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RESEARCH PAPER
CAA-RP-95-5

PERSONNEL ATTRITION RATES IN HISTORICAL LAND COMBAT OPERATIONS: LOSSES OF NATIONAL POPULATIONS, ARMED FORCES, ARMY GROUPS, AND LOWER LEVEL LAND COMBAT FORCES

APRIL 1996

PREPARED BY
TACTICAL ANALYSIS DIVISION

US ARMY CONCEPTS ANALYSIS AGENCY
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19 APR 1996

MEMORANDUM FOR DEPUTY UNDER SECRETARY OF THE ARMY (OPERATIONS RESEARCH), HEADQUARTERS, DEPARTMENT OF THE ARMY, WASHINGTON, DC 20310

SUBJECT: Personnel Attrition Rates in Historical Land Combat Operations: Losses of National Populations, Armed Forces, Army Groups, and Lower Land Combat Forces

1. The US Army Concepts Analysis Agency (CAA) is pleased to publish this Research Paper by Dr. Robert L. Helmbold. Its analysis of selected aspects of personnel losses and loss rates in combat operations spanning a wide range of scales gives US Army operations analysts a much improved foundation for judging future casualty numbers, casualty fractions, and casualty rates on the basis of historical land combat operations. Properly used, this information can be exploited to improve US Army treatment of personnel attrition in models, war games, studies, and analyses. Wide dissemination will make this work available to others for further use in their work.

2. Questions or inquiries should be directed to the Tactical Analysis Division, US Army Concepts Analysis Agency (CSCA-TA), 8120 Woodmont Avenue, Bethesda, MD 20814-2797, DSN 295-1611, commercial 301 295-1611.

E. B. VANDIVER III
Director

CAA-RP-95-5

RESEARCH PAPER
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PERSONNEL ATTRITION RATES IN HISTORICAL LAND COMBAT OPERATIONS: LOSSES OF NATIONAL POPULATIONS, ARMED FORCES, ARMY GROUPS, AND LOWER LEVEL LAND COMBAT FORCES

April 1996

Prepared by

TACTICAL ANALYSIS DIVISION

US Army Concepts Analysis Agency
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Bethesda, Maryland 20814-2797

PREFACE

The Personnel Attrition Rates (PAR) Study as a whole is limited to studying personnel strengths and battle casualties in historical land combat operations. Other types of attrition (nonbattle losses, losses to equipment, casualties to other services, and so forth) are outside PAR's scope, as are personnel losses in models, simulations, wargames, field experiments, or training exercises (like those of the National Training Center).

Phase 1, or PAR-P1, was devoted to assembling the available data and past studies on personnel strengths and attrition rates in land combat operations, preparing a comprehensive bibliography of it, and planning the approach to subsequent phases. Its specific objectives were to:

- Collect as many as possible of the available tabulated data and data-based studies of attrition rates in historical land combat operations,
- Prepare a comprehensive bibliography of such data and studies, and
- Outline an approach to accomplishing the subsequent phases of the PAR Study as a whole.

The bibliography of works collected during Phase 1 was published as *Personnel Attrition Rates in Land Combat Operations: An Annotated Bibliography,* US Army Concepts Analysis Agency Research Paper, CAA-RP-93-2, June 1993 (AD-A268 787). The collection of data and data-based studies consists of the files of pertinent documents maintained at the US Army Concepts Analysis Agency.

Phases 2 and 3 of the PAR Study converted some of the most important data to electronic form in order to facilitate their analysis, and performed selected analyses of the attrition data to derive information useful in US Army wargames, studies, and analyses. As of this writing, the following documents have been published during Phases 2 and 3:

- *Personnel Attrition Rates in Historical Land Combat Operations: Susceptibility and Vulnerability of Major Anatomical Regions,* CAA Research Paper CAA-RP-93-3, August 1993, AD-A270 766.
- *Personnel Attrition Rates in Historical Land Combat Operations: A Catalog of Attrition and Casualty Data Bases on Diskettes Usable With Personal Computers,* CAA Research Paper CAA-RP-93-4, September 1993, AD-A279 069 (report), AD-M000 344 (diskettes).
- *Personnel Attrition Rates in Historical Land Combat Operations: A Note on the Probability of Readmissions and Multiple Wounds,* CAA Research Paper, CAA-RP-94-2, 1 March 1995.
- *Personnel Attrition Rates in Historical Land Combat Operations: Some Empirical Relations Among Force Sizes, Battle Durations, Battle Dates, and Casualties,* CAA Research Paper, CAA-RP-95-1, 1 March 1995.
- *Personnel Attrition Rates in Historical Land Combat Operations: Addenda to the Annotated Bibliography,* CAA Research Paper, CAA-RP-95-2, 1 April 1995.

This paper, written as part of Phase 3, furnishes an additional analysis. It uses historical data to examine selected aspects of the personnel losses and loss rates of national populations and of armed forces at various echelons in wars, theater operations, and tactical actions. The basic approach used is to review the prior work in these areas, and then to analyze the available data for information related to selected aspects of personnel losses and loss rates. The coverage is therefore somewhat spotty and uneven. However, as Best (Robert J. Best, "Casualties and the Dynamics of Combat," RAC-TP-185, March 1966, pg 12) says, "Retrospective combat analysis resembles archaeology in the necessity to exploit information which may be fortuitously available." The primary data analysis technique used is descriptive statistics.

ACKNOWLEDGMENT

Many works were consulted for ideas and suggestions on alternative hypotheses and for an appreciation of the issues involved. Their discussions and analyses were instrumental in forming those put forward in this paper, and it is a pleasure to acknowledge our debt to each and every one of them. However, one author's works provided particularly important ideas and encouragement. Taken as a whole, these works were major advances beyond previous analyses of personnel casualties. They also served to suggest the format or arrangement of material adopted in this paper. Those works are

Best, Robert J., *Analysis of Personnel Casualties in the 25th Infantry Division 26-31 July 1950*, Operations Research Office, ORO Technical Memorandum ORO-T-22(FEC), 14 April 1952, 37 pp, UNCLASSIFIED, available from DTIC as ATI-171 207.

Best, Robert J., *A Study of Battle Casualties Among Equivalent Opposing Forces (Korea, September 1950)*, Operations Research Office (ORO), Technical Memorandum ORO-T-23(FEC), 14 April 1952 (originally issued 5 September 1951), 165 pp, UNCLASSIFIED, available from DTIC as AD-002-885.

Best, Robert J., *Casualties and the Dynamics of Combat*, Research Analysis Corporation (RAC), Technical Paper RAC-TP-185, March 1966, 144 pp, CONFIDENTIAL, available from DTIC as AD-372-260.

PERSONNEL ATTRITION RATES IN HISTORICAL LAND COMBAT OPERATIONS: LOSSES OF NATIONAL POPULATIONS, ARMED FORCES, ARMY GROUPS, AND LOWER LEVEL LAND COMBAT FORCES	SUMMARY CAA-RP-95-5

THE REASON FOR PERFORMING THIS RESEARCH was that the estimation of attrition in future combat engagements might be improved if the main features of losses over a wide span of operational levels were better known and understood.

THE SPONSOR was the Director, US Army Concepts Analysis Agency.

THE OBJECTIVE was to document selected personnel losses and loss rates for a wide span of operational levels, so that the relationships of rates at various levels would be better understood.

THE SCOPE OF THE RESEARCH is restricted to consider mainly total battle casualties (TBC), defined to be the sum of its principal components, namely, the killed in action (KIA), the wounded in action (WIA), and the captured or missing in action (CMIA). Organizational levels from Corps to nations are considered.

THE MAIN ASSUMPTION of this paper is that the bulk of the pertinent works has been collected and is on file at CAA, and that statistical procedures are appropriate for summarizing the empirical relationships inherent in these data. A secondary assumption, needed for application of the findings, is that the statistics of future military operations will be like the statistics of past battles: in other words, that trends of sufficiently long duration can be extrapolated to the near future with a reasonable degree of confidence.

THE BASIC APPROACH used in this research is to analyze the available data bases for information related to selected aspects of personnel attrition in wars, campaigns, and smaller-scale military operations. The primary technique used is descriptive statistics.

THE PRINCIPAL FINDINGS of the work reported herein are that:

a. Casualty numbers and rates vary widely from nation to nation, from theater to theater, and from year to year. They are strongly affected by dilution and attenuation effects. Also, most casualty rate distributions are approximately lognormal.

b. Up to about 20 percent of the total population can be mobilized in a military emergency. That would mobilize practically every male of military age. We have no record of any country exceeding a mobilization level of about 25 percent, and that level may be maintainable for only a relatively short period of time. In contrast, the US has never mobilized more than about 2 to 10 percent of its total population.

c. For the US population as a whole, peacetime death rates are about nine deaths per 1,000 person-years (9 deaths/kpy), but about 2 deaths/kpy for males of military age. The death rates of mobilized forces, averaged over the course of a war, are generally about twice the peacetime mortality rates for males of military age. Casualty rates of forces in a theater of combat, averaged over the course of a war, generally vary from about 5 to 30 battle deaths (BD) per 1,000 personnel-years (5 to 30 BD/kpy), plus 15 to 90 wounded not mortal (WNM) per 1,000 personnel-years (15 to 90 WNM/kpy).

d. In recent US experience, nonbattle deaths over the course of a war are mostly due to accidents. Deaths from disease are only about 20 percent of all nonbattle deaths and only about 5 percent of all (battle and nonbattle) deaths.

e. When viewed over relatively short time intervals, theater level total battle casualty (TBC) rates of 50 per 1,000 personnel years (50 TBC/kpy) to 250 TBC/kpy are not unusual. US army Group total battle casualty rates generally range from around 0.1 TBC per 1,000 personnel days (0.1 TBC/kpd) to about 20 TBC/kpd. US army total battle casualty rates generally range from around 0.1 TBC/kpd to about 20 TBC/kpd, with median values ranging from about 0.5 TBC/kpd to 8 TBC/kpd. US corps total battle casualty rates for a variety of combat situations, but typically associated with conducting a successful offensive operation, generally range from around 0.1 TBC/kpd to about 20 TBC/kpd, with median values ranging from about 0.7 TBC/kpd to 7 TBC/kpd. These values for corps apply to their nonzero casualty days. Zero casualty days can range from 0 to about 33 percent for a corps, depending on its sector of the front, mission, and so forth. For short, intense battles, corps TBC rates can be substantially higher than their long-term averages, and typically amount to about 100 TBC/kpd.

f. There is little trustworthy data regarding casualties to noncombatants during wars.

g. During a war, strengths and casualties surge and slow in a quasirhythmic, wavelike manner.

h. At the theater level, it appears that casualty numbers tend to increase faster than proportionately to the force's exposure level expressed in kpy. However, in World War II the US 12th Army Group's TBC numbers *declined* as its exposure in kpd increased, a trend opposite to that for theater forces. For army-sized formations, the relation of TBC numbers and exposure in 1,000 personnel-days (kpd) is inconsistent and variable. Usually, TBC numbers increase with increasing exposures in kpd, but some data bases show a *decrease* rather than an increase. However, even when the TBC number increases with exposure in kpd, the relationship is not necessarily one of simple proportionality. Instead, doubling the exposure may *more* than double the TBC number or it may *less* than double it. Similar remarks apply to the relation between the casualty numbers and exposure levels of corps-sized formations. These findings demonstrate that it is hazardous to apply a simple proportionality of casualties to exposure levels without considering other important factors.

i. The SCUD missile threat to combat forces in theater rear areas can be expected to produce about one or two killed or seriously injured casualties per impacting missile, unless the enemy is able to locate and target rear area targets in a timely and accurate fashion and friendly forces have no effective countermeasures against them.

j. It appears likely that killed in action (KIA) rates are about one-fifth the TBC rate, and that a large fraction of those initially classified as captured or missing in action (CMIA) are later reclassified as KIA.

k. The data in this paper suggest that, when viewed over several weeks or months duration, army Group TBC rates tend to decline exponentially. After transforming the data logarithmically, this is a linear trend, and on this general trend is superimposed a residual that can be represented by a simple, one-term autoregressive process having a normal random error. The same is true for army-level and corps-level formations, at least when viewed over several weeks or months duration for a basically successful offensive campaign.

l. Historically, over 99 percent of all army Group battle casualties are taken by formations at army level and below. Over 99 percent of all army battle casualties are taken by formations at corps level and below. Well over 90 percent of all corps battle casualties are taken by formations at division level and below.

m. Winners of army-sized engagements typically have about half the TBC rate of losers. Winners of corps-sized engagements also have about half the TBC rate of losers, although this ratio can vary substantially from battle to battle.

THE RESEARCH EFFORT was directed by Dr. Robert L. Helmbold, Tactical Analysis Division.

