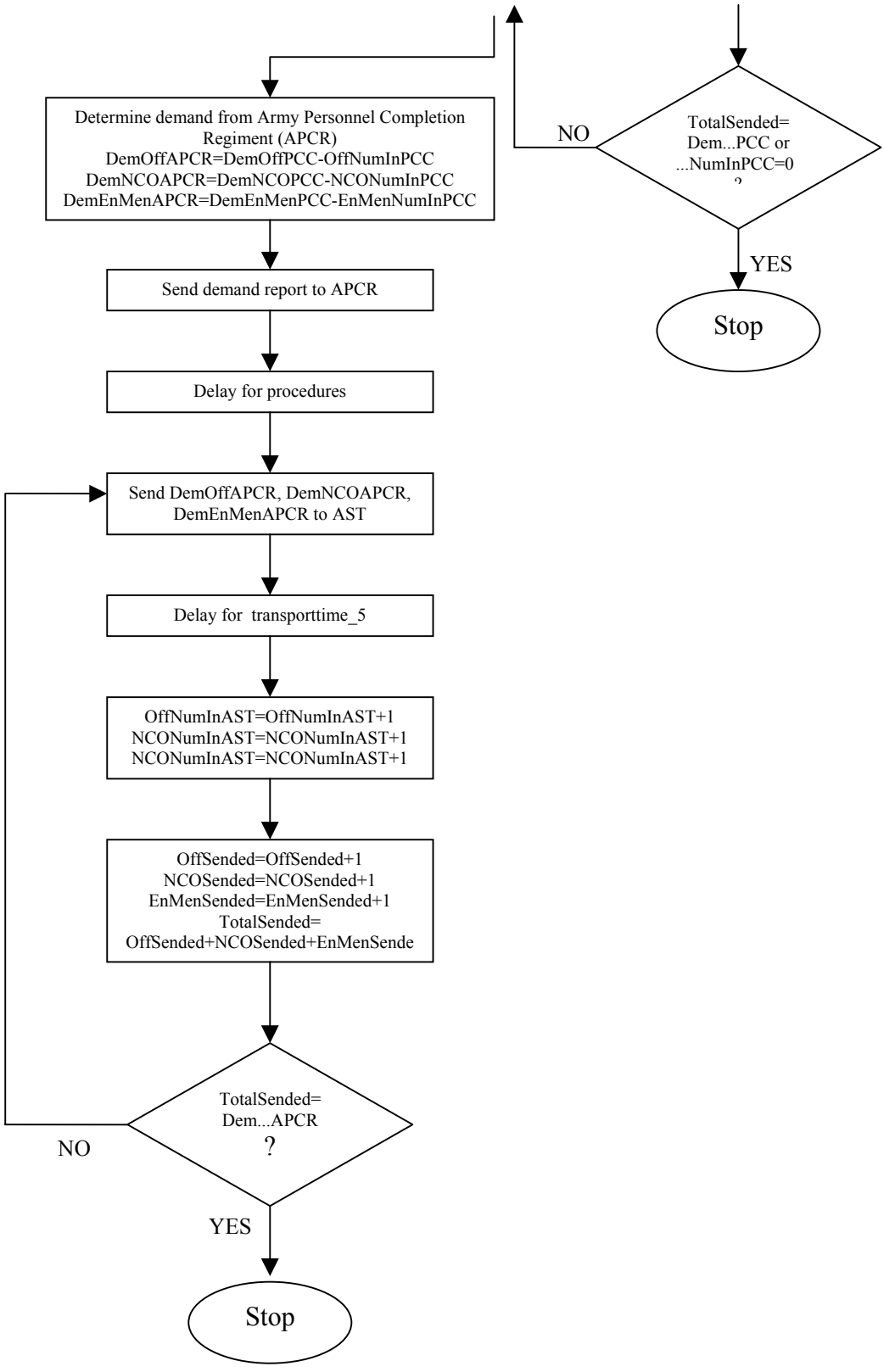


Figure 4.1: Flowchart of the model (Cont'd).

4.4. Data Collection and Input Data Analysis

We needed to collect some data about the number and type of casualties and the number of reserve personnel during a mobilization situation. This was maybe the most difficult part of this study since there were not much data and the data found are derived from the experiences of the past wars and the exercises performed at peacetime.

Data related to the number of casualties and the rate of O, NCO and E in this number could be found in some documents about the wars in twentieth century. The casualty amount per one day of the battle of any kind is given as rates in the documents. These rates are determined as constant numbers in these documents and we used these values as intervals of the uniform distribution. In this way, we randomized the daily total casualty numbers. By dividing 24 hour-period by these total numbers, we obtained the parameter of exponential distribution that is needed to generate Poisson arrivals of casualties. Inputting the original ratios in this way also helped randomizing the casualty numbers in a way that is much more closer to the real situation. Rates of casualty types mentioned in these documents are used as probabilities in the model.

Data related to the number of reserve personnel who are planned and assigned to a brigade, number of reserve personnel who are assigned and knows the mission, the number of reserve personnel who knows his assignment and is ready to join the unit in need and the number of personnel who can return to duty after treatment are collected in cooperation with the Mobilization Department of Ministry of Defense. These values are given as percentages via the planned numbers in the documents of Mobilization Department of Ministry of Defense. Again to satisfy the randomness, we gathered the needed values of different years and used triangular distribution. In Appendix D1, there exist the data and the triangular distribution parameters belong to the number of reserve personnel, who are planned to join brigade and AST and know their missions (who are given Mobilization Duty Order (MDO)). In Appendix D2, there exist the data and the triangular distribution parameters belong to the number of reserve personnel, who are planned to join PCC and know their missions (who are given Mobilization Duty Order (MDO)). In Appendix D3, there exist the data and the

triangular distribution parameters belong to the number of reserve personnel, who are given MDO and join their units on time during the field exercises.

Moreover, we needed to know interarrival times of reserve personnel. Nevertheless, because of the shortages, it was inevitable to find these times simply by dividing the necessary time periods with the total numbers occurred during this time period. The values found were used as the parameters of exponential distribution that provides Poisson arrivals for the reserve personnel.

Other data such as transportation velocities, time spent in demand determining process and prediction numbers of next days' demands are collected by using expert opinions.

4.5. Model Verification And Validation

Model verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. Model validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model (Kleijnen, 1999).

Simulation models are increasingly being used in problem solving and to aid in decision-making. The developers and users of these models, the decision-makers using information derived from the results of the models, and people effected by decisions based on such models are all rightly concerned with whether a model and its results are "correct". This concern is addressed through model verification and validation. Especially for our system, to construct a valid and correct model is very important, because decision makers of this system are commanders and the people affected by decisions based on this model are whole people of a nation. Since we did not have real output data, we were forced to use several methods from very beginning to the end and in every phase of the model's life cycle to identify and rectify the errors. Since some of these methods are used for both verification and validation, we explained the verification and validation activities under single topic.

4.5.1. Face Validation

In this method, the project team members, potential users of the model and the people knowledgeable about the system, subjectively compare real system and the model to decide whether the model and its results are reasonable (Balcı, 1985). A face validation study is conducted for the study of Personnel Mobilization and Completion System. The people involved in this study were:

- Developers of this model.
- A member from the Mobilization Department of Ministry of Defense whose mission is to assign reserve personnel to the units of the Army according to the plans prepared at peacetime.
- A member from the Mobilization Department of Ministry of Defense Department Of Defense whose mission is to coordinate and document the personnel mobilization exercises.
- A member from the General Staff who has worked in this system as an applier.
- A member from Personnel Branch School who teaches this system to cadets.

They are wanted to analyze the simulation results and observe the animation of the model that are related with their expertness. As a result of face validation the model is found to be sufficiently valid.

4.5.2. Turing Test

This test also depends on expert's knowledge. Two groups of outputs one of which belongs to the model and the other belongs to the actual system are submitted to experts and they are wanted to identify to which group an output belongs. If they are able to differentiate some or all of the outputs, detecting how they managed to do this helps much in finding the inconsistencies and observation of no difference can be evaluated as an evident in validity (Balcı, 1985).

Since every year some exercises are planned to inspect the activities of Brigade Acceptance Unit (BAU) which is a subunit of this system where the reserve personnel of the brigade first joins this unit after a mobilization declaration, It was possible to find outputs belong to the real system. So a turing test is conducted for

the subsystem “reserve personnel flow” to BAU by first constructing two sets of outputs including the average and total numbers of joining O, NCO and E just after the mobilization declaration. Then these outputs were presented to two officers who have coordinated such exercises previously and they were asked to identify a difference. Their failure in differentiating these outputs again proved our model’s validity.

4.5.3. Data Analysis

This category consists of several methods used to ensure that proper operations are applied to data objects, the data used by the model are properly defined and the defined data are properly used. One of them is data flow analysis used to assess model accuracy with respect to the use of model variables (Balcı, 1985). To implement this method in Personnel Mobilization and Completion Model, a data flow graph is constructed in which the nodes are the statements and corresponding variables and the arcs represent control flow by donating the flowchart of which some part is shown in Figure 4.2.

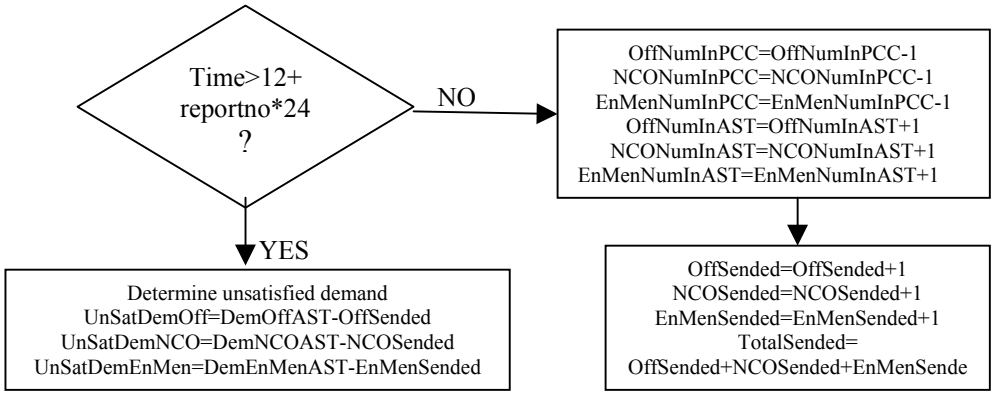


Figure 4.2: One part of the structure used in data flow analysis.

4.5.4. Syntax Analysis

Syntax Analysis is carried out by the compilers of the programming languages. The model of the Personnel Mobilization System is constructed by using ARENA 3.0, so its compiler helped most in finding the locations and reasons of syntax errors by pointing out them in small windows as shown in Figure 4.3.

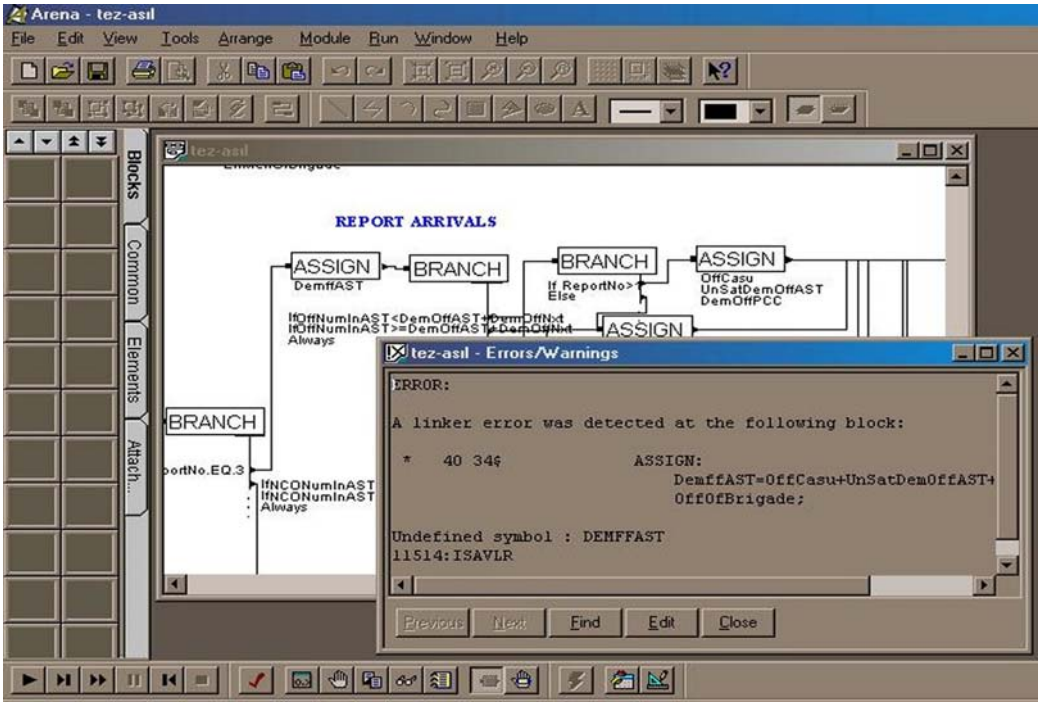


Figure 4.3: Compiler of Arena 3.0.

4.5.5. Execution Profiling

This method is used to reveal errors by examining high-level information about the activities and events during the execution of the model (Balcı, 1985). To apply execution profiling, the model was subject to some instrumentation to get the high-level information such as the histograms of NCO number in brigade, NCO number in AST, NCO number in PCC, etc. which are shown in Figure 4.4 and Figure 4.5.

4.5.6. Visualization/Animation

Using this method greatly assists in model V&V. To see the dynamic behavior of the model such as graphical images of entities during execution enables us to discover errors easily.

Watching the animation of the Personnel Mobilization Model helped much in detecting the bugs and inconsistencies in the model. To animate the model almost all variables` values, flow of entities, transporters and the real time are represented by graphical images using the animation facilities of Arena 3.0 simulation program as seen in Figure 4.6.

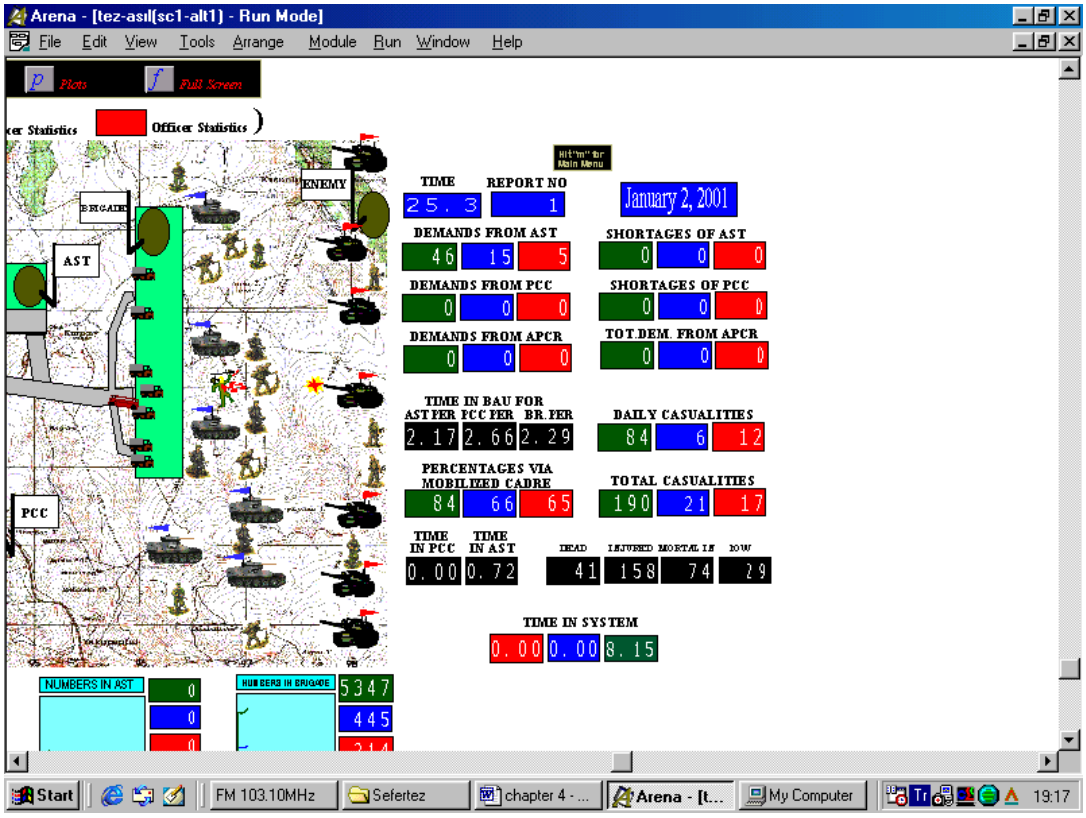


Figure 4.4: Statistics collected during execution of the model.

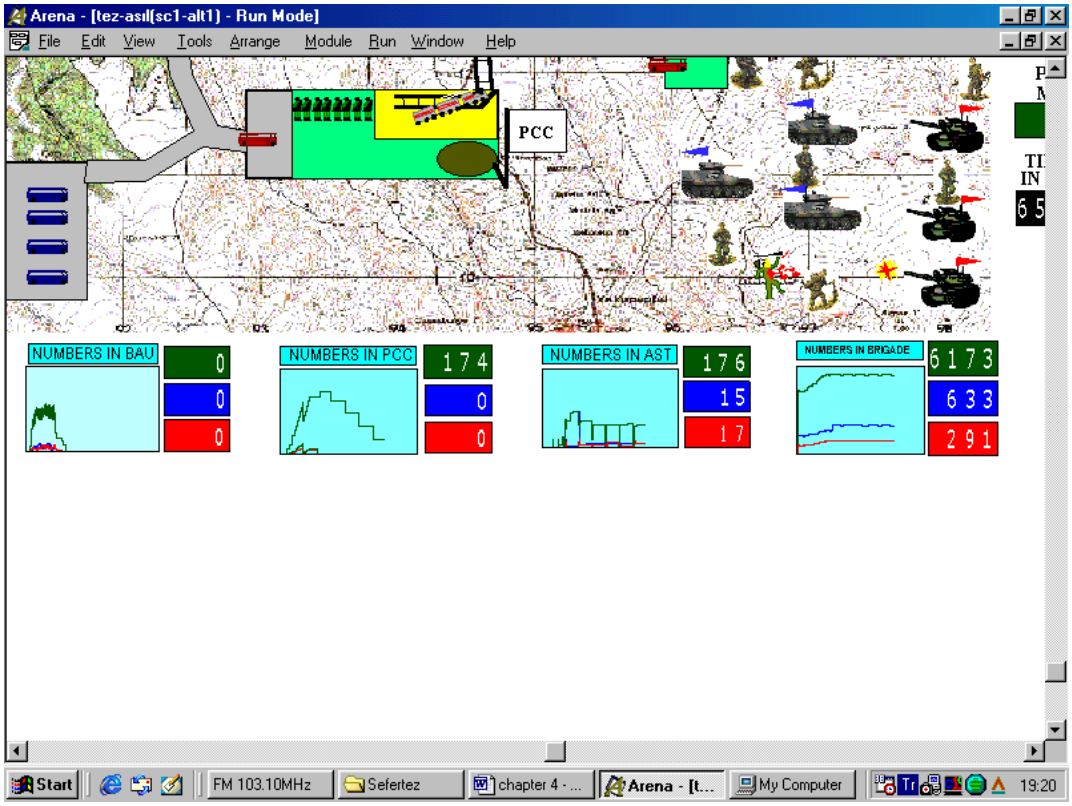


Figure 4.5: Plots collected during the execution of the model.

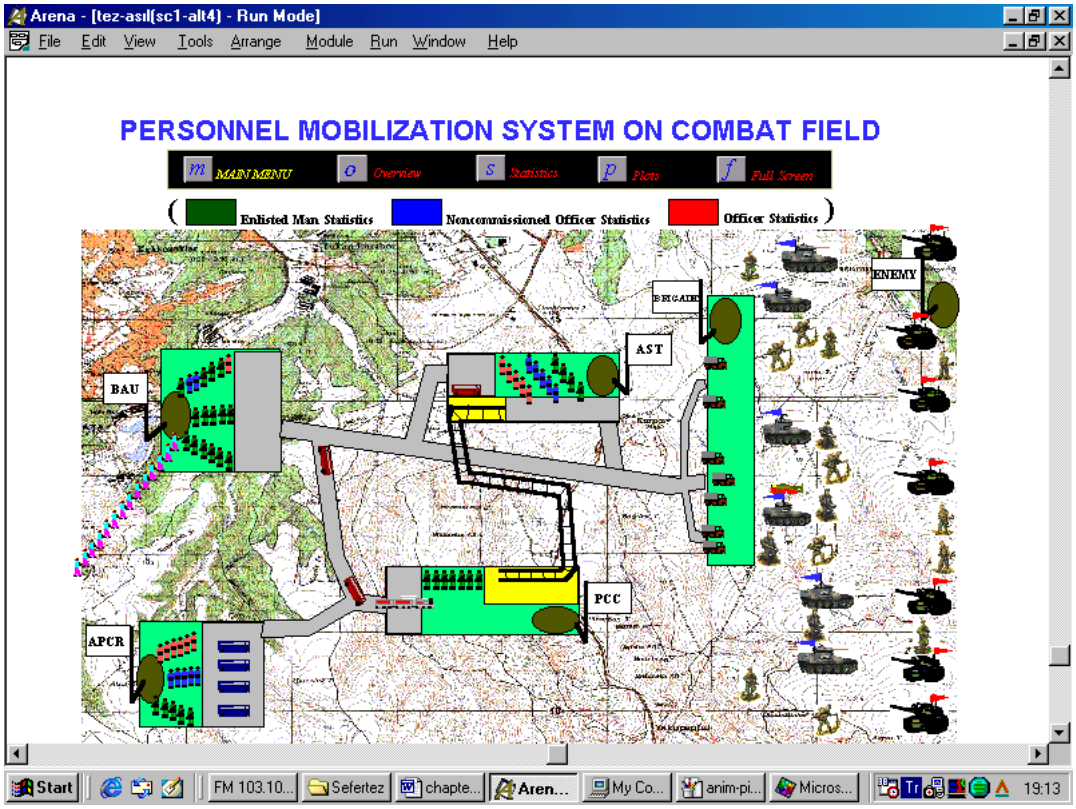


Figure 4.6: Animation example for the model of Personnel Mobilization and Completion System.

CHAPTER 5

SIMULATION EXPERIMENT AND ANALYSIS OF RESULTS

In the first part of this chapter, we will present a primary study analyzing the existing system under normal conditions. In the second part, there will be an analysis of comparisons between the existing system and the proposed systems. In the third part, a study for the optimization problem of the reserve personnel requirement plans, which are prepared during peacetime, is presented.

5.1. Primary Analysis of the Existing System

After modeling the personnel mobilization and completion system, the first study we conducted was the primary analysis of the results of 20 simulation replications performed by the model. The model was run under the normal conditions for the existing system. In other words, the model of the existing system was subject to the warfare for which the system was planned during peacetime. It was exactly the situation in which the personnel mobilization and completion plans of the brigade were prepared as if the brigade was to face with a defense operation and it really performed a defensive operation. The casualty numbers, which were used in the preparation phase of the plans, were injected into the model during the execution phase. In this way, we provided that the model of the existing system was run under normal conditions. After this step, we collected the statistics in Table 5.1 of which detailed data exists in Appendix E. On the Table 5.1, one can observe the summary statistics of critical performance measures, which are used for primary analysis,

Table 5.1: Summary statistics for the existing system (20 replications). (Explanations of the abbreviations in the table can be found in the glossary section)

		MEAN	VARIANCE	ST. DEV.	CONF. INT. (α=0,05)	EXPLANATION
PERCENTAGES VIA MOB.CAD.	O	90.66	0.772988	0.87919	0.821765	represents the average number of personnel who are present at the brigade as the unit of percentages
	NCO	90.48	0.494026	0.70287	0.656956	
	E	95.70	0.064354	0.25368	0.237109	
TOTAL DEMAND FROM APCR	O	82.6	541.3053	23.2659	21.74615	represents the total number of personnel who are demanded from APCR as extra personnel
	NCO	191.1	746.7263	27.3262	25.54124	
	E	284.8	26679.54	163.338	152.6688	
SHORTAGES OF AST	O	6.5	11.21053	3.34821	3.129495	represents the total number of personnel who are not supplied on time for the brigade
	NCO	7.55	17.10263	4.13553	3.865385	
	E	0	0	0	0	
TIME IN SYSTEM	O	110.0	64.7393	8.04607	7.520475	represents the average time spent from the entrance in BAU to the arrival in brigade in hours
	NCO	93.72	33.70869	5.80591	5.426655	
	E	104.2	30.93146	5.56160	5.198302	
TIME IN	PCC	68.32	248.4873	15.7634	14.73375	avg. time spent in PCC
TIME IN	AST	19.54	14.67537	3.83084	3.5806	avg. time spent in AST
CASUALTY AMOUNT	O	102.0	160.78	12.68	11.85	represents the total number of casualties occurred in the first ten days
	NCO	126.2	226.51	15.05	14.06	
	E	1545.	13056.3	114.26	106.8	
NUMBERS IN BRIGADE	O	290.2	7.34	2.71	2.53	represents the average number of personnel present at brigade
	NCO	597.6	5.82	2.41	2.25	
	E	6077.	251.68	15.86	14.82	
NUMBERS IN AST	O	9.04	1.28	1.13	1.06	represents the average number of personnel present in AST
	NCO	13.04	115.39	10.74	10.04	
	E	152	15.79	3.97	3.71	
NUMBERS IN PCC	O	2.85	0.27	0.52	0.49	represents the average number of personnel present in PCC
	NCO	3.11	0.3	0.55	0.51	
	E	300.1	6247.88	79.04	73.88	
CASUALTY TYPES	POW	175.6	395.72	19.89	18.59	represents the total number of the types of casualties occurred in the first ten days
	INJURED	1273.	9808.66	99.03	92.56	
	DEAD	312.2	722.8	26.88	25.12	
	MORT.INJ.	597.9	2055.41	45.33	42.37	
TIME IN BAU FOR	BR.PER	4.95	0.0074	0.086	0.08	represents the average time spent from the entrance in BAU to the departure from BAU in hours
	PCC PER.	6.34	0.036	0.19	0.17	
	AST PER.	12.9	0.208	0.45	0.42	

validation and alternative system comparisons.

Since our model is a sufficiently valid representation of the real system, decision maker may conclude that:

If the units of the brigade are planned to defense and performs a defensive operation in which the numbers of casualties occurs as predicted and the mobilization declaration takes places at the same time with the beginning of combat, the commander of the brigade should expect:

- During the first ten days of the combat, brigade would combat with a human power of 90.66% officers, 90.48% noncommissioned officers and 95.7% enlisted on the average with respect to 100% cadre.
- Brigade would need an extra amount of 82.6 officers, 191.1 noncommissioned officers and 284.8 enlisted on the average that may be supplied by Army Personnel Completion Regiment (APCR) in that period.
- There will be 6.5 reserve officers and 7.55 reserve noncommissioned officers on the average that may not be supplied on time (in 24 hours) by Administrative Service Team (AST) to the units of brigade in need although they reported their demands.
- The reserve personnel assigned to brigade would have the chance to spend only four or five days on the average on the rear zone. Exact results are 110.07 hrs for officers, 93.72 hrs for noncommissioned officers and 104.2 hrs for enlisted on the average.
- The amount of time that reserve personnel would spend in Personnel Completion Company (PCC) will be 68.32 hrs and this amount will be 19.54 hrs for AST.
- During the first ten days, the distribution of the ranks among the casualties would be 102.05 officers, 126.25 noncommissioned officers and 1545.85 enlisted on the average.
- The average numbers present in the brigade would be 290.21 officers, 597.67 noncommissioned officers and 6077.68 enlisted.
- The average numbers present in the PCC would be 9.04 officers, 13.04 noncommissioned officers and 152 enlisted.

- The average numbers present in the AST would be 2.85 officers, 3.11 noncommissioned officers and 300.1 enlisted.
- Total numbers of species of casualties would be: 175.6 Prisoner Of War (POW), 1273.35 injured, 312.2 dead and 597.95 mortal injured on the average.
- The reserve personnel assigned to brigade would spend 4.95 hrs before arrival in brigade, 6.34 hrs before arrival in PCC and 12.9 hrs before arrival in AST upon their arrival in BAU.

Most of these issues give some idea about the behavior and some probable improper functioning of the existing system to the commanders. This issue should be evaluated in accordance with a brigade of which mobilized cadre is 7000 totally (316 O, 653 NCO and 6031 E). For instance we know that this brigade would have only 290.21 officers, 597.67 noncommissioned officers and 6077.68 enlisted on the average in the first ten-day period. This shows a significant symptom of a manpower problem for that brigade. Another example is the information about the amount of time that a reserve personnel would have chance to spend at the rear zone. This amount is 110.07 hrs for officers, 93.72 hrs for noncommissioned officers and 104.2 hrs for enlisted on the average for that brigade. The orientation and refreshment trainings of reserve personnel can be planned just at the peacetime by using this information.

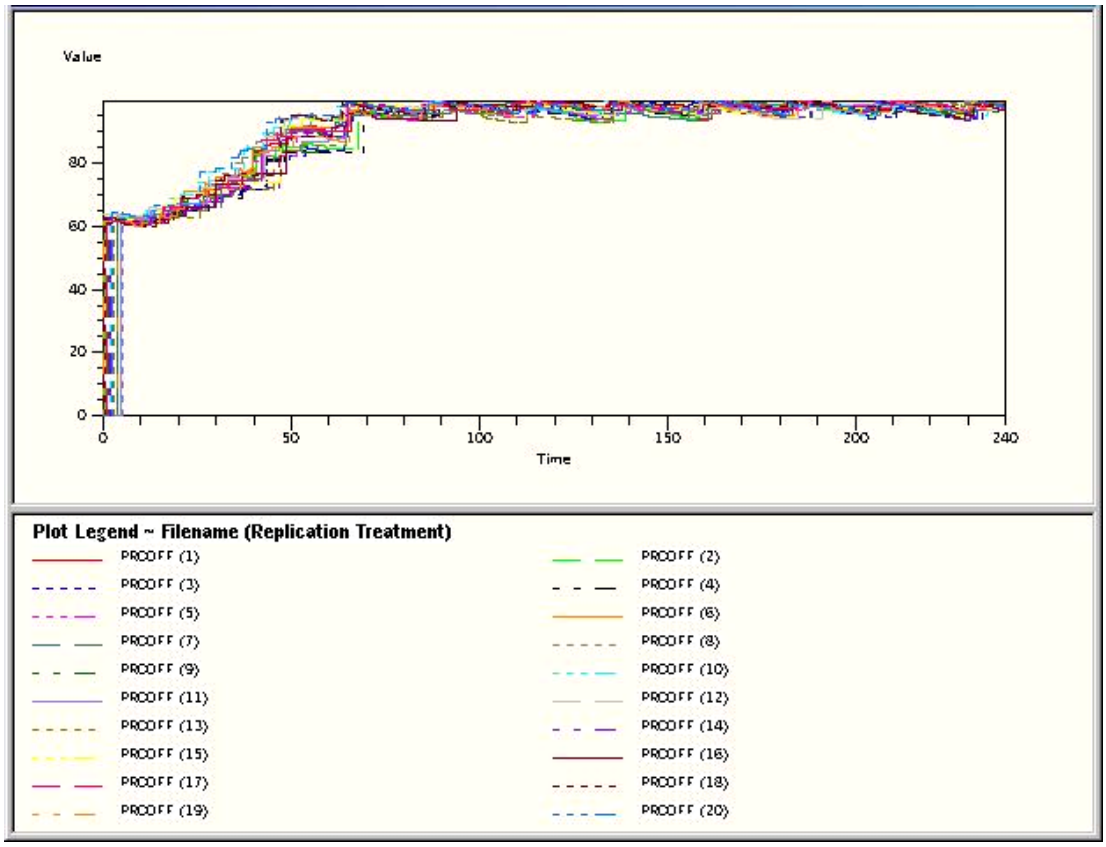
After performing such investigations on these performance measures, we decided to perform further analyses over the numbers in brigade and the numbers of reserve personnel who are demanded as extra personnel from APCR. Because some further analyses on these measures can provide critical information for the decision makers.

5.1.1. Further Analysis of Numbers in Brigade

Information including average number of personnel that the brigade will have during the first ten days of the combat is important, however there is a more important information that can help decision maker very much. If one remembers the flow of personnel mobilization and completion system, initially it needs the reserve

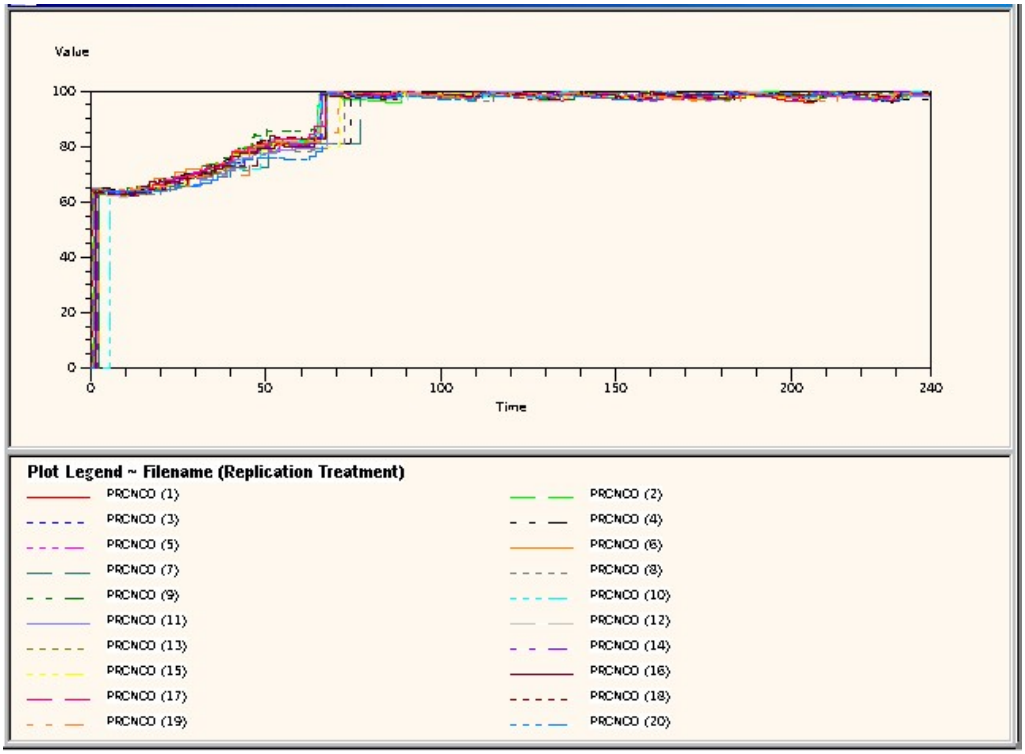
personnel to leave their home just after the mobilization declaration and to arrive in BAU of the brigade that they are assigned to. Moreover, upon their arrival in BAU they need to spend some equipage time and then a transportation time to the brigade or completion units. As a result, the system needs some amount of time just at the beginning of mobilization to complete 100% cadre of the brigade. To find the amount of this time, which we can name it as warm-up period, we used a graphical interpretation of 20 replications. In Figure 5.1, we present the percentages of numbers of O, NCO and E respectively via 100% cadre over ten days (240 hrs.).

As seen on Figure 5.1(a), results belonging to 20 replications points out that this warm-up period is approximately 65 hrs for O. If we look at the Figure 5.1(b), we can say that this period is approximately 70 hrs for NCO and if we look at the Figure 5.1(c), this period is approximately 55 hrs for E.