COMMENTS AND SUGGESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-TA, 8120 Woodmont Avenue, Bethesda, Maryland, 20814-2797.

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CHAPTER 1

EXECUTIVE SUMMARY

1-1. BACKGROUND. In April 1992, the US Army Concepts Analysis Agency (CAA) started a three-phased study of personnel attrition data—the Personnel Attrition Rates (PAR) Study. PAR as a whole is limited to studying personnel strengths and battle casualties in historical land combat operations. Other types of attrition (nonbattle losses, losses to equipment, casualties to other services, and so forth) are outside PAR's scope, as are personnel losses in models, simulations, wargames, field experiments, or training exercises (such as those of the National Training Center).

Phase 1, or PAR-P1, was devoted to assembling the available data and past studies on personnel strengths and attrition rates in land combat operations, preparing a comprehensive bibliography of it, and planning the approach to subsequent phases. Its specific objectives were to:

- Collect as many as possible of the available tabulated data and data-based studies of attrition rates in historical land combat operations,
- Prepare a comprehensive bibliography of such data and studies, and
- Outline an approach to accomplishing the subsequent phases of the PAR Study.

In earlier phases of the PAR Study, some of the most important data were converted to electronic form in order to facilitate their analysis, and some selected analyses of it were performed to derive information useful in US Army wargames, studies, and analyses. As of this writing, the following documents have been published:

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- *Personnel Attrition Rates in Historical Land Combat Operations: Some Empirical Relations Among Force Sizes, Battle Durations, Battle Dates, and Casualties*, CAA Research Paper, CAA-RP-95-1, March 1995, AD-A298 124.

- *Personnel Attrition Rates in Historical Land Combat Operations: Addenda to the Annotated Bibliography*, CAA Research Paper CAA-RP-95-2, April 1995, AD-A294 527.

The present paper, written as part of Phase 3, furnishes additional analyses. It uses selected historical data to illustrate various aspects of the casualty rates for military conflicts. These are arranged by operational level, beginning with wars and progressing downward in echelon through theater of war, army group, army, corps, division, regiment, and battalion, company and lower echelon units, and individuals. Throughout, emphasis is on the rates of total battle casualties (TBC), defined to be the sum of the killed in action (KIA), the wounded in action (WIA) and the captured or missing in action (CMIA).

1-2. OBJECTIVE. The objective of this research paper is to examine the historical evidence for illustrative casualty numbers and rates as related to various echelons of organization, and thereby to establish a baseline for projections into the future.

1-3. SCOPE

a. PAR as a whole is limited to studying personnel strengths and battle casualties of land combat forces. Other types of attrition (nonbattle losses, losses to equipment, casualties to other services, and so forth) are outside PAR's scope. PAR is concerned only with historical data on actual combat operations; it will not deal with personnel losses in models, simulations, wargames, field experiments, or training exercises (such as those of the National Training Center). PAR focuses mainly on either original or translated works in English, although some important work in other languages may be included. Studies of personnel attrition are also included, provided they contain cogent analyses of a publicly available, nonproprietary body of tabulated data on attrition in actual combat operations. Since trends in attrition over long periods of time are of interest, data on ancient as well as recent battles are solicited. However, as no contract support is anticipated and in-house resources are limited, no systematic effort is made to extract data from the archives or primary source materials, and no original historical research is envisioned. Thus, PAR relies almost exclusively on secondary works that contain data in readily usable tabulated form. All works received prior to the cutoff date of 31 May 1994 are included.

b. The issues to be examined in this paper are grouped into two general groups, as listed below. They were gleaned from a variety of sources. Each of these general groups is analyzed in its own chapter. These chapters list more specific issues whose resolution would illuminate that group's general issue.

- Group 1–What empirical trends in force sizes, battle durations, force ratios, casualty numbers, casualty exchange ratios, casualty fractions, and fractional exchange ratios of the opposing sides persisted over extended periods of time?

- Group 2–How are force sizes, battle durations, force ratios, casualty numbers, casualty fractions, and casualty rates interrelated?

c. Additional issues, which we hope to examine in future works, include such items as the following.

- Group 3–How are force sizes, battle durations, force ratios, casualty numbers, casualty fractions, and casualty rates related to winning and losing?

- Group 4–How are force sizes, battle durations, force ratios, casualty numbers, casualty fractions, and casualty rates related to various situational and environmental factors, such as the rate of advance, nationality, tactics, terrain, and supporting fires, among others?

- Group 5–How do casualty numbers, casualty fractions, and casualty rates vary over relatively brief periods of time?

- Group 6–What proportion of the total battle casualty number are due to killed in action, wounded in action, died of wounds, captured, and missing in action?

- Group 7–How are force sizes, battle durations, force ratios, casualty numbers, casualty fractions, and casualty rates distributed statistically?

- Group 8–What other questions should be addressed?

1-4. ASSUMPTIONS

a. The main assumptions of this paper are (i) that the bulk of the pertinent works has been collected and is on file at CAA and (ii) that statistical procedures are appropriate for summarizing the empirical relationships implicit in these data. A secondary assumption, needed for application of the findings, is that the statistics of near-future battles will be like the statistics of the battles of the past 400 years or so—in particular, that trends of sufficiently long duration can be extrapolated to the near future with a reasonable degree of confidence.

b. The following caveats should be borne in mind by any potential users of this information.

(1) Marginal distributions may be misleading as to the multivariate distribution.

(2) Trends with respect to time affect projections of past experience to the future.

(3) Typical values give only general guidance, and often need to be modified to apply to the specific case. In this regard, attention should be given to variations with the level of operation, organizational echelon, theater, enemy characteristics, tactical situation, general intensity or level of activity, allocation of effort, and so forth.

1-5. APPROACH. The basic approach used in this study was to review the prior work in this area and where possible to contribute to it. We focused on the analysis of the general trends in and relations among force sizes, battle durations, and casualties. Our efforts seek to advance the state of the art over prior efforts by (i) giving the Constant Fallacy (Helmbold-1994) appropriate recognition, (ii) using a regression model that includes the battle duration and battle date as potentially important factors, (iii) employing robust regression to minimize the distorting effects of a few gross errors in the data, (iv) systematically using more than one data base at a time in order to determine the sensitivity of the results to different sets of data, and (v) using several dependent variables, to include the casualty numbers as well as the casualty exchange ratio. The primary data analysis technique used is descriptive statistics.

1-6. FINDINGS, OBSERVATIONS, AND CONCLUSIONS. The following are applicable to the period from 1600 AD to the present. Since they have persisted for a long period of time despite major changes in tactics and weaponry, they presumably can be extrapolated to the near future with a fair degree of confidence:

a. Casualty numbers and rates vary widely from nation to nation, from theater to theater, and from year to year. They are strongly affected by dilution and attenuation effects. Also, most casualty rate distributions are approximately lognormal.

b. Up to about 20 percent of the total population can be mobilized in a military emergency. That would mobilize practically every male of military age. We have no record of any country exceeding a mobilization level of about 25 percent, and that level may be maintainable for only a relatively short period of time. In contrast, the US has never mobilized more than about 2 to 10 percent of its total population.

c. For the US population as a whole, peacetime death rates are about nine deaths per 1,000 person-years (9 deaths/kpy), but about 2 deaths/kpy for males of military age. The death rates of mobilized forces, averaged over the course of a war, are generally about twice the peacetime mortality rates for males of military age. Casualty rates of forces in a theater of combat, averaged over the course of a war, generally vary from about 5 to 30 battle deaths (BD) per 1,000 personnel-years (5 to 30 BD/kpy), plus 15 to 90 wounded not mortal (WNM) per 1,000 personnel-years (15 to 90 WNM/kpy).

d. In recent US experience, nonbattle deaths over the course of a war are mostly due to accidents. Deaths from disease are only about 20 percent of all nonbattle deaths and only about 5 percent of all (battle and nonbattle) deaths.

e. When viewed over relatively short time intervals, theater level total battle casualty (TBC) rates of 50 per 1,000 personnel years (50 TBC/kpy) to 250 TBC/kpy are not unusual. US army Group total battle casualty rates generally range from around 0.1 TBC per 1,000 personnel days (0.1 TBC/kpd) to about 20 TBC/kpd. US army total battle casualty rates generally range from around 0.1 TBC/kpd to about 20 TBC/kpd, with median values ranging from about 0.5 TBC/kpd to 8 TBC/kpd. US corps total battle casualty rates for a variety of combat situations, but typically associated with conducting a successful offensive operation, generally range from around 0.1 TBC/kpd to about 20 TBC/kpd, with median values ranging from about 0.7 TBC/kpd to 7 TBC/kpd. These values for corps apply to their nonzero casualty days. Zero casualty days can range from 0 to about 33 percent for a corps, depending on its sector of the front, mission, and so forth. For short, intense battles, corps TBC rates can be substantially higher than their long-term averages, and typically amount to about 100 TBC/kpd.

f. There is little trustworthy data regarding casualties to noncombatants during wars.

g. During a war, strengths and casualties surge and slow in a quasirhythmic, wavelike manner.

h. At the theater level, it appears that casualty numbers tend to increase faster than proportionately to the force's exposure level expressed in kpy. However, in World War II the US 12th Army Group's TBC numbers *declined* as its exposure in kpd increased, a trend opposite to that for theater forces. For army-sized formations, the relation of TBC numbers and exposure in 1,000 personnel-days (kpd) is inconsistent and variable. Usually, TBC numbers increase with increasing exposures in kpd, but some data bases show a *decrease* rather than an increase. However, even when the TBC number increases with exposure in kpd, the relationship is not necessarily one of simple proportionality. Instead, doubling the exposure may *more* than double the TBC number or it may *less* than double it. Similar remarks apply to the relation between the casualty numbers and exposure levels of corps-sized formations. These findings demonstrate that it is hazardous to apply a simple proportionality of casualties to exposure levels without considering other important factors.

i. The SCUD missile threat to combat forces in theater rear areas can be expected to produce about one or two killed or seriously injured casualties per impacting missile, unless the enemy is able to locate and target rear area targets in a timely and accurate fashion and friendly forces have no effective countermeasures against them.

j. It appears likely that killed in action (KIA) rates are about one-fifth the TBC rate, and that a large fraction of those initially classified as captured or missing in action (CMIA) are later reclassified as KIA.

k. The data in this paper suggest that, when viewed over several weeks or months duration, army Group TBC rates tend to decline exponentially. After transforming the data logarithmically, this is a linear trend, and on this general trend is superimposed a residual that can be represented by a simple, one-term autoregressive process having a normal random error. The same is true for army-level and corps-level formations, at least when viewed over several weeks or months duration for a basically successful offensive campaign.

l. Historically, over 99 percent of all army Group battle casualties are taken by formations at army level and below. Over 99 percent of all army battle casualties are taken by formations at corps level and below. Well over 90 percent of all corps battle casualties are taken by formations at division level and below.

m. Winners of army-sized engagements typically have about half the TBC rate of losers. Winners of corps-sized engagements also have about half the TBC rate of losers, although this ratio can vary substantially from battle to battle.

CHAPTER 2

LOSSES IN WARS

2-1. INTRODUCTION. This chapter takes up the question of losses in wars as a whole. It deals primarily with battle deaths (BD), for the available data often do not permit a more detailed description of the losses. For our purposes, we define battle deaths to be the sum of the killed in action (KIA) and the died of wounds (DOW) suffered in combat. The treatment given here is intended to be illustrative, rather than exhaustive. Thus, we present some examples of losses in wars but do not attempt a comprehensive review of that subject.

2-2. DEFINITIONS. This paragraph introduces terminology that is used consistently throughout the remainder of this paper.

a. Loss Rate. Here, as in other parts of this paper, loss rates are expressed as the average number of losses of a certain type per thousand personnel in the exposed population per unit of time. This is more briefly expressed as losses per thousand per unit time, and symbolized by L/kpt, where L is the type of loss in question and t is the unit of time used. Normally, the unit of time will be either a year a month, or a day. Thus, L/kpy stands for the (average) rate of "type L" losses per thousand exposed personnel per year, L/kpm stands for the (average) loss rate per thousand exposed personnel per month, and L/kpd stands for the (average) loss rate per thousand exposed personnel per day. The general formula for computing these (average) rates is given by the formula

$$\mathrm{L} / \mathrm{kpt} = \frac{\text{No. of losses of type L in the exposed population}}{\int_{t_1}^{t_2} p(t)dt},$$

where $p(t)$ is the number of personnel in the exposed population at time t, and the time interval runs from t_1 to t_2. The integrated population size in the denominator is used as a measure of the total exposure to the risk of loss. The total elapsed time, $T = t_2 - t_1$, is conventionally expressed in units of a year, a month, or a day. Note that, strictly speaking, L/kpt depends on the starting and ending points of the time interval and the type of population exposed, as well as on the type of loss being considered. These dependencies are often suppressed for convenience. An expression such as "the (average) loss rate per thousand personnel in US Army Expeditionary Forces per year for the period 1 July 1917 through 31 October 1918, inclusive" can be used whenever it is important to call attention to the specific population and time period used to compute the average rate.

b. Example. For example, suppose that the personnel exposed to a risk of battle death rose linearly from zero at time t_1 to 1,000,000 over the course of 10 months, so that $t_2-t_1 = 10$ months. Then the time integral of the number of exposed personnel is equal to 5,000,000 personnel-months for the period t_1 to t_2. If during this 10 month period they suffered 10,000 battle deaths, then their (average) battle death rate is defined to be 10,000/5,000,000 = 0.002

battle deaths per personnel-month, or 2.0 BD/kpm for the period t_1 to t_2. This is equivalent to an average loss rate over that 10 month period of $1.2 \times 2.0 = 2.4$ BD/kpy, or to $2.0/30.44 = 0.066$ BD/kpd. An analogous approach applies to figuring the average loss rates for other types of losses, such as killed in action (KIA), wounded in action (WIA), died of wounds (DOW), captured or missing in action (CMIA), and disease or nonbattle injured (DNBI).

c. Approximations. If the detailed history of personnel strength, $p(t)$, is not known, then various approximations to it may be adopted. For example, the available data may report only the average value, *pavg*, of $p(t)$ over some period of time, T. Then the time integral of $p(t)$ over that same period is estimated as equal to the product $pavg \times T$. Various approximations for the other quantities used in loss rate computations may be used on occasion.

d. Other Quantities of Interest. On occasion we may be concerned with the *population* size at some instant of time, $p(t)$, with the *number* of losses of type L that occurred over some period of time, or with the *fraction* of losses of type L incurred by some nominal population size, p_0. The latter is usually expressed as the number of losses of type L per thousand of the nominal population and defined by the formula

$$\mathrm{L/kp} = \frac{\text{No. of losses of type L in the exposed population}}{p_0}.$$

e. Dilution and Attenuation

(1) Published casualty rates are generally affected by some degree of dilution and attenuation. By dilution we mean that not all portions of the population used as a basis for computing a published (average) casualty rate are equally exposed to the risk in question. Thus, casualty rates for the more exposed portions of the population are diluted by other, less exposed, portions of the population. By attenuation we mean that the level of risk is not constant over the time period used as a basis for computing a published (average) casualty rate. Thus, casualty rates for the higher-risk times are attenuated by casualty rates at lower-risk times. Accordingly, we anticipate that casualty rates based on large populations and long time periods will be lower than those based on small populations and shorter time periods. Indeed, we will find that these dilution and attenuation effects can result in average casualty rates orders of magnitude lower than the undiluted and unattenuated rates. Accordingly, these effects are extremely important and must be carefully borne in mind when interpreting the significance of casualty rates.

(2) Table 2-1, adapted from Laird, illustrates how important the effects of dilution and attenuation can be.

Table 2-1. Effects of Dilution on Average Death Rates

Source of risk	Population exposed to risk	Average death rate (deaths /kpy)
Traffic accidents	Entire US	0.3
All accidents	Entire US	0.5
All causes	All US 21-year olds	1.2
All causes	All US 21-year old males	1.8
Enemy action	Whole US Army (Vietnam era)	3.6
Enemy action	Whole US Army (Korea)	6.4
Enemy action	Whole US Army (WWII)	9.2
All causes	Entire US	9.5
Enemy action	Army non-divisional troops in combat zone	25.0
Enemy action	Army divisional troops in combat zone	170.0

2-3. ISSUES TO BE EXAMINED. Some of the issues to be examined in this chapter are listed below.

- How does mortality in war compare with mortality in peacetime?
- What empirical trends in mortality in war persisted over extended periods of time?
- What is the probability that an individual selected at random from the exposed population will die if the exposed population is taken to include all who served, only those who served in a combat theater, just those who served on the front lines, just those who served in a quiet sector of the front, or just those who served in an active sector of the front?
- What is the distribution of the mortality rate across wars?
- How does the mortality rate vary depending on which side was the aggressor, or on which side won?

2-4. SOME EXAMPLES OF PEACETIME MORTALITY OF MALES OF MILITARY AGE. As noted earlier, our treatment is selective and illustrative rather than exhaustive. In order to provide a baseline for comparison, we begin with a brief discussion of the peacetime population exposed and their mortality.

a. Military Service Personnel. The personnel in military service are drawn from the population at large. However, at any given point in time only a relatively small percentage of the total population are serving in the military. This is illustrated by Figure 2-1, which shows for the period 1800 to the present the population of the United States, the number serving in the military, and the percentage serving in the military. As can be seen, the percentage of the US population serving in the military never exceeded 8.6 percent, a level that was reached for a brief time during World War II. The next-highest levels reached were about 3 percent during the American Civil War, 2.7 percent during World War I, 2.3 percent during the Korean War, and 1.8 percent during the Vietnam War. (All data in this subparagraph are based on Statistical Abstracts and Historical Statistics of the US unless otherwise noted.)

(1) The reason for these low mobilization percentages can be rationalized as follows.

(a) First, slightly less than half the population are males. Traditionally the fighting forces have been drawn almost entirely from the male segment of the population. In 1992, males constituted 48.73 percent of the total US population.

(b) Second, depending on the age distribution within the population at any given time, only about half the males are of military age—the remainder being either too old or too young. In 1992, for example, 47.78 percent of the US males were 15 to 44 years old, inclusive, which for purposes of illustration we take to be representative of the "military age" bracket. Table 2-2 shows the number of US males of military age as a percentage of the total US population for various years.

Table 2-2. Males of Military Age as a Percent of the Population

Year	US population	Males of military age (15-44)	Fraction males of military age (%)
1800	5,297,000	825,274	15.6
1850	23,261,000	4,168,390	17.9
1900	76,094,000	18,472,676	24.3
1950	151,234,000	33,102,249	21.9

(c) Third, not all the males of military age are fit for military service—they may be too short or too tall, blind or otherwise handicapped, institutionalized, or unsuited to military service for other reasons. For example, in World War II, the US classified 36,677,000 of its selective service registrants as candidates for military service, or 27 percent of the average US total population for the 1940-1945 period. Of those so classified, only 17,955,000 (49 percent of those classified) were examined for fitness. Of those examined, 6,420,000 were rejected (37 percent of those examined and 18 percent of those classified). Those examinees who passed and were subsequently inducted numbered 10,022,000 (56 percent of those examined and 27 percent of those classified). The percent of draftees examined who were subsequently rejected was 31 percent for the US Civil War, 21 percent for World War I, 37 percent for World War II, 32 percent for the Korean War, and 45 percent for the Vietnam War. Regarding service in the armed forces of the United Kingdom during World War II, Mellor states that, "Most of these men were drawn from the younger age groups between 18 and 30. Three out of every five men born between 1905 and 1927 and seven out of every ten born between 1915 and 1927 served in the Armed Forces."

(d) Fourth, not all of those fit for military service can be spared from employment in the civilian economy—some must be left to work the farms, manufacture weapons of war, provide essential services to the civilian community, and so forth. For example, in World War II about 1,513,000 (8 percent of those examined by the US) were neither rejected nor inducted.

(2) The proportion of the population mobilized by the principal nations in World War I and World War II is shown in Figure 2-2. The unusually high value of 25 percent mobilized in World War II is for Yugoslavia. The highest values of percent mobilized in World War I are for Serbia (24 percent), Great Britain (22 percent), and France (22 percent). Note, however, that mobilizations in excess of 20 percent of a nation's population have been extremely rare, even under the desperate stresses of World War I and World War II. It is interesting to note that, as a rule, the percent of the population mobilized in World War I was higher than that in World War II. In fact, the median percent mobilized is about 14 percent for World War I as compared to only about 7 percent for World War II. The reasons for this are not clear. (Data of Figure 2-2 based on Wright.)

b. Mortality in Peacetime. The peacetime mortality rate varies with the individual's age, sex, race, nationality, economic status, season of the year, geographic location, and several other factors. Major branches of theoretical and applied statistics have been developed to study the dependence of mortality on such factors, and these actuarial sciences figure largely in national census bureau and insurance corporation activities. For our purposes, we focus on the mortality of males of military age, which we take to be 15 through 44 years of age. This defines the population at risk. Actually, even within this age bracket, younger males have markedly lower mortality rates than older ones, as illustrated in Figure 2-3. Moreover, it seems plausible that those males who are fit for military service might have a lower average mortality than those unfit for military service, and hence lower than the entire population of males of military age. However, the readily available data do not provide the information needed for a quantitative assessment of this difference. Thus, for simplicity in later presentations, we adopt the peacetime mortality rates for all males in the 15-44 year age bracket as being typical of those fit for military service. Figure 2-4 shows these mortality rates for the US. The US experience from 1900 to the mid-1960s is about the same as for many other nations, as illustrated by the data shown in Figure 2-5. The main points to be observed here are that, at least for nations with medical and public health technologies similar to those of European countries, peacetime death rates for males of military age:

(i) Have been dropping more rapidly than for the population as a whole,

(ii) Have historically been much lower than for the population as a whole, and

(iii) In the 1990-2000 era are expected to be about one to 2 deaths/kpy.

(The data in this subparagraph is based on Preston and Statistical Abstracts and are heavily weighted toward nations with medical and public health technologies similar to those of European countries.)

2-5. SOME EXAMPLES OF CASUALTY FRACTIONS AND RATES RELATIVE TO NATIONAL POPULATION. As before, our treatment is selective and illustrative rather than exhaustive. Here we take up battle deaths in relation to the national population as a whole.

a. Battle Deaths Relative to National Population. Figure 2-6 shows the mortality rates from all causes, and for battle deaths, for British and French nations by century since 1600 (the 1900 data used end at 1930, but are normalized to a time span of a century). For example, considering the entire population of Britain in the 1600s to constitute the population at risk, the mortality rate from battle deaths was about 0.45 BD/kpy, while the mortality rate from all causes was about 30 deaths/kpy, or about 67 times the battle death rate. Another way of putting this is to say that the probability a member of the British population selected at random in the 1600s would die in battle was about 0.45 / 30 = 0.015, or about 1 chance in 67. In the early 1900s, this probability of dying in battle rose to about 0.58 / 12 = 0.048, or roughly 1 chance in 21. (The data in this subparagraph are based on Wright.)

b. Casualty Fractions Relative to National Populations for Interstate and Civil Wars. Figure 2-7 shows the distribution of battle death fractions for 139 participants in 106 major civil wars between 1916 and 1980 and for 302 participants in various interstate wars between 1817 and 1980. For these data, the prewar population is used as an estimate of the average population size during the participant's period of participation, and so these battle death rates are based on considering the entire prewar national population to be at risk. The source defines battle deaths to include all "battle-related" deaths. These clearly include all military personnel killed in action and died of wounds. They also appear to include an unknown number of "collateral damage" deaths to non-military personnel, as well as an unknown number of other deaths to military personnel. In addition, the data for interstate wars include battle-related deaths of native troops from the participant's colonies, protectorates, and dominions if they fought on the same side as the member nation. The data for civil wars include battle related deaths incurred by the opposition forces as well as the identified government forces—the numbers listed are the totals for the nation-participant in which the civil war was fought.

As can be seen, the two distributions shown in Figure 2-7 are quite similar. Both are approximately lognormal with BD/kp medians in the 0.24 to 0.27 range and standard deviations of the logarithms in the 2.4 to 2.8 range.

The civil and interstate war data were used to perform multiple regressions, assuming a relation of the form:

$$\ln(BD) = C_0 + C_1 \ln(Pop) + C_2(StartDate - 1800) + \varepsilon ,$$

where *BD* is the number of the participant's battle related deaths, *Pop* his prewar population, and *StartDate* the calendar date he first started to participate. The *C*'s are unknown coefficients to be fitted to the data, and ε is the residual error of the fit. Table 2-3 summarizes the regression results. The ± values are plus or minus one standard error. RMSE is the standard deviation of the residuals (ε). R-squared is the fraction of the variance in ln(*BD*) that is accounted for by the nonresidual part of the regression, as measured by the square of the correlation coefficient. The regression coefficients C_1 are certainly significantly greater than zero. The C_2 coefficients are probably not significantly different from zero. The general explanatory power of the regression, as indicated by R-squared, is rather poor—certainly not good enough for definitive predictions of battle deaths in future wars. Nevertheless, it may be useful for certain rough estimates employed for general guidance purposes, and gives a general idea of how battle death rates depend on the factors that define it. Indeed, the latter illustrates the point that battle death fractions are not constants, but depend in a highly nonlinear fashion on their defining factors. This can be shown by writing the regression equation in terms of *BD*, *Pop,* and *StartDate* rather than in the logarithmic form as given earlier. (Data in this subparagraph based on ICPSR.)