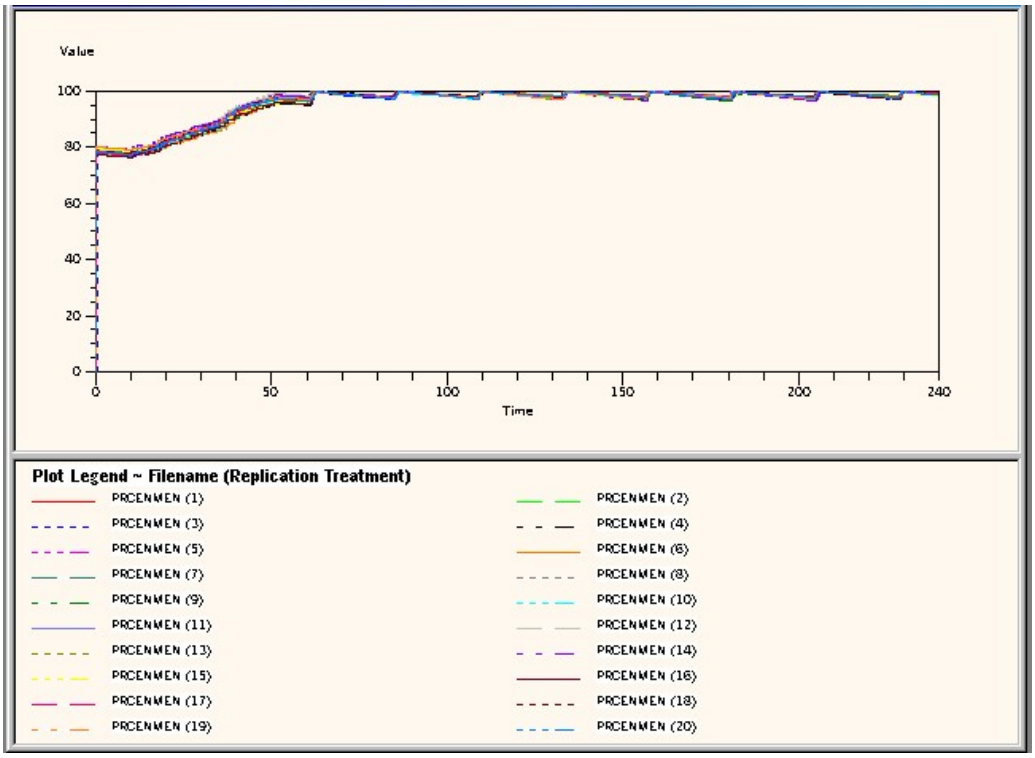


a) O percentages via 100% cadre numbers for the first ten days.

Figure 5.1: Plots for personnel percentages via 100% cadre numbers.



b) NCO percentages via 100% cadre numbers for the first ten days.



c) Enlisted percentages via 100% cadre numbers for the first ten days.

Figure 5.1: Plots for personnel percentages via 100% cadre numbers (Cont'd).

In other words, after these amounts of time the system can enable the brigade to reach its 100% mobilized cadre approximately and then serves as only the supplier of the reserve personnel demanded because of casualties occurred. To know this warm-up period is very important for the system's properly working. The time of mobilization declaration may be adjusted in accordance with these results. Briefly, we can conclude that if it is possible, mobilization should be declared at least 70 hrs before the combat begins for the brigade.

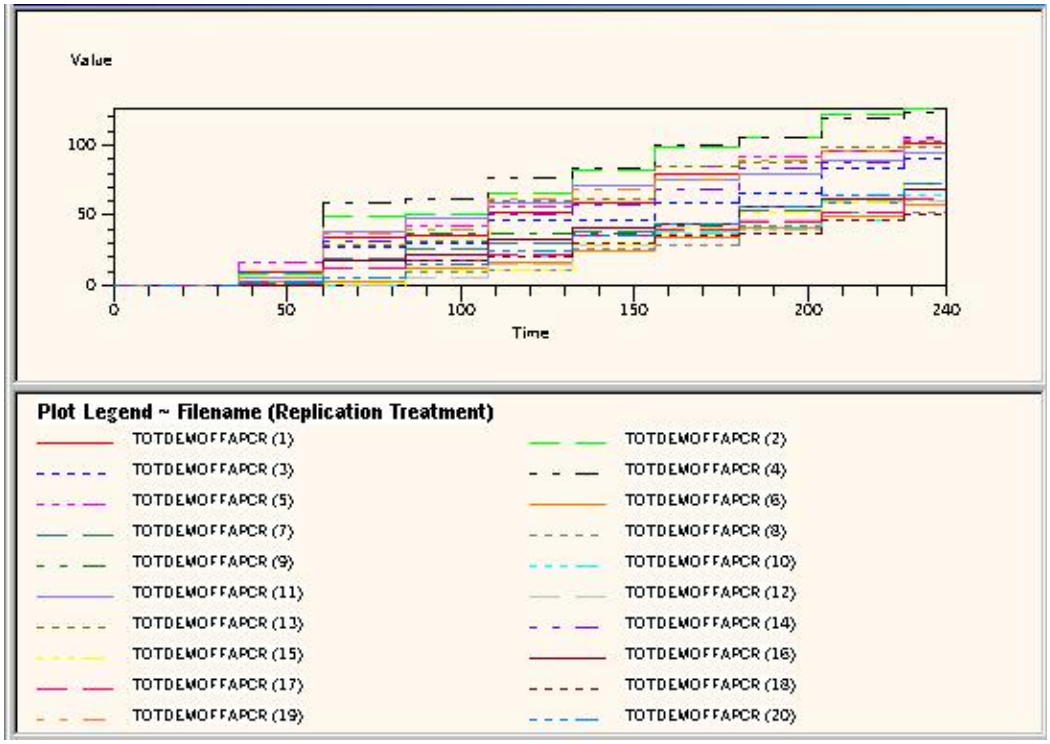
5.1.2. Further Analysis of Total Demand from APCR

As seen on the Table 5.1, brigade would need some amount of extra reserve personnel during this ten-day period. We know the amount of problem but we do not know when this problem may arise. Having this information can help especially the decision makers responsible for APCR. Since the nature of this system requires the deployment of reserve personnel in groups, between the arrivals of these groups it is assumed that the units of the Army would not need reserve personnel (extra personnel) other than the ones who are assigned to that units. In such a case, it is the duty of APCR to supply this extra demand. Therefore, the appearing time of this demand will surely be helpful information for APCR activities. To determine this time we executed 20 replications and collected the data belong to the demand from APCR over the ten-day period and visualized by using the Output Analyzer facility of ARENA 3.0. The summary of these statistics that belong to O, NCO and E are presented in Table 5.2.

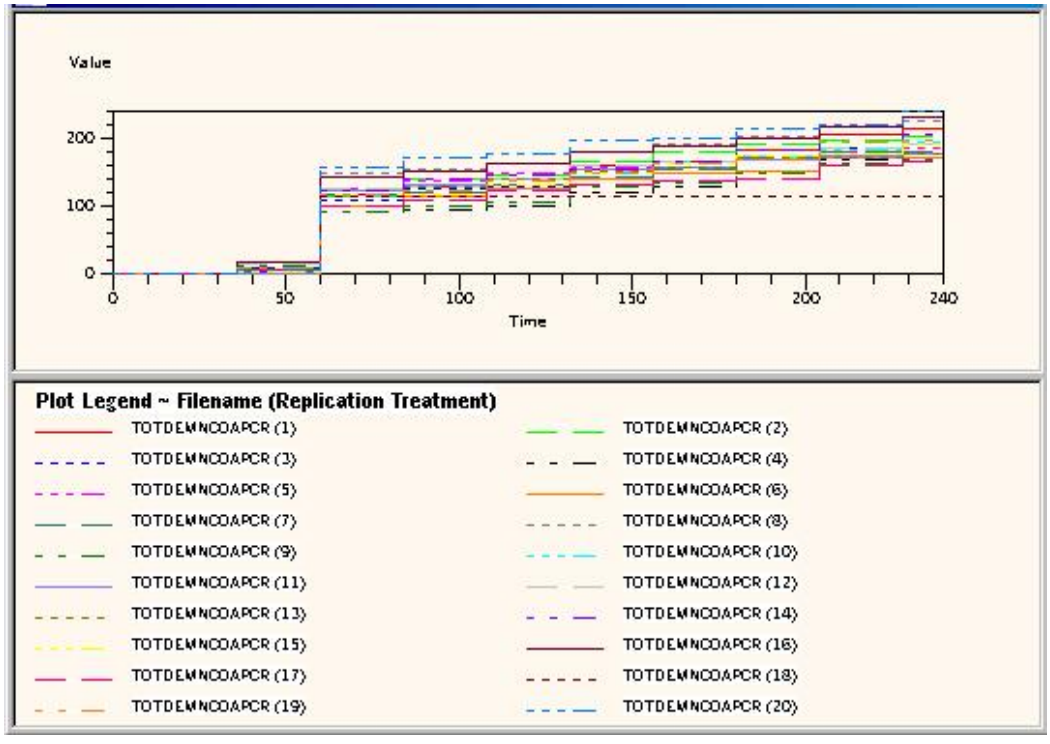
Table 5.2: Summary statistics for the starting time of extra O, NCO and E demand.

PER.	REPLICATION NUMBER																				MEAN
TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
O	36	60	60	36	36	84	60	84	36	84	60	84	60	36	60	60	60	60	60	60	**58.8**
NCO	60	60	60	60	60	60	60	60	60	60	60	36	60	60	60	36	60	36	60	60	**56.4**
E	204	156	180	180	180	204	228	180	156	180	204	252	156	204	156	252	228	180	204	204	**194.4**

According to the results obtained, we can conclude that APCR must be ready for unexpected O demand 58.8 hrs, NCO demand 56.4 hrs and E demand 194.4 hrs after the combat begins for the brigade. These results can also be observed visually for O, NCO and E in Figure 5.2.

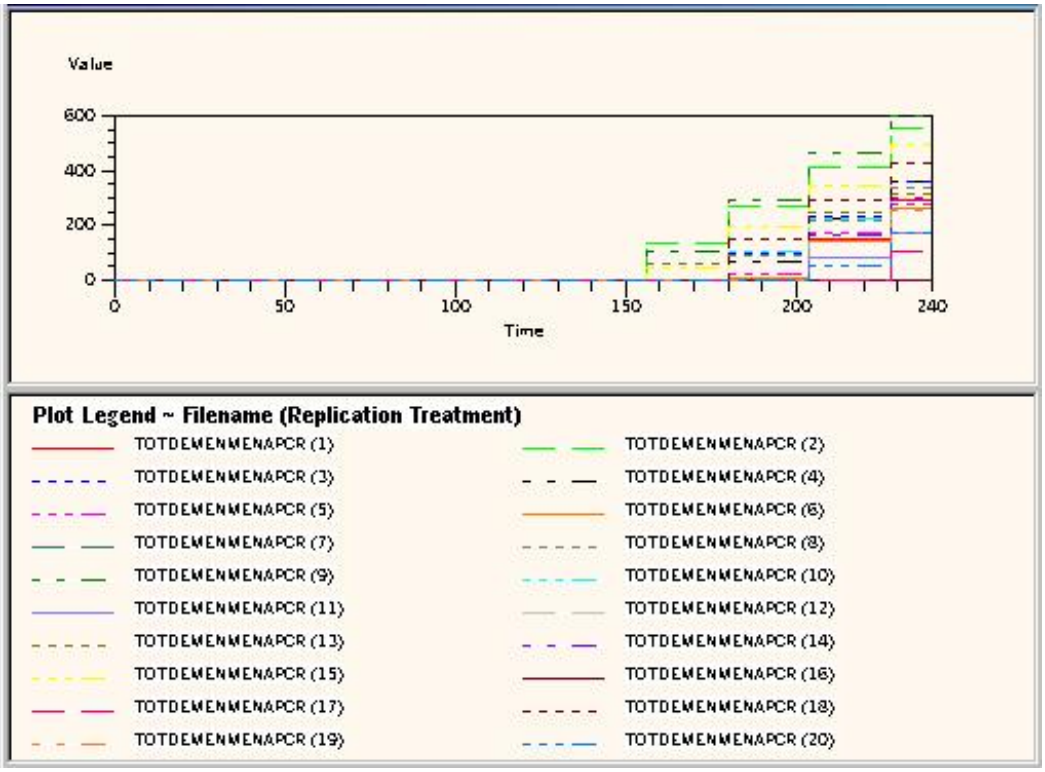


a) Extra O demand for the first ten days.



b) Extra NCO demand for the first ten days.

Figure 5.2: Extra reserve personnel demand from APCR for the first ten days.



c) Extra E demand for the first ten days.

Figure 5.2: Extra reserve per. demand from APCR for the first ten days (Cont'd).

According to these observations, there seems a very serious problem especially for O and NCO demands reported by the brigade. If we take into consideration that the model of the personnel mobilization and completion system is exercised under normal conditions, expecting no extra demand from APCR is natural. Although we expect some demand from APCR according to the first impressions that we have during the data collection phase, such earlier demands forced us to focus on this problem. This problem was surely the result of a difference between the planned and the actual numbers of reserve personnel. After some investigation, the possible results are found as follows:

- If the data presented in Appendix E1 and E2, which are related to the number of reserve personnel who are planned and assigned to a brigade, number of reserve personnel who are assigned and knows the mission, the number of reserve personnel who knows his assignment and is ready to join the unit in need and the number of personnel who can return to duty after treatment is inspected, this may explain us some part of the difference between the

planned numbers and the actual numbers of reserve personnel. Each step described above causes some decrease from the planned numbers.

- The sources of reserve O and NCO are much more limited with respect to the sources of E. Therefore, too earlier demands of E from APCR did not occurred with respect to that of O and NCO.

5.1.3. Summary

In this section, as a first step we conducted a primary analysis of the existing system by using 20 replications of the model. In this way, we aimed to collect some statistics that may be helpful for the commanders who are responsible for this system. During this stage, according to several performance measures, we observed that the system would deviate from the expected responses that it was planned even under the normal conditions.

As a next step, we performed some further analysis that mostly based on visual observations about the performance measures "existing numbers in brigade" and "total demand from APCR". Because we evaluated them as the most critical measures that can mirror the problems in the system. By analyzing the O, NCO and E numbers present at the first ten days of the combat, we found that the system needs some amount of time which we named it "warm-up period" to increase the numbers of personnel to the level required by the 100% mobilized cadre. After this warm-up period, the personnel mobilization and completion system can go on its mission of replacing the casualties with reserve personnel. The results showed that this period is approximately 65 hrs for O, 70 hrs for NCO and 55 hrs for E. Therefore, we concluded that the time of mobilization declaration should be adjusted in accordance with these results, in other words, if it is possible, mobilization should be declared at least 70 hrs before the combat begins for the brigade. By analyzing the total demands from APCR occurred during the first ten-day period, we found that there is a serious amount of demand from APCR that is unwanted under normal circumstances. The results of these further analyses showed that APCR must be ready for unexpected O demands 58.8 hrs, NCO demands 56.4 hrs and E demands 194.4 hrs after the combat begins for the brigade. This early and critical amount of demands forced us to focus on this performance measure in the following studies.

5.2. Comparisons of Alternatives

In this section, we present a study of comparing different alternatives of the existing system. These comparisons are performed under different scenarios, which have different rates for casualty numbers to see the performance of these systems for especially increased arrival rates.

Before beginning any statistical study, it would help to identify the alternatives and scenarios that will be included. Four alternatives will be compared under three different scenarios. (1) First of these alternatives is the existing system, (2) second is the modified version of the existing system, (3) third is the marginal approach that was mentioned previously in Chapter 3, and (4) fourth alternative is the modified version of the marginal approach. The modifications mentioned here have been explained in detail previously in Chapter 3 and they are the same for both existing system and the marginal approach.

These alternatives will be compared under three different scenarios to see their performance for different arrival rates. In fact, these scenarios are some kinds of operations that a brigade may have to perform on combat field. In military literature, it is well known that different warfare types cause different densities in the numbers of casualties. For instance, an offensive warfare with the equal combat powers in each side causes more casualties than that of a defensive warfare. These facts hold true in the documents related to the past wars too. Since the personnel mobilization and completion plans are prepared according to only one possible operation type, brigade's performing different operations would be the best factor forcing the system under consideration. Because, there is not much thing to do to change personnel completion plans that had been prepared at peacetime while brigade is already on combat field. (1) First of these scenarios is "organized position defensive combat" for which the peacetime plans are prepared. (2) Second is "attack to organized position" in which the history noted the most casualties had occurred. (3) Third is "attack to organized position" in which expected casualty numbers are doubled. Third scenario is designed to force the alternative systems more and it can be thought as the warfare in which Nuclear, Biological and Chemical (NBC) weapons are used.

Again it is well known in military literature that usage of these weapons causes mass casualties on the battlefield.

These comparisons are performed by using four main performance measure; (1) percentages of the personnel existing in brigade via the 100% mobilized cadre, (2) total number of extra reserve personnel demanded from APCR, (3) the number of the reserve personnel who are not supplied on time by AST and (4) the average amount of time that the reserve personnel spend between the entrance in BAU and arrival in brigade for any combat position.

First performance measure (main criterion 1) is used in comparisons because the personnel mobilization and completion system serves mainly to provide mobilized cadre of brigade at once and then to maintain these numbers. In military history, it is accepted that if the numbers in a unit of the Army falls below the 70% of the mobilized cadre then that unit has lost its combat power. Therefore, we thought that using this criterion in comparisons is seriously important. Higher the degree of this criterion satisfied, the better the system is.

Second performance measure (main criterion 2) determines the number of reserve personnel that the brigade have to demand from APCR because of the shortages of the reserve personnel assigned to its own completion units. Since in conceptual model calling the next reserve personnel groups earlier is not an alternative solution for this problem, the only thing that APCR can execute to solve this problem is to provide these personnel from the completion units of the other units of Army which are in less need. However, we believe that such precautions do not guarantee that the exact number of demanded extra reserve personnel would be supplied on time. This was the reason that we preferred this performance measure among the others as a criterion for the comparisons. Smaller the degree of this criterion satisfied, the better the system is.

Third performance measure (main criterion 3) determines the number of reserve personnel demanded from AST by the troops on battlefield and AST is not able to supply on time. This shortage occurs because of the lack of these reserve personnel in AST or in PCC or due to the transportation times needed to supply them to the battlefield. Such numbers of personnel are added to the next day's report as unsatisfied demand and show the improper functionality of the system. Smaller the degree of this criterion satisfied, the better the system is.

The last performance measure (main criterion 4) informs us about the average amount of time that the reserve personnel spend before joining their units on battlefield. It is wanted that they spend as much time as possible at rear zone. Because although these reserve personnel had already some experiences in military actions previously, after some time of no activeness they need some refreshment training which enables them to adopt their new missions, units and the combat physiology. Therefore, higher the degree of this criterion satisfied, the better the system is.

Finally, we defined three sub criteria for each main criterion, which are the same for four criteria. These sub criteria are O, NCO and E. Since the effects of each criterion are different for each type we use them in comparisons. In other words the comparisons included twelve criteria, of which brief descriptions are written below:

C1: Percentages via mobilized cadre (officer)

C2: Percentages via mobilized cadre (noncommissioned officer)

C3: Percentages via mobilized cadre (enlisted)

C4: Total demand from APCR (officer)

C5: Total demand from APCR (noncommissioned officer)

C6: Total demand from APCR (enlisted)

C7: Shortages of AST (officer)

C8: Shortages of AST (noncommissioned officer)

C9: Shortages of AST (enlisted)

C10: Time in system (officer)

C11: Time in system (noncommissioned officer)

C12: Time in system (enlisted)

5.2.1. Selecting the Best of k Systems

During the selection process of the best system among k systems, if X_{ij} is the jth replication of ith system, $\mu_i = E(X_{ij})$ and μ_{i1} is the best value according to the criteria under consideration, we can not select the best system according to the averages of X_{ij}'s obtained from a limited amount of replications. Because we know that the averages of X_{ij}'s can be equal to the real mean of the criteria (μ_i) with which we are trying to estimate the best system only when we are able to execute infinite

number of replications. Since this is impossible, we can achieve a comparison between the alternative systems by making additional replications upon some initial number of replications.

For our system four main types of criteria are taken as the performance measure of interest, the goal here is to select the system with the minimum expected values for criteria 2 and 3 and the maximum expected values for criteria 1 and 4. In a stochastic simulation, such a correct selection can never be guaranteed with certainty. A compromise solution offered by indifferent zone selection is to guarantee to select the best system with high probability, say $1-\alpha$, whenever it is at least a user-specified amount better than the others; this difference is called the indifference zone. Moreover, if μ_{i1} and μ_{i2} are actually very close to each other we might not care if we erroneously choose i_2, so that we want a method that avoids making a large number of replications to resolve this unimportant difference. At this point, "indifference zone approach" enables us to get P(Correct Selection)≥P* provided that $\mu_{i1} - \mu_{i2} \geq d^*$, where the minimal correct selection probability $P^*>1/k$ and the indifference amount $d^*>0$ are both specified by the analyst. If, unknown to the user, some system happens to be within the indifference zone, d, of the best, then it can be shown that the probability of selecting a good system (i.e. one of the systems within the indifference zone) is at least $1-\alpha$ (Law and Kelton, 1991). The statistical procedure developed by Dudewicz and Dalal (1975) involves "two-stage" sampling from each of the k systems and enables us to be confident with at least P* that the selected system is the best and to decide how much replications for each alternative we should do. Additionally, it results an ordering which will help us in further analyses among the alternatives.

This method needs normally distributed X_{ij}'s and independent samples, moreover it is advised that this method should be used when μ_i's are very close to each other. Below are the stages of this procedure:

STAGE 1

1.Run each alternative model with an initial number of replications ($n_{(0)}\geq 20$).

2.Calculate the sample means and the variances related to these initial numbers of replications.

$$\overline{X}_i^{(1)}(n_0) = \frac{\sum_{j=1}^{n_0} X_{ij}}{n_0} \quad , \text{ and } \quad S_i^2(n_0) = \frac{\sum_{j=1}^{n_0} \left[X_{ij} - \overline{X}_i^{(1)}(n_0)\right]^2}{n_0 - 1}$$

for i=1,2,....,k

3.Then calculate the total sample size needed for each alternative *i* using the formula below:

$$N_i = \max\left\{n_o + 1, \left\lceil \left(\frac{h_1 * S_i(n_0)}{d^*} \right)^2 \right\rceil \right\}$$

where

$\lceil x \rceil$: the smallest integer that is greater than or equal to the real number x

h_1 : from table10.11 in Appendix10B of (Law and Kelton,1991)

STAGE 2

1. Execute N_i- $n_{(0)}$ additional replications for each system i.

2. Calculate the means related to these additional replications

$$\overline{X}_i^{(2)}(N_i - n_0) = \frac{\sum_{j=n_0+1}^{N_i} X_{ij}}{n_0}$$

3. Then calculate the weights for each stage samples using the formula below:

$$W_{i1} = \frac{n_0}{N_i}\left[1 + \left\{\left(1 - \frac{N_i}{n_0}\left(1 - \frac{(N_i - n_0)d^{*2}}{h^2 S_i^2(n_0)}\right)\right)\right\}^{1/2}\right]$$

$$W_{I2} = 1 - W_{i1}$$

4. Finally define the weighted averages according to the formula below:

$$\tilde{X}_i(N_i) = W_{i1}\overline{X}_i^{(1)}(n_0) + W_{i2}\overline{X}_i^{(2)}(N_i - n_0)$$

and select the system with the smallest/largest $\tilde{X}_i(N_i)$.

5.2.2. Comparison of the Alternatives under the First Scenario

In accordance with the indifference zone approach and Dalal&Dudewicz (D&D) procedure, we performed initially 20 replications and only up to 100 total replications for each alternative because of the computer time limitations. Summarized statistics for each of the criteria are presented in Table 5.3. First column of this table shows the criterion, second column shows the number of alternative, third column shows the average values related with the initial replications, fourth one shows the variance related with the initial replications, fifth one shows the total number of replications that should be executed, sixth one shows the average values related with the additional replications, seventh one shows the weight for the initial replications, eighth one shows the weight for the additional replications, tenth one shows the number of appendices where the detailed statistics related with initial replications and eleventh one shows the number of appendices where the detailed statistics related with additional replications. In the table, also the values of d and h_1 for each criterion that are used in calculations are presented. While applying D&D procedure, we determined the value of d generally smaller than the difference between the first and the second best alternative but sometimes we avoid using such a d value for the comparisons in which the difference between the first and the second best alternative is too small. Since using so small d values would cause too many additional replications, we determined the values of d in a way that although they are not smaller than the difference between the average values of first and second best alternative, they are sufficiently small that we can think the alternatives of which average value is within this amount range of that of the best alternative do not affect our correct selection. In this way, we determined sufficiently sensitive d values for our comparisons. When the rankings belong to initial replications and the rankings belong to total number of replications are considered, it can be observed that they are different for some criteria. These differences are present in also for the other scenarios and they are caused by the close performances of alternatives for those criteria. D&D procedure is one of the best methods in finding the best when the alternatives have such close values.

Table 5.3: Summary statistics of D&D comparison results for the first scenario.

1	2	3	4	5	6	7	8	9	10	11
C1		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.3	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	90.661	0.77299	83	90.748	0.27105	0.72895	90.7246	F1	G1
	2	90.861	0.49101	53	90.763	0.42641	0.57359	90.805	F2	G2
	3	95.972	0.54691	59	95.999	0.38552	0.61448	95.9887	F3	G3
	4	96.905	0.40107	43	96.748	0.49435	0.50565	96.8257	F4	G4
	Ranking: X4>X3>X2>X1									
C2		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.2	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	90.486	0.49403	119	90.712	0.18465	0.81535	90.6701	F1	G1
	2	91.05	0.17015	41	90.507	0.51183	0.48817	90.7847	F2	G2
	3	97.812	0.17581	43	97.582	0.5309	0.4691	97.7042	F3	G3
	4	97.736	0.56283	136	97.737	0.17242	0.82758	97.7367	F4	G4
	Ranking: X4>X3>X2>X1									
C3		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.12	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	95.708	0.06435	43	95.766	0.47718	0.52282	95.7384	F1	G1
	2	95.776	0.39176	262	95.758	0.08651	0.91349	95.7594	F2	G2
	3	97.624	0.02217	21	97.88	1.09012	-0.0901	97.6004	F3	G3
	4	97.51	0.04888	33	97.557	0.65732	0.34268	97.5258	F4	G4
	Ranking: X3>X4>X2>X1									
C4		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	5	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	82.6	541.305	209	80.038	0.11379	0.88621	80.3291	F1	G1
	2	86.2	319.011	123	84.313	0.18064	0.81936	84.6535	F2	G2
	3	45.45	152.05	59	50.103	0.38337	0.61663	48.3189	F3	G3
	4	49.1	114.095	44	49.292	0.47989	0.52011	49.1997	F4	G4
	Ranking: X3<X4<X1<X2									
C5		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	10	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	191.1	746.726	72	199	0.30102	0.69898	196.622	F1	G1
	2	190.4	616.568	60	202.78	0.3849	0.6151	198.012	F2	G2
	3	92.85	403.924	39	83.842	0.54469	0.45531	88.7486	F3	G3
	4	95.05	687.208	67	94.887	0.3524	0.6476	94.9445	F4	G4
	Ranking: X3<X4<X1<X2									
C6		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	40	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	284.8	26679.5	161	309.63	0.14527	0.85473	306.019	F1	G1
	2	267.1	12828	78	274.67	0.30364	0.69636	272.373	F2	G2
	3	266.8	23209.4	140	339.46	0.16398	0.83602	327.547	F3	G3
	4	257.15	13512.3	82	358.34	0.28623	0.71377	329.374	F4	G4
	Ranking: X2<X1<X3<X4									

Table 5.3: Summary statistics of D&D comparison results for first scenario (Cont'd).

1	2	3	4	5	6	7	8	9	10	11
C7		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	1	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	6.5	11.2105	108	6.975	0.2018	0.7982	6.87914	F1	G1
	2	0	0.1	21	0	1.92451	-0.9245	0	F2	G2
	3	6.1	3.88421	38	5.6111	0.59211	0.40789	5.90059	F3	G3
	4	0	0.1	21	0	1.92451	-0.9245	0	F4	G4
	Ranking: X4=X2<X3<X1									
C8		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	2	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	7.55	17.1026	42	8.5909	0.54944	0.45056	8.01899	F1	G1
	2	0	0.1	21	0	2.93132	-1.9313	0	F2	G2
	3	9.6	16.4632	40	9.45	0.55161	0.44839	9.53274	F3	G3
	4	0.05	0.05	21	0	3.75912	-2.7591	0.18796	F4	G4
	Ranking: X2<X4<X1<X3									
C9		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	1	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	0	0.1	21	0	1.92451	-0.9245	0	F1	G1
	2	0	0.1	21	0	1.92451	-0.9245	0	F2	G2
	3	0.35	2.45	24	0	0.88428	0.11572	0.3095	F3	G3
	4	1.95	76.05	732	2.1125	0.03232	0.96768	2.10725	F4	G4
	Ranking: X1=X2<X3<X4									
C10		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	5	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	110.08	64.7393	25	106.54	0.82511	0.17489	109.46	F1	G1
	2	106.56	80.1375	31	108.33	0.68124	0.31876	107.129	F2	G2
	3	110.85	77.7101	30	113.16	0.69513	0.30487	111.551	F3	G3
	4	100.48	133.677	52	108.34	0.43634	0.56366	104.91	F4	G4
	Ranking: X3>X1>X2>X4									
C11		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	3	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	93.726	33.7087	37	92.541	0.62289	0.37711	93.2789	F1	G1
	2	92.963	21.4123	23	87.727	0.89413	0.10587	92.4082	F2	G2
	3	113.95	22.5071	25	110.82	0.87958	0.12042	113.576	F3	G3
	4	112.74	73.7574	79	112.76	0.27466	0.72534	112.754	F4	G4
	Ranking: X3>X4>X1>X2									
C12		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	3	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	104.21	30.9315	34	98.96	0.67171	0.32829	102.483	F1	G1
	2	101.72	33.489	36	104.92	0.59435	0.40565	103.019	F2	G2
	3	100.58	17.8246	21	103.34	1.02061	-0.0206	100.522	F3	G3
	4	96.595	18.888	21	105.86	0.99528	0.00472	96.6383	F4	G4
	Ranking: X2>X1>X3>X4									

When the final values of each alternative are considered, it can be observed that the values of alternative 1 and 2, alternative 3 and 4 are very close to each other with respect to the differences between the values of these two groups. This shows that the effect of the small modification is not as much as that of the marginal approach. This result is intuitive, because the modification described previously is made just to prevent O and NCO shortages of AST that are occurred generally in the first days of battle while the marginal approach is expected to affect all performance measures. Additionally, although alternative 2 is improved version of alternative 1, alternative 3 is improved version of alternative 1 and alternative 2 and alternative 4 is improved version of alternative 3, these primary results discouraged the expectations that alternative 4 is the best one. In general, alternative 4, which is expected to be the best, seems to fail for the main criteria 3 and 4 (shortages of AST and the time spent at the rear zone) while it is always among the best alternatives for the main criteria 1 and 2. If we focus on the amount of these failures, again in general we can say that these failures are not so much when the values of the best alternative for those criteria are considered. Here a natural question may arise: Why the alternative, which is expected to be the best fails for the measures of shortage amount of AST and the average time that reserve personnel spent at the rear zone? Then it can be shown that this inconsistency is caused by the difference of calculations performed for each alternative system during the stage of the reserve personnel requirement preparations. At this stage, after the real personnel requirements are determined, 10% of these enlisted requirements are added to the requirement forms to be assigned by Mobilization Department of the Ministry of National Defense. Since the requirements for alternative 1 and 2 contain also the reserve personnel who will be used in completing the mobilized cadre, the amount of these additionally planned enlisted increases. But in other alternatives, requirements include only the personnel who will be assigned instead of the casualties occurred on battlefield. On the first days of the combat-that the most of the shortages of AST occur, flow of much reserve personnel into the system enables them to lessen the amount of shortages.

On the other hand, if it is considered that each criterion has the same importance level for the commanders, it is hard to select the best system with these results. Because there is no alternative that declares its superiority with the numbers of first places that it gets.

5.2.3. Comparison of the Alternatives under the Second Scenario

For the second scenario we performed initially 20 replications and only up to 80 total replications for each alternative because of the computer time limitations. Summarized statistics for each of the criteria are presented in Table 5.4. The interpretation of the data in this table is the same with that of Table 5.3.

When the results are considered, it can be seen that again the conclusions, which were made for the first scenario are valid for also the second scenario except an increase in the shortages of AST for the alternatives 1 and 2. This difference, which is caused by the increased casualty arrival rate, makes second group (alternatives 3 and 4) tend to be our best systems as they are expected. Moreover, as the arrival rate increased, the values of these two groups get closer to each other for the performance measure of shortages of AST. This is also a symptom of the intuitive expectation that the marginal approach has really an improving effect especially when the casualty arrival rate is increased.

Once more we are failed to select the best system by looking at the numbers of first places that any alternative system gets. In this scenario, the casualty arrival rate was approximately 188% of that of the first scenario and we realized that this increase in the casualty flow did not help us selecting the best system.

5.2.4. Comparison of the Alternatives under the Third Scenario

For the third scenario, we performed initially 20 replications and only up to 100 total replications for each alternative. Summarized statistics for each of the criteria are presented in Table 5.5. The interpretation of the data in this table is the same as the one explained in Section 5.2.2.

In this scenario, we increased the casualty arrival rate in a way that it is two times bigger than that of the scenario 2. In this way we aimed to force the alternative systems more and to see whether the results would change.

Table 5.4: Summary statistics of D&D comparison results for the second scenario.

1	2	3	4	5	6	7	8	9	10	11
C1		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.4	3.101	0.05				
	ALT	X_{i20}	VAR(20)	N_i	$X_{i(Ni-20)}$	W_{i1}	W_{i2}	X_i	REP's	REP's
	1	88.779	1.19994	73	88.7	0.3233	0.6767	88.7256	H1	I1
	2	89.173	0.86489	52	89.208	0.39399	0.60601	89.1945	H2	I2
	3	94.357	0.80701	49	94.55	0.45796	0.54204	94.4616	H3	I3
	4	94.935	0.60662	37	94.93	0.60128	0.39872	94.9327	H4	I4
	Ranking: X4>X3>X2>X1									
C2		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.2	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	89.63	0.23329	57	89.728	0.41187	0.58813	89.6873	H1	I1
	2	89.962	0.3014	73	90.113	0.31258	0.68742	90.0661	H2	I2
	3	96.489	0.16361	40	96.533	0.56509	0.43491	96.5077	H3	I3
	4	97.025	0.05223	21	96.52	1.12703	-0.127	97.0892	H4	I4
	Ranking: X4>X3>X2>X1									
C3		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.2	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	94.275	0.29194	71	94.321	0.33018	0.66982	94.3058	H1	I1
	2	94.338	0.12099	30	94.391	0.75022	0.24978	94.3509	H2	I2
	3	96.155	0.14299	35	96.238	0.63807	0.36193	96.1852	H3	I3
	4	96.132	0.19167	47	96.128	0.49549	0.50451	96.1298	H4	I4
	Ranking: X3>X4>X2>X1									
C4		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	7	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	165.1	1318.09	259	173.93	0.08669	0.91331	173.168	H1	I1
	2	175.4	654.674	129	201.08	0.17809	0.82191	196.509	H2	I2
	3	134.15	656.239	129	134.05	0.16978	0.83022	134.067	H3	I3
	4	142.95	1137.42	224	147.33	0.10617	0.89383	146.868	H4	I4
	Ranking: X3<X4<X1<X2									
C5		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	12	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	315.65	958.345	64	308.77	0.31541	0.68459	310.942	H1	I1
	2	328.8	1019.12	69	314.22	0.3433	0.6567	319.228	H2	I2
	3	208.9	1091.46	73	203.49	0.29153	0.70847	205.068	H3	I3
	4	210.2	665.116	45	218.68	0.50143	0.49857	214.428	H4	I4
	Ranking: X3<X4<X1<X2									
C6		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	60	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	1438.5	138879	371	1471.9	0.05599	0.94401	1470	H1	I1
	2	1490.2	54272.5	145	1492.6	0.14282	0.85718	1492.27	H2	I2
	3	1515	107093	287	1471.9	0.08426	0.91574	1475.5	H3	I3
	4	1478.3	129321	346	1585	0.06722	0.93278	1577.84	H4	I4
	Ranking: X1<X3<X2<X4									

Table 5.4: Summary statistics of D&D comparison results for second scenario (Cont'd).