Table 2-3. Summary of Multiple Regression Results for Battle Death Fractions.

War type	C_0	C_1	C_2	RMSE	R-squared
Civil	5.588±1.2	0.137±0.07	0.017±0.02	1.087	0.031
Interstate	–0.204±0.9	0.527±0.06	–0.025±0.02	1.297	0.227

c. Casualty Rates Relative to National Populations for Interstate and Civil Wars. Figure 2-8 shows the distribution of battle death rates for 139 participants in 106 major civil wars between 1916 and 1980 and for 302 participants in various interstate wars between 1917 and 1980. For these data, the prewar population is used as an estimate of the average population size during the participant's period of participation, and so these battle death rates are based on considering the entire prewar national population to be at risk. As in the preceding subparagraph, the source defines battle deaths to include all "battle related" deaths. These clearly include all military personnel killed in action and died of wounds. They also appear to include an unknown number of "collateral damage" deaths to nonmilitary personnel, as well as an unknown number of other deaths to military personnel. In addition, the data for interstate wars include battle related deaths of native troops from the participant's colonies, protectorates, and dominions if they fought on the same side as the member nation. The data for civil wars include battle related deaths incurred by the opposition forces as well as the identified government forces—the numbers listed are the totals for the nation participant in which the civil war was fought.

As can be seen, the two distributions shown in Figure 2-8 are quite similar. Both are approximately lognormal with BD/kpy medians in the 0.3 to 0.5 range and standard deviations of the logarithms in the 2.4 to 2.9 range. The very high values (such as those above 10 BD/kpy) are usually associated with very brief participation durations, so that the *proportion* of battle deaths seldom approaches 100 percent of the population. For example, Poland is rated at 122 BD/kpy for the brief period of its participation in the early days of World War II preceding its surrender to Germany. But Poland's participation lasted for only 0.075 years, so the proportion of its battle related deaths amounted to $0.075 \times 122 = 9$ BD/kp (battle related deaths per thousand population), or slightly less than 1 percent. Belgium is rated at 23 BD/kpy for the period of its participation during World War II. On the other hand, some nations have fairly high values based on longer participation. For example, during World War II, we find 4 BD/kpy for Japan, 9

BD/kpy for Germany, and 11 BD/kpy for the USSR. The corresponding figures for the UK and the US are 1.0 BD/kpy and 0.8 BD/kpy, respectively.

The civil and interstate war data were used to perform multiple regressions, assuming a relation of the form:

$$\ln(BD) = C_0 + C_1 \ln(Pop) + C_2 \ln(Months) + C_3(StartDate - 1800) + \varepsilon ,$$

where *BD* is the number of the participant's battle related deaths, *Pop* his prewar population, *Months* the duration of his participation in months, and *StartDate* the calendar date he first started to participate. The *C*'s are unknown coefficients to be fitted to the data, and ε is the residual error of the fit. Table 2-4 summarizes the regression results. The ± values are plus or minus one standard error. RMSE is the standard deviation of the residuals (ε). R-squared is the fraction of the variance in ln(*BD*) that is accounted for by nonresidual part of the regression, as measured by the square of the correlation coefficient. The regression coefficients C_1 and C_2 are certainly significantly greater than zero. The C_3 coefficients may be greater than zero, but not as certainly as for C_1 and C_2. The general explanatory power of the regression, as indicated by R-squared, is not good enough for definitive predictions of battle deaths in future wars. Nevertheless, it may be useful for certain rough estimates employed for general guidance purposes and gives a good general idea of how battle death rates depend on the factors that define it. Indeed, the latter illustrates the point that battle death rates are not constants, but depend in a highly nonlinear fashion on their defining factors. This can be shown by writing the regression equation can be written in terms of *BD*, *Pop*, *Months*, and *StartDate* rather than in the logarithmic form as given earlier. (Data in this subparagraph bases on ICPSR.)

Table 2-4. Summary of Multiple Regression Results for Battle Death Rates

War type	C_0	C_1	C_2	C_3	RMSE	R-squared
Civil	3.945±1.1	0.185±0.07	0.446±0.07	0.027±0.02	1.054	0.309
Interstate	1.008±0.8	0.356±0.05	0.603±0.05	0.028±0.02	1.137	0.459

d. Ubiquity of the Lognormal Distribution. We have seen in the two immediately preceding paragraphs that the BD/kp and the BD/kpy rates are distributed approximately lognormally. It is an interesting fact that each of the factors entering into the computation of these fractions or rates (that is, the number of battle related deaths, prewar population size, and duration of participation) is also distributed approximately lognormally. Figure 2-9 illustrates this for the distribution of the number of battle deaths. Both distributions have medians close to 4,000 battle deaths and the differences between them are not significant considering their standard errors. One striking aspect of Figure 2-9 is the "graininess" of the battle death estimates—that is, they have a very strong tendency to cluster around "round numbers" such as 100, 1,000, 5,000, 10,000, *etc.* battle deaths. As we proceed, we will find that the lognormal distribution is ubiquitous and provides an acceptable fit to many loss fractions and rates, and even to each of the factors entering into their computation. In this connection, we remark that the conventional statistical measures of the goodness of fit to these lognormal distributions (such as the Kolmogorov-Smirnov and similar tests) are overly conservative when the data are even moderately grainy.

We remark that our Figure 2-9 is the counterpart to Lewis Fry Richardson's famous graph of the number and "magnitude" of deadly quarrels, that is, their frequency distribution by the logarithm of the number of battle deaths. See, for example, Richardson and also Weiss.

2-6. SOME EXAMPLES OF CASUALTY FRACTIONS AND CASUALTY RATES RELATIVE TO MOBILIZED FORCES. As noted earlier, only a relatively small fraction of a nation's population can be mobilized. Therefore, the casualty fractions or rates based on the population as a whole do not give a very good indication of the corresponding rates for mobilized forces. Indeed, if the casualty fraction or casualty rate to the population at large is P and the fraction of the population mobilized is m, then the casualty fraction or rate to the mobilized forces is $M = P/m$. Since the fraction of the population mobilized is nominally about 1/10, we anticipate that M will nominally be about $10P$. For example, because battle death fractions relative to the population as a whole are nominally about 0.3 BD/kp and because the fraction of the population mobilized in US wars generally ranged from 1/10 to 1/100, we anticipate nominal battle death fractions for US mobilized forces of around 3 to 30 BD/kp.

a. Casualty Fractions of Mobilized Forces

(1) World Wars I and II. Figure 2-10 shows for various countries the cumulative distribution of the percent of their mobilized forces that died in the World Wars. The unusually high fraction of BD/kp to mobilized forces in World War I is for Rumania (450 BD/kp). The unusually high fractions of BD/kp to mobilized forces in World War II are for Rumania (460 BD/kp), Hungary (42 BD/kp), USSR (34 BD/kp), and Germany (32 BD/kp). (Data in this subparagraph based on Wright.)

(2) US Wars. Table 2-5 shows US battle death experience as a percentage of the number serving. In this table, battle deaths include killed in action, died of wounds, and died while missing or captured. The number serving and battle deaths in the Revolutionary War are unknown—estimates range from 184,000 to 250,000 serving and about 4,400 battle deaths, which corresponds to about 18 to 24 BD/kp. For the World Wars, "Army" includes Air Service. For World War I, battle deaths include casualties suffered by American forces in northern Russia to 25 August 1919 and in Siberia to 1 April 1920. (Data in this subparagraph based on Goldich.)

Table 2-5. Battle Deaths as a Fraction of the Forces Mobilized in Some US Wars

War name	Population	Number serving	Battle deaths	Battle deaths (BD/kp)
Revolutionary War	All Services	Unknown	4,435	Unknown
War of 1812	All Services	286,730	2,260	7.9
Mexican War	All Services	78,718	1,733	22.0
Civil War (Union)	Army only	2,128,948	138,154	64.9
Spanish-American	Army only	280,564	369	13.0
World War I	Army only	4,057,101	50,510	12.4
World War II	Army only	11,260,000	234,874	20.9
Korean War	Army only	2,834,000	27,704	9.8
Vietnam War	All Services	8,400,000	45,941	5.5

b. Casualty Rates of Mobilized Forces. Casualty rates to mobilized forces should consider the average duration of service. For example, the proper figure for the number of personnel years of service (and hence of exposure to the risks typical of mobilized forces) when a million men are mobilized for a war that lasts 10 years is not necessarily 10,000,000 personnel years. For example, if the average duration of service is 1 year and the average force during the 10-year war is 100,000, then a million men were mobilized, but the exposure is only 1,000,000 personnel years. Unfortunately, sources seldom report either the average duration of service or the average mobilized force size. However, we did find the data shown in Table 2-6. In this table, battle deaths and wounds not mortal (WNM) are casualties resulting from enemy action. Battle deaths include killed in action, died of wounds, and died while missing or captured. The corresponding BD/kpy rates are generally within a factor or two or three of the peacetime mortality of males of military age. Apparently, mobilization in and of itself, while it may increase the average death rate somewhat, does not do so dramatically. (All data in this subparagraph derived from Statistical Abstracts.)

Table 2-6. Rates of Battle Death and Wounds Not Mortal for Mobilized US Forces

War	Number of personnel serving	Average duration of service (months)	Battle deaths (BD)	Wounds not mortal (WNM)	BD/kpy	WNM/kpy
Civil War	2,213,000	20	140,000	282,000	38.0	76.5
Spanish-American	307,000	8	250	2,000	1.2	9.8
World War I	4,735,000	12	53,000	204,000	11.2	43.1
World War II	16,113,000	33	292,000	671,000	6.6	15.1
Korean Conflict	5,720,000	19	34,000	103,000	3.8	11.4
Vietnam Conflict	8,744,000	23	47,000	153,000	2.8	9.1

c. Casualty Rates of Forces in a Combat Theater. We anticipate that casualty rates to mobilized forces in a combat theater will be higher than those for the mobilized forces as a whole, due to attenuation and dilution effects. Table 2-7 shows these rates for US forces in several wars. Table 2-8 shows the battle death rates estimated for US forces in Vietnam during that war. These battle death rates are substantially higher than the contemporary peacetime mortality rates were for males of military age. This is particularly noticeable in the Vietnam data. We conclude that service in a theater of combat substantially increases the average death rate above peacetime levels. (All data in this subparagraph derived from Statistical Abstracts.)

Table 2-7. Rates of Battle Death and Wounds Not Mortal for US Forces Abroad

War	Personnel serving	Fraction serving abroad (%)	Average abroad duration (months)	Battle deaths (BD)	Wounds not mortal (WNM)	BD/kpy	WNM/kpy
Civil War	2,213,000	None	NA	140,000	282,000	NA	NA
Spanish-American	307,000	29	1.5	250	2,000	6.5	52.1
World War I	4,735,000	53	6	53,000	204,000	22.4	86.2
World War II	16,113,000	73	16	292,000	671,000	13.6	31.2
Korean Conflict	5,720,000	56	13	34,000	103,000	5.5	16.6
Vietnam Conflict	8,744,000	UNK	UNK	47,000	153,000	18.5	61.6

Table 2-8. Battle Death Rate by Year for US Forces in Vietnam

Year	Military forces in Vietnam	Battle Deaths	BD/kpy
1965	184,300	1,432	7.8
1966	385,300	5,047	13.1
1967	485,600	9,463	19.5
1968	536,100	14,623	27.3
1969	475,200	9,426	19.8
1970	234,600	4,230	18.0
1971	156,800	1,376	8.8
1972	24,200	361	14.9
Total	2,482,100	45,958	18.5

2-7. MISCELLANEOUS OBSERVATIONS ON BATTLE CASUALTIES TO NATIONAL POPULATIONS AND MOBILIZED FORCES

a. Casualties to Noncombatants

(1) Little has been done in the way of careful research on losses to noncombatants in wars. Deciding what noncombatant casualties to include presents various conceptual issues. It certainly seems appropriate to include, for example, noncombatant deaths due to the direct effects of military weapons (as included in the phrase "collateral damage"), or from fires and buildings collapsed by bombing. However, it is not so clear how many of the casualties to noncombatants from the indirect adverse effects of military operations should be included. Such indirect adverse effects may impact on their access to proper food, clothing, shelter, medical care, and safe working or living conditions. While it is not clear how many casualties from such indirect effects are included, it appears that noncombatant deaths in wars have been large—often as large or larger than the deaths to the mobilized forces themselves. Consult Blyth for an interesting proposed approach to estimating casualty numbers while taking into account various types of uncertainty. (Data in this subparagraph derived from Eckhardt. Other potential sources include Bodart and Kellogg, Dumas and Vedel-Peterson, and Kohn.)