1	2	3	4	5	6	7	8	9	10	11
C7		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	3	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	20.1	127.568	137	23.617	0.17124	0.82876	23.0145	H1	I1
	2	3.85	25.5026	28	2.5	0.7893	0.2107	3.56555	H2	I2
	3	17.9	96.0947	103	16.933	0.21646	0.78354	17.1426	H3	I3
	4	3.4	105.095	113	5.2333	0.20733	0.79267	4.85322	H4	I4
	Ranking: X2<X4<X3<X1									
C8		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	4	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	29.75	104.197	63	29.395	0.35353	0.64647	29.5207	H1	I1
	2	8.3	61.3789	37	4.4706	0.56781	0.43219	6.64498	H2	I2
	3	27.5	120.474	73	27.434	0.31436	0.68564	27.4547	H3	I3
	4	7.45	227.734	137	6.0167	0.15682	0.84318	6.24144	H4	I4
	Ranking: X4<X2<X3<X1									
C9		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	20	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	36.6	10180.8	245	17.95	0.09037	0.90963	19.6353	H1	I1
	2	5.75	161.145	21	0	1.40014	-0.4001	8.0508	H2	I2
	3	26.95	3977.84	96	26.883	0.23362	0.76638	26.8989	H3	I3
	4	25.6	6283.73	152	53.617	0.15819	0.84181	49.1848	H4	I4
	Ranking: X2<X1<X3<X4									
C10		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	5	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	115.91	76.9061	30	118.06	0.72272	0.27728	116.507	H1	I1
	2	109.8	586.082	226	112.96	0.10271	0.89729	112.636	H2	I2
	3	108.65	549.348	212	111.84	0.1111	0.8889	111.483	H3	I3
	4	112.56	45.5048	21	98.2	1.04756	-0.0476	113.241	H4	I4
	Ranking: X1>X4>X2>X3									
C11		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	3	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	98.633	443.235	474	99.583	0.04816	0.95184	99.5369	H1	I1
	2	99.867	27.3473	30	99.677	0.7437	0.2563	99.8179	H2	I2
	3	118.43	30.1591	33	119.81	0.68189	0.31811	118.865	H3	I3
	4	117.02	50.5807	55	118.85	0.42762	0.57238	118.071	H4	I4
	Ranking: X3>X4>X2>X1									
C12		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	3	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	105.03	548.239	586	109.31	0.03769	0.96231	109.148	H1	I1
	2	108.82	37.7199	41	108.49	0.55357	0.44643	108.672	H2	I2
	3	102.51	493	527	108.81	0.04208	0.95792	108.545	H3	I3
	4	108.42	30.6434	33	107.78	0.64948	0.35052	108.192	H4	I4
	Ranking: X1>X2>X3>X4									

Table 5.5: Summary statistics of D&D comparison results for the third scenario.

1	2	3	4	5	6	7	8	9	10	11
C1		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.5	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	85.972	0.85664	33	86.485	0.62502	0.37498	86.1645	J1	K1
	2	87.082	0.65204	26	86.185	0.8499	0.1501	86.9474	J2	K2
	3	91.969	0.81948	32	91.98	0.68466	0.31534	91.9725	J3	K3
	4	93.061	1.40089	54	92.996	0.39269	0.60731	93.0211	J4	K4
	Ranking: X4>X3>X2>X1									
C2		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.2	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	88.207	0.18467	45	88.27	0.50237	0.49763	88.2384	J1	K1
	2	88.352	0.33037	80	88.48	0.28693	0.71307	88.4437	J2	K2
	3	95.152	0.12476	30	95.33	0.67381	0.32619	95.2097	J3	K3
	4	95.667	0.17852	43	95.745	0.48714	0.51286	95.7069	J4	K4
	Ranking: X4>X3>X2>X1									
C3		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	0.15	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	92.79	0.05622	25	92.838	0.88055	0.11945	92.7953	J1	K1
	2	92.728	0.13311	57	92.596	0.37185	0.62815	92.6454	J2	K2
	3	94.673	0.05391	24	94.753	0.90945	0.09055	94.6802	J3	K3
	4	94.675	0.09745	42	94.72	0.52213	0.47787	94.696	J4	K4
	Ranking: X4>X3>X1>X2									
C4		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	9	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	254.45	785.313	94	248.59	0.24993	0.75007	250.058	J1	K1
	2	252.5	435.211	52	253.75	0.42364	0.57636	253.22	J2	K2
	3	213.4	591.305	71	218.14	0.32974	0.67026	216.575	J3	K3
	4	216.55	1238.47	148	218.2	0.16291	0.83709	217.931	J4	K4
	Ranking: X3<X4<X1<X2									
C5		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	9	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	410.15	649.292	78	417.59	0.30404	0.69596	415.325	J1	K1
	2	421.15	737.818	88	423.15	0.25585	0.74415	422.636	J2	K2
	3	308.7	512.853	61	311.56	0.34826	0.65174	310.565	J3	K3
	4	310.6	925.2	110	305.09	0.19661	0.80339	306.171	J4	K4
	Ranking: X4<X3<X1<X2									
C6		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	60	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	2558	55831.1	150	2546.6	0.15924	0.84076	2548.39	J1	K1
	2	2574.6	35439.9	95	2590.6	0.23474	0.76526	2586.84	J2	K2
	3	2522.8	39792.1	107	2553.3	0.21875	0.78125	2546.64	J3	K3
	4	2574.8	63486.7	170	2541.5	0.13361	0.86639	2545.96	J4	K4
	Ranking: X4<X3<X1<X2									

Table 5.5: Summary statistics of D&D comparison results for third scenario(Cont'd).

1	2	3	4	5	6	7	8	9	10	11
C7		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	5	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	54.8	90.2737	35	54.533	0.61558	0.38442	54.6975	J1	K1
	2	25.65	163.397	63	21.698	0.34016	0.65984	23.0421	J2	K2
	3	45.35	185.397	72	52.404	0.32175	0.67825	50.1343	J3	K3
	4	10.3	212.642	82	10.306	0.26554	0.73446	10.3047	J4	K4
	Ranking: X4<X2<X3<X1									
C8		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	6	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	70.8	170.695	46	73.769	0.48148	0.51852	72.3396	J1	K1
	2	36.45	262.261	71	41.333	0.33396	0.66604	39.7025	J2	K2
	3	71.25	209.039	56	77.25	0.38296	0.61704	74.9523	J3	K3
	4	33.3	338.853	91	29.028	0.25015	0.74985	30.0968	J4	K4
	Ranking: X4<X2<X1<X3									
C9		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	22	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	179.2	4371.22	87	172.1	0.24747	0.75253	173.86	J1	K1
	2	177.4	4395.2	88	173.87	0.26413	0.73587	174.801	J2	K2
	3	161.8	1933.43	39	182.53	0.57457	0.42543	170.618	J3	K3
	4	208.25	8069.25	161	188.56	0.14568	0.85432	191.431	J4	K4
	Ranking: X3<X1<X2<X4									
C10		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	2	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	109.47	22.0999	54	108.41	0.43219	0.56781	108.87	J1	K1
	2	107.1	31.4355	76	107.51	0.29627	0.70373	107.384	J2	K2
	3	110.25	18.3411	45	107.1	0.51572	0.48428	108.722	J3	K3
	4	104.55	23.2403	56	105.42	0.38018	0.61982	105.089	J4	K4
	Ranking: X1>X3>X2>X4									
C11		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	2	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	101.4	8.58541	21	103.06	0.98052	0.01948	101.435	J1	K1
	2	98.362	5.03546	21	99.799	1.13492	-0.1349	98.1681	J2	K2
	3	111.62	13.0321	32	112.02	0.6958	0.3042	111.744	J3	K3
	4	108.98	15.1665	37	107.18	0.60113	0.39887	108.264	J4	K4
	Ranking: X4>X3>X1>X2									
C12		n_0	k	d	h_1	α			INITIAL	ADD.
		20	4	1	3.101	0.05				
	ALT	Xi20	VAR(20)	Ni	Xi(Ni-20)	Wi1	Wi2	Xi	REP's	REP's
	1	103.15	5.48809	53	102.45	0.40904	0.59096	102.739	J1	K1
	2	101.98	4.73639	46	103.53	0.48427	0.51573	102.78	J2	K2
	3	102.67	4.78312	46	102.45	0.43974	0.56026	102.546	J3	K3
	4	101.98	4.57013	44	101.57	0.47179	0.52821	101.763	J4	K4
	Ranking: X2>X1>X3>X4									

As a result, we found that forcing the systems caused fourth alternative's getting closer to its expected first place. When the rankings are considered, it can easily be seen that alternative 4 got almost all of the first places except the fourth main criterion (time in system). This result shows that the rankings occurred by the time that a reserve personnel spends at the rear zone is not affected by the increased arrival rates. In fact, this result is also intuitive. Because, the casualty flow is the same for each alternative system. That is to say, the same casualty arrival rate is inputted for each alternative and the amount of reserve personnel who would be replaced with the casualties is planned according to these rates for all alternatives. Since the casualty occurrences and the reports demanding reserve personnel instead of them take place approximately at the same time for each alternative system, identical casualty flows in different scenarios is not an abnormal functioning. Moreover, we observe that the differences between the values of alternatives for the time in system main criterion are not important. Because, in a ten-day period 1.01 hrs, which is the difference between the values of the worst and the best alternatives for the main criterion 4, is not a significant time period.

Although this is only a simple comment and needs to be explained scientifically, if we suppose that this type of reasoning is true and take into consideration that the superiority of the fourth alternative for other criteria, alternative 4 can be accepted as the best system under scenario 3.

5.2.5. Summary

In Section 5.2, we performed a comparative study to find the best system under a specific scenario, for each performance measure. For this purpose we defined three alternative systems, three different scenarios and four basic performance measures. These alternatives were:

(1) Existing system
(2) Modified version of the existing system
(3) Marginal approach that was mentioned previously in Chapter 3
(4) Modified version of the marginal approach. (The modifications mentioned here have been explained in detail previously in Chapter 3 and they are the same for both existing system and the marginal approach)

Comparisons were made for three different scenarios. These were:

(1) “organized position defensive combat” for which the peacetime plans are prepared.
(2) “attack to organized position” in which the history noted the most casualties had occurred.
(3) “attack to organized position” in which expected casualty numbers are doubled. Third scenario is designed to force the alternative systems more and it can be thought as the warfare in which Nuclear, Biological and Chemical (NBC) weapons are used. Again it is well known in military literature that usage of these weapons causes mass casualties on the battlefield.

The performance measures used in the comparisons were:

(1) Percentages of the personnel existing in brigade via the 100% mobilized cadre.
(2) Total number of extra reserve personnel demanded from APCR.
(3) The number of the reserve personnel who are not supplied on time by AST.
(4) The average amount of time that the reserve personnel spend between the entrance in BAU and arrival in brigade for any combat position.

Additionally we defined three sub criteria for each main criterion, which were the same for four criteria. These sub criteria were O, NCO and E. Since the effects of each criterion were different for each type we used them in comparisons. In other words, the comparisons included twelve criteria.

Dalal&Dudewicz’s procedure was used during the comparisons and for each criterion and scenario we found the best system separately as summarized in Table 5.6. Results showed that an alternative system might be the best with respect to a certain criterion while it was not the best with respect to another criterion. Especially, for the third and fourth performance measures, alternative 4 did not behave as it was expected. Because we knew that alternative 4 was the improved version of the marginal approach, which was explained previously. Moreover, we observed that increased casualty arrival rate caused alternative 4 got its expected first places in the rankings. However, the rankings for the fourth performance measure did not change much when the effect of increased arrival rate on other performance measures is

Table 5.6: Summary table for D&D comparison results for each scenario.

	D E F E N S E												
	CRITERION 1 (percentages via mob.cad.)			CRITERION 2 (demand from APCR)			CRITERION 3 (shortages of AST)			CRITERION 4 (time in system)			TOTAL # OF 1st PLACES
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E	
ALT1	90.72	90.67	95.73	80.31	196.62	306.01	6.87	8.01	0.00	109.46	93.27	102.48	1
ALT2	90.86	90.78	95.75	84.65	198.01	272.37	0.00	0.00	0.00	107.12	92.40	103.01	5
ALT3	95.97	97.70	97.60	48.31	88.74	327.54	5.90	9.53	0.30	111.55	113.57	100.52	5
ALT4	96.90	97.73	97.52	49.19	94.94	329.37	0.00	0.18	2.10	104.90	112.75	96.63	3
	O F F E N S E												
ALT1	88.72	89.68	94.32	173.16	310.94	1469.99	23.01	29.52	19.63	116.50	99.53	109.14	1
ALT2	89.19	90.06	94.35	196.50	319.22	1492.27	3.56	6.64	8.05	112.63	99.81	108.67	3
ALT3	94.46	96.50	96.18	134.06	205.06	1475.50	17.14	27.45	26.89	111.48	118.86	118.86	5
ALT4	94.93	97.08	96.12	146.86	214.42	1577.84	4.85	6.24	49.18	113.24	118.07	118.07	3
	O F F E N S E (Casualties Doubled)												
ALT1	86.16	88.23	92.79	250.05	415.32	2548.39	54.69	72.33	173.86	108.87	101.43	102.73	1
ALT2	86.94	88.44	92.64	253.22	422.63	2586.84	23.04	39.70	174.80	107.38	98.16	102.77	1
ALT3	91.97	95.20	94.68	216.57	310.56	2546.63	50.13	74.95	170.61	108.72	111.74	102.54	3
ALT4	93.02	95.70	94.69	217.93	306.17	2545.96	10.30	30.09	191.43	105.08	108.26	101.76	7

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considered. Moreover, we realized that the differences between the values of alternatives are not so much for some criteria. Since we aimed to find the best system by considering all criteria, we decided to perform some further analyses considering these results, which are explained in the subsequent sections.

According to results obtained up to now, it can be concluded that although the marginal approach has a greater effect with respect to that of the modification, in fact this approach does not so much effect on the better performance of the system as it is expected. Because we were not able to select the best system by using the D&D procedure results. If we remember that marginal approach affect almost all of the systems in Army and it may have critical amount of additional costs, the difficulty in choosing the alternatives 3 or 4 as the best system shows the symptom of an offer, which may be considered as an unfeasible solution for the problems of the Personnel Mobilization and Completion System by the decision makers.

5.3. Solution of the Multiple Objective Problem

In previous sections, we performed alternative system design comparisons for each of the twelve criteria. As a result the summary tables for each scenario in Table 5.6 are obtained. The values belong to the alternative, which is the best for that criterion is pointed by using a different color on the table. In the right most side of the tables how many first places an alternative got totally is identified. According to these results, we know which criteria is the best for any criteria in any scenario. For instance, we can say with a high confidence level that alternative 4 is the best for criteria 1 and for O in scenario 1. Additionally, if we assume that all criteria have the same level of importance, we can determine the best alternative system by looking at the number of first places that an alternative got totally. For instance, in Table 5.6, alternative 4 is the best alternative in scenario 3 with its 7 first places. However, such type of ordering has several problems. Here is the list of these problems:

- There is no alternative that has all first places with respect to all criteria and scenarios. If we consider all scenarios and the total number of first places that an alternative gets, it is hard to present a best alternative system. For instance,

while the alternatives 2 and 3 are the best in scenario 1 with five first places for each, in scenario 3, alternative 4 is clearly the best with seven first places.

- In case we have an alternative, which has the most first places for each scenario, we should develop a selection process that takes into account also the criteria for which that alternative is not the best.
- The differences between the values of alternatives especially between 1 and 2 or 3 and 4 are not so large that this may cause a failure in correct selection if all criteria are considered together. For instance, the difference between the best and the second best alternative for criteria 1 and for O in scenario 1 is only 0.93% while this difference is 6.04% between the best and third.
- Finally, the criteria under consideration may not have the same level of importance with the others. For instance, criteria 1 may be more important than the others while one determines the best system for all criteria together.

All these problems point out that the study under consideration is subject to a multiple objective problem. In other words, we should determine a function in which each criterion has a weight. If we denote v_a is the total value of alternative *a* (*a*=1,2,3,4), w_{ij} is the weight of jth sub criterion of ith criterion and $x_{ij}(a)$ is the performance value of alternative *a* for jth sub criterion of criterion i (i= 1,2,3,4 and j=1,2,3); our value function can be written for alternative *a* as:

$$v_a(x_{11}(a),x_{12}(a),x_{13}(a),.....,x_{43}(a))=w_1(w_{11}x_{11}(a)+w_{12}x_{12}(a)+w_{13}x_{13}(a))+.....+ w_4(w_{41}\,x_{41}(a)+w_{42}\,x_{42}(a)+w_{43}\,x_{43}(a)) \quad (1)$$

The alternative having the largest value with respect to the function above can be selected as the best alternative that we are looking for. However, at this point, we face with some problems. First of these problems is the different ranges of values that the criteria possesses. For a performance measure in which the maximum value is the best, a criterion having a larger weight than that of any other criteria may have least effect inside the value function just because of the smallness of its borders of value range.

For instance, for a maximization problem, say we have two criteria and two alternatives as shown in Table 5.7. Criterion A is two times more important than

criterion B (weight of criteria A is 0.66 and weight of criteria B is 0.33) and they have some ranges of values that any alternative can take values only between the borders of these ranges. If we have two alternatives of which values for each criterion are shown in Table 5.7 and if we consider the total values of each alternative, we realize that, because of the problem mentioned above, we will have to choose the second alternative although it has the smallest value for the criterion A which is in fact more important for the decision maker.

Table 5.7: Example for the value range problem for the criteria.

	CRITERIA A (w=0.66) (range=[1,50])	CRITERIA B (w=0.33) (range=[400,600])	VALUE
ALTERNATIVE 1	50	400	165
ALTERNATIVE 2	1	600	198.66

In order to prevent this problem, we applied normalization to the values of each alternative. In this way we aimed to express the different types of ranges in the interval [0,1]. For any criterion, the best alternative took the value 1, the worst alternative took the value 0 and the others took some value between 0 and 1 in accordance with their closeness to the best or worst values. Since the best value is not always the one having the largest value, we used two formulas to enable the best alternative to take the value 1 during normalization process. For the normalization of the values belong to criteria 1 and 4 in which the best value is the one having the largest value, the formula below is used:

$$\mathrm{Norm}(\mathbf{X}_{ij}(a)) = \frac{Z - \mathrm{Min}(\mathbf{X}_{ij})}{\mathrm{Max}(\mathbf{X}_{ij}) - \mathrm{Min}(\mathbf{X}_{ij})} \qquad i = 1,..,4 \quad j = 1,.,3 \quad a = 1,..,4$$

For example, for criteria 1 and for O in scenario 1, the normalized value of alternative 1 was found as:

$$\mathrm{Norm}(\mathbf{X}_{11}(1)) = \frac{90.72 - 90.72}{96.9 - 90.72} = 0$$

and for alternative 2 the normalized value is 0.02, for alternative 3 it is 0.85 and for alternative 4 it is 1.

For the normalization of the values belong to criteria 2 and 3 in which the best value is the one having the smallest value, the formula below is used:

$$\text{Norm}(\mathbf{X}_{ij}(a)) = \frac{\text{Max}(\mathbf{X}_{ij}) - Z}{\text{Max}(\mathbf{X}_{ij}) - \text{Min}(\mathbf{X}_{ij})} \qquad i = 1,..,4 \quad j = 1,.,3 \quad a = 1,..,4$$

For example, for criterion 2 and for O in scenario 1, the normalized value of alternative 1 was found as:

$$\text{Norm}(\mathbf{X}_{11}(1)) = \frac{84.65 - 80.31}{84.65 - 48.31} = 0.12$$

and for alternative 2 the normalized value is 0, for alternative 3 it is 1 and for alternative 4 it is 0.98.

Summary results of these normalization processes are presented in Table 5.8. As a next step, we found the weights for each criterion. In this step, *Analytic Hierarchy Process* (Saaty,1988) was used to make decisions in situations involving multiple objectives. In order to obtain weights for each objective (criteria for our system), firstly we wrote down an nxn matrix A (known as the pair wise comparison matrix). The entry in row i and column j of A (call it a_{ij}) indicates how much more important objective i is than objective j. "Importance" is to be measured on an integer-valued 1-9 scale, with each number having the interpretation shown in Table 5.9. For all i, it is necessary that $a_{ii}=1$. If for example, $a_{13}=3$, objective 1 is weakly important than objective 3. If $a_{ij}=k$, then for consistency, it is necessary that $a_{ji}=1/k$. Thus, if $a_{13}=3$, then $a_{31}=1/3$ must hold. For example, for our system of which objectives are:

Objective 1: (criterion 1) Percentages via mobilized cadre (C1)

Objective 2: (criterion 2) Total demand from APCR (C2)

Objective 3: (criterion 3) Shortages of AST (C3)

Objective 4: (criterion 4) Time spent at rear zone (C4)

Table 5.8: Summary table for the normalized values.

	D E F E N S E											
	CRITERION 1 (percentages via mob.cad.)			**CRITERION 2** (demand from APCR)			**CRITERION 3** (shortages of AST)			**CRITERION 4** (time in system)		
	O	**NCO**	**E**	**O**	**NCO**	**E**	**O**	**NCO**	**E**	**O**	**NCO**	**E**
ALT1	0.00	0.00	0.00	0.12	0.01	0.41	0.00	0.16	1.00	0.69	0.04	0.92
ALT2	0.02	0.02	0.01	0.00	0.00	1.00	1.00	1.00	1.00	0.33	0.00	1.00
ALT3	0.85	1.00	1.00	1.00	1.00	0.03	0.14	0.00	0.86	1.00	1.00	0.61
ALT4	1.00	1.00	0.96	0.98	0.94	0.00	1.00	0.98	0.00	0.00	0.96	0.00
	O F F E N S E											
ALT1	0.00	0.00	0.00	0.37	0.07	1.00	0.00	0.00	0.72	1.00	0.00	0.05
ALT2	0.08	0.05	0.02	0.00	0.00	0.79	1.00	0.98	1.00	0.23	0.01	0.00
ALT3	0.92	0.92	1.00	1.00	1.00	0.95	0.30	0.09	0.54	0.00	1.00	1.00
ALT4	1.00	1.00	0.97	0.80	0.92	0.00	0.93	1.00	0.00	0.35	0.96	0.92
	O F F E N S E (Casualties Doubled)											
ALT1	0.00	0.00	0.07	0.09	0.06	0.94	0.00	0.06	0.84	1.00	0.24	0.96
ALT2	0.11	0.03	0.00	0.00	0.00	0.00	0.71	0.79	0.80	0.61	0.00	1.00
ALT3	0.85	0.93	1.00	1.00	0.96	0.98	0.10	0.00	1.00	0.96	1.00	0.77
ALT4	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	0.00	0.00	0.74	0.00

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Here is an example pairwise comparison matrix determined by one of the decision makers:

$$\begin{array}{c} \\ C1 \\ C2 \\ C3 \\ C4 \end{array} \begin{array}{c} \begin{array}{cccc} C1 & C2 & C3 & C4 \end{array} \\ \begin{bmatrix} 1 & 1/2 & 1/2 & 3 \\ 2 & 1 & 1/2 & 6 \\ 2 & 1 & 1 & 5 \\ 1/3 & 1/6 & 1/5 & 1 \end{bmatrix} \end{array}$$

Table 5.9: Interpretation of entries in a pair wise comparison matrix

Value of a_{ij}	**Interpretation**
1	objectives i and j are of equal importance
3	objective i is weakly more important than objective j
5	experience and judgment indicate that objective i is strongly more important than objective j
7	objective i is very strongly or demonstrably more important than objective j
9	objective i is absolutely more important than objective j
2,4,6,8	intermediate values-for example, a value of 8 means that objective i is midway between strongly and absolutely more important than objective j

In fact, some of the decision maker's comparisons may be inconsistent. If we illustrate what an inconsistency means, for instance, since $a_{12}=a_{13}=1/2$, both C2 and C3 are two times more important than C1. Consistency of preferences would imply that C2 and C3 should be of equal importance. But, since $a_{13}=1/2$, we can say that comparison matrix of this decision maker has a little bit inconsistency. However, we did not take into account such inconsistencies while constructing the pair wise comparison matrix because we believed that trying to adjust the matrices might canalize the decision makers to some specified values. Therefore, we skip the calculations related with inconsistencies.

To describe how Analytic Hierarchy Process (AHP) determines the w_i's let's suppose the decision maker is perfectly consistent. Then her pair wise comparison matrix should be of the following form:

$$A = \begin{bmatrix} \frac{W_1}{W_1} & \frac{W_1}{W_2} & \cdots & \frac{W_1}{W_n} \\ \frac{W_2}{W_1} & \frac{W_2}{W_2} & \cdots & \frac{W_2}{W_n} \\ \vdots & \vdots & & \vdots \\ \frac{W_n}{W_1} & \frac{W_n}{W_2} & \cdots & \frac{W_n}{W_n} \end{bmatrix} \quad (2)$$

Now suppose that a consistent decision maker has a pair wise comparison matrix A of the form (2). Then to recover the vector $\mathbf{w}=[w_1\ w_2\ \ldots\ w_n]$ from A consider the system of n equations

$$A\mathbf{w}^T=\Delta\mathbf{w}^T \quad (3)$$

where Δ is an unknown n-dimensional column vector. For any number Δ, (3) always has the trivial solution $\mathbf{w}=[0\ 0\ \ldots\ 0]$. It can be shown that if A is the pair wise comparison matrix of a perfectly consistent decision maker and we do not allow $\Delta=0$ then the only nontrivial solution to (3) is $\Delta=n$ and $\mathbf{w}=[w_1\ w_2\ \ldots\ w_n]$. This shows that the weights can be obtained from the only nontrivial solution to (3). Now suppose that the decision maker is perfectly consistent. Let Δ_{max} be the largest number for which (3) has a nontrivial solution (call this solution $\mathbf{w}_{max}$). If the decision maker's comparisons do not deviate very much from perfect consistency, we would expect Δ_{max} to be close to n and $\mathbf{w}_{max}$ to be close to $\mathbf{w}$. Saaty (1988) verified that this intuition is indeed correct and suggested approximating $\mathbf{w}$ by $\mathbf{w}_{max}$.

Here is a simple two-stage method to approximate Δ_{max} and $\mathbf{w}_{max}$:

STEP 1

For each A's columns, do the following. Divide each entry in column i of A by the sum of the entries in column i. This yields a new matrix (call it A_{norm}, for normalized) in which the sum of entries in each column is 1. For our example Step 1 yields

$$A_{norm} = \begin{bmatrix} 0.1876 & 0.1879 & 0.2272 & 0.2000 \\ 0.3752 & 0.3759 & 0.2272 & 0.4000 \\ 0.3752 & 0.3759 & 0.4545 & 0.3333 \\ 0.0625 & 0.0626 & 0.0909 & 0.0666 \end{bmatrix}$$

STEP 2

To find an approximation to $\mathbf{w}_{max}$ (to be used as our estimate of $\mathbf{w}$), proceed as follows. Estimate w_i as the average of entries in row i of A_{norm}. For our example step 2 yields

$$W_1 = \frac{0.1876 + 0.1879 + 0.2272 + 0.2000}{4} = 0.2$$

$W_2 = 0.344$, $W_3 = 0.384$ and $W_4 = 0.07$

We performed all these procedures related with AHP by using the software package Expert Choice (by Expert Choice Inc.) that gives the exact values of Δ_{max} and $\mathbf{w}_{max}$ and a measure of decision maker's consistency. The study of describing weights is conducted also for the sub criteria of each main criterion. Because we believed that although these sub criteria are the same for all main criteria, they might have different levels of importance. While executing AHP for our problem, six officers having different ranks and positions in Army are used as decision makers. After any necessary details were mentioned, they were asked separately to construct the pair wise comparison matrices. In Table 5.10, the weights that each officer identified and the average of these weights that will be used in our study are presented. The pairwise matrices that are formed by those officers are presented in Appendix L.

After having the weights for each criteria, there remained only writing down our value function (1) for each criteria in each scenario by using the values in Table 5.8 and 5.10. If we write down the value functions for the first scenario (Defensive operation):

v_1=0.409*(0.683*0+0.193*0+0.122*0)+0.291*(0.621*0.12+0.289*0.01+0.089*0.41)+0.173*(0.689*0+0.197*0.16+0.113*1)+0.124*(0.139*0.69+0.228*0.04+0.631*0.92)=0.144

similarly v_2=0.292, v_3=0.76 and v_4=0.843.

Table 5.10: Summary table for the weights of decision makers.

	PERSONAL WEIGHTS											
	CRITERION 1 (prc. via mob.cad.)			**CRITERION 2** (dem. from APCR)			**CRITERION 3** (shortages of AST)			**CRITERION 4** (time in system)		
PER1	0.192			0.53			0.235			0.039		
PER2	0.296			0.144			0.16			0.4		
PER3	0.664			0.184			0.11			0.041		
PER4	0.579			0.264			0.093			0.063		
PER5	0.194			0.352			0.331			0.124		
PER6	0.53			0.275			0.112			0.082		
AVG	**0.409166667**			**0.2915**			**0.1735**			**0.124833333**		
	O	**NCO**	**E**	**O**	**NCO**	**E**	**O**	**NCO**	**E**	**O**	**NCO**	**E**
PER1	0.727	0.182	0.091	0.615	0.319	0.066	0.733	0.199	0.068	0.101	0.226	0.674
PER2	0.78	0.149	0.066	0.731	0.188	0.081	0.785	0.149	0.066	0.075	0.333	0.592
PER3	0.749	0.198	0.052	0.756	0.188	0.056	0.719	0.223	0.058	0.06	0.193	0.747
PER4	0.635	0.287	0.078	0.455	0.455	0.091	0.588	0.323	0.089	0.174	0.192	0.634
PER5	0.582	0.109	0.309	0.571	0.286	0.143	0.582	0.109	0.309	0.286	0.143	0.571
PER6	0.625	0.238	0.136	0.6	0.3	0.1	0.727	0.182	0.091	0.143	0.286	0.571
AVG	**0.683**	**0.1938**	**0.122**	**0.6213**	**0.2893**	**0.0895**	**0.689**	**0.1975**	**0.1135**	**0.1398**	**0.2288**	**0.6315**

Since we normalized the real values of alternatives in such a way that the worst alternative took the value 0 and the best one took the value 1, naturally the alternative that has the maximum value for the function within each scenario would be the best one. In other words, for the first scenario our best alternative system is the fourth one. The results for the other two scenarios are written as follows:

If we write down the value functions for the second scenario (Offensive operation): v_1=0.135, v_2=0.224, v_3=0.828, v_4=0.88 and if we write down the value functions for the third scenario (Offensive operation with doubled casualties): v_1=0.167, v_2=0.251, v_3=0.786, v_4=0.868.

Finally all these studies showed us that the alternative 4 is the best in all three scenarios with its highest value for the function (1) then third, second and first alternatives follow.

5.3.1. Summary

In this section we tried to find the best alternative system considering all of the criteria. Since there was no system that is the best for all criteria, we constructed the value function. This function would help us to find only one ranking for each criterion by enabling us to consider the performance value of each alternative and the weight of each criterion simultaneously. In order to find these weights, we applied Analytic Hierarchy Process (AHP) and in order to avoid some miscalculations that can be caused by the different ranges of values that the criteria possess, we normalized the values in Table 5.6 and obtained the Table 5.8.

As a result, we found the fourth alternative system as the best one and third, second and first ones followed it in subsequent order. Another observation was that the first and second alternatives have values that are close to each other for each scenario. This situation is valid for the third and the fourth alternatives. But, we observed a significant difference between the values of these groups. In other words, we showed that the marginal approach has a great effect on the well functioning of the system while revising the systems has a respectively little effect. On the other hand, the difficulty in choosing the best system should not be forgotten. When possible costs of the marginal approach are considered, it does not have so much effect on the performance of the Personnel Mobilization and Completion System as it is expected. Therefore, the decision makers should notice the feasibility of this approach.

5.4. Optimization of the Reserve Personnel Assignments

In Section 5.2, the existing system had been studied and according to the primary analyses, it had been confirmed that under the normal conditions the personnel mobilization and completion system would have faced with serious reserve personnel shortages at the very early stages of the combat. In the following sections 5.3 and 5.4, alternative system designs are compared to find out the system that could best tolerate mainly this problem as well as the others. In this section, it will be

supposed that existing system does not have alternatives and it will be tried to find out the optimal numbers of reserve personnel who will be assigned to the brigade during peacetime to solve this problem. In other words, in case no alternative system is found to be affordable, studies to be conducted in this section will be an alternative for the solution of the problems of existing system.

In a simulation process, if we denote our model as a function, say g, input variables are transformed into the output variables by the effect of function g as shown in Figure 5.3 (E is sampling error caused by statistical variation).

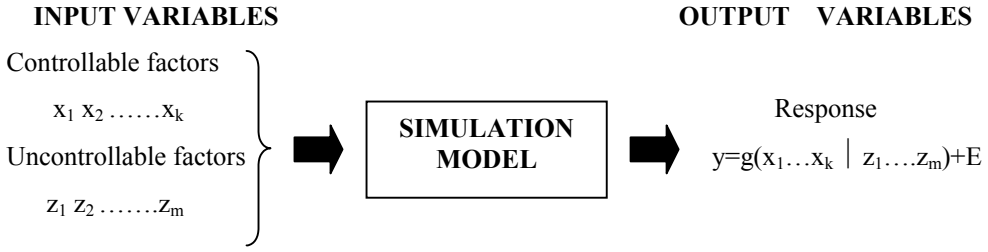


Figure 5.3: Flow of input variables through the simulation model.

If there are k controllable factors in the simulation, the response lies on a surface in k+1 dimensional space. The surface is referred to as *response surface*. In optimization studies, the goal is to find the best values of the controllable variables to produce the optimum response. The controllable variables that are subject to changes in order to find the optimum response are called as factors and the values that these factors get in each iteration of the optimization process are called levels.

After reminding the basic stones of an optimization study, if we focus on the optimization problem of reserve personnel assignments, it is sufficient to concentrate on one factor at a time. In other words, increasing or decreasing the number of reserve personnel assigned to PCC would be enough in seeking the optimum. It had been observed that early shortages in reserve personnel appeared in PCC. This problem causes extra demands from APCR and low percentages via mobilized cadre of brigade. Therefore, the number of reserve personnel that Mobilization Department of the Ministry of National Defense can assign to PCC is supposed to be a controllable variable. It is obvious that the more reserve personnel are assigned to the brigade, the less shortages will happen. But another thing that is also obvious that Mobilization Department of Ministry of Defense does not have this luxury; moreover

the remaining reserve personnel after the ten-day period may cause some problems when the next reserve personnel groups begin to be sent to the completion units. Therefore, the numbers that are planned to be assigned during peacetime must be adjusted so that at the end of the first ten days of the combat, both the shortages of PCC and the numbers of remaining reserve personnel in that unit should be minimum. If we let U be the shortages of PCC and V be the numbers of remaining reserve personnel, our goal is to satisfy equation (4):

$$y = g(x_1 \ldots x_k \mid z_1 \ldots . z_m) + E = \text{Min}(U+V) \qquad (4)$$

In order to achieve optimum one can use the procedure shown below:

PROCEDURE

1. Initialize the variables.

$$x_1 = c_1,\ x_2 = c_2, \ldots\ldots, x_k = c_k$$

$$y = g(x_1 = c_1, \ldots . x_k = c_k \mid z_1 \ldots . z_m) + E$$

For our case the controllable variables (x_i's) and their initial values (c_i's) are:

- x_1 (the number of reserve personnel that Mobilization Department of the Ministry of National Defense can assign to PCC)=130 for O, 270 for NCO and 1420 for E.
- x_2 (number and capacity of transportation vehicles assigned to AST, BAU, PCC and APCR)=7 vehicles with capacity of 10 personnel for AST, 3 buses with capacity of 60 personnel for BAU, one train with an unlimited capacity for PCC and 4 buses with capacity of 60 personnel for APCR.
- x_3 (mobilized cadre of the brigade)=7000 personnel totally (316 O, 653 NCO and 6031 E).
- x_4 (distances between brigade, AST, BAU, APCR, PCC): brigade-AST=10 km, brigade-BAU=90 km, APCR-AST=250 km, BAU-AST=80 km, BAU-PCC=100 km, AST-PCC=180 km.

and the uncontrollable variables (z_i's) are:

- z_1 (number of casualties).
- z_2 (initial number of personnel just at the decision of mobilization).
- z_3 (the time needed for reporting and demand determination activities).