(2) Table 2-9 shows noncombatant deaths in the Vietnam War, as reported by Mullin and Preston. They attribute their data for assassinations to the US Defense Department, for civilians killed to the Senate Subcommittee on Refugees and Escapees, and for the civilian Viet Cong killed to the US State Department.

Table 2-9. Noncombatant Deaths in the Vietnam War

Year	Killed	Assassinated by Viet Cong or North Vietnamese Army	Civilian Viet Cong killed by Saigon government	Total
1965	25,000	UNK	UNK	25,000
1966	50,000	1,732	UNK	51,732
1967	60,000	3,706	UNK	63,706
1968	100,000	5,389	2,559	107,948
1969	60,000	6,202	6,187	72,389
1970	30,000	5,947	8,191	44,138
1971	25,000	3,537	3,650	32,187
1972	65,000	4,194	#N/A	69,194
Total	415,000	30,707	20,587	466,294

b. Battle and Nonbattle Casualties. Although our main focus of interest is on battle casualties, it is appropriate to mention the relative number or percentage of battle and nonbattle deaths. Of course, in each case, the percentage of battle and nonbattle deaths adds to 100 percent. These percentages are shown in Figure 2-11. The data used include the American Civil War, the Boer War, World War I, World War II, and US forces in Korea. The fitted curves in this figure are cubic functions of the calendar date. The apparent decline in the percentage of battle relative to nonbattle deaths starting around 1950 is an artifact of the cubic function rather than a characteristic of the data. However, the main point to be gathered from this figure is that there has been a dramatic change in the relative proportions of battle and nonbattle deaths during the century from about 1850 to 1950. This same period parallels the rise of modern public health, advances in surgical technology, and the development of effective antibiotics. The dramatic decline in the proportion of nonbattle deaths is largely due to the reduction in deaths from illness occasioned by these medical advances. It is not clear that medical advances in the prevention and treatment of disease can further reduce substantially the proportion of nonbattle deaths, because most of the nonbattle deaths nowadays are due to accidents rather than to disease. For example, in WWII, the US Army had a total of 229,823 battle deaths (75 percent of all deaths) and only 76,407 nonbattle deaths (25 percent of all deaths). Only 14,904 of the nonbattle deaths were due to disease—that is about 20 percent of the nonbattle deaths and only 5 percent of all deaths. So even if *all* disease deaths could have been avoided, it would have made but a modest reduction in the proportion of nonbattle deaths. Major future reductions in the proportion of nonbattle deaths may, perhaps, be sought in the area of better accident prevention and treatment. (Data for Figure 2-11 derived from multiple sources including Ayres, Beebe and DeBakey, Goldich, Historical Statistics of the US, and Mitchell. US Army WWII data derived from Reister-WWII.)

2-8. INTRAWAR DYNAMICS

In this paragraph, intrawar dynamics are taken to involve the development of personnel strengths and losses over time during the course of a war. Two theories dealing with these aspects of intrawar dynamics will be discussed: Voevodsky's theory and a theory based on Lanchester's square law. The latter is a new and original proposal.

a. Voevodsky's Theory

(1) Many observers have noted that military operations such as battles and wars often appear to exhibit fairly well defined "cycles," each cycle consisting of an escalation phase followed by a deescalation phase. Indeed, this sort of quasi- or pseudocyclic behavior is often ascribed to other forms of human activity, including business cycles in economics, power or prestige in national and international politics, and—on a grand scale—even the rise and fall of civilizations. In some cases, the escalation phase consists of several escalation stages, one following on another. Voevodsky has coined the phrase "crisis wave" to refer to one such escalation stage. He presents several charts, similar to the one shown in Figure 2-12, that illustrate the presence of such crisis waves in defense expenditures, military personnel strength, and personnel casualties. On such a chart, steep upward slopes correspond to an escalation stage and shallow slopes to a slowing of escalation (that is, to a "cresting" of the crisis wave). Figure 2-12 shows two crisis waves, each marked by a rise and stabilization of US Department of Defense (DOD) strength and cumulative casualties. The first crisis wave or escalation stage culminates toward the end of 1964. It is followed by a second crisis wave or escalation stage that begins in early 1965 and culminates in a higher level of strength and cumulative casualties. Not shown on this chart is the deescalation phase of the complete cycle, during which strength levels and casualty rates both decline. Figure 2-13 shows a complete escalation/deescalation cycle for US Army strength in World War I. (Data for Vietnam from Voevodsky, data for WWI from Ayres.)

(2) Voevodsky has proposed a theory for the dynamics of crisis waves. It is based on the following postulates regarding strengths and casualties in a war. (In the following, i and j are conjugate indices. That is, $i = 1$ if and only if $j = 2$, and $i = 2$ if and only if $j = 1$. With this convention each of Voevodsky's postulates—and hence all formulas derived from them—are symmetric in the sense that interchanging the indices i and j leads either to another postulate or to a formula that can be validly derived from the postulates.)

Postulate 1.- The casualty exchange ratio is constant. That is, in each war, the casualties to one side are proportional to the number of casualties on the other side. In symbols,

$$C_i(t) = K_{ij}C_j(t), \tag{2-1}$$

where $C_i(t)$ is side i's (cumulative) casualty number and the constant of proportionality is characteristic of a particular crisis wave. Voevodsky presents a chart like that of Figure 2-14 in support of this postulate. If the postulate applies to a war, then plotting one side's losses against its opponent's losses on log-log scales should yield a straight line parallel to the theoretical "line of proportionality" shown in Figure 2-14. Although few wars have enough data on both side's losses to draw such a graph, the figure does show that this postulate may apply reasonably well to at least some wars.

Postulate 2.- Each side's casualties are related to that side's strength via a power function. that is,

$$C_i(t) = K_iS_i^{p_i}(t), \tag{2-2}$$

where the constants are characteristic of a particular crisis wave. A chart like the one shown in Figure 2-15 could be offered in support of this postulate. If the postulate applies to a crisis wave, then plotting each side's losses against its strength on log-log paper should yield a straight line. As can be seen, this chart—as well as most of Voevodsky's other data—only very weakly support this postulate.

Postulate 3.- The casualty production rate per unit of opposing force declines linearly with increasing opposing force size, that is,

$$C_i'(t)\Big/S_j(t) = L_j\left[1 - \frac{S_j(t)}{S_j(\infty)}\right], \tag{2-3}$$

where primes denote differentiation. Here $S_j(\infty)$ is the maximum military strength side j can (or will) commit. Both it and the constant L_j are characteristic of a particular crisis wave.

A differential equation for the strength can be derived from these postulates. The derivation proceeds as follows. Substitute from (2-1) into (2-3). Then substitute from (2-2) into that result. Change variables to normalized or "dimensionless" form by writing $S_j(t) = y_j(t)S_j(\infty)$, $q_j = 2 - p_j$, and

$$\tau_j = \frac{K_{ij}K_jS_j(\infty)^{1-q_j}}{L_j}(2-q_j)$$

to obtain

$$y_j' = \frac{y_j^{q_j}(1-y_j)}{\tau_j}. \tag{2-4}$$

This nonlinear differential equation will have closed form solutions only for special values of the exponent q_j. We note the following special cases:

(a) If $q_j = 0$, so that $p_j = 2$, then the solution of (2-4) is the saturated exponential function

$$y_j(t) = 1 - \left[1 - y_j(0)\right]\exp\left(-\frac{t-t_0}{\tau_j}\right). \tag{2-5}$$

(b) If $q_j = 1$, so that $p_j = 1$, then the solution of (2-4) is the logistic function

$$y_j(t) = \frac{1}{1 + \frac{1-y_j(0)}{y_j(0)}\exp\left(-\frac{t-t_0}{\tau_j}\right)}. \tag{2-6}$$

(c) If $q_j = -1$, so that $p_j = 3$ (values apparently favored by Voevodsky), then the solution of (2-4) is

$$\ln\left(\frac{1-y_j(t)}{1-y_j(0)}\right) + \left[y_j(t) - y_j(0)\right] = -\frac{t-t_0}{\tau_j}. \tag{2-7}$$

If, following Voevodsky, we neglect the term $y_j(t) - y_j(0)$ on the LHS as compared to the $\ln(\cdot)$ term, then we find the approximate relationship

$$y_j(t) \approx 1 - [1 - y_j(0)]\exp\left(-\frac{t - t_0}{\tau_j}\right),$$

that is, approximately the same as the saturated exponential function of (2-5).

(3) Voevodsky has tested his theory by fitting functions of the saturated exponential form given by equation (2-5) to data he has collected on the temporal evolution of strengths during the escalation phase of an escalation/deescalation cycle. We have done our own computations fitting the logistic form given by equation (2-6) to several data bases. It has four parameters that can be selected to fit a particular crisis wave—they are t_0, τ, $S(0)$, and $S(\infty)$. In some cases we had to assume an escalation phase consisting of two or more crisis wave stages to obtain a satisfactory fit. The quality of these fits is discussed in more detail in paragraph 2-8c, below.

b. A Lanchester-type Theory

(1) It is possible to construct a Lanchester-type theory that accounts for the main features of Voevodsky's crisis waves. As with Voevodsky's theory, it may or may not be applicable to the deescalation phase of the escalation/deescalation cycle. This theory assumes that the dynamics are governed by Lanchester's square law with reinforcement rate terms, that is

$$S_i'(t) = -A_{ij}S_j(t) + R_i. \tag{2-8}$$

Here $S_i(t)$ is the committed military strength of side *i* at time *t*, A_{ij} is the attrition to side *i* per unit strength of side *j* per unit time, and R_i is the rate at which side *i*'s military strength is being reinforced (and may be positive, zero, or negative). The indices *i* and *j* are conjugate in the sense described in the preceding paragraph. This theory postulates that the attrition coefficients and the reinforcement rates are constant throughout any given crisis wave. Notice that equation (2-8) implies that $S_i(t)$ will increase, be stationary, or decrease according as to whether the RHS is positive, zero, or negative. In particular, $S_i(t)$ is stationary when $S_j(t) = R_i / A_{ij}$, and it is theoretically possible for both sides simultaneously to reach this "stability" point. With the postulated constancy of the parameters, the solution of equation (2-8) for times *t* not less than t_0 is

$$S_i(t)/S_i(t_0) = \left(1 - \frac{\mu_{ij}r_j}{\lambda}\right)\cosh\lambda(t - t_0) + \left(\frac{r_i}{\lambda} - \mu_{ij}\right)\sinh\lambda(t - t_0) + \frac{\mu_{ij}r_j}{\lambda}, \tag{2-9}$$

where we have put

$$r_i = \frac{R_i}{S_i(t_0)},$$

$$\lambda = \sqrt{A_{ij} A_{ji}} ,$$

$$\mu_{ij} = \frac{S_j(t_0)}{S_i(t_0)} \sqrt{\frac{A_{ij}}{A_{ji}}} ,$$

and the conjugacy of the indices provides all other quantities of interest. Note that equation (2-9) has five parameters that can be adjusted to fit a particular crisis wave. They are t_0, $S(0)$, λ, μ, and r. In some cases we had to assume an escalation phase consisting of two or more crisis wave stages to obtain a satisfactory fit. The quality of these fits is discussed in more detail in paragraph 2-8c, below.

c. Discussion of the Theories of Intrawar Dynamics

(1) The first point to address is which theory best fits the available data on the evolution of strength during a war. Figure 2-16 illustrates the logistic and Lanchester fits to the data on US DOD strength in Vietnam, assuming two crisis waves. Here the Lanchester formulation seems to give the better fit.

Figure 2-17 illustrates the logistic and Lanchester fits to the data on US Army strength in World War I, assuming a single crisis wave throughout the escalation phase (no attempt was made to fit the deescalation phase of the cycle). Here the logistic formulation appears to give the better fit. However, We note the following points. First, neither Voevodsky nor Lanchester fit the downward phase of the crisis wave. Second, Voevodsky seems to fit these data rather better than Lanchester. In particular, the Voevodsky fits tend to level off at about the right time, while the Lanchester fits tend to continue rising much more steeply than the data. This may be due to the fact that Voevodsky's assumptions happen to match the World War I scenario rather well. Third, I suspect that the Lanchester fit could be substantially improved, and perhaps even represent the downward phase of the crisis wave, if at an appropriate time the reinforcement terms for each side were changed from positive to negative. In contrast, Voevodsky's theory in its present form does not represent any downward phase of the crisis wave and would have to be almost completely reworked to include such phenomena.