- z_4 (arrival time of reserve personnel to completion units).
- z_5 (the equipage time needed for the reserve personnel to come from their home).
- z_6 (amount of demand from completion units and the rate of O, NCO and E numbers in these demands).

2. Optimize over x_1 (hold all other controllable variables constant).

$$h(x_1)= g(x_1=c_1 \mid x_2=c_2,.... x_k=c_k , z_1....z_m)+E$$

3. Evaluate at $x_1=c_1+\Delta$ and $x_1=c_1-\Delta$. If the value of the function is improved, repeat the procedure until failure.

4. If the stopping criterion is not satisfied, go to step 2, else stop. For our case the stopping rule is the point where the direction of the steepest descent points back toward previous experimental point.

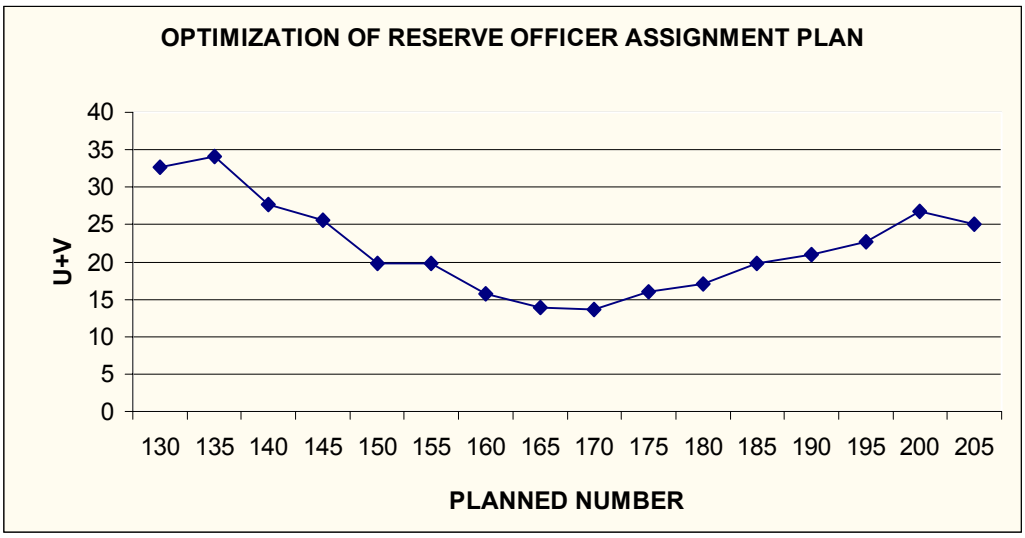
We performed this procedure for each types of reserve personnel (O, NCO, E) separately and presented the results that belong to 35 replications of the model in the following sections.

5.4.1. Optimization of Officer Assignment Plans

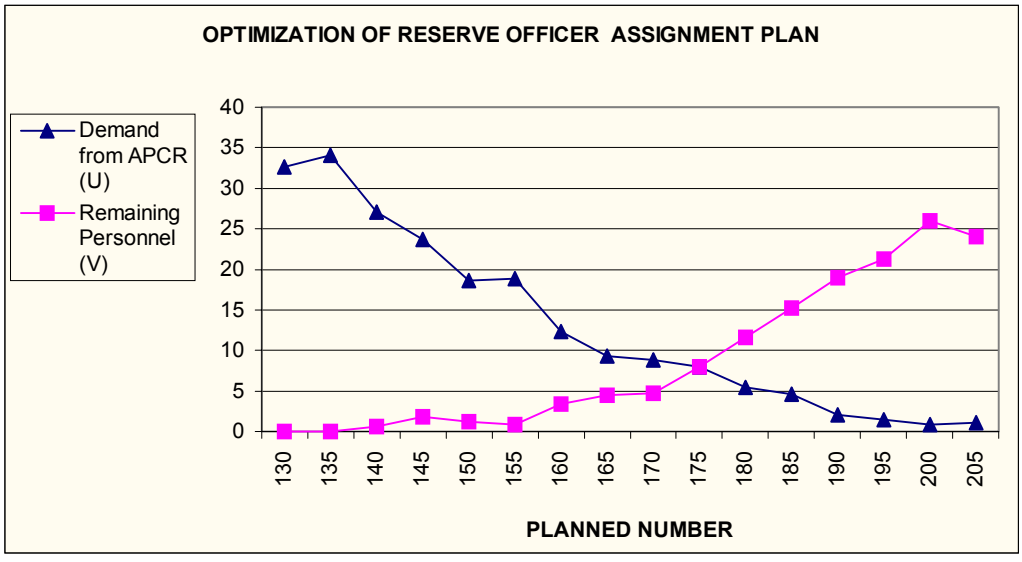
While performing this optimization study for O, to save computer time, we used the past experiences for determining the initial level of the number of reserve O to be assigned. The numbers that PCC had to demand from APCR are added to the numbers that assigned to PCC for normal conditions, and the initial level is determined as 130 officers. The value of Δ was determined as 5 officers and related statistics are presented in Appendix M1. To illustrate the improvement we also derived the Figures 5.4(a) and 5.4(b).

As seen on Figure 5.4(a), as the numbers of O assigned to PCC is increased, the shortages of PCC decreases and the number of reserve O remaining in PCC after the ten-day period begins to increase. If we look into Figure 5.4(b) in which U+V is presented to see where this function is minimum, it can be concluded that the optimum number is 170 O. This result does not conflict with the one that we can observe from Figure 5.4(a). This number is 2.36 times bigger than the numbers that

could be assigned and 2.02 times bigger than the numbers that were planned to be assigned to PCC for normal conditions. In other words, Mobilization Department of the Ministry of National Defense should plan a number of officers 2.02 times bigger than that of the ones which are planned based on the coarse casualty amount of the brigade per each reserve personnel group to tolerate the improperness of the existing system.



a) Illustration of improvements in U and V separately for O.

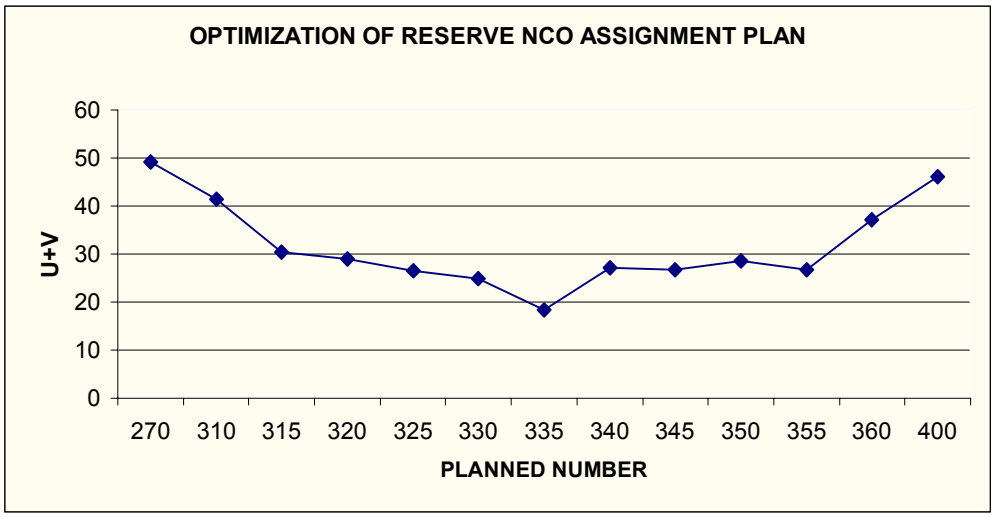


b) Illustration of improvement in U+V.

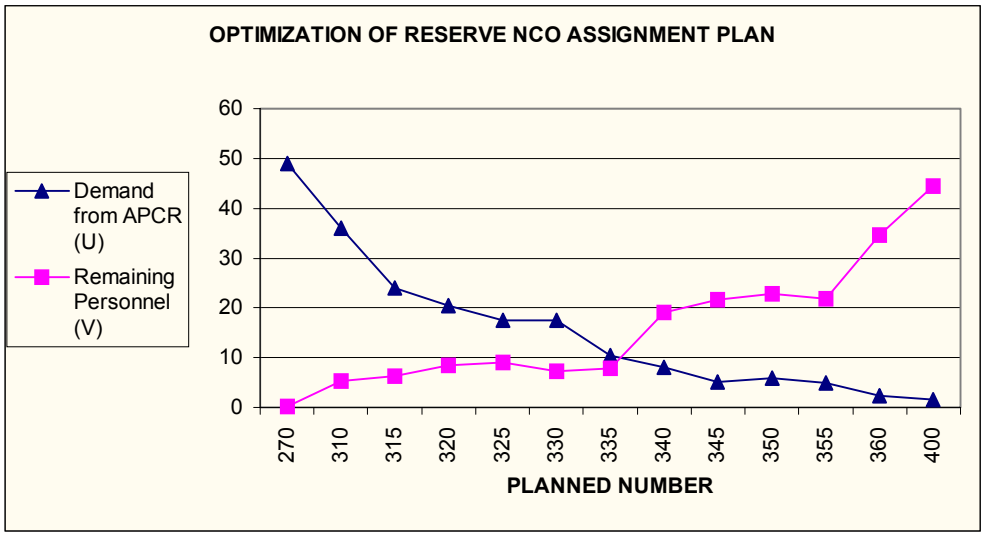
Figure 5.4: Illustration of improvements.

5.4.2. Optimization of NCO Assignment Plans

For NCO, we determined the initial level as 270 noncommissioned officers by using the method described in Section 5.5.1. The value of Δ was determined as 5 NCO and the summary statistics were presented in Appendix M2. To illustrate the improvement we also derived the Figures 5.5(a) and 5.5(b). As seen on Figure 5.5(a), as the numbers of NCO assigned to PCC is increased, the shortages of PCC decreases and the number of reserve NCO remaining in PCC after the ten-day period begins to increase. Figure 5.5(b) also shows the point where U+V is minimum.



a) Illustration of improvements in U and V separately for NCO.



b) Illustration of improvement in U+V.

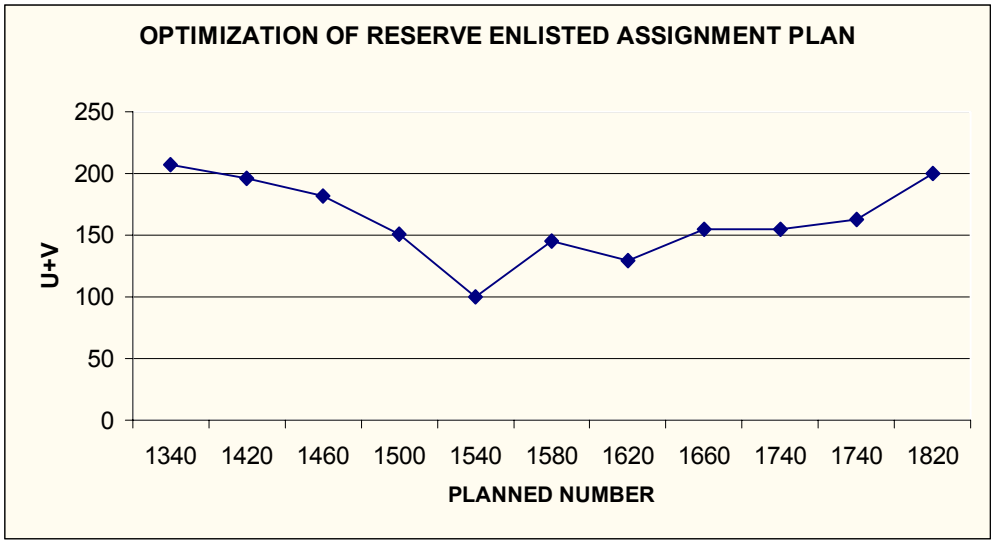
Figure 5.5: Illustration of improvements.

The optimum number observed in these figures is 4.78 times bigger than the numbers that could be assigned and 3.16 times bigger than the numbers that were planned to be assigned to PCC for normal conditions. That is to say, Mobilization Department of the Ministry of National Defense should plan a number of noncommissioned officers 3.16 times bigger than that of the ones which are planned based on the coarse casualty amount of the brigade per each reserve personnel group to tolerate the improperness of the existing system.

5.4.3. Optimization of Enlisted Assignment Plans

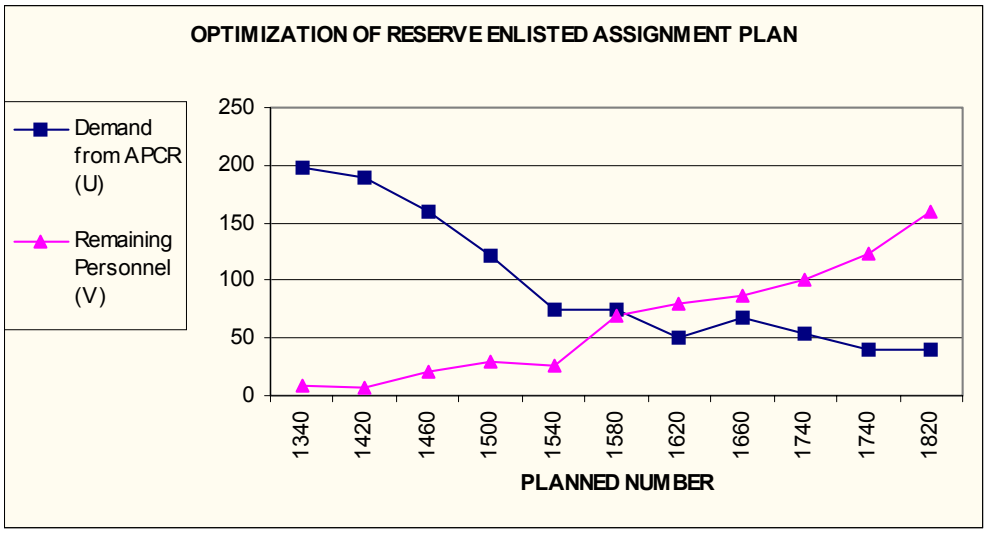
In the optimization study of enlisted assignment plans, we determined the initial level as 1420 enlisted again by using the method explained in Section 5.4.1. The value of Δ was determined as 20 enlisted and the summary statistics were presented in Appendix M3. The improvement caused by the increase of this initial number is presented in the Figures 5.6(a) and 5.6(b).

As seen on Figure 5.6(a), the relation between the numbers of enlisted assigned to PCC, the shortages of PCC and the number of reserve enlisted remaining in PCC after the ten-day period is the same with that of O and NCO.



b) Illustration of improvements in U and V separately for E.

Figure 5.6: Illustration of improvements.



b) Illustration of improvement in U+V.

Figure 5.6: Illustration of improvements.(cont'd)

The illustrations in these figures points out the minimum point as 1540 E that makes us conclude that Mobilization Department of the Ministry of National Defense should plan a number of enlisted 1.23 times bigger than that of the ones which are planned based on the coarse casualty amount of the brigade per each reserve personnel group to tolerate the improperness of the existing system.

5.4.4. Summary

In this section, the alternatives of the existing system were supposed to be unaffordable and the number of reserve personnel that Mobilization Department of the Ministry of National Defense can plan for the PCC was supposed to be unlimited. Under these circumstances, we searched a solution, which can tolerate the improper functions of the existing system by using this ability of the department. It was obvious that the more reserve personnel were planned, the less shortages would occur in PCC and much better the system functioned. However, the numbers must have been properly adjusted so that at the end of the ten-day period there should be no remaining personnel in PCC. Because these remaining personnel might cause some problems for the completion units when the next groups of reserve personnel began to arrive. Briefly, the main problem was to find the numbers, which were

assigned to PCC satisfying minimum number of shortages and minimum number of remaining personnel.

We used single-factor method among the adaptive search techniques to find the optimum value satisfying the function (4). We also carried out some graphs to illustrate these optimum points. The results showed us that this optimum point was 170 personnel for O, 335 personnel for NCO and 1540 personnel for E. These numbers are compared with the numbers planned actually and found that Mobilization Department of the Ministry of National Defense should have planned 202% for O, 316% for NCO and 123% for E of the actual numbers. In other words, if the alternatives of the existing system are supposed to be unaffordable and the number of reserve personnel that Mobilization Department of the Ministry of National Defense can plan for the PCC was supposed to be unlimited, these increased rates can be solution to the problems identified in Section 5.1.

When the additional costs caused by the improvement of the existing system are considered, such a solution is really an efficient one with respect to generating alternative systems. Because planning the reserve personnel with increased rates during peacetime needs only executing additional assignments on the records of reserve personnel, who are already exists in the sources of Mobilization Department of the Ministry of National Defense. That is to say, precautions that can be resulted from this optimization study have no additional cost.

CHAPTER 6

CONCLUSION

This study is conducted to model and analyze the Personnel Mobilization and Completion System in Turkish Army. Turkish Armed Forces maintains the number of personnel in their units at minimum level during peacetime because of some political and economical reasons, but it sustains some activities under the name of Personnel Mobilization and Completion System to enable these units to reach their personnel numbers sufficient to combat in war situation. Today, for only a small part of this system Turkish Armed Forces can perform field exercises to see its behavior. There is no study trying to analyze all aspects of this system, which has a very important role in directly affecting the combat power of the Army. It is planned to analyze and, if there is any, to offer some solutions for the problems by using the simulation method. We believe that by using the simulation model of this system a scientific support mechanism for the commanders during the decision process can be provided. Moreover, by using this model, some improper functions can be detected earlier just at peacetime and some probable solutions can be evaluated with the help of studies including alternative system comparisons and optimization of some decision variables.

Furthermore, this study presents an example since it is the first time that Personnel Mobilization and Completion System is under a scientific investigation and simulation method is used as a tool. We believe that usage of simulation in military studies is necessary and powerful. Because, many of these studies and projects have no chance to be analyzed because of the impossibility of the generation of war situations that are needed for meaningful results. Too many military systems

have this property just as our system and simulation can provide an environment for them to be studied on.

Firstly, we developed a sufficiently valid simulation model for the system by using Arena 3.0 Simulation Software Package. The model represents the activities at brigade level because the other levels can be thought as extraordinary positions and the system can be observed with its all components at brigade level. Moreover, this is the most general situation that one may come across in Turkish Army. By using this simulation model, as a first step we conduct a primary analysis of the existing system. In this way, we aim to collect some statistics that may be helpful for the commanders who are responsible for this system. During this stage, according to several performance measures, we observe that the system will deviate from the expected responses that it is planned even under the normal conditions.

As a next step, we perform some further analysis that mostly based on visual observations about the performance measures "existing numbers in brigade" and "total demand from APCR". Because we evaluate them as the most critical measures that can mirror the problems in the system.

By analyzing the O, NCO and E numbers present at the first ten days of the combat, we find that the system needs some amount of time which we name it "warm-up period" to increase the numbers of personnel to the level required by the 100% mobilized cadre. After this warm-up period can the Personnel Mobilization and Completion System go on its mission of replacing the casualties with reserve personnel. The results show that this period is approximately 65 hrs. for O, 70 hrs for NCO and 55 hours for E. Therefore, we conclude that the time of mobilization declaration should be adjusted in accordance with these results, in other words, if it is possible, mobilization should be declared at least 70 hrs. before the combat begins for the brigade.

By analyzing the total demands from APCR occurred during the first ten-day period, we find that there is a serious amount of demand from APCR that is unwanted under normal circumstances. The results of these further analyses show that APCR must be ready for unexpected O demands 58.8 hrs, NCO demands 56.4 hrs and E demands 194.4 hrs after the combat begins for the brigade. These early and critical amounts of demands force us to focus on this performance measure in the following studies.

Next, we aim to perform a comparison study to find some other alternatives that can tolerate the bottlenecks (problem areas) of the existing system. For this purpose we define three alternative systems, three different scenarios and four basic performance measures. In fact, these comparisons are executed among four systems including the existing system (as discussed in Chapter 5.2. pp. 51).

Comparisons are made for three different scenarios and for four performance measures to observe their behavior for different operation types. That is to say, they are subject to different arrival rates of casualties (as discussed in Chapter 5.2. pp. 51-52). Additionally, we define three sub criteria for each main criterion, which are the same for four criteria. These sub criteria are O, NCO and E. Since the effects of each criterion are different for each type, we use them in comparisons. In other words, the comparisons include twelve criteria.

Dalal&Dudewicz's procedure is used during the comparisons. For each criterion and scenario we find the best system separately. Results show that an alternative system might be the best with respect to a criterion while it was not the best with respect to another one. Since we aim to find the best system by considering all criteria, we decide to perform some further analyses. Since we believe that each criterion has not the same importance in the business of ordering the alternative systems, we start these further analyses by constructing the value function below:

$$v_a(x_{11}(a),x_{12}(a),x_{13}(a),.....,x_{43}(a))=w_1(w_{11}x_{11}(a)+w_{12}x_{12}(a)+w_{13}x_{13}(a))+.....+ w_4(w_{41}\,x_{41}(a)+w_{42}\,x_{42}(a)+w_{43}\,x_{43}(a))$$

where v_a is the total value of alternative a (a=1,2,3,4), w_{ij} is the weight of jth sub criterion of ith criterion and x_{ij} is the performance value of alternative a for jth sub criterion of criterion i (i= 1,2,3,4 and j=1,2,3). This value function is used to value each alternative system and mainly depends on the assignment of weights for each criterion. In order to find these weights, we apply Analytic Hierarchy Process (AHP). Although there some other methods used in multicriteria decision-making, we used AHP because of its simplicity in both applications and interactions with the decision makers. To avoid some miscalculations that can be caused by the different ranges of values that the criteria possess, we normalize the real values that the alternative systems get for each criterion.

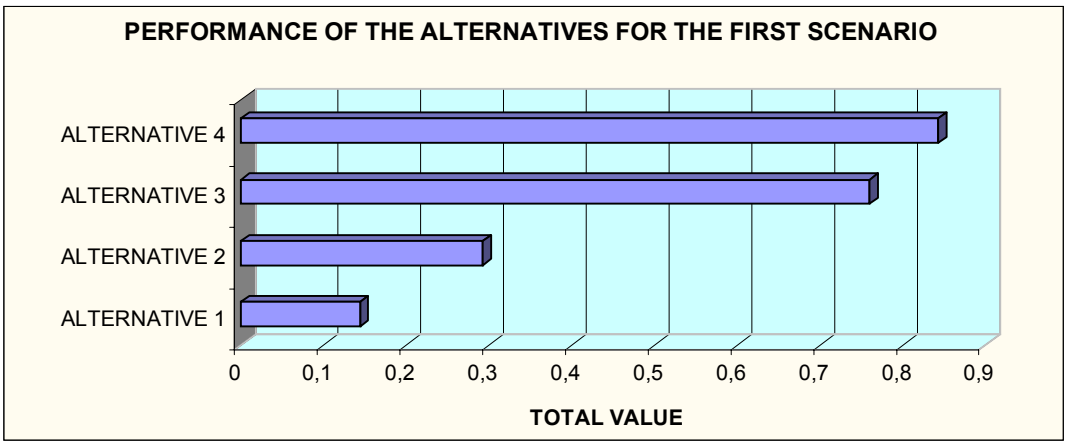


Figure 6.1: Total values of each alternative in the first scenario.

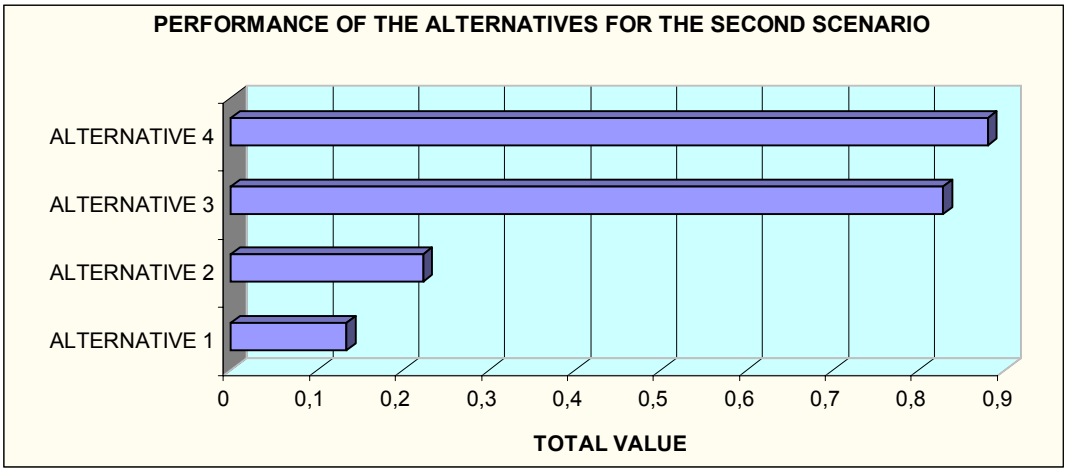


Figure 6.2: Total values of each alternative in the second scenario.

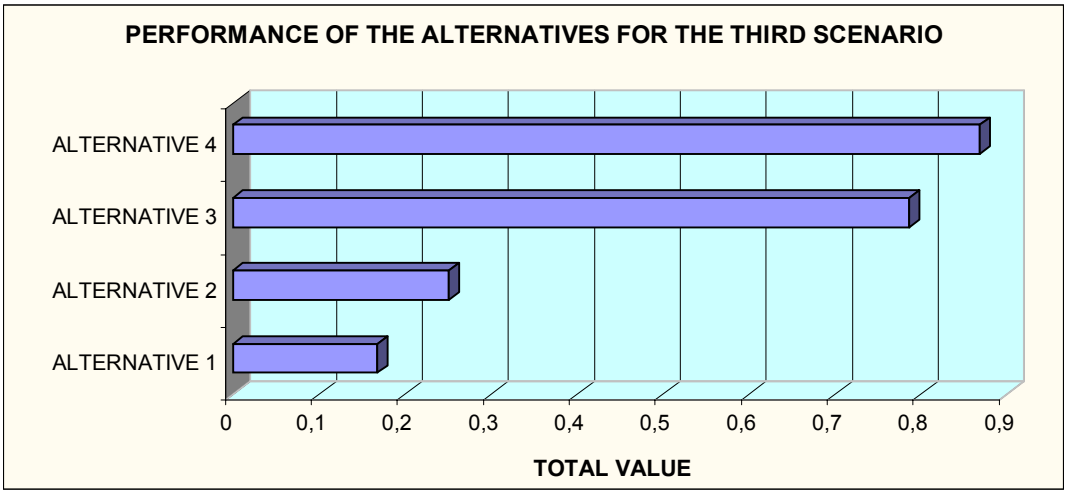


Figure 6.3: Total values of each alternative in the third scenario.

Finally we put the necessary values inside the value function for each criterion and find the fourth alternative system as the best one and third, second and first ones follow it in subsequent order for all of the scenarios. These results can be observed on the Figures 6.1, 6.2 and 6.3. If one look at the differences between the values that each alternative system get for each scenario, one may observe that the marginal approach has a great effect on the well functioning of the system while revising the systems has a respectively little effect.

As a final study, we consider the case that the alternatives of the existing system are unaffordable and the number of reserve personnel that Mobilization Department of the Ministry of National Defense can plan for the PCC is unlimited. Under these circumstances, we search a solution, which can tolerate the improper functions of the existing system by using this ability of the department. It is obvious that the more reserve personnel are planned, the less shortages will occur in PCC and much better the system functions. However, the numbers must be properly adjusted so that at the end of the ten-day period there should be no remaining personnel in PCC. Because these remaining personnel may cause some problems for the completion units when the next groups of reserve personnel begins to arrive. Briefly, here the main problem is to find the numbers, which are assigned to PCC and which are satisfying minimum number of shortages and minimum number of remaining personnel.

We use single-factor method, which is among the adaptive search techniques to find the optimum value satisfying the function below:

$$y = g(x_1 \ldots x_k \mid z_1 \ldots . z_m) + E = \text{Min}(U+V)$$

where y is response, function g is the simulation model of our system, x_i's are controllable factors, z_i's are uncontrollable factors, E is sampling error caused by statistical variation, U is the shortages of PCC and V is the numbers of remaining reserve personnel at the end of the ten-day period.

The results show that this optimum point is 170 personnel for O, 335 personnel for NCO and 1540 personnel for E in a brigade having a mobilized cadre of 7000 personnel totally. These issues are compared with the numbers planned actually and

found that Mobilization Department of the Ministry of National Defense should plan 202% for O, 316% for NCO and 123% for E of the actual numbers.

While presenting the results of studies, we tried to present almost all of them in units of ratios so that these results can be used not only for brigades but also for all units of Army. The studies performed in this thesis are only basic and critical ones that can be performed by using the simulation model developed for the Personnel Mobilization and Completion System. With only small adjustments, this model can be used in some further analyses such as comparisons of other alternative systems, experimentation of some proposals, observations of the behavior of the system for the units different than brigade, etc. Furthermore, if this model is used for each unit of the Army separately, Mobilization Department of the Ministry of National Defense can get very helpful information about the level of readiness of the units. In this way, critical units can be determined and on time precautions can be made for these units just at peacetime.

Another extension of the model and this study may be injecting the military arms and proficiency of the reserve personnel into the studies performed. In this thesis, for simplicity, we assumed that the reserve personnel in completion units fit the demanded personnel by the means of military arms and they differ only in types (O, NCO, E). We made this assumption by thinking that in case there are unmatched personnel according to demand, these reserve personnel can be oriented for the demanded position by additional precautions. However, for the best performance of the Personnel Mobilization and Completion System, reserve personnel and their position in brigade should fit each other.

In this thesis, while comparing some alternative systems with the existing one, we presented the effect of marginal approach (as discussed in Chapter 5.2. pp. 51) on the Personnel Mobilization and Completion System. Since this approach affects almost all of the systems in Army especially the ones about logistics, other systems, which may be affected by this marginal approach, can be investigated by using simulation method. After modeling these systems, effects of this approach can be analyzed and correlations among these systems can be detected. In this way, the real effect of the marginal approach can be observed.

For all further research directions mentioned above, cost analyses can be performed again by using their simulation models.

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APPENDICES

APPENDIX A: Model file of the code written by using Arena 3.0

APPENDIX B: Experimental file of the code written by using Arena 3.0

APPENDIX C: A representative output file for the code written for the existing system

APPENDIX D1: The data and the triangular distribution parameters belong to the number of reserve personnel, who are planned to join brigade and AST and who are given MDO

APPENDIX D2: The data and the triangular distribution parameters belong to the number of reserve personnel, who are planned to join PCC and who are given MDO

APPENDIX D3: The data and the triangular distribution parameters belong to the number of reserve personnel, who are given MDO and join their units on time during the field exercises

APPENDIX E: Summary statistics for the existing system (20 replications)

APPENDIX F1: Statistics of initial replications for alternative 1 (existing system) in scenario 1

APPENDIX F2: Statistics of initial replications for alternative 2 in scenario 1

APPENDIX F3: Statistics of initial replications for alternative 3 in scenario 1

APPENDIX F4: Statistics of initial replications for alternative 4 in scenario 1

APPENDIX G1: Statistics of additional replications for alternative 1 in scenario 1

APPENDIX G2: Statistics of additional replications for alternative 2 in scenario 1

APPENDIX G3: Statistics of additional replications for alternative 3 in scenario 1

APPENDIX G4: Statistics of additional replications for alternative 4 in scenario 1

APPENDIX H1: Statistics of initial replications for alternative 1 (existing system) in scenario 2

APPENDIX A: Model file of the code written by using Arena 3.0

REPORT ARRIVALS SUBMODEL

```
8$      CREATE,     1,12:24,10;
9$      ASSIGN:     ReportNo=ReportNo+1;
79$     BRANCH,     1:
                    If,ReportNo.EQ.1,82$,Yes:
                    If,1<ReportNo<5,80$,Yes:
                    If,ReportNo>4,81$,Yes;
82$     ASSIGN:     DemOffNxt=0:
                    DemNCONxt=0:
                    DemEnMenNXT=0;
10$     BRANCH,     1:
                    If,ReportNo.EQ.3,20$,Yes:
                    Else,21$,Yes;
20$     ASSIGN:     ShortOffAST=ShortOffAST+DemOffAST:
                    DemOffAST=OffCasu+DemOffAST+316-InOffNum-OffOfBrigade;
22$     BRANCH,     2:
                    If,OffNumInAST<DemOffAST+DemOffNxt,84$,Yes:
                    If,OffNumInAST>=DemOffAST+DemOffNxt,25$,Yes:
                    Always,31$,Yes;
84$     BRANCH,     1:
                    If,ReportNo>1,24$,Yes:
                    Else,25$,Yes;
24$     ASSIGN:     OffCasu=0:
                    UnSatDemOffAST=0:
                    DemOffPCC=DemOffAST-OffNumInAST+DemOffNxt;
173$    BRANCH,     1:
                    If,DemOffPCC-OffNumInPCC>0,11$,Yes:
                    Else,83$,Yes;
11$     ASSIGN:     DemOffAPCR=DemOffPCC-OffNumInPCC:
                    TotDemOffAPCR=TotDemOffAPCR+DemOffAPCR;
174$    ASSIGN:     DemOffPCC=OffNumInPCC;
83$     BRANCH,     1:
                    If,ReportNo.eq.1,199$,Yes:
                    If,ReportNo>1,191$,Yes;
199$    ASSIGN:     DemOffAPCR=0;
191$    DELAY:      unif(0.4,0.6);
185$    SIGNAL:     4,DemOffPCC;
188$    SIGNAL:     7,DemOffAPCR;
S1      SIGNAL:     1,DemOffAST;
184$    DISPOSE;

25$     ASSIGN:     OffCasu=0:
                    UnSatDemOffAST=0:
                    DemOffPCC=0;
197$    ASSIGN:     DemOffAPCR=0:NEXT(83$);

31$     ASSIGN:     ShortNCOAST=ShortNCOAST+DemNCOAST:
                    DemNCOAST=NCOCasu+DemNCOAST+653-InNCONum-NCOOfBrigade;
23$     BRANCH,     2:
                    If,NCONumInAST<DemNCOAST+DemNCONxt,85$,Yes:
                    If,NCONumInAST>=DemNCOAST+DemNCONxt,27$,Yes:
                    Always,32$,Yes;
85$     BRANCH,     1:
                    If,ReportNo>1,26$,Yes:
                    Else,27$,Yes;
26$     ASSIGN:     NCOCasu=0:
```

```
                UnSatDemNCOAST=0:
                DemNCOPCC=DemNCOAST-NCONumInAST+DemNCONxt;
177$    BRANCH,     1:
                If,DemNCOPCC-NCONumInPCC>0,175$,Yes:
                Else,176$,Yes;
175$    ASSIGN:     DemNCOAPCR=DemNCOPCC-NCONumInPCC:
                TotDemNCOAPCR=TotDemNCOAPCR+DemNCOAPCR;
178$    ASSIGN:     DemNCOPCC=NCONumInPCC;
176$    BRANCH,     1:
                If,ReportNo.eq.1,198$,Yes:
                If,ReportNo>1,192$,Yes;
198$    ASSIGN:     DemNCOAPCR=0;
192$    DELAY:      unif(0.4,0.6);
186$    SIGNAL:     5,DemNCOPCC;
189$    SIGNAL:     8,DemNCOAPCR;
SIGN2   SIGNAL:     2,DemNCOAST;
193$    DISPOSE;

27$     ASSIGN:     NCOCasu=0:
                UnSatDemNCOAST=0:
                DemNCOPCC=0;
196$    ASSIGN:     DemNCOAPCR=0:NEXT(176$);

32$     ASSIGN:     ShortEnMenAST=ShortEnMenAST+DemEnMenAST:
                DemEnMenAST=EnMenCasu+DemEnMenAST+6031+316-InEnMenNum-
                EnMenOfBrigade;
28$     BRANCH,     1:
                If,EnMenNumInAST<DemEnMenAST+DemEnMenNxt,86$,Yes:
                If,EnMenNumInAST>=DemEnMenAST+DemEnMenNxt,30$,Yes;
86$     BRANCH,     1:
                If,ReportNo>1,29$,Yes:
                Else,30$,Yes;
29$     ASSIGN:     EnMencasu=0:
                UnSatDemEnMenAST=0:
                DemEnMenPCC=DemEnMenAST-EnMenNumInAST+DemEnMenNxt;
182$    BRANCH,     1:
                If,DemEnMenPCC-EnMenNumInPCC>0,180$,Yes:
                Else,181$,Yes;
180$    ASSIGN:     DemEnMenAPCR=DemEnMenPCC-EnMenNumInPCC:
                TotDemEnMenAPCR=TotDemEnMenAPCR+DemEnMenAPCR;
183$    ASSIGN:     DemEnMenPCC=EnMenNumInPCC;
181$    BRANCH,     1:
                If,ReportNo.eq.1,179$,Yes:
                If,ReportNo>1,D1,Yes;
179$    ASSIGN:     DemEnMenAPCR=0;
D1      DELAY:      unif(0.4,0.6);
187$    SIGNAL:     6,DemEnMenPCC;
190$    SIGNAL:     9,DemEnMenAPCR;
SIGN3   SIGNAL:     3,DemEnMenAST;
194$    DISPOSE;

30$     ASSIGN:     EnMencasu=0:
                UnSatDemEnMenAST=0:
                DemEnMenPCC=0;
195$    ASSIGN:     DemEnMenAPCR=0:NEXT(181$);

21$     ASSIGN:     ShortOffAST=ShortOffAST+DemOffAST:
                DemOffAST=OffCasu+DemOffAST;
74$     BRANCH,     2:
                If,OffNumInAST<DemOffAST+DemOffNxt,84$,Yes:
```

```
                If,OffNumInAST>=DemOffAST+DemOffNxt,25$,Yes:
                Always,77$,Yes;
77$     ASSIGN:     ShortNCOAST=ShortNCOAST+DemNCOAST:
                DemNCOAST=NCOCasu+DemNCOAST;
75$     BRANCH,     2:
                If,NCONumInAST<DemNCOAST+DemNCONxt,85$,Yes:
                If,NCONumInAST>=DemNCOAST+DemNCONxt,27$,Yes:
                Always,78$,Yes;
78$     ASSIGN:     ShortEnMenAST=ShortEnMenAST+DemEnMenAST:
                DemEnMenAST=EnMenCasu+DemEnMenAST;
76$     BRANCH,     1:
                If,EnMenNumInAST<DemEnMenAST+DemEnMenNxt,86$,Yes:
                If,EnMenNumInAST>=DemEnMenAST+DemEnMenNxt,30$,Yes;
80$     ASSIGN:
DemOffNxt=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*0.027*0.058):

DemNCONxt=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*0.027*0.073
):

DemEnMenNxt=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*0.027*0.8
69):NEXT(10$);

81$     ASSIGN:
DemOffNxt=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*0.025*0.058):

DemNCONxt=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*0.025*0.073
):

DemEnMenNXT=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*0.025*0.
869):NEXT(10$);
```

AST SUBMODEL

```
ST1     STATION,    AST;
142$    BRANCH,     1:
                If,TrID.eq.train,144$,Yes:
                If,TrID.eq.bus,146$,Yes:
                If,TrID.eq.truck,148$,Yes;
144$    FREE;
143$    SPLIT:      M;
254$    DUPLICATE:  1,256$;
150$    BRANCH,     1:
                If,PerRank.EQ.1,149$,Yes:
                If,PerRank.EQ.2,151$,Yes:
                If,PerRank.EQ.3,152$,Yes;
149$    ASSIGN:     OffNumInPCC=OffNumInPCC-1:
                M=AST:
                OffNumInAST=OffNumInAST+1:MARK(timein);
170$    BRANCH,     2:
                If,tnow<12+24*ReportNo,252$,Yes:
                Always,Q4,Yes;
252$    DELAY:      0.51:NEXT(S1);

Q4      QUEUE,      QueOffAST;
W1      WAIT:       1,DemOffAST;
35$     ASSIGN:     DemOffAST=DemOffAST-1;
160$    ASSIGN:     UnSatDemOffAST=DemOffAST:NEXT(Q1);

Q1      QUEUE,      QueBrg;
40$     GROUP:      10,Last;
```

```
41$         QUEUE,        VehicleQ;
38$         REQUEST,      1:VEHICLE(RAN,NUM),,AST;
135$        ASSIGN:       TrID=VEHICLE;
238$        TALLY:        TimeAST,int(timein),1;
39$         TRANSPORT:    VEHICLE(NUM),Brigade;

151$        ASSIGN:       NCONumInPCC=NCONumInPCC-1:
                          M=AST:
                          NCONumInAST=NCONumInAST+1:MARK(timein);
171$        BRANCH,       2:
                          If,tnow<12+24*ReportNo,247$,Yes:
                          Always,Q2,Yes;
247$        DELAY:        0.5:NEXT(SIGN2);

Q2          QUEUE,        QueNCOAST;
33$         WAIT:         2,DemNCOAST;
36$         ASSIGN:       DemNCOAST=DemNCOAST-1;
161$        ASSIGN:       UnSatDemNCOAST=DemNCOAST:NEXT(q1);

152$        ASSIGN:       EnMenNumInPCC=EnMenNumInPCC-1:
                          M=AST:
                          EnMenNumInAST=EnMenNumInAST+1:MARK(timein);
172$        BRANCH,       2:
                          If,tnow<12+24*ReportNo,251$,Yes:
                          Always,Q3,Yes;
251$        DELAY:        0.52:NEXT(SIGN3);

Q3          QUEUE,        QueEnMenAST;
34$         WAIT:         3,DemEnMenAST;
37$         ASSIGN:       DemEnMenAST=DemEnMenAST-1;
162$        ASSIGN:       UnSatDemEnMenAST=DemEnMenAST:NEXT(Q1);

256$        ASSIGN:       M=AST;
255$        ALLOCATE,     1:Train;
257$        MOVE:         Train,PCC;
259$        FREE;
258$        DISPOSE;

146$        FREE;
145$        SPLIT:        M;
154$        BRANCH,       1:
                          If,PerRank.EQ.1,153$,Yes:
                          If,PerRank.EQ.2,155$,Yes:
                          If,PerRank.EQ.3,156$,Yes;
153$        ASSIGN:       OffNumInBAU=OffNumInBAU-1:
                          M=AST:
                          OffNumInAST=OffNumInAST+1:MARK(timein):NEXT(170$);

155$        ASSIGN:       NCONumInBAU=NCONumInBAU-1:
                          M=AST:
                          NCONumInAST=NCONumInAST+1:MARK(timein):NEXT(171$);

156$        ASSIGN:       EnMenNumInBAU=EnMenNumInBAU-1:
                          M=AST:
                          EnMenNumInAST=EnMenNumInAST+1:MARK(timein):NEXT(172$);

148$        FREE;
147$        SPLIT:        M;
231$        DUPLICATE:    1,233$;
CHECK6      BRANCH,       1:
```

```
                If,PerRank.EQ.1,157$,Yes:
                If,PerRank.EQ.2,158$,Yes:
                If,PerRank.EQ.3,159$,Yes;
157$    ASSIGN:     picture=OFFICER:
                M=AST:
                OffNumInAST=OffNumInAST+1:MARK(timein):NEXT(170$);

158$    ASSIGN:     picture=NCO1:
                M=AST:
                NCONumInAST=NCONumInAST+1:MARK(timein):NEXT(171$);

159$    ASSIGN:     picture=ENMEN1:
                M=AST:
                EnMenNumInAST=EnMenNumInAST+1:MARK(timein):NEXT(172$);

233$    ASSIGN:     M=AST;
232$    ALLOCATE,   1:Truck(CYC,IND);
234$    MOVE:       Truck(IND),APCR;
253$    FREE;
235$    DISPOSE;
```

PCC SUBMODEL

```
S3      STATION,    PCC;
73$     FREE;
42$     SPLIT:      M;
44$     BRANCH,     1:
                If,PerRank.EQ.1,43$,Yes:
                If,PerRank.EQ.2,45$,Yes:
                If,PerRank.EQ.3,46$,Yes;
43$     ASSIGN:     OffNumInBAU=OffNumInBAU-1:
                M=PCC:
                OffNumInPCC=OffNumInPCC+1:MARK(timin):NEXT(QU4);

QU4     QUEUE,      QueOffPCC;
W4      WAIT:       4,DemOffPCC;
51$     QUEUE,      QueB;
52$     GROUP:      DemOffPCC+DemNCOPCC+DemEnMenPCC,Last;
53$     QUEUE,      TrainQ;
49$     REQUEST,    1:Train,,PCC;
134$    ASSIGN:     TrID=Train;
239$    TALLY:      TimePCC,int(timin),1;
50$     TRANSPORT:  Train,AST;

45$     ASSIGN:     NCONumInBAU=NCONumInBAU-1:
                M=PCC:
                NCONumInPCC=NCONumInPCC+1:MARK(timin):NEXT(Q5);

Q5      QUEUE,      QueNCOPCC;
47$     WAIT:       5,DemNCOPCC:NEXT(51$);

46$     ASSIGN:     EnMenNumInBAU=EnMenNumInBAU-1:
                M=PCC:
                EnMenNumInPCC=EnMenNumInPCC+1:MARK(timin):NEXT(Q6);

Q6      QUEUE,      QueEnMenPCC;
48$     WAIT:       6,DemEnMenPCC:NEXT(51$);
```

BRIGADE SUBMODEL

```
S2          STATION,      Brigade;
130$        BRANCH,       1:
                  If,TrID.eq.vehicle,71$,Yes:
                  If,TrID.eq.bus,132$,Yes;
71$         FREE;
65$         SPLIT:        M;
67$         BRANCH,       1:
                  If,PerRank.EQ.1,272$,Yes:
                  If,PerRank.EQ.2,273$,Yes:
                  If,PerRank.EQ.3,274$,Yes;
272$        TALLY:        timeoff,int(tin),1;
66$         ASSIGN:       OffNumInAST=OffNumInAST-1:
                  M=Brigade:
                  OffNumInBrigade=OffNumInBrigade+1;
72$         ASSIGN:       TotCurrNum=TotCurrNum+1;
70$         DISPOSE;

273$        TALLY:        timenco,int(tin),1;
68$         ASSIGN:       NCONumInAST=NCONumInAST-1:
                  M=Brigade:
                  NCONumInBrigade=NCONumInBrigade+1:NEXT(72$);

274$        TALLY:        timeenmen,int(tin),1;
69$         ASSIGN:       EnMenNumInAST=EnMenNumInAST-1:
                  M=Brigade:
                  EnMenNumInBrigade=EnMenNumInBrigade+1:NEXT(72$);

132$        FREE;
131$        SPLIT:        M;
139$        BRANCH,       1:
                  If,PerRank.EQ.1,138$,Yes:
                  If,PerRank.EQ.2,140$,Yes:
                  If,PerRank.EQ.3,141$,Yes;
138$        ASSIGN:       OffNumInBAU=OffNumInBAU-1:
                  M=Brigade:
                  OffNumInBrigade=OffNumInBrigade+1:NEXT(72$);

140$        ASSIGN:       NCONumInBAU=NCONumInBAU-1:
                  M=Brigade:
                  NCONumInBrigade=NCONumInBrigade+1:NEXT(72$);

141$        ASSIGN:       EnMenNumInBAU=EnMenNumInBAU-1:
                  M=Brigade:
                  EnMenNumInBrigade=EnMenNumInBrigade+1:NEXT(72$);

87$         BEGIN,        Yes;
```

INITIALIZE SUBMODEL

```
90$         CREATE,       1:,1;
106$        ASSIGN:       InOffNum=AINT(unif(195,205)):
                  InEnMenNum=AINT(unif(4900,5100)):
                  InNCONum=AINT(unif(414,426));
88$         ASSIGN:       EnMenNumInBrigade=InEnMenNum:
                  NCONumInBrigade=InNCONum:
                  OffNumInBrigade=InOffNum;
107$        ASSIGN:
TotCurrNum=NCONumInBrigade+OffNumInBrigade+EnMenNumInBrigade:
```

```
                EnMen=

AINT((1966*TRIA(0.844,0.929,0.99)*TRIA(0.896,0.907,0.914))+(1252*TRIA(0.505,0.918,0.997)*
TRIA(0.896,0.907,0.914))):
                NCO=

AINT((155*TRIA(0.747,0.865,0.975)*TRIA(0.81,0.874,0.926))+(70*TRIA(0.635,0.894,0.991)*TRI
A(0.81,0.874,0.926))):
                Off=

AINT((101*TRIA(0.858,0.917,0.995)*TRIA(0.774,0.877,0.947))+(72*TRIA(0.797,0.923,1)*TRIA(
0.774,0.877,0.947)));
109$        ASSIGN:     OffArr=42/Off:
                NCOArr=42/NCO:
                EnMenArr=42/EnMen;
105$        ASSIGN:
First=AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*unif(0.031,0.041));
108$        ASSIGN:     fir=24/first;
114$        DISPOSE;
```

RESERVE PERSONNEL FLOW SUBMODEL

```
314$        CREATE,     1,6:expo(42/(Off+NCO+EnMen)),Off+NCO+EnMen;

275$        STATION,    ENT;
323$        TRACE,      -1,"-Arrived to system at station ENT\n":;
278$        ASSIGN:     Picture=CIVILIAN;
288$        STORE:      STO1;
299$        DELAY:      0.;
302$        UNSTORE;
327$        TRACE,      -1,"-Transferred to next module\n"::NEXT(211$);

211$        STORE:      STO1;
163$        BRANCH,     1:
                With,NCO/(Off+NCO+EnMen),0$,Yes:
                With,EnMen/(Off+NCO+EnMen),3$,Yes:
                With,Off/(Off+NCO+EnMen),2$,Yes;
0$          ASSIGN:     NCONumInBAU=NCONumInBAU+1:
                M=BAU:
                PerRank=2:
                PerType=disc(0.74,10,1,12):MARK(tin);
165$        DELAY:      UNIF(1,2);
212$        UNSTORE:    STO1:NEXT(169$);

169$        STATION,    BAU;
375$        TRACE,      -1,"-Arrived to station BAU\n":;
355$        STORE:      STO1;
354$        DELAY:      0.;
374$        DELAY:      0.000:NEXT(1$);

1$          BRANCH,     1:
                If,Pertype.EQ.11,166$,Yes:
                If,PerType.EQ.10,168$,Yes:
                If,PerType.EQ.12,167$,Yes;
166$        ASSIGN:     PerOfAST=PerOfAST+1;
203$        BRANCH,     1:
                If,PerRank.EQ.1,204$,Yes:
                If,PerRank.EQ.2,205$,Yes:
                If,PerRank.EQ.3,206$,Yes;
```

```
204$        ASSIGN:       picture=officer:
                          OffOfAST=OffOfAST+1;
A1          BRANCH,       1:
                          If,NT(BUS).EQ.0.AND.TNOW.GT.48,260$,Yes:
                          Else,261$,Yes;
260$        ASSIGN:       GR1=NQ(QueAST);
GRO1        QUEUE,        QueAST;
G1          GROUP,        PerType:GR1,Last;
6$          QUEUE,        BusQAST;
16$         REQUEST,      2:BUS(RAN,NOM);
136$        ASSIGN:       TrID=BUS;
240$        TALLY:        TimeBAUAST,int(tin),1;
18$         TRANSPORT:    BUS(NOM),AST;

261$        ASSIGN:       GR1=60:NEXT(GRO1);

205$        ASSIGN:       picture=nco1:
                          NCOOfAST=NCOOfAST+1:NEXT(A1);

206$        ASSIGN:       picture=enmen1:
                          EnMenOfAST=EnMenOfAST+1:NEXT(A1);

168$        ASSIGN:       PerOfBrigade=PerOfBrigade+1;
12$         BRANCH,       1:
                          If,PerRank.EQ.1,13$,Yes:
                          If,PerRank.EQ.2,14$,Yes:
                          If,PerRank.EQ.3,15$,Yes;
13$         ASSIGN:       picture=officer:
                          OffOfBrigade=OffOfBrigade+1;
A3          BRANCH,       1:
                          If,NT(BUS).EQ.0.AND.TNOW.GT.48,264$,Yes:
                          Else,265$,Yes;
264$        ASSIGN:       GR3=NQ(QueBrigade);
GRO3        QUEUE,        QueBrigade;
4$          GROUP,        PerType:GR3,Last;
213$        QUEUE,        BusQBrigade;
214$        REQUEST,      1:BUS(RAN,NOM);
216$        ASSIGN:       TrID=BUS;
242$        TALLY:        TimeBAUBrigade,int(tin),1;
215$        TRANSPORT:    BUS(NOM),Brigade;

265$        ASSIGN:       GR3=60:NEXT(GRO3);

14$         ASSIGN:       picture=nco1:
                          NCOOfBrigade=NCOOfBrigade+1:NEXT(A3);

15$         ASSIGN:       picture=enmen1:
                          EnMenOfBrigade=EnMenOfBrigade+1:NEXT(A3);

167$        ASSIGN:       PerOfPCC=PerOfPCC+1;
207$        BRANCH,       1:
                          If,PerRank.EQ.1,208$,Yes:
                          If,PerRank.EQ.2,209$,Yes:
                          If,PerRank.EQ.3,210$,Yes;
208$        ASSIGN:       picture=officer:
                          OffOfPCC=OffOfPCC+1;
A2          BRANCH,       1:
                          If,NT(BUS).EQ.0.AND.TNOW.GT.48,262$,Yes:
                          Else,263$,Yes;
262$        ASSIGN:       GR2=NQ(QuePCC);
```

```
GRO2        QUEUE,        QuePCC;
5$          GROUP,        PerType:GR2,Last;
7$          QUEUE,        BusQPCC;
17$         REQUEST,      3:BUS(RAN,NOM);
137$        ASSIGN:       TrID=BUS;
241$        TALLY:        TimeBAUPCC,int(tin),1;
19$         TRANSPORT:    BUS(NOM),PCC;

263$        ASSIGN:       GR2=60:NEXT(GRO2);

209$        ASSIGN:       picture=nco1:
                          NCOOfPCC=NCOOfPCC+1:NEXT(A2);

210$        ASSIGN:       picture=enmen1:
                          EnMenOfPCC=EnMenOfPCC+1:NEXT(A2);

3$          ASSIGN:       EnMenNumInBAU=EnMenNumInBAU+1:
                          M=BAU:
                          PerRank=3:
                          PerType=disc(0.5,10,0.63,11,1,12):MARK(tin):NEXT(165$);

2$          ASSIGN:       OffNumInBAU=OffNumInBAU+1:
                          M=BAU:
                          PerRank=1:
                          PerType=disc(0.71,10,1,12):MARK(tin):NEXT(165$);
```

CASUALTY FLOW SUBMODEL

```
422$        CREATE,       1,0.01:expo(fir),first;

383$        STATION,      CASU1;
431$        TRACE,        -1,"-Arrived to system at station CASU1\n":;
386$        ASSIGN:       Picture=BOMB;
396$        STORE:        STO2;
407$        DELAY:        0.;
410$        UNSTORE;
435$        TRACE,        -1,"-Transferred to next module\n"::NEXT(115$);

115$        DUPLICATE:    1,221$;
92$         ASSIGN:       TotCasu=TotCasu+1:
                          CasuType=disc(0.058,4,0.131,5,1,6):
                          TotCurrNum=TotCurrNum-1;
99$         BRANCH,       1:
                          If,CasuType.EQ.4,102$,Yes:
                          If,CasuType.EQ.5,101$,Yes:
                          If,CasuType.EQ.6,100$,Yes;
102$        ASSIGN:       OffCasu1=OffCasu1+1:
                          OffNumInBrigade=OffNumInBrigade-1:
                          OffCasu=OffCasu+1:
                          PrcOff=(OffNumInBrigade/316)*100;
TYPE        BRANCH,       1:
                          With,0.1,93$,Yes:
                          With,0.18,94$,Yes:
                          With,0.72,95$,Yes;
93$         COUNT:        PrisonerInWar,1;
96$         DISPOSE;

94$         COUNT:        Dead,1;
97$         DISPOSE;
```

```
95$         COUNT:      Injured,1;
119$        BRANCH,     1:
                With,0.4667,120$,Yes:
                With,0.0083,98$,Yes:
                With,0.0089,124$,Yes:
                With,0.0311,122$,Yes:
                With,0.0454,125$,Yes:
                With,0.0604,123$,Yes:
                With,0.0753,126$,Yes:
                With,0.0885,127$,Yes:
                With,0.1015,128$,Yes:
                With,0.1139,129$,Yes;
120$        COUNT:      MortalInjured,1;
121$        DISPOSE;

98$         DELAY:      48:NEXT(CHECK18);

CHECK18     BRANCH,     1:
                If,CasuType.EQ.4,89$,Yes:
                If,CasuType.EQ.5,103$,Yes:
                If,CasuType.EQ.6,104$,Yes;
89$         ASSIGN:     PerRank=1:NEXT(CHECK6);

103$        ASSIGN:     PerRank=2:NEXT(CHECK6);

104$        ASSIGN:     PerRank=3:NEXT(CHECK6);

124$        DELAY:      72:NEXT(CHECK18);

122$        DELAY:      96:NEXT(CHECK18);

125$        DELAY:      120:NEXT(CHECK18);

123$        DELAY:      144:NEXT(CHECK18);

126$        DELAY:      168:NEXT(CHECK18);

127$        DELAY:      192:NEXT(CHECK18);

128$        DELAY:      216:NEXT(CHECK18);

129$        DELAY:      239:NEXT(CHECK18);

101$        ASSIGN:     NCOCasu1=NCOCasu1+1:
                NCONumInBrigade=NCONumInBrigade-1:
                NCOCasu=NCOCasu+1:
                PrcNCO=(NCONumInBrigade/653)*100:NEXT(TYPE);

100$        ASSIGN:     EnMenCasu1=EnMenCasu1+1:
                EnMenNumInBrigade=EnMenNumInBrigade-1:
                EnMenCasu=EnMenCasu+1:
                PrcEnMen=(EnMenNumInBrigade/(316+6031))*100:NEXT(TYPE);

221$        DUPLICATE:  1,217$;
CHECK10     BRANCH,     1:
                If,TNOW>19,112$,Yes:
                If,TNOW<=19,116$,Yes;
```

```
112$        ASSIGN:
Second=4*(AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*unif(0.022,0.03
2)));
111$        ASSIGN:       Sec=96/Second;
116$        DISPOSE;

217$        STORE:        STO2;
222$        DELAY:        0.03;
236$        ASSIGN:       picture=mort;
237$        DELAY:        0.04;
218$        UNSTORE:      STO2;
223$        DISPOSE;


501$        CREATE,       1,24:expo(Sec),Second;

462$        STATION,      CASU2;
510$        TRACE,        -1,"-Arrived to system at station CASU2\n":;
465$        ASSIGN:       Picture=BOMB;
475$        STORE:        STO3;
486$        DELAY:        0.;
489$        UNSTORE;
514$        TRACE,        -1,"-Transferred to next module\n"::NEXT(117$);

117$        DUPLICATE:    1,224$:NEXT(92$);

224$        DUPLICATE:    1,219$;
91$         BRANCH,       1:
                  If,TNOW>110,113$,Yes:
                  If,TNOW<=110,118$,Yes;
113$        ASSIGN:
Third=5*(AINT((OffNumInBrigade+NCONumInBrigade+EnMenNumInBrigade)*unif(0.02,0.03)));
110$        ASSIGN:       thr=120/third;
118$        DISPOSE;

219$        STORE:        STO3;
225$        DELAY:        0.03;
243$        ASSIGN:       picture=mort;
244$        DELAY:        0.04;
220$        UNSTORE:      STO3:NEXT(118$);


580$        CREATE,       1,120:expo(thr),Third;

541$        STATION,      CASU3;
589$        TRACE,        -1,"-Arrived to system at station CASU3\n":;
544$        ASSIGN:       Picture=BOMB;
554$        STORE:        STO4;
565$        DELAY:        0.;
568$        UNSTORE;
593$        TRACE,        -1,"-Transferred to next module\n"::NEXT(226$);

226$        DUPLICATE:    1,227$:NEXT(92$);

227$        STORE:        STO4;
228$        DELAY:        0.03;
245$        ASSIGN:       picture=mort;
246$        DELAY:        0.04;
229$        UNSTORE:      STO4;
230$        DISPOSE;
```

APCR SUBMODEL

```
249$        STATION,      APCR;
250$        FREE;

248$        CREATE,       10000,47:,1;
164$        BRANCH,       1:
                  With,0.35,200$,Yes:
                  With,0.35,201$,Yes:
                  With,0.30,202$,Yes;
200$        ASSIGN:       picture=OFFICER:
                  PerRank=1;
57$         QUEUE,        QueOffAPCR;
54$         WAIT:         7,DemOffAPCR;
62$         QUEUE,        QuAST;
63$         GROUP:        DemEnMenAPCR+DemOffAPCR+DemNCOAPCR,Last;
64$         QUEUE,        TruckQ;
60$         REQUEST,      1:Truck(CYC,IND),,APCR;
133$        ASSIGN:       TrID=truck;
61$         TRANSPORT:    Truck(IND),AST;

201$        ASSIGN:       picture=NCO1:
                  PerRank=2;
58$         QUEUE,        QueNCOAPCR;
55$         WAIT:         8,DemNCOAPCR:NEXT(62$);

202$        ASSIGN:       picture=ENMEN1:
                  PerRank=3;
59$         QUEUE,        QueEnMenAPCR;
56$         WAIT:         9,DemEnMenAPCR:NEXT(62$);


266$        CREATE,       1,66:,1;
270$        ASSIGN:       M=BAU:
                  PerType=12:NEXT(A2);


267$        CREATE,       1,60:,1;
271$        ASSIGN:       M=BAU:
                  PerType=10:NEXT(A3);


268$        CREATE,       1,63:,1;
269$        ASSIGN:       M=BAU:
                  PerType=11:NEXT(A1);
```

APPENDIX B: Experimental file of the code written by using Arena 3.0

```
BEGIN,       Yes,No;

PROJECT,   Personnel Mobilization and Completion System ,LEVENT
              KARAMALAK,20/10/2000;

ATTRIBUTES:   NUM:
        timein:
        tin:
        picture:
        CasuType:
        NOM,1:
        timin:
        TrID:
        PerType:
        IND,:
        PerRank;

STORAGES:    STO1:
        STO2:
        STO3:
        STO4;

VARIABLES:    PerOfAST:
        DemEnMenPCC:
        OffOfBrigade:
        EnMenCasu1:
        OffNumInAST:
        No:
        DemOffPCC:
        DemNCONxt:
        PerOfBrigade:
        InNCONum:
        DemNCOAPCR:
        EnMenNumInBAU:
        ShortEnMenAST:
        ShortOffAST:
        OffArr,1:
        Third,1:
        DemEnMenAST:
        UnSatDemOffAST:
        ReportNo:
        OffNumInBAU:
        GR1,60:
        NCOOfPCC:
        OffOfPCC:
        DemOffAST:
        OffCasu:
        NCO,1:
        Second,1:
        EnMenOfBrigade:
        NCOOfBrigade:
        GR2,60:
        TotDemNCOAPCR:
        EnMenNumCasu:
        GR3,60:
        EnMenOfPCC:
```

EnMenInBrigade:
DemNCOPCC:
NCOOfAST:
OffOfAST:
OffNumInBrigade:
TotCurrNum:
InEnMenNum:
DemOffAPCR:
PrcNCO:
ShortNCOAST:
NCOArr,1:
EnMen,1:
Thr,1:
NCONumInPCC:
EnMencasu:
EnMenOfAST:
PrcEnMen:
UnSatDemNCOAST:
DemNCOAST:
UnSatDemEnMenAST:
EnMenNumInBrigade:
EnMenArr,1:
Off,1:
Fir,1:
DemEnMenNXT:
TotDemOffAPCR:
NCONumInAST:
First,1:
TotCasu:
DemOffNxt:
DemEnMenAPCR:
TotDemEnMenAPCR:
Sec,1:
InOffNum:
EnMenNumInPCC:
PerOfPCC:
PrcOff:
NCONumInBrigade:
No2:
OffNumInPCC:
NCONumInBAU:
NCOCasu1:
OffCasu1:
NCOCasu:
EnMenNumInAST;

QUEUES: QueOffAST,FirstInFirstOut:
QueBrigade,FirstInFirstOut:
QueB,FirstInFirstOut:
QueAST,FirstInFirstOut:
QueOffAPCR,FirstInFirstOut:
QueEnMenPCC,FirstInFirstOut:
TruckQ,FirstInFirstOut:
QueNCOPCC,FirstInFirstOut:
QueEnMenAST,FirstInFirstOut:
QueNCOAST,FirstInFirstOut:
QueBrg,FirstInFirstOut:
BusQBrigade,FirstInFirstOut:
TrainQ,FirstInFirstOut:
BusQPCC,FirstInFirstOut:

```
        QuAST,FirstInFirstOut:
        BusQAST,FirstInFirstOut:
        QueNCOAPCR,FirstInFirstOut:
        QueEnMenAPCR,FirstInFirstOut:
        QueOffPCC,FirstInFirstOut:
        QuePCC,FirstInFirstOut:
        VehicleQ,FirstInFirstOut;

PICTURES:   BOMB:
        MORT:
        ENMEN1:
        NCO1:
        OFFICER:
        CIVILIAN;

STATIONS:   1,BAU:
        2,Brigade:
        3,PCC:
        4,APCR:
        5,AST:
        CASU3:
        ENT:
        CASU1:
        CASU2;

DISTANCES:  TruckMap,APCR-AST-250:
        BauMap,ENT-BAU-0:
        BusMap,BAU-AST-80,BAU-Brigade-90,BAU-PCC-100:
        TrainMap,AST-PCC-180,PCC-AST-180:
        VehicleMap,AST-Brigade-10;

TRANSPORTERS: Train,1,DISTANCE(TrainMap),80---,STATION(PCC)-Active:
        Truck,4,Distance(TruckMap),80---,STATION(APCR)-Active:
        BUS,3,Distance(BusMap),80---,STATION(BAU)-Active:
        VEHICLE,7,Distance(VehicleMap),50---,Station(Brigade)-Active;

COUNTERS:   PrisonerInWar,,Replicate:
        Dead,,Replicate:
        Injured,,Replicate:
        MortalInjured,,Replicate;

TALLIES:    TimeBAUBrigade:
        TimeBAUAST:
        timeoff:
        TimePCC:
        TimeAST:
        timeenmen:
        TimeBAUPCC:
        timenco;

DSTATS:     DemEnmENPCC:
        DemOffPCC:
        OffNumInAST:
        ShortEnMenAST:
        ShortOffAST:
        InNCONum:
        DemEnMenAST:
        DemOffAST:
        OffCasu:
        TotDemNCOAPCR:
```

DemNCOPCC:
OffNumInBrigade:
PrcNCO:
ShortNCOAST:
InEnMenNum:
NCONumInPCC:
EnMenCasu:
PrcEnMen:
DemNCOAST:
EnMenNumInBrigade:
TotDemOffAPCR:
NCONumInAST:
TotDemEnMenAPCR:
EnMenNumInPCC:
InOffNum:
PrcOff:
NCONumInBrigade:
OffNumInPCC:
NCOCasu:
EnMenNumInAST;

REPLICATE, 2,0.0,240,Yes,Yes;

APPENDIX C: A representative output file for the code written for the existing system.