(2) In an effort to compare systematically their agreement with the available data, we fitted both Voevodsky's logistic function and Lanchester's equations to all of our data on the evolution of strengths during a war. In each case, the fitting was done by choosing the parameter values (four for the logistic and five for the Lanchester formulation) in such a way as to minimize the sum of the squares of the logarithmic residual errors. Here, the logarithmic residual error of the fit at a given data point is given by the expression: $\ln(ObservedValue \,/\, FittedValue)$. For example, if at some data point the observed value is 1,231,685 and the fitted value is 1,500,000, then the logarithmic residual error for that data point is $\ln(1{,}231{,}685/1{,}500{,}000) = -0.1971$. Figure 2-18 compares the resulting fits in terms of the sum of the squares of the logarithmic residual errors. Table 2-10 lists the data bases used for the points plotted in Figure 2-18.

Table 2-10. Data Files Mentioned in Figure 2-18

Data file	Description	No. of crisis waves assumed for fitting	Data points total	Data points used for fitting the escalation phase
CivNoStr-1	US Civil War, North	1	6	use all
CivSoStr-1	US Civil War, South	1	6	use all
WWIArStr-1	WWII US Army strength	1	29	use 1-20
WWIArStr-2	WWII US Army strength	2	29	use 1-20
WWI,AEF-1	WWI AEF strength	1	29	use 4-20
WWIBrStr-1	WWI British Expeditionary Force	1	5	use all
WWIIUSTR-1	World War II US Army strength	1	48	use 1-44
WWIIUSTR-2	World War II US Army strength	2	48	use 1-44
WWIIUSTR-3	World War II US Army strength	3	48	use 1-44
KoreaStr-1	US Army forces in Korea	1	16	use 2-16
KoreaStr-2	US Army forces in Korea	2	16	use 2-16
NamArStr-1	US Army in Vietnam	1	15	use all
NamArStr-2	US Army in Vietnam	2	15	use all
NamDoStr-2	DOD strength in Vietnam	2	16	use all

(3) Figure 2-18 provides no foundation for claiming that either formulation systematically gives the better fit. Both formulations provide quite acceptable fits, considering the number of data points involved, their likely accuracy, and the simplifications introduced in the theoretical development of the formulas used to fit the data. In some cases, Voevodsky's theory fits a bit better, in other cases, Lanchester's does. For both formulations, we sometimes had to omit a few points in order to get a good fit. Whether this is due to data inaccuracies or to limits on the applicability of the theories is an open issue. Because at present our data on intrawar dynamics are insufficient to determine whether Voevodsky's or Lanchester's theory is "better" in the sense of giving a superior fit, the choice is largely swayed by aesthetic considerations. Our own preference on aesthetic grounds is Lanchester, for it implies the existence of a culmination or stationary point and relates it to other quantities that (at least in principle) could be estimated. Voevodsky's theory, in contrast, rather baldly assumes the existence of an ultimate strength value and merely fits it to the data without relating it to any more fundamental quantities. Moreover, some of Voevodsky's postulates are quite wrong in some cases. Note that both theories are clearly intended to apply to the escalation phase of a given crisis wave, but neither addresses the issue of how many crisis waves will occur, much less what their characteristics will be (as specified by the parameters governing such things as their time of onset, speed of development, cresting or culmination level of strength, or time to the next major change). Voevodsky's theory was never intended to be applicable to the deescalation phase of the escalation/deescalation cycle, and it is not clear how to modify it to do so. The

Lanchester formulation may be able to model the downward deescalation/demobilization phase of the crisis wave by letting the reinforcement terms for each side go negative at appropriate times.

2-9. CHAPTER SUMMARY

a. Casualty rate distributions usually are approximately lognormal.

b. Up to about 20 percent of the total population can be mobilized in a military emergency. That would mobilize practically every male of military age. We have no record of any country exceeding a mobilization level of about 25 percent, and that level may be maintainable for only a relatively short period of time. In contrast, the US has never mobilized more than about 2 to ten percent of its total population.

c. Casualty rates are strongly affected by dilution and attenuation effects.

d. US peacetime death rates are about 9 deaths/kpy for the population as a whole, and about 2 deaths/kpy for males of military age.

e. Death rates (deaths/kpy) for mobilized forces, averaged over the course of a war, are about twice the peacetime mortality rates for males of military age.

f. Casualty rates of forces in a theater of combat, averaged over the course of a war, generally vary from about 5 to 30 battle deaths per 1,000 personnel years (5 to 30 BD/kpy), plus 15 to 90 wounded not mortal per 1,000 personnel years (15 to 90 WNM/kpy).

g. There is little trustworthy data regarding casualties to noncombatants during wars.

h. In recent US experience, nonbattle deaths over the course of a war are mostly due to accidents. Disease deaths are only about 20 percent of nonbattle deaths and only about 5 percent of all (battle and nonbattle) deaths.

i. During a war, strengths and casualties surge and slow in a quasirhythmic, wavelike manner.

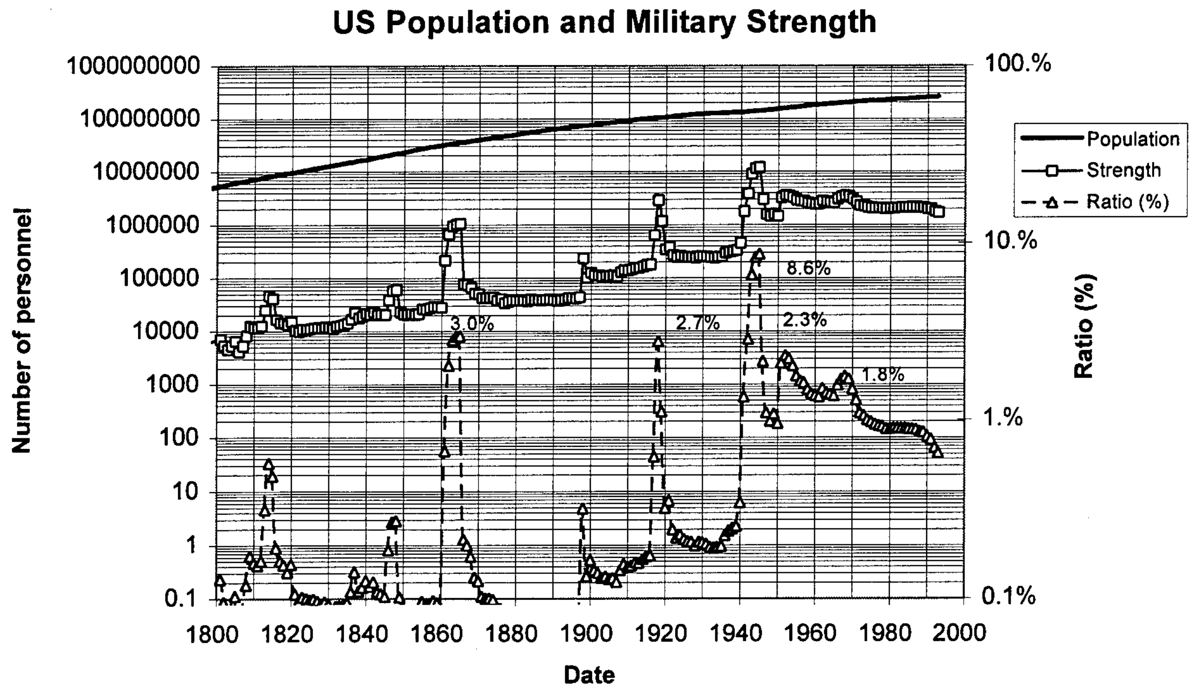

Figure 2-1. US Total Population, Military Strength, and Percent Serving

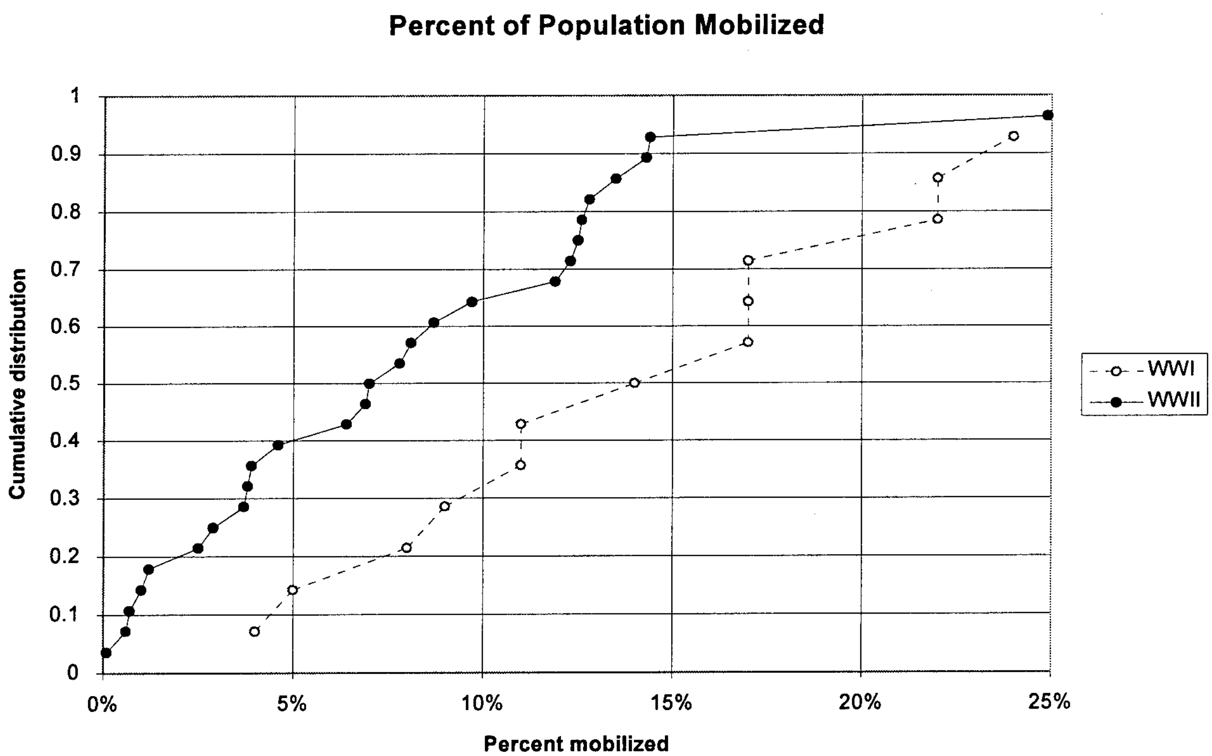

Figure 2-2. Percent of Population Mobilized by Various Nations in WWI and WWII

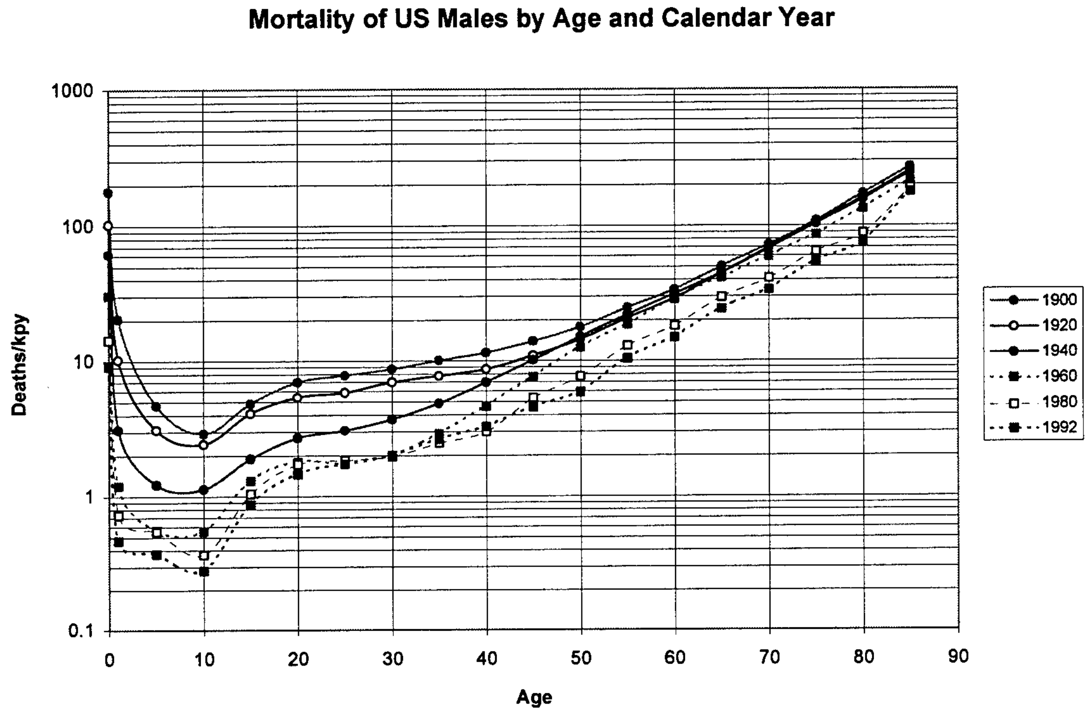

Figure 2-3. Peacetime Mortality of US Males by Age and Calendar Year

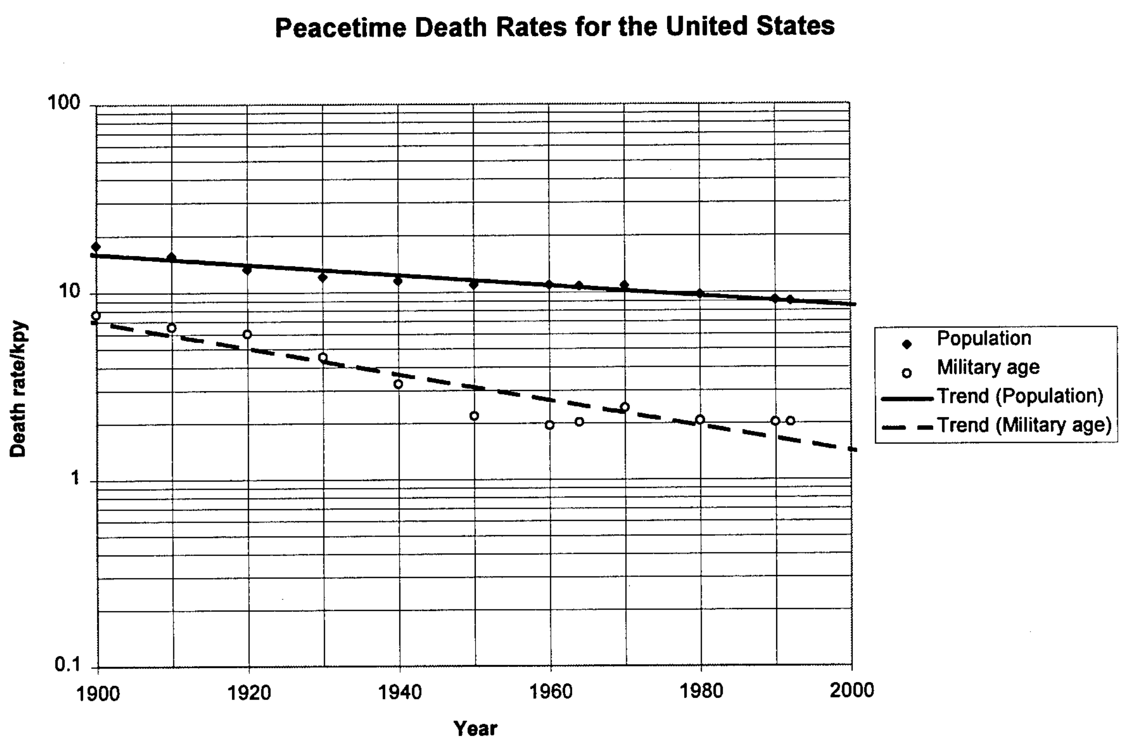

Figure 2-4. Peacetime Mortality of US Males of Military Age

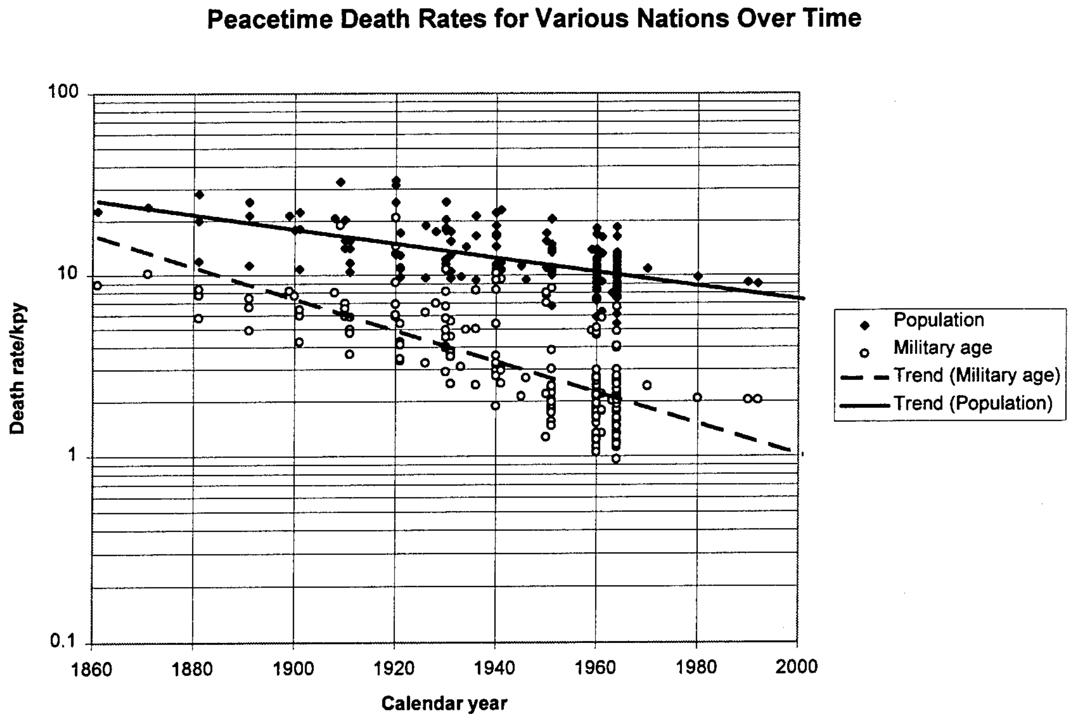

Figure 2-5. Peacetime Mortality of Males of Military Age

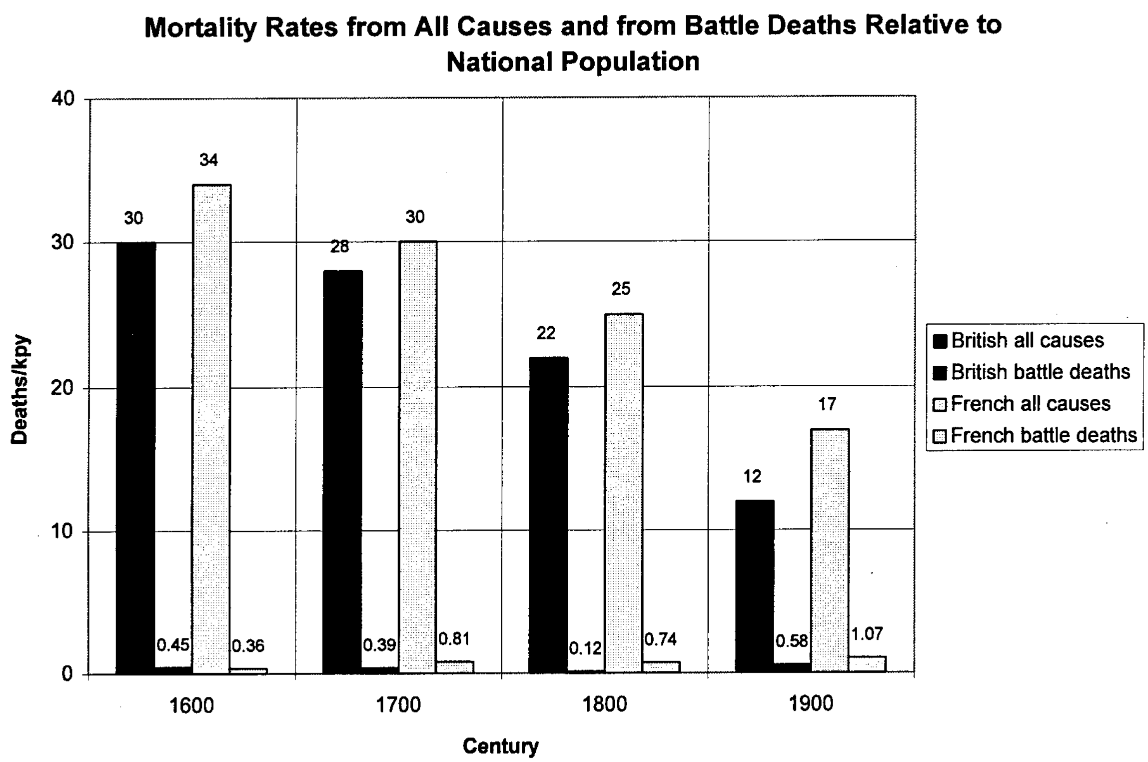

Figure 2-6. Civilian and Military Death Rates