ARENA Simulation Results
levent - License #9810738

Summary for Replication 1 of 20

Project : Personnel Mobilization and Completion System

Analyst : LEVENT KARAMALAK

Replication ended at time : 240.0

Model revision date : 20/10/2000

Run execution date : 6/ 2/2001

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum
TimeBAUAST	12.686	(Insuf)	2.1655	64.125
TimeBAUBrigade	4.8056	(Insuf)	1.5490	61.250
timeoff	116.66	(Insuf)	11.911	229.30
TimePCC	80.585	(Insuf)	1.2223	136.07
TimeAST	19.578	(Insuf)	.70000	60.728
timeenmen	111.90	(Corr)	4.0911	229.30
TimeBAUPCC	6.2834	(Insuf)	1.3473	67.125
timenco	98.536	(Insuf)	10.982	229.30

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
DEMENMENPCC	93.300	(Insuf)	.00000	207.00	.00000
ENMENCASU1	774.36	(Corr)	.00000	1624.0	1624.0
OFFNUMINAST	8.3441	(Insuf)	.00000	39.000	12.000
DEMOFFPCC	3.5000	(Insuf)	.00000	20.000	.00000
INNCONUM	421.00	(Insuf)	.00000	421.00	421.00
SHORTOFFAST	5.0000	(Insuf)	.00000	6.0000	6.0000
SHORTENMENAST	.00000	(Insuf)	.00000	.00000	.00000
DEMENMENAST	7.8669	(Insuf)	.00000	206.00	.00000
DEMOFFAST	1.8221	(Insuf)	.00000	28.000	.00000
TOTDEMNCOAPCR	122.05	(Insuf)	.00000	215.00	215.00
OFFNUMINBR	288.37	(Insuf)	.00000	316.00	312.00
DEMNCOPCC	5.3000	(Insuf)	.00000	33.000	.00000
INENMENNUM	5016.0	(Insuf)	.00000	5016.0	5016.0
SHORTNCOAST	12.750	(Insuf)	.00000	15.000	15.000
PRCNCO	90.611	(Insuf)	.00000	99.693	98.315
PRCENMEN	95.798	(Corr)	.00000	99.873	98.881
NCONUMINPCC	3.2892	(Insuf)	.00000	36.000	.00000
ENMENNUMINBR	6082.9	(Corr)	.00000	6340.0	6276.0
DEMNCOAST	4.3872	(Insuf)	.00000	122.00	.00000
TOTDEMOFFAPCR	49.600	(Insuf)	.00000	102.00	102.00
TOTDEMENMENAPCR	29.85	(Insuf)	.00000	291.00	291.00

NCONUMINAST	11.388	(Insuf)	.00000	130.00	18.000
INOFFNUM	197.00	(Insuf)	.00000	197.00	197.00
ENMENNUMINPCC	331.40	(Insuf)	.00000	725.00	.00000
NCONUMINBR	594.70	(Insuf)	.00000	652.00	642.00
PRCOFF	89.731	(Insuf)	.00000	99.683	98.734
OFFNUMINPCC	2.4705	(Insuf)	.00000	24.000	.00000
OFFCASU1	60.201	(Insuf)	.00000	116.00	116.00
NCOCASU1	80.883	(Insuf)	.00000	164.00	164.00
ENMENNUMINAST1	51.06	(Insuf)	.00000	266.00	191.00

COUNTERS

Identifier	Count	Limit
Dead	329	Infinite
PrisonerInWar	181	Infinite
Injured	1394	Infinite
MortalInjured	628	Infinite

APPENDIX D1: The data and the triangular distribution parameters belong to the number of reserve personnel, who are planned to join brigade and AST and who are given MDO

DATA	GIVEN MDO			NOTIFIED MDO			RATE		
SOURCE	OFFICER	NCO	ENLISTED	OFFICER	NCO	ENLISTED	OFFICER	NCO	ENLISTED
1	437	136	7299	416	116	7010	0,951945	0,852941	0,960406
2	1156	521	8026	1077	472	7552	0,931661	0,90595	0,940942
3	1281	304	6011	1155	230	5074	0,901639	0,756579	0,844119
4	663	301	4090	626	251	3823	0,944193	0,833887	0,934719
5	705	238	11483	612	197	10169	0,868085	0,827731	0,88557
6	751	630	7950	730	598	7248	0,972037	0,949206	0,911698
7	1219	988	9646	1144	931	9198	0,938474	0,942308	0,953556
8	838	374	5433	738	365	4966	0,880668	0,975936	0,914044
9	1331	575	8125	1262	460	7814	0,948159	0,8	0,961723
10	3170	559	42872	2799	478	39492	0,882965	0,855098	0,921161
11	917	619	7504	787	525	6547	0,858233	0,848142	0,872468
12	575	168	7729	509	136	7284	0,885217	0,809524	0,942425
13	821	408	5669	752	365	5559	0,915956	0,894608	0,980596
14	804	486	6353	800	474	6290	0,995025	0,975309	0,990083
15	912	718	9576	801	537	8873	0,878289	0,747911	0,926587
16	411	244	4481	383	230	4068	0,931873	0,942623	0,907833
17	1371	860	12437	1251	684	11798	0,912473	0,795349	0,948621
				PARAMETERS FOR THE TRIANGULAR DISTRIBUTION			**AVERAGE**	**AVERAGE**	**AVERAGE**
							0,917464	0,865477	0,929209
							MIN VALUE	**MIN VALUE**	**MIN VALUE**
							0,858233	0,747911	0,844119
							MAX VALUE	**MAX VALUE**	**MAX VALUE**
							0,995025	0,975936	0,990083

APPENDIX D2: The data and the triangular distribution parameters belong to the number of reserve personnel, who are planned to join PCC and who are given MDO

DATA	GIVEN MDO			NOTIFIED MDO			RATE		
SOURCE	OFFICER	NCO	ENLISTED	OFFICER	NCO	ENLISTED	OFFICER	NCO	ENLISTED
1	484	73	10665	453	70	10249	0,93595	0,958904	0,960994
2	239	118	6747	232	117	6623	0,970711	0,991525	0,981621
3	1084	250	17957	1008	190	16832	0,929889	0,76	0,93735
4	1371	228	10395	1286	226	5250	0,938001	0,991228	0,505051
5	1100	957	8856	1050	838	8736	0,954545	0,875653	0,98645
6	954	222	9699	859	194	8344	0,900419	0,873874	0,860295
7	3170	559	42872	2799	478	39492	0,882965	0,855098	0,921161
8	1549	247	12335	1549	157	12300	1	0,635628	0,997163
9	400	124	8483	350	121	8147	0,875	0,975806	0,960391
10	1230	355	13409	1193	348	12672	0,969919	0,980282	0,945037
11	875	245	10870	855	237	9875	0,977143	0,967347	0,908464
12	356	73	14005	291	62	12819	0,817416	0,849315	0,915316
13	359	94	10762	342	93	10236	0,952646	0,989362	0,951124
14	1517	103	5648	1372	81	5051	0,904417	0,786408	0,894299
15	983	196	10309	945	187	9933	0,961343	0,954082	0,963527
16	430	106	10383	343	94	10071	0,797674	0,886792	0,969951
17	1193	1708	19418	1118	1490	18693	0,937133	0,872365	0,962664
							AVERAGE	AVERAGE	AVERAGE
				PARAMETERS FOR THE TRIANGULAR DISTRIBUTION			0,923834	0,894334	0,918874
							MIN VALUE	MIN VALUE	MIN VALUE
							0,797674	0,635628	0,505051
							MAX VALUE	MAX VALUE	MAX VALUE
							1	0,991525	0,997163

APPENDIX D3: The data and the triangular distribution parameters belong to the number of reserve personnel, who are given MDO and join their units on time during the field exercises

DATA	RESERVE PERSONNEL WITH MDO			JOINED RESERVE PERSONNEL			RATE		
SOURCE	OFFICER	NCO	ENLISTED	OFFICER	NCO	ENLISTED	OFFICER	NCO	ENLISTED
1	93	95	1325	72	77	1188	0,774194	0,810526	0,8966038
2	134	157	1596	127	139	1459	0,947761	0,88535	0,9141604
3	123	149	804	112	138	732	0,910569	0,926174	0,9104478
							AVERAGE	AVERAGE	AVERAGE
				PARAMETERS FOR THE TRIANGULAR DISTRIBUTION			0,877508	0,874017	0,9070706
							MIN VALUE	MIN VALUE	MIN VALUE
							0,774194	0,810526	0,8966038
							MAX VALUE	MAX VALUE	MAX VALUE
							0,947761	0,926174	0,9141604

APPENDIX E: Summary statistics for the existing system (20 replications)

REP. NO	PERFORMANCE MEASURE																
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM			TIME IN PCC	TIME IN AST	CASUALTY AMOUNT		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E			O	NCO	E
1	89,73	90,61	95,79	102	215	291	6	15	0	116,66	98,53	111,9	80,58	19,57	116	164	1624
2	89,86	91,08	95,62	126	203	554	6	7	0	118,36	94,78	107,18	49,1	17,89	128	136	1641
3	90,05	90,92	95,36	90	194	361	5	8	0	110,27	93,72	103,07	60,75	19,29	99	127	1601
4	89,52	90,12	95,33	123	181	361	8	4	0	104,25	104,93	107,19	59,89	19,08	112	133	1529
5	90,39	89,71	95,97	103	186	278	19	4	0	102,93	94,22	107,6	63,86	20,06	115	120	1528
6	91,26	90,75	95,44	57	173	261	8	7	0	102,52	91,87	96,94	59,87	20,6	102	120	1451
7	89,85	89,56	95,81	72	182	106	7	1	0	105,26	94,89	107,32	85,37	21,58	92	106	1606
8	90,56	88,64	95,56	52	227	337	4	15	0	107,26	94,3	103,54	60,46	19,58	97	133	1554
9	90,12	91,16	95,48	73	168	599	6	8	0	111,38	97,64	110,43	44,94	13,39	107	126	1713
10	91,92	89,58	95,58	64	196	313	6	2	0	121,97	94,42	100,06	65,78	19,35	102	127	1542
11	90,15	90,42	95,9	95	177	172	6	4	0	99,76	78,22	92,84	71,47	21,53	91	97	1333
12	91,92	90,84	96,23	60	191	0	3	16	0	116,95	88,94	107,42	95,53	24,15	97	129	1386
13	89,24	91,25	95,8	99	177	315	4	8	0	102,29	83,26	93,7	47,31	20,05	105	117	1388
14	90,27	90,77	95,91	106	207	301	6	5	0	115,82	97,09	112,71	79,74	19,6	114	126	1720
15	91,22	90,45	95,57	73	191	495	8	6	0	122,07	94,65	106,97	49,21	6,4	109	124	1651
16	90,88	90,9	95,98	68	232	0	7	11	0	101,29	97,83	105,1	98,28	23,5	75	142	1344
17	91,49	91,34	95,87	62	167	102	3	6	0	101,02	93,36	101,98	86,03	23,32	80	120	1518
18	91,62	91,2	95,28	51	116	427	6	9	0	108,87	92,21	106,13	58,7	21,11	91	107	1626
19	90,94	90,45	95,9	104	198	252	8	6	0	107,05	100,43	104,12	74,23	20,12	110	121	1558
20	92,23	89,96	95,78	72	241	171	4	9	0	125,59	89,22	97,9	75,41	20,77	99	150	1604
MEAN	90,661	90,4855	95,708	82,6	191,1	284,8	6,5	7,55	0	110,08	93,726	104,21	68,3255	19,547	102,05	126,25	1545,9
VARIANCE	0,77299	0,49403	0,064354	541,3053	746,72632	26679,537	11,211	17,103	0	64,739	33,709	30,931	248,4873	14,6754	160,787	226,51	13056
ST. DEV.	0,8792	0,70287	0,25368	23,26597	27,326293	163,33872	3,3482	4,1355	0	8,0461	5,8059	5,5616	15,76348	3,83084	12,6802	15,05	114,26
CI(α=0,05)	0,82177	0,65696	0,237109	21,74615	25,541242	152,66885	3,1295	3,8654	0	7,5205	5,4267	5,1983	14,73375	3,5806	11,8519	14,067	106,8

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APPENDIX E: Summary statistics for the existing system (20 replications). (continued)

REP. NO	PERFORMANCE MEASURE															
	NUMBERS IN BRIGADE			NUMBERS IN AST			NUMBERS IN PCC			CASUALTY TYPES				TIME IN BAU FOR		
	O	NCO	E	O	NCO	E	O	NCO	E	POW	INJURED	DEAD	MORT.INJ.	BR.PER	PCC PER	AST PER
1	288,37	594,7	6082,9	8,34	11,38	151,1	2,47	3,28	331,4	181	1394	329	628	4,8	6,28	12,68
2	286,52	598,51	6071,9	8,82	10,83	147,14	2,08	2,53	191,4	192	1360	353	656	5,12	6,75	12,9
3	286,62	597,58	6055,3	9,27	11,15	151,99	3,57	3,22	265,4	187	1329	311	629	4,93	6,16	12,89
4	286,87	599,52	6053,2	8,25	11,93	150,57	2,29	4,93	290,8	182	1271	321	576	4,95	6,22	13,25
5	287,79	598,58	6093,6	8,21	11,6	145,48	2,92	2,62	310	185	1261	317	605	4,86	6,41	12,99
6	293,07	598,51	6059,5	9,03	11,97	151,69	3,74	3,41	267,9	159	1225	289	582	4,88	6,25	12,9
7	289,89	597,72	6083,3	8,57	11,83	159,95	3,06	2,44	428,6	159	1333	312	619	4,94	5,98	11,6
8	292,68	593,82	6068	8,98	10,75	151,55	3,96	2,82	272,4	188	1294	302	624	4,92	6,32	13
9	288,97	602,76	6062,6	13,54	10,42	148,86	2,49	3,24	204,1	198	1403	345	641	5,01	6,77	12,92
10	293,69	598,33	6068,9	9,39	11,11	149,74	2,79	3,42	264,1	186	1273	312	581	5,04	6,26	13,18
11	290,4	596,74	6089,3	8,31	12,22	153,79	2,47	3,13	268,8	130	1103	288	516	5,04	6,42	13,09
12	293,27	598,64	6110,4	9,78	11,06	158,89	3,28	3,09	464,9	140	1178	294	563	4,89	6,25	13,43
13	286,5	599,13	6083	9,03	11,44	149,11	3,36	3,09	193,3	177	1143	290	517	5,07	6,52	12,84
14	289,31	597,73	6089,3	8,37	10,84	154,88	2,94	2,49	346,2	212	1433	315	653	4,93	6,33	13,13
15	291,58	596,27	6068,5	8,87	11,6	146,4	2,74	2,69	221,1	181	1371	332	663	5,05	6,43	13,22
16	290,27	598,22	6096,8	9,01	10,28	152,74	2,31	2,8	449,6	161	1150	250	547	5,01	6,17	13,17
17	291,88	599,68	6087,7	8,76	0,29	155,46	2,68	3,44	344,1	154	1099	291	536	4,87	6,32	13,18
18	292,48	598,71	6056	9,12	57,42	149,03	3,25	3,08	248,3	178	1250	288	591	4,99	6,52	13,01
19	288,64	597,33	6092	8,75	11,1	154,54	2,51	2,87	319,9	191	1312	354	637	4,99	6,2	12,9
20	295,54	591,07	6081,3	8,51	11,67	157,12	2,27	3,63	321	171	1285	351	595	4,83	6,36	11,73
MEAN	290,217	597,678	6077,675	9,0455	13,0445	152,0015	2,859	3,111	300,2	175,6	1273,4	312,2	597,95	4,956	6,346	12,901
VARIANCE	7,34745	5,82417	251,6799	1,289994	115,3911	15,79695	0,2798	0,3033	6248	395,73	9808,7	722,8	2055,418	0,00741	0,03626	0,2087
ST. DEV.	2,71062	2,41333	15,86442	1,135779	10,742025	3,9745377	0,529	0,5507	79,04	19,893	99,039	26,885	45,33672	0,08611	0,19041	0,4569
CI(α=0,05)	2,53355	2,25568	14,8281	1,061586	10,040317	3,7149067	0,4944	0,5147	73,88	18,593	92,569	25,129	42,37517	0,08048	0,17797	0,427

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APPENDIX F1: Statistics of initial replications for alternative 1 (existing system) under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	89,73	90,61	95,79	102	215	291	6	15	0	116,66	98,53	111,9
2	89,86	91,08	95,62	126	203	554	6	7	0	118,36	94,78	107,18
3	90,05	90,92	95,36	90	194	361	5	8	0	110,27	93,72	103,07
4	89,52	90,12	95,33	123	181	361	8	4	0	104,25	104,93	107,19
5	90,39	89,71	95,97	103	186	278	19	4	0	102,93	94,22	107,6
6	91,26	90,75	95,44	57	173	261	8	7	0	102,52	91,87	96,94
7	89,85	89,56	95,81	72	182	106	7	1	0	105,26	94,89	107,32
8	90,56	88,64	95,56	52	227	337	4	15	0	107,26	94,3	103,54
9	90,12	91,16	95,48	73	168	599	6	8	0	111,38	97,64	110,43
10	91,92	89,58	95,58	64	196	313	6	2	0	121,97	94,42	100,06
11	90,15	90,42	95,9	95	177	172	6	4	0	99,76	78,22	92,84
12	91,92	90,84	96,23	60	191	0	3	16	0	116,95	88,94	107,42
13	89,24	91,25	95,8	99	177	315	4	8	0	102,29	83,26	93,7
14	90,27	90,77	95,91	106	207	301	6	5	0	115,82	97,09	112,71
15	91,22	90,45	95,57	73	191	495	8	6	0	122,07	94,65	106,97
16	90,88	90,9	95,98	68	232	0	7	11	0	101,29	97,83	105,1
17	91,49	91,34	95,87	62	167	102	3	6	0	101,02	93,36	101,98
18	91,62	91,2	95,28	51	116	427	6	9	0	108,87	92,21	106,13
19	90,94	90,45	95,9	104	198	252	8	6	0	107,05	100,43	104,12
20	92,23	89,96	95,78	72	241	171	4	9	0	125,59	89,22	97,9
MEAN	90,661	90,4855	95,708	82,6	191,1	284,8	6,5	7,55	0	110,079	93,7255	104,205
VARIANCE	0,77299	0,49403	0,064354	541,3053	746,72632	26679,537	11,2105	17,10263	0	64,7393	33,70869	30,93146
ST. DEV.	0,8792	0,70287	0,25368	23,26597	27,326293	163,33872	3,34821	4,135533	0	8,04607	5,805918	5,561606
CI(α=0,05)	0,82177	0,65696	0,237109	21,74615	25,541242	152,66885	3,1295	3,865385	0	7,52048	5,426655	5,198302

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APPENDIX F2: Statistics of initial replications for alternative 2 under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	90,04	91,31	95,94	125	208	179	0	0	0	103,45	93,78	97,83
2	90,51	91,6	95,36	76	161	401	0	0	0	98,72	86,811	92,41
3	91,12	91,78	95,83	72	193	349	0	0	0	100,77	98,63	98,43
4	88,83	90,86	95,59	82	171	192	0	0	0	104,423	85,7	102,7
5	90,63	90,43	95,67	106	210	187	0	0	0	118,63	87,33	104,14
6	91,3	90,54	95,66	67	165	341	0	0	0	115,48	92,39	105,33
7	90,53	91,2	95,7	110	152	176	0	0	0	105,23	88,98	96,87
8	91	90,59	95,62	86	184	218	0	0	0	104,24	87,14	95,37
9	91,6	91,49	95,35	83	197	444	0	0	0	95,76	91,79	96,74
10	90,87	91,35	95,55	78	171	506	0	0	0	126,01	95,62	104,96
11	91,38	90,47	95,94	60	216	281	0	0	0	92,45	95,06	101,6
12	90,71	91,4	95,5	103	230	275	0	0	0	105,87	98,94	101,73
13	91,1	90,79	95,56	103	179	125	0	0	0	105,5	89,19	92,43
14	90,94	90,99	95,54	108	159	273	0	0	0	112,64	92,54	106,39
15	91,05	90,85	95,68	72	174	399	0	0	0	104,06	96,68	105,72
16	90,81	90,69	95,62	86	237	142	0	0	0	102,23	96,54	101,97
17	92,09	91,04	98,35	80	226	67	0	0	0	124,82	97,05	111,04
18	91,65	90,78	95,78	58	196	236	0	0	0	110,24	96,33	112,48
19	89,95	91,2	95,72	90	197	270	0	0	0	100,11	88,05	97,09
20	91,11	91,63	95,55	79	182	281	0	0	0	100,66	100,7	109,23
MEAN	90,861	91,0495	95,7755	86,2	190,4	267,1	0	0	0	106,56465	92,96255	101,723
VARIANCE	0,4910095	0,1701524	0,3917629	319,01053	616,56842	12827,989	0	0	0	80,137518	21,412277	33,489
ST. DEV.	0,7007207	0,4124953	0,6259097	17,860866	24,830796	113,26071	0	0	0	8,9519561	4,6273402	5,78697
CI(α=0,05)	0,6549471	0,3855496	0,585023	16,69413	23,208759	105,86212	0	0	0	8,3671822	4,3250658	5,40894

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APPENDIX F3: Statistics of initial replications for alternative 3 under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	96,13	98,22	97,78	45	84	0	6	16	0	95,74	113,39	98,82
2	95,98	98,33	97,84	43	67	0	4	7	0	105,478	111,86	95,25
3	96,05	97,41	97,69	62	79	153	7	6	0	116,47	104,73	94,12
4	95,23	97,94	97,57	37	100	418	4	11	0	109,94	116,14	104,31
5	96,62	98,09	97,66	52	107	246	8	11	0	104,43	109,98	96,41
6	95,33	98,18	97,92	37	63	38	5	9	0	103,57	118,38	98,88
7	96,13	97,73	97,75	52	115	389	9	12	0	112,11	118,55	101,51
8	95,67	97,93	97,48	19	73	370	3	4	0	116,3	113,31	107,24
9	95,16	98,24	97,56	54	96	247	9	9	0	121,73	114,2	97,9
10	96,13	97,54	97,47	44	120	176	4	13	0	123	111,17	98,44
11	94,22	97,04	97,59	41	62	148	9	5	0	94,79	104,79	92,92
12	96,63	96,82	97,72	56	122	323	7	11	0	112,58	107,82	107,22
13	95,74	97,75	97,42	42	64	457	3	4	0	123,18	116,19	105,46
14	97,4	97,32	97,36	38	110	435	6	12	0	106,51	121,58	105,05
15	97,15	98,06	97,52	49	98	440	4	7	7	109,37	119,87	101,84
16	96,35	97,84	97,6	33	123	380	6	20	0	99,18	110,3	99,51
17	95,92	97,5	97,79	43	97	151	8	10	0	113,23	115,19	103,73
18	96,47	98,07	97,67	55	96	186	7	11	0	124,23	116,32	101,93
19	95,08	98,14	97,46	76	96	414	7	9	0	116,72	117,06	97,95
20	96,04	98,09	97,62	31	85	365	6	5	0	108,38	118,25	103,09
MEAN	95,9715	97,812	97,6235	45,45	92,85	266,8	6,1	9,6	0,35	110,8469	113,954	100,579
VARIANCE	0,5469082	0,1758063	0,0221713	152,05	403,92368	23209,432	3,8842105	16,463158	2,45	77,710079	22,507088	17,8246
ST. DEV.	0,7395324	0,4192926	0,1489004	12,330856	20,097853	152,34642	1,9708401	4,0574817	1,5652476	8,815332	4,7441636	4,221919
CI(α=0,05)	0,6912235	0,3919029	0,1391737	11,52536	18,784989	142,39461	1,8420977	3,7924325	1,463	8,2394829	4,4342578	3,946128

APPENDIX F4: Statistics of initial replications for alternative 4 under scenario 1.

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REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	95,91	98,06	97,62	49	106	246	0	0	0	94,74	118,27	103,06
2	95,15	98,71	97,52	43	72	203	0	0	0	108,06	103,94	92,83
3	97,16	97,85	97,38	59	60	250	0	0	0	99,42	109,14	95,21
4	96,72	97,32	97,36	30	132	453	0	0	0	108,36	126,42	104,9
5	96,9	96,53	97,72	54	141	214	0	0	0	100,15	106,23	97,51
6	97,14	98,06	97,48	46	100	248	0	0	0	106,08	114,06	91,33
7	96,87	97,85	97,72	48	86	157	0	0	0	105,63	101,86	93,98
8	96,96	98,2	97,51	47	120	433	0	0	0	109,01	124,84	103,67
9	97,11	96,72	97,39	50	131	473	0	1	0	86,49	119,15	94,2
10	97,32	98,28	97,74	39	80	121	0	0	0	90,21	107,36	93,52
11	97,56	98,19	97,64	48	56	217	0	0	0	78,42	116,59	95,35
12	96,85	97,22	97,74	41	55	279	0	0	0	94,56	116,22	95,83
13	97,78	98,44	97,31	34	86	447	0	0	0	99,54	110,85	96,85
14	97,57	97,81	97,4	58	97	231	0	0	0	84,44	113,19	92,12
15	97,71	97,94	97,02	52	124	210	0	0	39	88,28	94,01	88,75
16	97,2	97,6	97,45	57	115	211	0	0	0	108,09	109,17	99,23
17	96,56	97,59	97,16	80	104	196	0	0	0	108,48	120,19	98,68
18	96,65	95,62	97,98	46	72	41	0	0	0	100,15	120,85	95,57
19	96,86	98,28	97,45	58	87	339	0	0	0	128,72	121,05	102,53
20	96,12	98,45	97,6	43	77	174	0	0	0	110,78	101,35	96,77
MEAN	96,905	97,736	97,5095	49,1	95,05	257,15	0	0,05	1,95	100,4805	112,737	96,5945
VARIANCE	0,4010684	0,5628253	0,0488787	114,09474	687,20789	13512,34	0	0,05	76,05	133,67743	73,757401	18,88797
ST. DEV.	0,6332996	0,7502168	0,2210852	10,681514	26,21465	116,2426	0	0,22360	8,720665	11,561895	8,5882129	4,34603
CI(α=0,05)	0,5919302	0,70121	0,2066432	9,983759	24,502215	108,6492	0	0,209	8,151	10,806631	8,0272001	4,062131

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APPENDIX G1: Statistics of additional replications for alt. 1 under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	92,23	90,53	95,19	72	206	527	6	8	0	119,71	93,2	100,73
22	92,23	90,88	96,09	75	192	182	9	6		108,95	87,27	105,01
23	89,92	90,6	95,97	89	195	91	3	5		107,12	87,66	103,86
24	91	91,07	95,75	69	223	330	7	13		101,34	92,57	100,87
25	91,39	91,52	95,97	63	165	305	8	2		95,6	96,96	108,95
26	90,86	91,98	95,48	64	150	149	10	10			98,59	93,2
27	90,46	90,01	95,68	68	193	171	5	6			94,63	93,08
28	91,58	90,93	95,45	71	199	470	6	17			97,73	99,42
29	91,69	90,55	96,01	67	178	127	4	6			95,33	95,19
30	90,4	90,86	95,92	73	204	376	7	7			91,97	102,54
31	92,01	90,74	95,47	51	191	531	10	6			94,07	101,85
32	91,57	90,33	95,43	51	200	282	4	9			91,75	93,7
33	90,44	89,68	95,97	67	206	371	13	6			87,42	94,2
34	91,03	91,07	95,68	90	204	448	4	13			91,2	92,84
35	90,52	91,33	95,67	62	197	562	22	12			94,22	
36	90,07	89,91	96,05	117	227	44	5	11			89,94	
37	89,9	90,61	95,76	79	169	220	6	4			88,69	
38	90,84	90,2	96,35	71	214	26	6	15				
39	92,09	90,98	95,57	38	183	350	4	10				
40	91,14	90,66	95,9	73	212	79	12	8				
41	89,51	90,18	95,8	101	221	215	7	10				
42	89,64	89,95	95,75	96	212	198	6	5				
43	89,5	90,121	95,71	93	201	30	10					
44	92,15	90,8		71	217	158	9					
45	91,71	89,86		92	205	265	9					
46	90,14	91,33		91	181	616	5					
47	89,86	91,28		109	176	327	7					
48	91,65	90,98		42	163	441	4					
49	90,25	89,89		80	194	2	5					
50	90,43	90,3		75	232	532	7					
51	90,54	91,09		90	204	396	2					
52	90,31	90,75		94	231	0	4					
53	90,2	90,77		99	183	190	2					
54	89,22	90,44		71	186	81	6					
55	90,6	90,73		82	239	295	6					
56	90,92	90,67		109	232	535	4					
57	89,62	91,4		112	175	403	7					
58	92,78	90,58		32	198	106	4					
59	90,48	92,41		79	143	380	2					
60	89,21	90,21		85	185	397	8					
61	89,83	90,81		113	225	216	8					
62	93,35	90,53		45	202	245	8					
63	92,48	91,04		57	211	255	8					
64	90,24	91,56		104	166	317	9					
65	90,25	90,89		88	223	528	3					
66	91,33	90,2		62	233	501	5					
67	90,1	90,97		70	210	749	4					
68	92,06	91,52		68	166	128	7					
69	90,94	90,83		79	195	483	16					
70	89,15	90,44		105	203	447	3					
71	90,11	90,6		93	231	586	5					
72	89,09	90,22		101	197	442	9					
73	90,3	91,01		73		541	5					
74	91,15	90,22		78		326	9					
75	90,86	90,92		65		290	5					
76	91,31	90,68		71		312	10					
77	89,88	92,18		100		295	9					
78	91,41	91,74		70		77	5					
79	90,25	90,93		78		4	10					
80	90,58	91,71		83		398	7					
81	91,19	90,06		82		374	12					
82	90,35	91,08		109		236	7					
83	90,84	90,5		95		280	10					
84		90,35		89		582	9					
85		90,8		98		191	18					
86		90,68		66		432	7					
87		91,12		73		49	6					
88		89,7		84		405	4					
89		90,87		59		296	8					
90		90,07		124		552	5					
91		90,8		76		285	3					
92		90,09		46		100	4					
93		89,91		66		680	4					
94		90,15		95		308	6					
95		90,3		73		229	9					
96		90,4		80		353	6					
97		90,43		90		176	7					
98		90,5		81		125	7					
99		90,94		120		358	8					
100		91,02		81		411	8					
$X_{i(Ni-20)}$	90,75	90,71	95,77	80,04	199	309,6	6,975	8,591	0	106,5	92,54	98,96

APPENDIX G2: Statistics of additional replications for alt. 2 under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	90.88	89.52	95.58	68	182	153	0	0	0	108.9	87.51	99.22
22	90.36	90.98	95.58	126	196	311				103.6	84.32	105.1
23	89.83	89.39	95.7	87	229	208				106.4	91.35	105
24	90.36	91.61	95.55	57	185	418				105.1		101.9
25	91.07	89.93	96.01	91	211	285				113.2		110.8
26	90.54	89.66	95.75	93	233	301				110.7		107.4
27	90.08	90.18	96.12	95	229	113				99.75		101.2
28	91.18	90.03	95.84	94	215	435				104.4		113.6
29	90.76	90.07	95.77	63	244	460				109.8		105
30	92.45	91.02	96.06	78	195	190				113		110.8
31	91.42	90.83	95.86	105	209	117				117		105.6
32	90.07	90.99	95.12	53	208	583						94.73
33	90.05	91.03	96.07	82	198	154						104.5
34	90.83	91.58	95.99	98	167	217						110.3
35	89.93	91.25	95.75	50	178	324						108.9
36	90.99	90.59	95.31	89	208	417						94.79
37	89.5	90.25	95.5	73	189	506						
38	91.96	90.2	95.93	102	198	241						
39	90.33	90.15	95.55	107	221	457						
40	90.31	90.37	95.55	54	236	322						
41	92.01	91.02	95.24	80	206	468						
42	91.34		95.56	104	226	407						
43	90.22		95.65	93	199	298						
44	89.6		95.8	90	194	151						
45	91.32		95.48	101	199	215						
46	90.01		95.84	90	206	378						
47	91.55		95.88	123	190	194						
48	89.3		95.62	90	202	189						
49	91.28		95.48	79	190	261						
50	90.78		96.02	39	158	58						
51	92.81		95.99	64	225	130						
52	90.63		96.2	79	212	116						
53	91.44		95.47	61	205	432						
54			96.3	110	207	3						
55			95.9	94	191	247						
56			95.53	69	237	355						
57			95.65	94	206	443						
58			95.74	112	135	215						
59			95.6	59	194	341						
60			95.55	99	198	170						
61			95.35	64		519						
62			96.33	106		0						
63			96.04	80		251						
64			95.75	64		95						
65			95.31	88		318						
66			95.7	93		602						
67			95.78	63		285						
68			95.54	53		155						
69			95.6	85		84						
70			95.53	81		525						
71			95.78	87		202						
72			96.1	68		171						
73			96.22	69		55						
74			96.07	101		169						
75			95.41	49		468						
76			95.76	108		244						
77			95.76	80		247						
78			95.93	90		258						
79			95.87	83								
80			95.79	97								
81			95.72	113								
82			95.8	124								
83			96.05	108								
84			95.59	57								
85			95.67	70								
86			96.04	83								
87			96.3	78								
88			96.07	91								
89			95.92	92								
90			95.26	86								
91			95.87	94								
92			95.25	78								
93			95.49	105								
94			95.85	77								
95			96.21	94								
96			95.73	70								
97			96.09	78								
98			95.28	109								
99			96.19	54								
100			95.54	80								
$X_{i(Ni-20)}$	90,76	90,51	95,76	84,31	202,8	274,7	0	0	0	108,3	87,73	104,9

APPENDIX G3: Statistics of additional replications for alt. 3 under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	95.47	97.85	97.88	23	76	227	5	5	0	101.2	112.5	103.3
22	96.61	97.97		60	118	76	4	7	0	118.3	119.2	
23	95.94	97.81		26	93	131	3	9	0	112.6	101.6	
24	95.94	97.08		49	65	183	7	9	0	130.4	111.3	
25	96.45	97.9		30	73	170	9	10		111.4	109.5	
26	95.31	97.8		73	62	162	3	6		125.6		
27	95.52	97.39		67	84	187	5	8		116.3		
28	95.15	98.02		83	115	516	5	5		113		
29	96.99	98.25		49	66	415	7	8		95.08		
30	97.14	96.33		45	91	196	6	5		107.5		
31	97.15	97.3		40	82	348	3	7				
32	96.05	98.14		34	72	397	3	7				
33	93.93	95.91		24	62	222	4	5				
34	96.43	97.14		55	101	377	5	19				
35	96.8	97.92		41	82	0	13	10				
36	96.7	97.63		47	150	392	6	30				
37	97.36	97.3		41	62	368	11	13				
38	96.09	97.8		58	82	359	2	4				
39	92.82	97.48		64	57	524		11				
40	95.88	98		32		369		11				
41	96.02	97.77		40		247						
42	94.31	97.44		48		272						
43	96.6	98.16		13		261						
44	96.65			76		287						
45	95.48			84		128						
46	94.91			60		393						
47	96.23			72		495						
48	96.15			45		269						
49	95.98			33		345						
50	93.25			138		1873						
51	96.22			63		230						
52	95.81			35		190						
53	96.29			60		770						
54	97.68			25		239						
55	96.45			41		382						
56	97.45			39		414						
57	96.58			46		330						
58	96.23			59		727						
59	95.96			36		146						
60						103						
61						347						
62						102						
63						506						
64						340						
65						321						
66						138						
67						50						
68						577						
69						259						
70						473						
71						429						
72						260						
73						195						
74						221						
75						691						
76						183						
77						125						
78						243						
79						168						
80						356						
81						256						
82						392						
83						286						
84						669						
85						168						
86						234						
87						50						
88						229						
89						106						
90						306						
91						449						
92						870						
93						282						
94						327						
95						882						
96						313						
97						374						
98						175						
99						226						
100						859						
$X_{i(Ni-20)}$	96	97,58	97,88	50,1	83,84	339,5	5,611	9,45	0	113,2	110,8	103,3

APPENDIX G4: Statistics of additional replications for alt. 4 under scenario 1.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	97.2	97.81	97.71	65	116	423	0	0	0	101.6	116.3	105.9
22	96.38	97.23	97.4	52	120	400			0	116.5	106.8	
23	96.35	97.89	97.49	35	108	350			0	110.5	112.1	
24	96.45	97.97	97.56	43	132	222			0	115.8	117.4	
25	96.41	98.16	97.64	48	93	342			0	107.8	105.5	
26	96.55	98.42	97.68	68	60	390			0	117.3	106.7	
27	96.64	98.01	97.61	62	131	291			0	115.8	123.1	
28	96.87	98.54	97.47	30	98	184			0	108	115.1	
29	97.27	97.87	97.63	67	116	395			0	114.6	122.1	
30	97.56	98.38	97.58	45	105	216			0	111	99.46	
31	97.02	97.85	97.42	47	80	507			0	92	108.7	
32	96.82	97.35	97.55	59	113	265			0	111.4	108.9	
33	97.05	97.62	97.5	56	118	379			0	115	115.8	
34	97.27	95.97		22	72	341			0	100.1	126.2	
35	96.44	96.9		51	98	47			0	102.2	122.4	
36	97.11	97.44		48	77	413			0	99.48	105.3	
37	96.23	97.26		46	106	387			0	120.6	124.7	
38	96.6	97.72		57	82	107			0	85.68	109.2	
39	95.45	98.23		48	74	102			0	101.5	124.5	
40	96.6	97.72		59	120	363			0	117.4	120.6	
41	97.6	98.19		23	83	90			0	88.56	108.4	
42	96.97	98.08		34	53	249			0	109.7	109.5	
43	96.37	97.25		73	101	358			0	124	123.5	
44		98.31		45	105	413			0	106.6	100.9	
45		98.26			76	289			0	117.4	113.4	
46		96.84			73	510			0	112.3	117.3	
47		98.33			77	318			0	107.9	115	
48		97.34			110	258			0	108.5	112.9	
49		98			82	331			0	102.4	112.3	
50		97.96			111	328			0	112.8	110.9	
51		98.21			80	367			0	107.2	108.1	
52		97.78			122	707			0	105.1	107.7	
53		97.84			86	280			0		109.5	
54		97.37			115	195			0		106.7	
55		98.3			110	428			0		116.9	
56		98.36			110	352			0		122	
57		98.15			99	252			0		98.95	
58		98.23			85	543			0		112.4	
59		97.48			115	716			0		119.3	
60		98.13			80	157			0		116.5	
61		97.5			125	497			0		112.2	
62		98.52			58	343			0		107.3	
63		97.08			92	351			0		117.8	
64		96.44			133	1289			0		85.83	
65		97.42			83	117			0		109.6	
66		97.88			114	478			0		114.6	
67		98.51			121	1034			0		104.9	
68		97.78			88	735			0		113.4	
69		97.9			87	427			0		111.5	
70		97.43			80	135			0		115.2	
71		97.08			93	349			0		126.7	
72		98.55			89	279			0		125.3	
73		96.15			98	208			0		119.6	
74		97.62			85	236			0		119.2	
75		98.29			82	232			0		107.9	
76		98.28			95	254			0		109.8	
77		97.97			69	462			0		105.4	
78		98.4			81	324			0		102	
79		97.83			66	421			0		112.1	
80		97.85			85	72			0			
81		98.07			77	385			0			
82		97.36			90	290			0			
83		96.84				488			0			
84		98.18				261			0			
85		98.25				205			142			
86		97.46				368			0			
87		97.55				194			0			
88		97.97				557			0			
89		97.76				799			27			
90		98.2				312			0			
91		97.61				530			0			
92		96.97				520			0			
93		97.43				25			0			
94		98.12				272			0			
95		97.32				331			0			
96		97.8				262			0			
97		94.7				285			0			
98		98.51							0			
99		97.42							0			
100		98.2							0			
$X_{i(Ni-20)}$	96,75	97,74	97,56	49,29	94,89	358,3	0	0	2,113	108,3	112,8	105,9

APPENDIX H1: Statistics of initial replications for alternative 1 (existing system) under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	87,8	89,16	94,4	174	359	1389	11	40	5	121,89	107,09	114,42
2	89,61	90,19	94,37	160	277	1371	9	19	0	119,33	103,25	113
3	87,63	90,14	94,3	165	316	1349	32	38	0	120,97	106,64	114,54
4	86,48	88,3	92,75	267	391	2492	49	54	391	99,69	94,68	90,65
5	88,28	89,2	94,51	180	296	1285	29	27	8	116,13	106,16	117,61
6	89,4	90,21	94,6	161	278	1350	6	24	0	118,47	102,27	112,21
7	89,77	90,15	94,73	148	296	1219	12	34	0	112,14	107,34	114,55
8	89,56	89,87	94,78	112	284	1046	9	19	0	125,63	101,24	110,8
9	88,13	89,85	94,19	173	310	1303	14	29	44	120,09	102,3	109,95
10	88,16	89,41	93,99	211	333	1699	40	26	0	102,85	98,28	101,78
11	89,09	89,18	94,46	133	333	1202	8	27	5	124,29	106,24	11,61
12	89,57	90,07	93,93	153	323	1668	22	29	0	105,56	101,09	98,07
13	90,7	89,6	94,75	119	291	1280	23	26	0	119,48	108,14	112,2
14	90,01	89,77	94,07	129	307	1446	9	36	0	118,39	107,59	115,59
15	88,18	89,89	94,58	187	306	1222	18	30	6	124,28	107,52	113,2
16	87,98	89,34	94,6	195	314	1238	20	27	0	115,48	101,33	116,33
17	89,46	89,58	94,56	142	299	1219	20	13	3	129,7	11,61	111,88
18	89,8	89,74	94,22	129	307	1369	22	16	0	111,26	102,01	116,06
19	88,93	89,85	94,7	164	313	1245	22	32	15	115,22	108,36	91
20	87,03	89,09	93,01	200	380	2378	27	49	255	97,39	89,52	115,06
MEAN	88,7785	89,6295	94,275	165,1	315,65	1438,5	20,1	29,75	36,6	115,912	98,633	105,0255
VARIANCE	1,1999397	0,2332892	0,2919421	1318,0947	958,34474	138878,79	127,56842	104,19737	10180,779	76,906059	443,23546	548,23909
ST. DEV.	1,0954176	0,4830002	0,5403167	36,305574	30,957144	372,66445	11,294619	10,207711	100,89985	8,76961	21,053158	23,414506
CI(α=0,05)	1,023861	0,4514489	0,5050212	33,933964	28,934912	348,32067	10,556814	9,5409069	94,308706	8,1967476	19,67789	21,884986

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APPENDIX H2: Statistics of initial replications for alternative 2 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	88,21	89,8	94,67	201	312	1105	14	3	0	124,09	102,63	109,51
2	89,91	90,52	94,32	184	293	1337	1	9	0	115,27	97,09	108,72
3	89,8	91,05	93,72	166	294	1739	1	2	43	108,07	94,09	102,91
4	89,57	90,25	94,8	192	283	1328	5	0	0	120,46	105,42	115,24
5	87,87	89,52	94,12	232	356	1806	14	12	23	109,91	91,7	104,72
6	87,89	90,54	94,42	208	305	1367	9	0	0	128,11	100,6	115,95
7	87,78	90,31	93,97	206	318	1690	7	7	0	108,78	93,11	101,69
8	90,2	89,72	94,47	144	338	1401	0	12	0	118,53	106,13	113,32
9	90,69	90,13	94,24	142	322	1234	1	0	0	128,61	98,72	109,37
10	90,1	89,58	94,95	179	345	1289	0	10	0	109,25	104,5	113,27
11	87,53	89,3	93,95	185	384	1604	5	25	0	106,92	94,23	99,37
12	90,02	90,11	94,77	160	334	1281	0	21	0	11,33	103,91	113,5
13	89,44	89,87	94,72	142	339	1311	0	0	0	122,48	104,67	120,34
14	88,9	90,6	94,4	153	274	1430	0	0	0	118,92	105,12	116,62
15	88,49	89,48	94,34	202	374	1707	6	20	16	110,86	92,94	102,81
16	89,32	89,93	93,79	180	337	1811	13	7	33	110,16	95,44	103,31
17	89,13	88,97	94,38	159	359	1612	1	11	0	104,81	102,15	102,77
18	89,22	89,1	94,41	162	375	1660	0	18	0	111	95,06	104,41
19	89,3	90,59	93,89	163	294	1870	0	2	0	112,99	101,78	104,07
20	90,09	89,87	94,42	148	340	1222	0	7	0	115,44	108,04	114,42

MEAN	89,173	89,962	94,3375	175,4	328,8	1490,2	3,85	8,3	5,75	109,7995	99,8665	108,816
VARIANCE	0,8648853	0,3013958	0,1209882	654,67368	1019,1158	54272,484	25,502632	61,378947	161,14474	586,08235	27,347266	37,7199
ST. DEV.	0,9299921	0,5489953	0,3478335	25,586592	31,923593	232,96456	5,050013	7,8344717	12,69428	24,209138	5,2294614	6,14165
CI(α=0,05)	0,8692417	0,5131329	0,3251118	23,915184	29,838229	217,74648	4,7201281	7,322696	11,865044	22,62771	4,8878542	5,74046

APPENDIX H3: Statistics of initial replications for alternative 3 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	93,144	96,15	96,2	158	258	1362	36	53	7	116,92	125,54	112,78
2	94,43	96,52	95,7	142	228	1780	19	22	9	110,78	114,33	102,8
3	95,13	96,94	96,47	128	177	1338	18	30	46	111,86	118,94	11,67
4	93,8	96,82	95,86	120	207	1741	6	39	11	109,01	114,93	99,23
5	95,07	96,9	96,44	120	193	1263	14	16	0	120,19	124,84	114,16
6	95,22	95,89	96,63	114	170	1234	11	17	0	114,26	128,03	111,13
7	92,94	95,67	95,23	193	235	2392	35	37	285	100,62	109,09	93,28
8	93,88	96,89	96,48	134	190	1271	13	28	0	115,4	123,69	113,76
9	94,87	96,57	96,64	129	164	1136	16	14	12	118,81	118,1	114,1
10	94,28	96,9	96,34	156	186	1311	31	27	0	111	118,89	111,08
11	95,84	96,66	96,58	84	176	1061	5	22	0	113,79	121,21	108,81
12	94,96	95,8	96,22	127	199	1730	14	12	58	107,37	113,55	103,93
13	94,66	95,94	95,96	133	289	1634	11	37	23	110,69	115,33	102,93
14	93,92	96,54	96,34	129	217	1371	30	31	0	118,04	121,29	116,06
15	94,68	96,45	96,39	134	213	1285	11	31	0	121,36	122,18	111,1
16	93,49	96,68	95,89	111	182	1904	24	16	15	108,67	111,52	104,15
17	92,69	96,75	95,96	139	215	1661	4	24	11	114,83	109,99	102,91
18	95,58	96,64	96,29	105	193	1279	13	26	5	121,45	119,48	110,66
19	93,5	96,21	95,72	189	260	1763	29	47	13	11,56	113,27	102,36
20	95,05	96,85	95,76	138	226	1784	18	21	44	116,42	124,31	103,32
MEAN	94,3567	96,4885	96,155	134,15	208,9	1515	17,9	27,5	26,95	108,6515	118,4255	102,511
VARIANCE	0,8070073	0,1636134	0,1429947	656,23947	1091,4632	107092,74	96,094737	120,47368	3977,8395	549,3478	30,159089	493
ST. DEV.	0,8983358	0,4044916	0,3781464	25,617171	33,037299	327,25027	9,8027923	10,97605	63,070116	23,43817	5,4917292	22,2036
CI(α=0,05)	0,8396533	0,3780687	0,3534446	23,943766	30,879185	305,87311	9,1624388	10,259056	58,950149	21,907104	5,1329897	20,75318

APPENDIX H4: Statistics of initial replications for alternative 4 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	93,99	97,08	96,36	164	225	1274	0	0	4	112,89	124,53	113,71
2	95,61	97,21	96,31	123	173	1408	0	0	0	113,14	124,78	109,2
3	92,45	96,48	94,71	242	277	2555	46	31	358	102,3	100,93	94,06
4	95,36	96,86	95,7	155	199	1881	4	7	1	110,01	114,68	102,52
5	95,62	97,08	96,33	113	202	1257	0	0	22	108,32	126,36	113,2
6	95,02	97,27	96,44	132	198	1129	0	0	0	113,36	120,47	111,73
7	95,27	97,45	96,62	128	186	1205	0	0	0	124,8	126,5	112,22
8	94,98	96,88	96,34	148	204	1387	0	0	0	116,8	118,85	115,16
9	94,85	97,15	96,22	127	196	1429	0	2	0	119,9	116,1	110,12
10	95,91	97,4	96,35	108	195	1192	0	0	0	104,98	117,9	110,45
11	94,88	96,9	96,07	161	214	1320	0	0	0	122,09	124,84	110,71
12	94,97	96,81	95,82	155	234	1761	3	6	22	108,23	109,37	104,67
13	95,41	96,98	96,42	134	197	1262	0	0	0	120,25	115,08	113,24
14	94,52	96,81	95,85	126	247	1729	6	60	14	104,72	116,87	102,23
15	94,32	96,94	95,95	177	246	1771	1	9	19	104,14	110,93	102,57
16	94,33	97,06	95,82	149	212	1799	7	9	46	107,14	115,43	104,12
17	94,69	96,8	95,84	190	231	1700	1	0	26	109,03	103,57	102,22
18	95,69	97,07	96,44	108	189	1246	0	0	0	112,21	120,546	112,24
19	95,56	97,05	96,48	96	194	1101	0	0	0	123,05	120,16	111,72
20	95,26	97,22	96,56	123	185	1159	0	25	0	113,81	112,57	112,22

MEAN	94,9345	97,025	96,1315	142,95	210,2	1478,25	3,4	7,45	25,6	112,5585	117,0233	108,4155
VARIANCE	0,6066155	0,0522263	0,1916661	1137,4184	665,11579	129321,04	105,09474	227,73421	6283,7263	45,504761	50,580729	30,6434
ST. DEV.	0,7788553	0,2285308	0,4377968	33,725634	25,789839	359,61235	10,251572	15,090865	79,269958	6,7457217	7,112013	5,535649
CI(α=0,05)	0,7279776	0,2136023	0,4091984	31,522555	24,105154	336,12118	9,5819029	14,105076	74,091761	6,3050669	6,6474308	5,17404

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APPENDIX I1: Statistics of additional replications for alt. 1 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	88,21	90,66	94,54	168	262	1146	17	18	0	117,4	106,2	118,3
22	88,25	90,11	94,6	175	296	1428	25	21	4	126,4	11,54	113,3
23	88,67	89,45	94,29	187	318	1266	37	52	0	115,4	106,6	116,6
24	88,29	89,39	94,65	190	318	1245	22	19	20	120,8	103,8	117,2
25	88,73	89,87	94,5	196	299	1354	20	35	0	126,6	98,23	103,4
26	88,03	90,5	93,63	172	309	1859	14	21	2	119,8	100,1	114,1
27	89,24	90,12	94,6	175	302	1257	16	33	0	117,2	103,3	111,2
28	88,51	90,53	94,26	152	266	1283	22	19	0	117,1	105,8	92,92
29	86,87	88,81	92,93	231	400	2560	42	56	361	103,1	93,9	101,7
30	89,01	90,28	93,73	176	262	1808	13	11	39	116,7	99,43	112,1
31	89,64	89,66	94,52	142	339	1335	14	43	0		100,8	115,8
32	91,11	89,88	94,68	112	311	1195	15	28	0		103,6	118,8
33	87,99	89,71	94,57	194	328	1362	22	38	0		109,3	105,5
34	89,24	89,33	93,72	180	340	1909	22	28	85		102,8	102,6
35	86,49	89,93	93,73	233	291	1768	44	10	38		100,5	100,4
36	89,85	90,35	93,77	96	275	1653	13	40	56		95,88	103,4
37	87,61	88,99	93,55	219	296	1844	24	19	8		99,49	114,6
38	88,3	89,82	94,9	179	314	1151	28	27	0		108,1	110,5
39	89,12	89,16	94,75	158	353	1226	25	44	0		103,1	114
40	88,04	89,81	94,77	168	312	1206	25	27	0		102,3	114,5
41	86,3	89,89	94,44	208	320	1350	30	39	0		101,9	114,3
42	90,15	89,19	94,97	123	316	901	8	24	0		100,7	112,8
43	89,95	89,64	94,5	180	324	1214	24	34	0		102,3	101,4
44	88,88	90,04	93,78	187	270	1727	34	18	3		96,3	100,9
45	88,98	89,01	93,63	169	328	1660	17	45	34		98,11	104
46	89,13	89,67	96,74	166	326	1707	19	31	0		101,3	116,4
47	88	89,72	94,4	193	295	1416	16	21	56		108	109,8
48	88,22	90,19	94,7	177	279	1212	20	27	1		99,7	100,5
49	88,27	89,55	94,32	179	320	1684	34	28	0		97,33	106,1
50	89,28	89,92	94,48	148	294	1627	19	28	16		97,56	105,3
51	89,62	89,4	93,68	170	329	1874	12	34	0		103,4	111,7
52	89,34	89,32	94,2	150	338	1357	14	50	0		100,9	102
53	88,13	89,51	93,81	198	324	1727	34	35	0		95,7	112,9
54	88,17	90,18	94,85	190	286	1133	20	35	68		102,7	109,8
55	90,2	90	94,53	141	277	1263	20	10	0		108,3	109,7
56	88,46	89,49	94,43	157	297	1208	17	30	33		105,6	103,6
57	87,72	88,85	94,13	190	377	1285	25	33	0		97,71	102,3
58	88,6		94,05	176	334	1727	22	24	57		94,11	111,2
59	89,56		94,44	184	282	1370	33	17	2		105,5	112,2
60	88,54		94,26	193	276	1306	29	16	0		100,9	113,9
61	89,38		94,6	164	294	1413	18	26	0		100,6	110,2
62	89,93		94,1	168	296	1089	12	33	0		99,8	113,6
63	88,86		94,91	148	295	1780	16	37	11		99,29	103,5
64	89,25		93,78	187	318	1394	36		0		93,8	113,5
65	88,95		94,43	162		1333	10		0		102,2	116,8
66	89,64		94,55	174		1329	13		0		105,2	108,7
67	88,04		94,14	160		1672	15		0		103,4	101,8
68	88,89		94,35	157		1668	18		53		94,67	100,6
69	87,15		93,85	226		1579	43		0		94,37	104,2
70	88,21		94,49	179		1333	15		0		98,08	109,7
71	89,12		94,14	160		1308	18		0		105,1	111,6
72	88,4			178		1411	12		0		101	110,2
73	88,6			153		1327	22		0		105,5	115,8
74				176		1263	20		16		108	116,6
75				183		1776	136		44		104,3	105
76				185		1234	23		0		93,71	114,8
77				156		1751	11		31		99,12	103,1
78				152		1382	14		0		93,18	116,3
79				182		1827	21		39		107,4	104,5
80				204		1840	37		0		93,73	116,8
$X_{i(Ni-20)}$	88,7	89,73	94,32	173,9	308,8	1472	23,62	29,4	17,95	118,1	99,58	109,3

APPENDIX I2: Statistics of additional replications for alt. 2 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	90,5	90,25	94,29	148	301	1293	0	3	0	115,2	101,6	111,1
22	88,62	89,75	94,11	208	327	1645	14	8		117,3	97,23	100,6
23	90,23	90,37	94,4	141	294	1600	1	2		107,5	93,43	104,4
24	90,76	89,76	94,3	147	307	1628	0	0		101,5	97,05	105,9
25	88,39	90,27	94,84	171	317	1075	0	0		109,8	96,42	114,1
26	89,03	90,4	94,56	164	279	1453	0	0		119,7	104,6	118,3
27	88,8	90,6	95,06	162	302	1132	5	5		116,7	106,5	113,9
28	88,88	89,83	94,58	161	317	1372	0	5		119,6	103,4	116,8
29	89,04	90,13	93,69	203	290	1664		1		112,4	97,52	100,9
30	89,83	89,97	94,08	137	327	1753		2		116,8	99,01	103,3
31	89,8	90,19		136	298	1349		0		106,4		109,5
32	88,62	88,23		222	406	2381		36		107,3		92,54
33	88,34	89,55		211	358	1699		10		111,9		102,7
34	89,53	90,2		133	281	1267		0		104,4		109,1
35	88,07	90,25		188	315	1201		1		112,5		109,4
36	87,07	90,53		229	288	1784		3		103,6		105,8
37	88,11	91,25		177	270	1335		0		113,7		114,4
38	89,49	90,32		161	313	1194				125,2		114,9
39	88,15	90,1		175	303	1289				118,1		111,4
40	88,39	89,94		1714	343	1156				118,2		111,5
41	89,69	89,72		165	343	1644				112,3		107,8
42	89,92	89,92		158	350	1327				121		
43	86,43	89,73		284	381	2679				96,89		
44	90,49	90,41		161	277	1320				109,8		
45	89,32	89,55		177	329	1383				114,6		
46	88,99	90,41		187	317	1848				106		
47	90,86	90,3		139	301	1289				116,6		
48	88,32	89,81		202	338	1730				108,6		
49	91,54	90,12		105	311	1134				130,8		
50	89,12	90,09		190	323	1764				107,2		
51	89,15	89,56		178	362	1642				103,9		
52	91,19	90,27		130	319	1752				105,5		
53		89,82		180	338	1882				113,1		
54		89,89		162	322	1198				119		
55		90,17		196	323	1698				113,2		
56		90,14		242	324	2549				104,9		
57		89,87		122	336	1325				118,3		
58		90,56		163	259	1430				119,7		
59		89,8		232	370	1666				111,1		
60		89,85		190	301	1654				108,3		
61		89,8		199	335	1129				117,2		
62		90,89		128	293	1420				107,5		
63		90,16		191	302	1154				119,2		
64		90,16		193	260	1429				117,1		
65		90,22		164	294	1063				120,5		
66		90,38		146	316	1175				124,3		
67		90,67		154	287	1213				118,5		
68		90,45		166	302	1401				107,7		
69		90,94		177	248	1330				112,5		
70		90,41		147		1352				121,7		
71		89,89		149		1244				112,4		
72		90,42		203		1925				104,4		
73		89,74		164		1199				112,2		
74				196		1423				118,9		
75				170		1265				113,7		
76				198		1761				98,34		
77				156		1171				110,3		
78				195		1372				117,7		
79				179		1854				108,2		
80				239		1493				116,9		
$X_{i(Ni-20)}$	89,21	90,11	94,39	201,1	314,2	1493	2,5	4,471	0	113	99,68	108,5

APPENDIX I3: Statistics of additional replications for alt. 3 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	93,63	96,68	96,37	119	205	1307	15	29	0	119,9	118,9	113,1
22	95,66	96,81	96,19	81	180	1224	10	29	12	111,7	123,8	109,6
23	95,02	95,85	96,54	77	187	1314	11	21	44	127,9	129	114,9
24	95,61	96,19	96,1	115	222	1647	15	39	35	104,4	103,6	100,5
25	95,12	95,69	96,17	141	185	1247	15	35	4	112,9	116,7	109,7
26	93,02	96,64	95,71	188	208	1883	17	16	61	119	118,6	103,1
27	94,94	96,21	96,53	115	209	1235	10	32	0	112,6	115,9	109,6
28	95,23	96,95	96,02	100	210	1622	6	38	0	109,5	117,6	102,8
29	93,67	96,73	96,66	156	235	1093	21	38	8	122,1	126	112,1
30	93,64	96,5	96,33	151	179	1352	12	21	0	121	114,6	110,1
31	94,42	96,73	95,74	164	225	1873	21	21	69	112,1	119,2	104,8
32	93,78	96,59	96,28	149	236	1397	12	22	0	123	126,1	111,2
33	94,55	96,78	96,05	142	205	1367	13	27	0	124,3	127,7	115,5
34	95,01	96,98	95,91	121	197	1650	11	17	59	11,17		104,3
35	94,03	96,21	95,8	163	259	1860	30	35	32	113,1		105,9
36	94,34	96,93	96,46	133	197	1311	10	26	13	112		111,7
37	94,18	96,71	96,38	119	198	1177	40	47	19	122,6		111,2
38	94,59	96,4	96,17	148	245	1711	21	31	41	106,1		100,7
39	94,62	97,05	96,39	138	198	1233	15	22	0	116,6		111,1
40	95,38	97,01	96,65	114	154	1298	12	8	0	108,4		110,5
41	94,53	95,06	96,46	131	149	1200	11	11	5	120,7		111,2
42	94,39	97,06	96,39	135	184	1243	20	11	0	113,4		110,7
43	95,23	97,4	96,52	104	145	1296	5	22	0	122,9		114,7
44	94,3	96,89	96,12	135	231	1639	11	41	0	113		102,6
45	95,01	95,88	96,16	138	220	1338	24	25	29	122,7		113,6
46	95,19	96,22	96,55	153	204	1185	34	29	2	11,91		106,2
47	94,9	96,6	96,42	128	200	1147	15	45	6	117,5		108,8
48	94,47	96,42	96,07	139	244	1721	12	33	3	111,5		102,7
49	95,21	96,36	95,91	126	159	1691	12	13	5	112,6		102,9
50	94,56	96,26	96,1	117	249	1628	26	51	2	100,5		102,7
51	94,98	96,3		110	231	1382	12	37	0	120,9		113,2
52	93,78	96,57		143	158	1751	14	9	9	106,4		104,9
53	94,21	96,96		160	209	1359	25	25	12	119,1		113,1
54	95,6	96,4		107	192	1263	11	16	0	124,9		114,1
55	94,11	96,62		140	203	1263	37	38	4	118,1		113,8
56	93,94			140	170	1351	10	15	10	120,6		114,9
57	94,56			134	216	1339	13	37	54	114,5		109,6
58	92,85			160	230	2298	23	32	248	105		94,99
59	94,41			171	252	1889	19	22	33	118,1		105,1
60	95,07			83	182	1220	11	15	0	115,8		112,2
61	95,31			95	189	1347	15	20	0	113,7		113,5
62	94,43			143	202	1622	15	35	0	110,9		103,6
63	94,29			161	189	1903	10	23	49	114,3		103,4
64	94,44			118	189	1379	7	23	0	124		113,6
65				188	247	2391	49	57	312	97,35		94,69
66				147	164	1685	20	11	41	111,8		103,3
67				147	187	1373	23	12	10	120,1		116,2
68				99	177	1319	9	24	0	115,8		113,2
69				149	191	1340	15	22	0	117,3		112,1
70				101	191	1342	10	24	0	110,9		110,3
71				135	205	1460	26	40	15	112,2		111,6
72				206	252	2582	38	53	335	97,31		94,19
73				133	240	1275	14	29	0	121,9		115,6
74				133		1302	10		0	119,9		114,2
75				136		1275	18		0	123,5		116,6
76				103		1227	16		9	117,7		111,8
77				139		1270	12		0	118,2		113,4
78				156		1725	19		23	107,3		103
79				135		1139	11		0	122,3		110,2
80				131		1352	17		0	113,7		109,8
$X_{i(Ni-20)}$	94,55	96,53	96,24	134,1	203,5	1472	16,93	27,43	26,88	111,8	119,8	108,8

APPENDIX I4: Statistics of additional replications for alt. 4 under scenario 2.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	93,59	96,52	94,66	199	266	2664	36	1	445	98,2	104,3	94,79
22	95,94		96,13	118	196	1688	0	12	51		111,8	101,7
23	95,06		95,86	153	254	1772	2	0	19		113,9	104
24	94,87		96,7	142	199	1160	0	0	0		117,2	112,2
25	95,33		96,4	136	207	1387	0	3	19		116,6	114,3
26	94,06		96,44	156	234	1291	0	0	7		125,8	114,6
27	95,01		96,48	98	193	1390	0	0	0		121,7	115,3
28	94,87		96	152	204	1720	10	4	0		109,4	102,2
29	96,2		96,32	129	208	1404	0	0	0		122,6	109,8
30	95,03		96,22	135	222	1744	4	0	31		114,6	105,5
31	95,17		96,45	118	169	1293	0	1	22		122,5	111,9
32	94,55		95,78	169	233	1825	3	4	72		114,2	101,5
33	94,55		96,49	105	193	1250	0	10	6		129,2	113,5
34	94,27		96,15	202	281	1665	10	4	46		111,8	
35	94,69		95,85	165	223	1652	1	1	0		107,1	
36	94,81		96,03	142	221	1668	8	13	9		114,1	
37	95,81		96,68	111	233	1105	0	10	0		128,4	
38			96,04	105	259	1621	0	33	0		113,3	
39			95,03	179	265	2471	22	0	298		104,2	
40			96,31	133	175	1191	0	0	0		118,2	
41			96,41	153	199	1283	0	2	0		116,5	
42			96,42	163	209	1184	0	0	0		126,3	
43			96,45	150	208	1281	1	11	0		125,2	
44			95,94	133	209	1792	3	2	79		113,1	
45			96,26	180	207	1285	11	1	51		122,3	
46			96,05	146		1611	0	6	51		109,3	
47			95,91	215		1625	8	48	0		113,1	
48				226		2565	54	0	327		102,2	
49				109		1331	0	0	0		124,9	
50				153		1577	3	0	0		190,9	
51				120		1422	0	12	0		124,4	
52				132		1669	0	0	36		114,2	
53				147		1392	0	0	15		118,7	
54				98		1373	0	5	10		114,2	
55				140		1290	0	0	0		124	
56				163		1235	0	23	2			
57				218		2468	28	7	291			
58				173		1726	5	8	0			
59				114		1361	0	0	0			
60				112		1430	0	0	7			
61				128		1671	0	41	1			
62				222		2697	30	23	352			
63				112		1142	0	0	0			
64				128		1291	0	26	41			
65				219		2576	33	0	415			
66				145		1700	0	6	4			
67				108		1335	0	0	0			
68				142		1326	0	0	0			
69				151		1734	4	7	9			
70				153		1822	5	0	63			
71				133		1234	0	0	0			
72				127		1074	0	0	0			
73				176		1449	0	0	39			
74				147		1376	0	0	0			
75				158		2003	11	0	45			
76				133		1275	0	0	0			
77				106		986	7	7	0			
78				182		1775	0	0	30			
79				99		1316	15	30	0			
80				179		2458	0	0	324			
$X_{i(Ni-20)}$	94,93	96,52	96,13	147,3	218,7	1585	5,233	6,017	53,62	98,2	118,9	107,8

APPENDIX J1: Statistics of initial replications for alternative 1 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	85,84	87,55	92,7	271	450	2679	67	93	168	111,49179	100,76224	104,07602
2	85	88,26	92,25	274	403	2984	51	53	347	103,63206	101,69405	104,69579
3	86,09	88	92,69	254	440	2697	49	74	272	106,89414	102,91403	100,38323
4	85,24	88,07	92,53	278	424	2701	68	57	107	117,114	105,78474	105,78468
5	85,41	88,17	92,98	253	394	2550	50	77	111	109,05911	97,774686	103,80718
6	86,34	88,3	93,05	226	387	2045	52	67	163	103,72171	102,07476	100,29851
7	85,86	89,06	93	284	393	2364	55	69	151	112,40771	101,23095	101,75879
8	84,86	87,89	92,48	264	434	2762	47	63	246	109,93709	101,27713	103,71278
9	87,6	88,39	93,17	207	424	2311	38	67	147	109,82729	104,05231	101,47231
10	86,48	88,79	93,06	220	370	2227	47	49	126	102,53763	96,070157	98,739163
11	85,66	87,94	92,65	264	440	2714	49	78	276	112,25275	104,92927	105,36081
12	85,67	87,77	92,98	237	418	2387	53	77	156	107,64133	103,95884	104,08923
13	87,57	88,13	92,75	221	411	2833	44	75	140	109,11766	97,619475	103,39228
14	84,31	87,35	92,67	314	461	2652	65	101	260	110,37068	98,983773	104,81109
15	85,79	88,37	92,58	279	382	2764	49	60	110	116,32424	99,967702	104,99421
16	86,66	88,97	92,9	255	391	2506	52	59	177	109,43695	107,56009	104,89058
17	87,11	88,57	93,05	236	385	2560	62	75	149	100,94146	101,19187	105,03297
18	84,61	88,07	92,83	290	409	2207	75	83	153	106,29254	97,853232	99,828277
19	86,57	88,38	92,62	223	382	2595	67	60	194	112,16952	101,47811	99,535625
20	86,77	88,11	92,85	239	405	2622	56	79	131	118,26164	100,88371	106,41861
MEAN	85,972	88,207	92,7895	254,45	410,15	2558	54,8	70,8	179,2	109,47156	101,40306	103,15411
VARIANCE	0,8566379	0,1846747	0,0562155	785,31316	649,29211	55831,053	90,273684	170,69474	4371,2211	22,099882	8,5854084	5,4880935
ST. DEV.	0,9255473	0,429738	0,2370981	28,023439	25,481211	236,28596	9,5012465	13,06502	66,11521	4,7010512	2,9300868	2,342668
CI(α=0,05)	0,8650873	0,401666	0,22161	26,192848	23,816687	220,85091	8,880591	12,211566	61,796328	4,3939617	2,738683	2,1896366

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APPENDIX J2: Statistics of initial replications for alternative 2 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	86,21	87,88	92,88	266	448	2652	29	51	174	102,60322	99,229314	105,363
2	86,71	87,9	92,18	273	435	2904	40	44	279	104,79848	101,21825	102,239
3	85,52	87,21	92,94	291	488	2365	37	72	146	104,67936	99,089942	104,059
4	87,64	88,796	92,56	238	400	2572	32	19	122	116,65362	99,558073	105,923
5	87,49	89,3	92,94	230	380	2461	15	16	198	108,39861	97,516629	102,45
6	87,51	87,75	92,7	241	420	2611	24	25	281	102,03507	97,898472	100,882
7	86,51	87,87	92,64	271	445	2614	13	45	233	116,91902	98,843772	100,603
8	87,17	88,81	92,52	245	438	2600	18	33	144	101,23441	99,815381	98,9669
9	87,49	88,33	92,89	252	444	2662	19	40	196	103,92944	97,954212	102,662
10	88,52	88,62	92,26	215	407	2757	23	37	222	110,90411	99,655337	97,8789
11	88,05	88,12	93,39	240	439	2354	9	47	103	110,75288	100,49029	101,232
12	86	88,76	92,83	270	391	2541	45	38	263	103,88616	97,165366	104,809
13	88,24	88,11	92,2	217	410	2841	1	49	122	99,003621	93,211082	103,622
14	87,57	87,93	92,67	247	438	2674	23	18	98	116,13985	98,990575	104,368
15	86,34	88,43	93,23	259	413	2327	21	53	141	109,36582	95,976136	101,824
16	87,6	89,04	93,33	236	402	2191	10	9	121	111,72385	101,59473	100,594
17	87,59	88,78	92,33	259	391	2714	32	16	104	105,51939	99,112518	100,597
18	86,41	88,49	92,66	290	421	2411	48	25	146	110,93367	99,682912	101,471
19	86,48	89,3	93,08	256	379	2436	38	38	146	103,24784	93,206975	99,6003
20	86,59	87,62	92,33	254	434	2805	36	54	309	99,19725	97,029369	100,505
MEAN	87,082	88,3523	92,728	252,5	421,15	2574,6	25,65	36,45	177,4	107,09628	98,361967	101,982
VARIANCE	0,6520379	0,330369	0,1331116	435,21053	737,81842	35439,937	163,39737	262,26053	4395,2	31,435538	5,0354558	4,73639
ST. DEV.	0,8074886	0,5747773	0,3648446	20,8617	27,162813	188,25498	12,782698	16,19446	66,296305	5,6067404	2,2439821	2,17632
CI(α=0,05)	0,7547406	0,5372308	0,3410116	19,498939	25,388441	175,95749	11,947686	15,13658	61,965592	5,240488	2,0973972	2,03416

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APPENDIX J3: Statistics of initial replications for alternative 3 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	90,11	95,22	94,44	273	314	2649	70	87	173	106,24705	108,98841	103,5484
2	92,04	95,33	94,46	219	301	2709	41	61	173	117,37291	111,03129	102,8576
3	92,32	95,66	94,5	204	293	2692	24	73	210	117,74113	106,10373	101,9411
4	91,86	95,68	94,8	227	260	2631	46	66	155	107,87863	106,70536	102,8477
5	92,03	94,88	94,7	225	306	2506	50	96	175	105,43873	112,65426	100,2186
6	91,85	95,07	94,7	207	310	2423	38	70	102	116,86214	117,76011	104,6182
7	92,75	95,26	94,76	188	310	2374	52	83	166	105,88849	111,32094	97,71814
8	93,38	95,44	94,36	191	277	3051	22	56	296	107,83359	107,59701	106,6525
9	91,81	94,88	94,45	217	340	2711	59	82	200	103,73186	112,03404	101,0827
10	91,98	95,03	94,31	211	314	2608	50	74	184	108,54125	113,38278	101,936
11	92,2	95,25	94,79	225	312	2563	42	66	107	110,95623	113,32361	103,6271
12	90,08	94,83	94,64	219	331	2485	51	70	164	111,90981	110,22395	100,6842
13	91,81	94,91	94,75	235	335	2484	60	77	114	109,09193	116,93054	104,2684
14	90,71	95,88	94,62	235	263	2503	73	35	134	111,62482	111,45021	101,7018
15	93,49	95,13	94,56	164	314	2343	33	83	147	108,56116	112,32637	104,218
16	92,31	94,6	94,91	210	325	2261	37	55	160	118,28259	118,36013	105,4616
17	92,21	95,21	94,79	224	300	2454	41	73	176	110,83054	112,49068	104,359
18	91,26	95,15	95,01	224	315	2193	44	53	142	108,25529	114,21115	100,3724
19	92,18	94,43	94,63	203	345	2588	28	90	103	109,74841	110,16951	104,8025
20	93	95,19	95,28	167	309	2227	46	75	155	108,14832	105,38735	100,424
MEAN	91,969	95,1515	94,673	213,4	308,7	2522,75	45,35	71,25	161,8	110,24724	111,62257	102,667
VARIANCE	0,8194832	0,1247608	0,0539063	591,30526	512,85263	39792,092	185,39737	209,03947	1933,4316	18,341073	13,032112	4,783116
ST. DEV.	0,9052531	0,3532149	0,2321773	24,316769	22,64625	199,47955	13,61607	14,458197	43,970804	4,282648	3,6100017	2,187034
CI(α=0,05)	0,8461187	0,3301417	0,2170107	22,728311	21,166916	186,44883	12,72662	13,513736	41,098473	4,00289	3,3741834	2,044169

APPENDIX J4: Statistics of initial replications for alternative 4 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERCENTAGES VIA MOB.CAD.			TOTAL DEMAND FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
1	90,59	95,36	94,66	284	329	2576	41	59	165	105,83435	107,08594	102,1863
2	90,47	95,43	94,97	288	308	2269	50	34	152	107,98332	105,74783	99,00565
3	93,79	96,36	94,81	198	277	2428	0	20	158	104,61642	108,80163	102,6305
4	91,35	95,76	94,79	248	320	2400	17	27	190	98,66076	108,4871	102,6077
5	94,44	96,01	94,95	170	280	2545	0	37	155	113,01638	110,53472	102,9959
6	94,25	95,83	94,47	190	289	2742	0	41	368	114,1541	109,62111	103,1039
7	93,37	95,92	94,64	210	293	2587	3	9	176	98,907113	110,73056	100,9614
8	92,59	95,43	94,2	231	322	2876	25	53	431	101,06068	100,97496	98,83731
9	93,36	94,93	94,91	207	362	2378	4	58	143	102,79062	105,68085	102,6561
10	93,75	95,61	95,1	206	317	2152	11	26	74	98,913367	107,41066	98,69991
11	92,82	95,99	94,3	250	306	2954	15	25	229	105,4108	116,07346	107,3394
12	94,08	95,82	94,15	185	293	3110	0	15	322	105,01778	111,03731	105,3121
13	92,61	95,26	94,55	226	348	2662	4	58	152	105,71035	111,91649	102,3672
14	93,67	95,69	94,7	186	286	2554	0	18	192	109,52808	108,32504	102,7478
15	94,13	95,97	94,5	165	283	2654	0	28	287	95,052179	102,03626	102,2023
16	93,51	95,13	95,01	222	361	2356	0	48	141	103,64894	116,49583	100,4169
17	93	96,36	95,03	214	265	2346	0	5	166	107,13928	111,644	101,0274
18	91,77	95,62	94,39	260	332	2786	22	17	217	106,93549	111,84446	103,2159
19	94,2	94,85	95,11	178	360	2302	0	67	139	106,23947	106,35296	99,29536
20	93,46	96,01	94,25	213	281	2819	14	21	308	100,39301	108,82117	101,9938
MEAN	93,0605	95,667	94,6745	216,55	310,6	2574,8	10,3	33,3	208,25	104,55062	108,98112	101,9801
VARIANCE	1,4008892	0,1785168	0,0974471	1238,4711	925,2	63486,695	212,64211	338,85263	8069,25	23,240291	15,166477	4,570132
ST. DEV.	1,1835917	0,4225125	0,3121652	35,191917	30,4171	251,96566	14,582253	18,40795	89,829004	4,8208185	3,8944161	2,137787
CI(α=0,05)	1,1062752	0,3949125	0,2917734	32,893055	28,430146	235,50636	13,629688	17,205477	83,961052	4,5059054	3,6400189	1,998139

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APPENDIX K1: Statistics of additional replications for alt. 1 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	86.38	88.49	92.67	255	435	2764	61	85	190	114.4	103.1	105
22	84.28	87.37	92.58	295	477	2506	66	88	164	99.68		103.6
23	87.03	87.07	92.59	229	454	2655	57	87	200	100.8		103.4
24	85.93	88.34	93.43	257	403	2209	61	66	164	104.4		100.9
25	88.47	88.86	92.92	180	384	2294	35	27	136	110.5		100.8
26	86.89	88.12		238	383	2697	50	83	218	107.7		104.3
27	87.1	88.18		228	403	2361	33	69	92	113.8		104.8
28	86.01	87.54		242	447	2437	55	96	170	112.5		103.1
29	85.64	88.72		272	407	2879	63	50	282	109.8		104.6
30	86.23	89.16		251	368	2208	49	58	95	109.8		102.3
31	87.29	89.01		203	383	2494	48	56	110	109.4		102.5
32	87.3	87.99		225	445	2479	45	86	112	103.8		103.3
33	85.76	87.88		249	444	2648	76	95	83	112.1		105.6
34		88.73		274	385	2766	53	51	190	103.5		104.4
35		88.56		264	406	2190	66	90	153	111.2		101
36		88.07		262	392	2507		59	227	112.1		99.61
37		87.97		212	424	2749		89	229	108.8		105.1
38		88.13		263	392	2926		59	242	105.6		103.7
39		87.11		218	466	2594		101	172	102.1		100.2
40		88.12		227	413	2522		78	192	112.5		101.1
41		88.46		257	384	2273		62	110	101.6		100.7
42		88.91		289	395	2274		77	121	114.9		101.3
43		88.62		308	398	2517		68	105	111.3		104.4
44		88.12		204	440	2253		95	205	110.5		100.1
45		89.22		246	352	2296		49	88	104.3		101.1
46				224	427	2822		94	243	101.6		101.2
47				208	458	2644			162	113		103.2
48				220	427	2331			140	108.9		102.1
49				255	397	2828			212	107.1		101.5
50				241	423	2766			258	109.2		101.3
51				196	405	2389			160	120.5		101.5
52				266	467	2681			277	110.2		102.3
53				244	380	2110			114	107		100.7
54				230	484	2798			290	101.6		
55				237	376	2948			325			
56				287	435	2918			299			
57				271	461	2857			157			
58				262	463	2579			115			
59				260	442	2624			149			
60				245	358	2541			203			
61				253	403	2668			294			
62				244	400	2376			179			
63				243	393	2440			127			
64				266	453	2688			245			
65				255	412	2559			180			
66				254	419	1977			133			
67				260	389	2497			140			
68				226	348	2305			209			
69				239	456	2363			138			
70				227	418	2375			225			
71				288	461	2324			99			
72				223	460	2374			99			
73				261	483	2468			134			
74				184	469	2417			147			
75				272	397	2339			68			
76				257	416	2764			188			
77				265	398	2302			116			
78				232	362	2780			304			
79				296		2426			101			
80				248		2799			119			
81				277		2575			207			
82				228		2472			147			
83				298		2597			131			
84				231		2732			176			
85				268		2579			116			
86				285		2617			170			
87				243		2421			185			
88				251		3074						
89				247		2347						
90				260		2584						
91				271		2428						
92				240		2697						
93				278		2946						
94				232		2581						
95						2618						
96						2312						
97						2861						
98						2919						
99						2383						
100						2408						
$X_{i(Ni-20)}$	86,49	88,27	92,84	248,6	417,6	2547	54,53	73,77	172,1	108,4	103,1	102,5

APPENDIX K2: Statistics of additional replications for alt. 2 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	87.31	88.02	92.84	256	458	2724	23	48	187	105.2	99.8	100.1
22	85.75	89.07	92.78	286	384	2314	36	26	103	104.1		99.89
23	85.48	87.74	92.3	269	499	2908	31	62	245	112.5		108.3
24	86.36	87.96	93.26	246	437	2203	18	59	80	108.6		100.7
25	85.89	88.24	85.89	273	417	2585	8	28	174	108.5		102.7
26	86.32	88.24	92.16	269	426	3010	30	59	327	104.9		105.4
27		88.34	93.24	236	425	2502	15	57	215	107.4		104.9
28		88.2	92.63	256	409	2462	29	26	133	106.9		99.48
29		88.3	92.76	239	419	2882	22	33	281	107.2		104.2
30		88.25	91.96	306	427	3157	46	29	383	109.9		106.1
31		87.56	92.11	263	486	3031	32	57	134	111.8		105.4
32		89.32	92.52	243	373	2761	30	19	411	100.7		104.8
33		88.51	93.48	247	440	2281	5	54	85	101.5		103.4
34		88.79	93.33	265	391	2410	10	30	97	116.1		105.9
35		88.84	92.65	240	386	2546	12	27	126	106.8		104.2
36		88.04	93.06	242	467	2403	11	65	136	105.6		105.6
37		88.29	92.78	264	429	2613	12	32	158	102.6		103.8
38		88.22	92.39	249	445	2568	23	26	128	112.1		102.6
39		88.48	92.48	212	439	2684	3	35	94	108.1		101.7
40		87.65	93.18	300	459	2428	48	48	129	112.9		105.9
41		87.99	93.39	271	451	2538	16	68	111	103.7		103
42		88.27	92.72	243	416	2656	10	39	337	109		101.9
43		88.4	92.62	261	414	2514	45	38	127	106.6		105.5
44		88.34	92.42	276	427	2712	41	26	251	115.5		104.6
45		88	93.17	274	457	2416	25	43	91	110.1		101.6
46		88.17	92.9	225	410	2597	0	49	156	97.58		100.1
47		87.9	93.15	205	466	2298	17	67	154	102.4		
48		88.37	92.75	256	455	2660	11	42	149	107.7		
49		88.68	92.83	250	425	2765	9	33	134	110.9		
50		89.45	92.29	285	386	2696	39	21	194	109.3		
51		88.25	92.91	203	441	2384	2	47	150	111.6		
52		88.18	92.97	210	438	2446	0	69	172	107.8		
53		88.35	93.09		436	2692	38	56	190	108.6		
54		89.09	92.55		393	2731	9	32	151	117.7		
55		88.29	92.78		447	2668	28	62	139	109.3		
56		89.81	93.1		361	2597	9	36	110	103.9		
57		88.94	92.63		392	2539	49	45	136	109.8		
58		88.2			457	2549	23	42	178	100.4		
59		87.6			495	2433	35	71	89	111.7		
60		88.26			439	2172	16	43	139	111		
61		88.7			400	2640	21	28	89	101.2		
62		89.02			402	2430	29	32	112	99.7		
63		88.48			384	2716	17	29	192	101.4		
64		88.64			402	2276		32	142	113.4		
65		89.66			369	2430		5	128	101.8		
66		88.72			421	2703		44	215	113.9		
67		88.12			452	2612		41	260	104		
68		88.62			413	2736		32	175	112.1		
69		89.45			365	2493		31	161	111.9		
70		87.9			462	3037		43	232	112		
71		88.74			417	2880		42	403	114		
72		88.58			417	2898			326	106.3		
73		88.69			418	2603			122	102.9		
74		88.97			395	2754			178	102.7		
75		88.02			458	2675			141	102.7		
76		89.37			382	2704			196	102.8		
77		88.15			424	2827			244			
78		88.82			421	2488			181			
79		89			440	2853			174			
80		88.58			404	2718			174			
81					373	2600			252			
82					378	2137			155			
83					408	2475			161			
84					443	2559			137			
85					447	2523			96			
86					450	2548			113			
87					409	2245			129			
88					398	2240			151			
89						2704						
90						2641						
91						2753						
92						2548						
93						2620						
94						2207						
95						2487						
96												
97												
98												
99												
100												
$X_{i(Ni-20)}$	86,19	88,48	92,6	253,8	423,1	2591	21,7	41,33	173,9	107,5	99,8	103,5

APPENDIX K3: Statistics of additional replications for alt. 3 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	90.48	95.01	94.59	276	328	2561	74	79	186	110.4	108.1	103.8
22	92.63	95.64	94.71	191	302	2444	58	66	177	105.4	110.1	100.8
23	92.6	95.62	94.82	170	281	2436	41	55	149	102.1	110.3	100.7
24	92.89	94.72	94.89	198	319	2410	46	74	131	104.6	116.2	105.2
25	92.09	95.26		207	268	2413	61	57	127	104.2	109.2	104.3
26	91.99	95.51		206	309	2291	55	79	157	109.2	111.3	100.8
27	92.46	95.33		210	308	2416	41	75	105	109	116.3	104.4
28	90.27	95.27		266	320	2910	64	72	306	107.9	115.4	106
29	90.79	95.62		252	280	2385	71	60	192	107.2	116.3	99.51
30	93.42	95.32		179	300	2557	41	79	129	105.6	110.7	101.6
31	92.42			217	348	2594	51	84	223	108.5	111.5	102.9
32	91.72			248	338	2345	57	105	113	108.3	108.7	102.1
33				205	333	3033	50	71	357	107.2		103.5
34				215	328	2845	49	73	257	112.2		105
35				168	296	2282	28	80	189	102.4		100.3
36				246	313	2559	70	90	164	109.3		104.7
37				193	278	2489	51	60	200	103.1		105.2
38				251	345	2492	56	81	173	110.1		101.2
39				263	321	2550	84	96	133	106.6		106.1
40				194	358	2729	43	90		105.8		104.7
41				256	330	2764	53	79		109.2		101.9
42				227	321	2468	53	87		110		104.3
43				181	332	2328	42	100		104.2		102.4
44				208	263	3152	43	52		111		106.8
45				181	293	2537	38	72		104		99.07
46				175	324	2605	38	76				104.8
47				218	281	2367	38	67				
48				219	294	2268	57	63				
49				203	334	2252	42	91				
50				244	276	2569	61	64				
51				238	302	2724	65	99				
52				186	331	2467	36	79				
53				206	314	2766	44	67				
54				214	314	2264	49	91				
55				200	333	2895	33	94				
56				228	337	2815	56	74				
57				285	373	2579	87					
58				236	331	2865	51					
59				237	254	2701	37					
60				212	284	2185	39					
61				197	280	2779	43					
62				221		2683	59					
63				229		2324	55					
64				238		2736	65					
65				223		2765	64					
66				204		2587	68					
67				216		2674	44					
68				230		3131	58					
69				240		2360	50					
70				182		3100	32					
71				236		2970	70					
72						2583	64					
73						2439						
74						2824						
75						2417						
76						2310						
77						2459						
78						2679						
79						2430						
80						2515						
81						2241						
82						2468						
83						2388						
84						2405						
85						2226						
86						2538						
87						2044						
88						2521						
89						2651						
90						2525						
91						2441						
92						2581						
93						2516						
94						2832						
95						2461						
96						2586						
97						2211						
98						2522						
99						2376						
100						2656						
$X_{i(Ni-20)}$	91,98	95,33	94,75	218,1	311,6	2553	52,4	77,25	182,5	107,1	112	103,2

APPENDIX K4: Statistics of additional replications for alt. 4 under scenario 3.

REP. NO	PERFORMANCE MEASURE											
	PERC. VIA MOB.CAD.			TOTAL DEM. FROM APCR			SHORTAGES OF AST			TIME IN SYSTEM		
	O	NCO	E	O	NCO	E	O	NCO	E	O	NCO	E
21	92.78	95.73	94.93	218	301	2395	0	9	112	101.6	104	99.25
22	93.76	95.99	94.71	176	262	2373	0	7	89	103.6	105.5	103.1
23	93.68	95.72	94.75	195	314	2474	5	23	183	100.8	109.1	100.7
24	92.74	95.55	94.78	232	317	2463	13	41	150	103.7	107.6	98.4
25	93.32	95.31	94.21	217	307	2797	6	25	168	102	104.1	103.9
26	93.06	95.65	94.26	214	304	2928	7	16	279	109.7	110.4	105.3
27	93.03	95.63	95.09	233	316	2443	19	28	119	100.4	114.8	99.67
28	93.55	95.85	94.99	212	300	2400	1	25	164	105.2	107.6	100.1
29	92.4	96.24	94.64	255	278	2560	29	2	140	110.3	107.7	101.3
30	93.43	95.27	94.96	191	330	2383	0	49	162	105.6	109.5	101.5
31	92.96	95.26	94.76	224	342	2510	8	32	138	115.7	109.6	103.1
32	92.9	95.05	94.92	241	358	2465	19	78	268	106	106.8	99.6
33	91.79	96.5	95.04	244	240	2219	17	13	157	101.7	99.31	98.76
34	92.82	95.74	94.28	221	321	3031	18	43	404	110.8	108.8	104.4
35	92.82	95.84	94.82	215	298	2469	18	33	190	101.3	105.2	100
36	91.73	95.47	94.2	283	314	3076	24	34	269	117.1	104.9	107.3
37	92.24	96.57	94.46	243	252	2575	22	6	176	109.4	107.2	101.5
38	93.07	96.15	94.87	231	308	2417	2	12	159	112.9		103.6
39	93.74	95.59	94.73	208	306	2548	3	24	107	96.53		102
40	92.47	94.99	94.74	241	337	2528	16	34	164	102.6		102.1
41	94	95.83	95.22	202	267	2109	0	5	122	98.05		97.13
42	93.79	95.97	94.47	202	310	2783	1	30	204	107.2		102.5
43	93.99	96.23		179	265	2340	0	0	155	92.67		99.73
44	93.68			198	278	2621	0	14	148	102.2		102.7
45	91.08			238	341	2847	15	44	233	109.8		
46	92.49			185	327	2545	0	38	173	107.1		
47	92.01			277	296	2636	12	13	135	112.8		
48	93.31			183	295	2507	1	27	188	110.8		
49	92.37			230	315	2465	19	28	229	104.9		
50	92.98			223	343	2759	4	37	271	97.8		
51	92.78			240	282	2260	18	17	137	102		
52	93.07			214	254	2665	24	7	313	103.9		
53	93.88			195	323	2470	0	31	136	106.9		
54	94.13			185	289	2704	13	23	194	103.8		
55				233	288	2666	13	37	297	104.5		
56				257	329	2556	17	29	155	113.8		
57				162	271	2279	0	20	123			
58				243	374	2782	6	92	169			
59				249	223	2360	16	0	155			
60				242	319	2845	8	15	276			
61				192	293	2473	3	18	217			
62				241	274	2519	30	29	129			
63				256	262	2923	22	14	344			
64				213	326	2038	8	62	109			
65				240	335	2856	24	22	352			
66				176	321	2634	0	26	212			
67				217	319	2505	3	48	177			
68				265	261	2836	30	0	249			
69				219	305	2575	9	29	153			
70				190	314	2375	0	44	210			
71				211	271	2225	0	29	157			
72				248	316	2419	16	40	160			
73				195	329	2863	4	36	288			
74				236	290	2324	16	21	115			
75				224	346	2135	11	42	153			
76				220	381	2974	3	61	333			
77				211	342	2699	5	37	206			
78				184	335	2436	7	47	191			
79				196	276	2363	0	24	151			
80				211	338	2472	3	36	157			
81				196	320	2908	15	44	399			
82				251	336	2467	36	37	162			
83				204	267	2516		27	132			
84				220	308	2478		17	137			
85				208	303	2256		32	136			
86				206	288	2684		10	144			
87				214	293	2348		37	245			
88				212	246	2631		21	285			
89				265	310	2374		27	121			
90				188	358	2536		88	195			
91				230	264	2476		15	142			
92				187	306	2182			125			
93				200	323	2569			137			
94				247	340	2814			177			
95				210	316	2518			178			
96				224	300	2637			216			
97				222	307	2273			131			
98				175	282	2480			185			
99				188	281	2613			204			
100				233	331	2664			160			
$X_{i(Ni-20)}$	93	95,74	94,72	218,2	305,1	2542	10,31	29,03	188,6	105,4	107,2	101,6

APPENDIX L: Personal pairwise matrices of main criteria and their sub criteria

PER1: Rank: Major **Position**: Operations O. of Mob. Dep. of Ministry of National Defense

	C1	C2	C3	C4
C1	1	1/3	1/2	9
C2	3	1	4	7
C3	2	1	1	7
C4	1/9	1/7	1/7	1

(inconsistency ratio=0.14)

O	1	3	4
NCO	1/3	1	2
E	1/4	1/2	1

(incons. ratio=0.02)

O	1	2	6
NCO	1/2	1	3
E	1/6	1/3	1

(incons. ratio=0)

O	1	6	6
NCO	1/6	1	4
E	1/6	1/4	1

(incons. ratio=0.21)

O	1	1/3	1/5
NCO	1/3	1	1/4
E	5	4	1

(incons. ratio=0.08)

PER2: Rank: Captain **Position:** Branch Tactics Teacher in Per. Branch School

	C1	C2	C3	C4
C1	1	3	2	1/2
C2	1/3	1	1	1/2
C3	1/2	1	1	1/2
C4	2	2	2	1

(inconsistency ratio=0.04)

O	1	7	8
NCO	1/7	1	3
E	1/8	1/3	1

(incons. ratio=0.1)

O	1	5	7
NCO	1/5	1	3
E	1/7	1/3	1

(incons. ratio=0.06)

O	1	7	8
NCO	1/7	1	3
E	1/8	1/3	1

(incons. ratio=0.1)

O	1	1/5	1/7
NCO	5	1	1/2
E	7	2	1

(incons. ratio=0.01)

PER3: Rank: Colonel **Position:** Manager of E Operations Department of Land Forces

	C1	C2	C3	C4
C1	1	6	7	9
C2	1/6	1	3	4
C3	1/7	1	1	1/2
C4	1/9	1/4	2	1

(inconsistency ratio=0.13)

O	1	6	9
NCO	1/6	1	6
E	1/9	1/6	1

(incons. ratio=0.21)

O	1	6	9
NCO	1/6	1	5
E	1/9	1/5	1

(incons. ratio=0.16)

O	1	5	8
NCO	1/5	1	6
E	1/8	1/6	1

(incons. ratio=0.19)

O	1	1/5	1/8
NCO	5	1	1/6
E	8	6	1

(incons. ratio=0.19)

APPENDIX L: Personal pairwise matrices of main criteria and their sub criteria (cont'd)

PER4: Rank: 1st Lieutenant **Position:** Commander of Signal Company of Brigade

	C1	C2	C3	C4
C1	1	3	6	7
C2	1/3	1	4	4
C3	1/6	1	1	2
C4	1/7	1/4	1/2	1

(inconsistency ratio=0.04)

O	1	3	6
NCO	1/3	1	5
E	1/6	1/5	1

(incons. ratio=0.09)

O	1	1	5
NCO	1	1	5
E	1/5	1/5	1

(incons. ratio=0)

O	1	2	6
NCO	1/2	1	4
E	1/6	1/4	1

(incons. ratio=0.01)

O	1	1/2	1/2
NCO	2	1	1/6
E	2	6	1

(incons. ratio=0.35)

PER5: Rank: 1st Lieutenant **Position**: Per. O of Support Command of Turkish General Staff

	C1	C2	C3	C4
C1	1	1/2	1/2	3
C2	2	1	1/2	6
C3	2	1	1	5
C4	1/3	1/6	1/5	1

(inconsistency ratio=0.02)

O	1	5	2
NCO	1/5	1	1/3
E	1/2	3	1

(incons. ratio=0)

O	1	2	4
NCO	1/2	1	2
E	1/4	1/2	1

(incons. ratio=0)

O	1	5	2
NCO	1/5	1	1/3
E	1/2	3	1

(incons. ratio=0)

O	1	2	1/2
NCO	1/2	1	1/4
E	2	4	1

(incons. ratio=0)

PER6: Rank: 1st Lieutenant **Position:** Mobilization O. of Brigade

	C1	C2	C3	C4
C1	1	2	6	5
C2	1/2	1	3	3
C3	1/6	1	1	2
C4	1/5	1/3	1/2	1

(inconsistency ratio=0.03)

O	1	3	4
NCO	1/3	1	2
E	1/4	1/2	1

(incons. ratio=0.02)

O	1	2	6
NCO	1/2	1	3
E	1/6	1/3	1

(incons. ratio=0)

O	1	4	8
NCO	1/4	1	2
E	1/8	1/2	1

(incons. ratio=0.01)

O	1	1/2	1/2
NCO	2	1	1/6
E	2	6	1

(incons. ratio=0)

APPENDIX M1: Optimization of officer assignment plans.

LEVEL	REP#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	AVG
130	**O SHORTAGE OF PCC**	38	0	37	7	49	35	61	20	41	35	27	13	28	53	42	21	16	32	33	45	23	44	12	36	21	39	18	29	36	19	54	43	29	45	62	**32,657**
135		44	35	47	44	11	25	35	39	39	43	14	38	45	39	36	23	23	18	55	54	19	42	15	29	41	16	12	48	23	20	48	59	38	41	35	**34,086**
140		22	24	39	34	35	41	34	29	24	28	18	34	61	34	45	12	16	0	33	21	13	21	36	59	42	15	28	0	18	36	29	41	13	13	0	**27,086**
145		20	34	20	0	39	0	39	11	15	0	4	63	10	33	41	0	26	25	18	39	0	56	0	41	26	48	11	0	38	46	36	11	26	24	29	**23,686**
150		0	11	30	5	21	18	13	0	53	21	16	23	14	46	27	11	21	0	15	49	12	29	0	29	38	26	17	0	56	0	29	0	8	14	0	**18,629**
155		28	32	0	3	28	19	15	12	67	30	9	51	5	51	0	18	4	0	43	6	0	7	16	28	29	0	41	12	25	17	0	48	3	14	0	**18,886**
160		21	0	22	43	0	0	33	11	0	0	10	11	11	9	0	3	0	11	11	51	12	0	28	0	18	0	24	0	18	11	19	22	31	0	0	**12,286**
165		0	7	18	0	29	0	0	9	0	0	6	2	3	24	34	0	0	0	27	32	0	8	0	0	16	0	9	11	0	28	33	0	16	0	15	**9,3429**
170		1	38	3	6	27	13	0	0	10	13	10	0	14	0	17	2	0	3	0	9	15	0	18	25	36	0	2	8	0	16	17	0	0	6	0	**8,8286**
175		0	2	39	0	0	7	26	0	3	0	5	1	6	10	25	0	0	36	2	0	0	21	5	3	1	0	19	11	0	2	8	10	14	21	4	**8,0286**
180		0	2	28	8	0	0	0	0	0	20	0	0	11	6	7	0	0	0	18	0	5	12	0	0	0	21	7	24	0	0	0	4	1	11	7	**5,4857**
185		7	18	6	0	0	0	27	0	0	16	0	0	0	0	0	10	0	0	18	0	0	12	5	0	0	10	0	0	0	3	8	21	0	0	0	**4,6**
190		0	1	25	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	5	0	0	0	0	6	0	9	0	0	0	16	0	0	3	4	**2,0571**
195		0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	7	0	0	0	0	11	3	0	0	0	9	0	0	0	1	0	**1,4286**
200		0	0	0	0	0	0	0	13	0	0	0	0	0	0	2	0	0	0	0	0	5	0	0	0	0	0	0	3	0	0	0	0	6	0	0	**0,8286**
205		0	0	11	0	0	0	0	0	0	0	0	2	11	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	6	0	0	**1,0571**

LEVEL	REP#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	AVG
130	**REMAINING O IN PCC**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
135		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**0,0286**
140		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	**0,6286**
145		0	0	0	1	0	16	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	**1,8286**
150		1	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	5	0	0	0	6	0	0	8	**1,2286**
155		0	0	10	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	5	0	0	0	12	0	0	0	0	0	0	**0,8857**
160		0	4	0	0	1	4	0	0	15	10	0	0	0	0	16	0	29	0	0	0	0	11	0	23	0	0	0	0	3	0	0	0	0	4	0	**3,4286**
165		3	0	0	29	0	5	5	0	11	0	0	0	0	0	0	26	22	9	0	0	0	0	6	13	0	0	0	11	0	0	0	0	18	0	0	**4,5143**
170		4	0	0	0	0	0	10	0	0	0	0	2	0	26	0	0	21	0	6	0	1	16	0	0	21	0	0	11	0	0	0	28	21	0	0	**4,7714**
175		28	5	0	33	16	0	0	43	0	20	0	0	0	0	0	6	12	0	2	11	0	0	39	0	18	0	0	0	0	5	14	0	2	10	17	**8,0286**
180		8	0	0	0	0	11	11	47	25	0	25	2	0	0	0	26	51	24	0	7	0	18	11	10	0	5	7	35	21	18	0	0	8	15	20	**11,571**
185		0	0	0	35	8	0	0	23	21	0	16	11	32	39	33	0	35	43	0	8	0	31	20	0	9	36	39	44	0	0	11	14	17	0	8	**15,229**
190		44	0	0	24	12	37	19	24	35	0	17	9	7	22	39	48	44	50	7	0	18	21	26	33	0	0	8	11	10	7	0	23	8	28	33	**18,971**
195		26	2	16	6	28	29	34	7	17	16	35	51	0	0	25	29	48	27	11	0	36	25	11	0	41	36	8	25	31	0	9	34	42	0	41	**21,314**
200		56	35	16	41	40	25	0	52	40	23	29	38	27	0	6	36	44	39	47	26	5	36	41	11	10	6	28	0	24	16	39	46	13	6	7	**25,943**
205		35	42	0	24	27	49	39	19	41	50	21	26	0	7	14	0	15	27	28	24	25	36	45	12	17	36	15	49	21	0	45	16	0	8	29	**24,057**

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APPENDIX M2: Optimization of noncommissioned officer assignment plans.

LEVEL	REP#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	AVG
270	NCO SHORTAGE OF PCC	49	88	49	71	38	0	93	30	101	51	38	26	25	66	52	10	97	17	85	25	84	21	45	33	26	49	65	21	36	87	56	35	54	12	77	**48,914**
310		18	5	19	2	83	50	23	10	0	34	0	79	0	0	0	0	39	57	0	47	66	89	24	74	13	69	85	0	77	24	65	44	56	99	11	**36,057**
315		42	0	18	33	23	12	64	0	28	67	12	1	0	0	44	18	25	5	0	7	43	36	11	58	12	44	0	63	28	48	26	9	46	18	0	**24,029**
320		51	49	0	0	0	55	32	0	3	44	8	0	43	49	0	0	26	50	0	0	51	32	69	25	0	41	2	34	0	8	7	31	0	9	0	**20,543**
325		32	0	0	11	0	14	57	0	0	7	0	7	41	0	24	24	0	50	8	0	21	36	0	8	0	1	41	0	7	28	55	49	61	14	14	**17,429**
330		33	0	0	0	56	15	10	0	25	59	7	16	70	38	0	0	10	57	0	38	0	15	8	0	25	16	0	39	0	11	10	39	0	0	18	**17,571**
335		7	0	28	0	0	0	1	13	8	0	0	28	0	10	0	45	38	0	0	0	36	12	10	5	0	0	14	7	16	3	0	39	12	0	33	**10,429**
340		16	0	0	0	0	48	9	7	0	0	22	0	0	45	0	0	0	0	25	7	0	0	0	21	28	8	0	15	0	0	0	7	9	0	14	**8,0286**
345		30	0	0	0	0	62	0	0	0	9	7	0	0	2	0	0	12	0	0	0	3	0	0	10	8	0	0	0	0	8	15	0	0	8	7	**5,1714**
350		0	50	0	8	0	0	51	34	0	2	0	0	0	0	13	0	0	0	0	0	25	0	0	0	5	0	0	4	0	9	0	0	0	1	2	**5,8286**
355		13	0	0	0	0	0	58	0	0	61	0	3	0	0	6	0	0	0	0	0	16	2	0	0	0	0	3	0	0	0	6	4	0	0	0	**4,9143**
360		24	0	8	0	0	0	0	0	0	0	0	0	0	17	6	0	0	0	0	0	8	0	0	12	0	0	0	0	3	0	0	0	8	0	0	**2,4571**
400		0	0	0	0	0	0	3	0	0	1	0	0	0	0	26	0	0	0	0	0	20	0	0	0	0	0	3	0	0	0	0	0	0	1	0	**1,5429**
270	REMAINING NCO IN PCC	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	**0,1714**
310		0	0	0	0	0	0	0	0	9	0	44	0	6	36	3	1	0	0	15	0	0	0	0	0	0	12	0	0	0	36	0	0	0	0	26	**5,3714**
315		0	50	0	0	0	0	0	37	0	0	0	0	31	8	0	0	0	0	2	0	26	0	0	0	0	9	0	0	6	0	0	33	0	21	0	**6,3714**
320		0	0	23	31	43	0	0	3	0	0	0	62	0	0	22	0	0	0	2	79	0	0	0	8	0	0	20	0	0	2	0	0	0	0	1	**8,4571**
325		0	42	30	0	34	0	0	0	10	0	14	0	0	2	0	0	27	0	0	33	0	0	0	0	12	0	0	18	0	0	23	0	33	0	39	**9,0571**
330		0	24	33	20	0	0	0	26	0	0	0	0	0	0	1	5	0	0	26	0	0	0	18	0	0	25	0	0	36	0	0	0	21	0	18	**7,2286**
335		0	46	0	2	5	12	0	0	0	35	10	0	24	0	2	0	0	5	45	21	0	0	3	0	8	0	9	6	18	0	12	0	9	4	0	**7,8857**
340		0	42	29	0	78	0	0	0	28	6	0	39	47	0	49	71	74	32	0	0	0	33	0	0	8	41	33	0	0	17	28	0	0	5	10	**19,143**
345		0	48	12	36	46	0	4	32	12	0	0	14	60	0	79	61	0	3	35	10	14	0	36	44	18	27	48	2	8	36	0	12	14	38	7	**21,6**
350		25	0	45	0	13	41	0	0	45	0	31	27	46	31	0	41	7	58	47	41	45	17	3	0	58	18	17	66	0	8	16	0	23	11	18	**22,8**
355		0	16	34	44	17	47	0	11	3	0	44	0	82	9	0	50	23	6	30	3	12	0	45	39	12	3	47	34	31	0	41	21	18	32	7	**21,743**
360		0	62	0	71	33	50	5	64	84	54	25	26	30	0	0	22	56	13	51	49	0	31	38	45	12	58	79	17	16	28	39	4	0	87	66	**34,714**
400		20	37	74	81	70	77	29	0	70	30	0	48	83	48	10	0	76	22	58	74	48	35	98	25	18	11	58	69	43	39	2	14	58	46	88	**44,543**

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APPENDIX M3: Optimization of enlisted assignment plans.

LEVEL	REP#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	AVG
1340	**O SHORTAGE OF PCC**	189	0	15	0	186	408	75	0	317	251	139	217	147	206	277	211	113	297	229	106	225	336	421	145	309	225	178	145	113	254	179	402	397	147	66	**197,86**
1420		0	96	42	320	355	228	220	37	254	387	0	335	174	81	325	469	0	358	168	0	303	212	125	179	312	65	186	0	452	56	299	175	335	0	71	**189,11**
1460		82	0	0	77	99	305	580	284	140	250	268	157	21	238	179	0	277	194	296	0	58	128	210	102	136	0	336	147	46	88	112	228	505	0	47	**159,71**
1500		0	70	276	132	0	217	64	9	427	0	57	25	0	184	0	87	65	274	125	198	0	45	28	114	314	56	111	323	0	258	69	0	398	347	0	**122,09**
1540		132	0	0	0	0	93	180	115	0	0	270	95	0	25	208	170	0	231	69	0	0	114	56	102	48	69	0	212	0	47	0	118	79	20	147	**74,286**
1580		0	0	0	333	103	97	211	0	0	307	0	0	139	0	98	0	0	0	128	119	0	0	154	69	0	47	221	79	32	0	159	302	0	0	41	**75,4**
1620		0	0	0	0	0	0	0	0	0	0	0	366	27	146	0	0	0	0	0	0	158	46	25	34	0	0	251	307	58	0	0	69	287	0	0	**50,686**
1660		0	323	13	195	188	481	159	0	0	8	23	174	0	0	0	503	23	0	0	25	0	0	0	12	0	0	0	18	0	0	0	0	59	178	0	**68,057**
1740		0	0	38	226	0	0	0	298	0	162	0	0	0	0	0	335	0	227	0	285	0	0	0	0	0	48	0	0	0	145	0	0	0	110	0	**53,543**
1740		0	0	0	389	0	0	0	389	0	35	0	0	0	0	0	0	172	0	0	0	65	0	0	0	48	0	0	125	0	0	69	0	0	87	0	**39,4**
1820		0	0	0	0	0	37	0	382	0	0	45	0	0	0	156	0	0	0	0	234	0	0	65	0	0	32	0	0	289	0	0	0	25	0	142	**40,2**
1340	**REMAINING O IN PCC**	0	155	0	125	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	**8,9143**
1420		117	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	17	0	0	26	0	0	0	0	0	0	15	0	0	0	23	0	0	0	33	**7,0571**
1460		0	35	139	0	0	0	0	0	0	0	0	0	0	0	0	169	0	0	0	126	0	0	0	0	0	123	0	0	65	0	0	0	102	0	0	**21,686**
1500		1	0	0	0	228	0	0	0	0	127	0	0	196	0	103	0	0	0	0	0	145	0	0	0	104	0	0	0	0	99	0	0	0	0	0	**28,657**
1540		0	7	32	85	140	0	0	0	42	85	0	0	49	0	0	0	10	0	0	93	0	0	0	48	0	0	68	0	0	104	0	0	0	0	145	**25,943**
1580		97	194	332	0	0	0	0	108	132	0	128	96	0	65	0	261	23	74	0	0	0	0	142	0	0	34	56	178	98	0	0	251	102	0	66	**69,629**
1620		63	226	101	58	394	277	113	30	45	24	23	0	0	0	200	133	212	23	32	208	0	0	0	58	0	135	56	47	0	21	0	178	89	0	21	**79,057**
1660		75	0	0	0	0	0	0	297	96	0	0	0	108	340	48	0	0	113	248	0	445	0	178	154	95	0	210	0	154	0	147	36	304	0	0	**87,086**
1740		159	110	0	0	99	142	16	0	387	0	420	2	182	85	208	0	23	0	13	0	0	395	254	103	86	8	118	24	0	310	88	15	98	125	74	**101,26**
1740		116	168	144	0	13	202	15	0	25	0	60	196	43	210	352	94	0	237	118	162	256	310	97	46	185	146	126	0	64	361	108	87	74	204	105	**123,54**
1820		176	519	15	69	391	0	171	0	305	80	0	493	214	43	0	141	14	311	203	0	305	46	78	402	69	321	247	109	128	0	360	120	14	0	243	**159,63**

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BIOGRAPHY

Levent Karamalak is a graduate student in the Department of Industrial Engineering at Bilkent University. His research interests include simulation and modeling of military systems. Graduating with B.S. degree in System Engineering from the Turkish Military Academy in 1996, he began his career as a personnel officer. He has served as personnel mobilization officer and administrator of central office of a brigade in Kırklareli for two years. He is now a first lieutenant and his mission is administrative and kozmik officer of central office of Corps Head quarters.