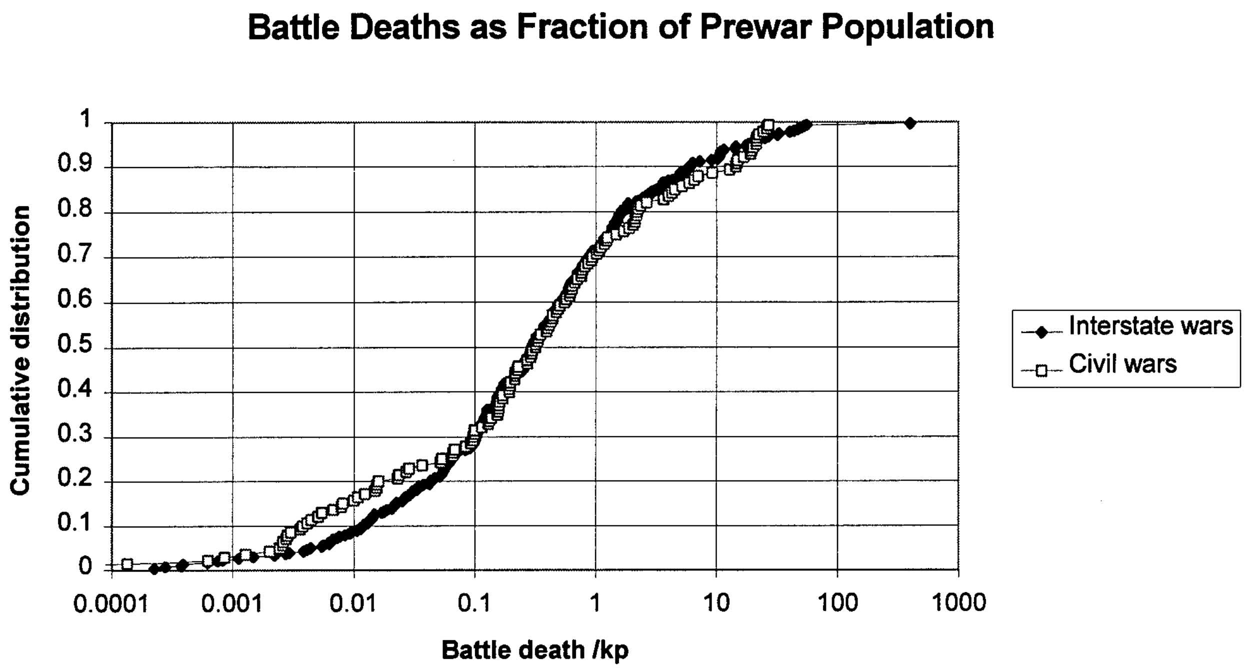

Figure 2-7. Distribution of Battle Deaths as Fraction of Prewar Population

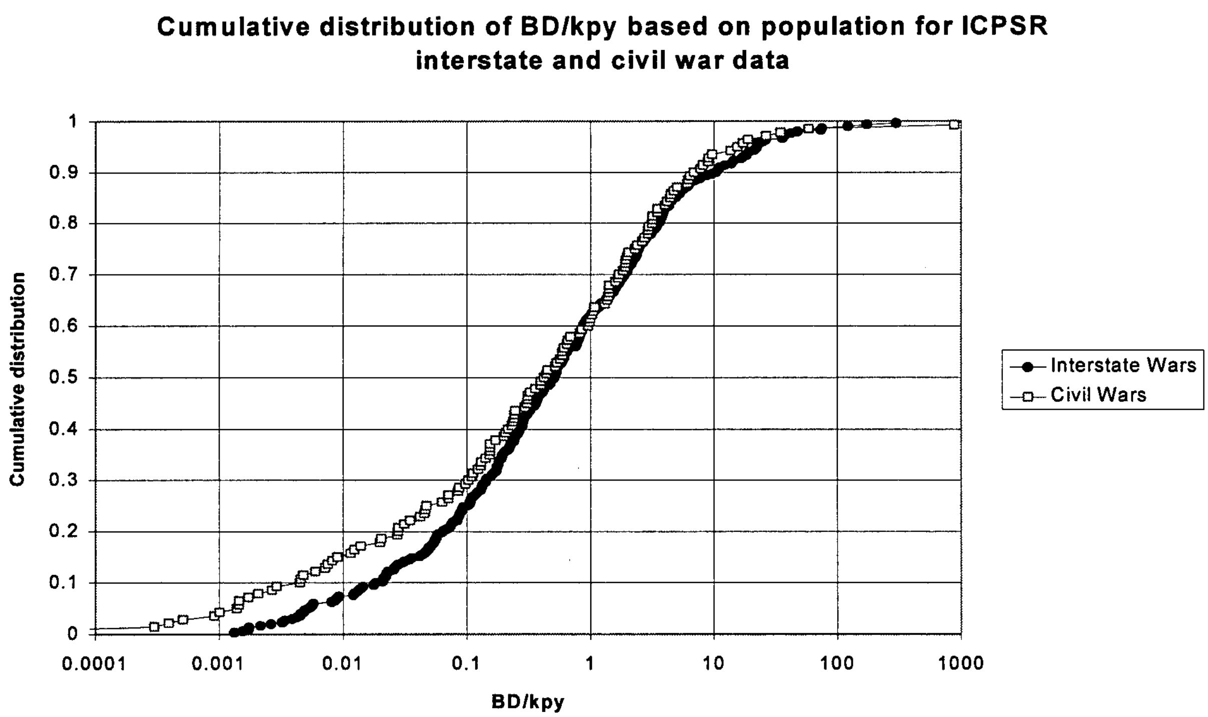

Figure 2-8. Distribution of Battle Death Rates Based on National Population

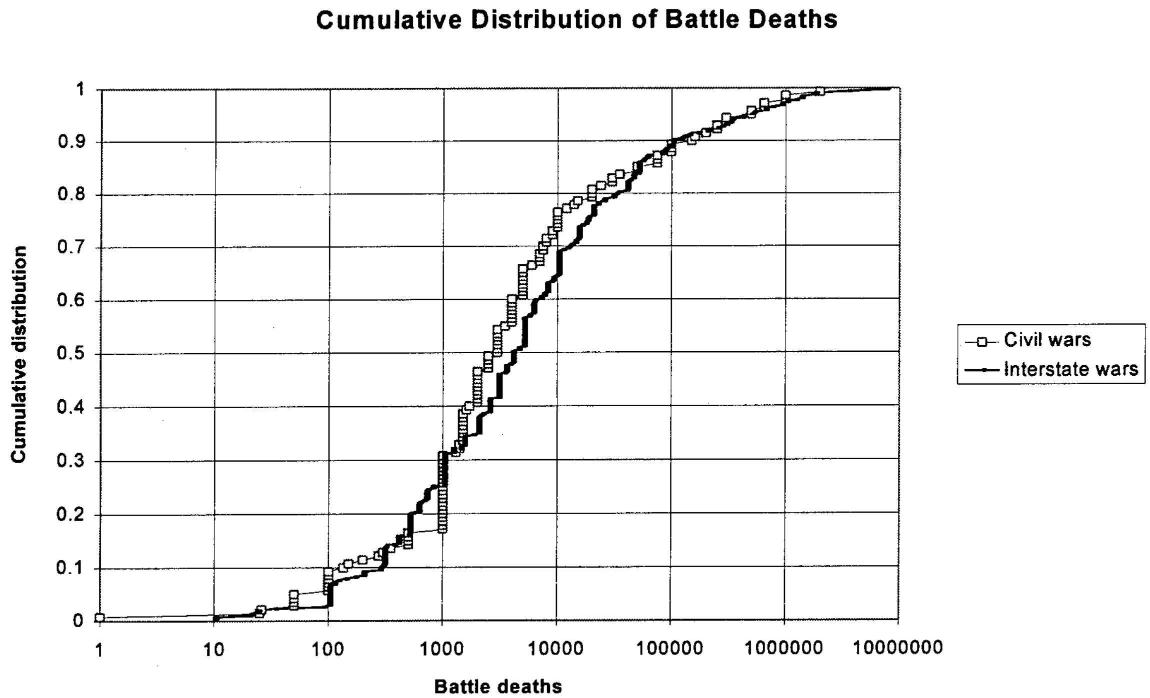

Figure 2-9. Cumulative Distribution of Battle Deaths

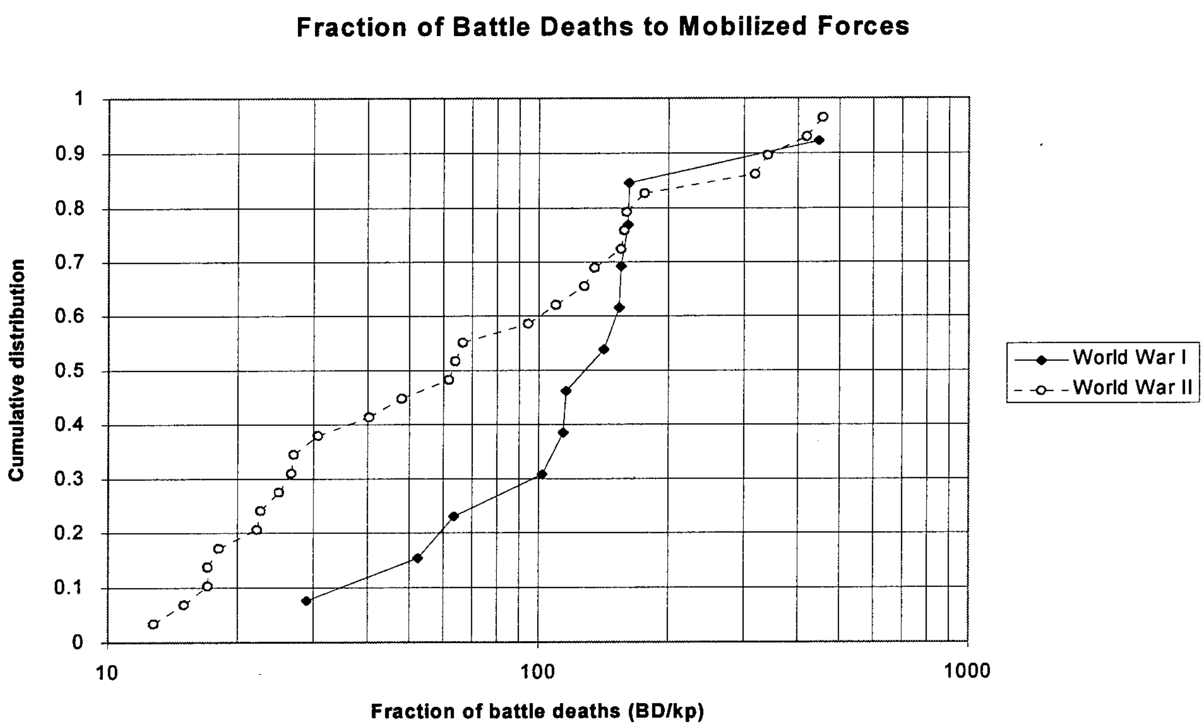

Figure 2-10. Fraction of Battle Deaths to Mobilized Forces

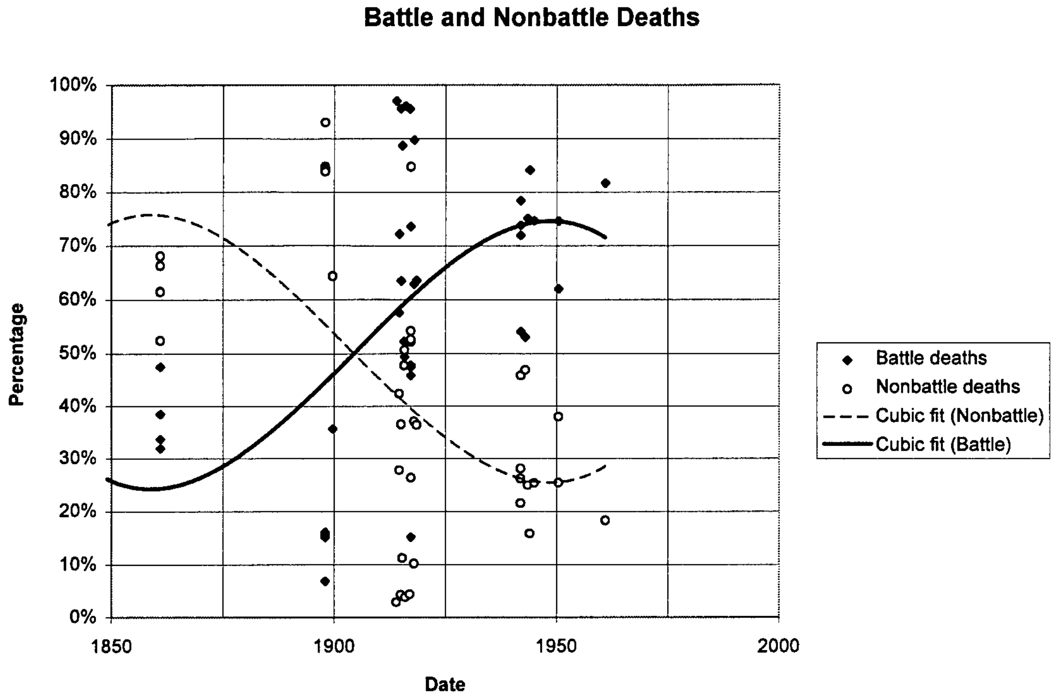

Figure 2-11. Percentage of Battle and Nonbattle Deaths

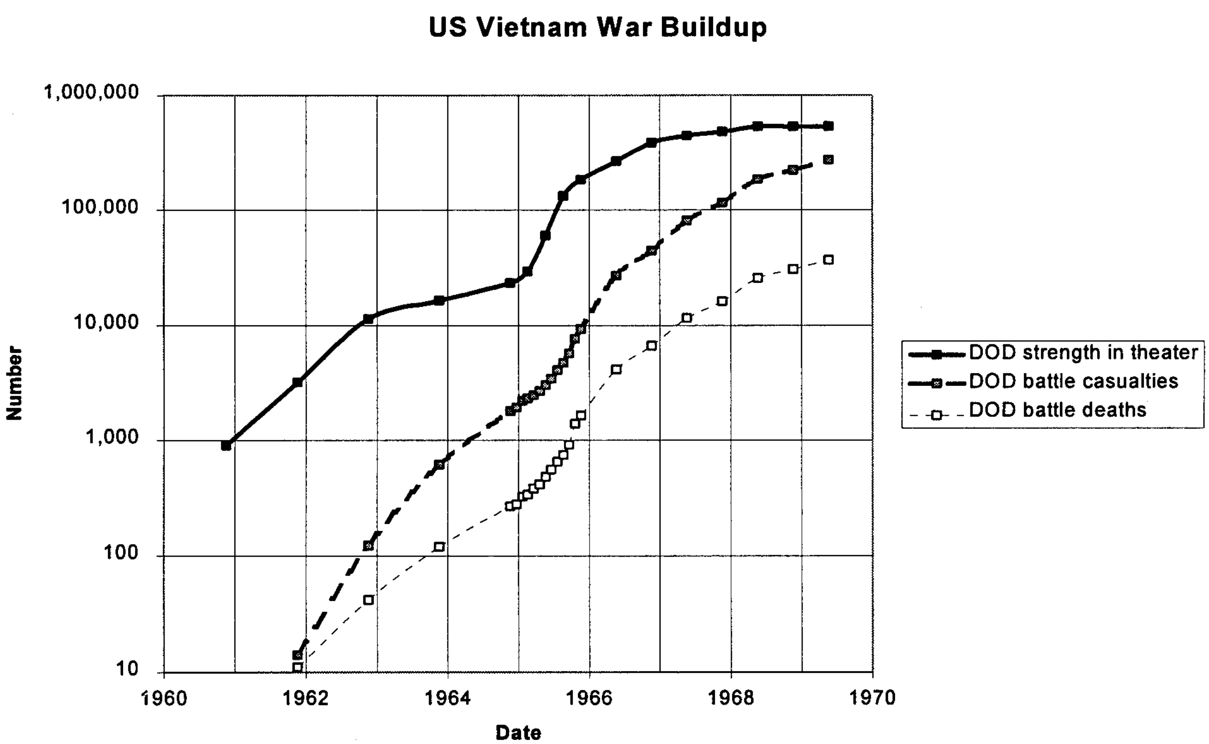

Figure 2-12. Voevodsky Crisis Waves for the Vietnam War

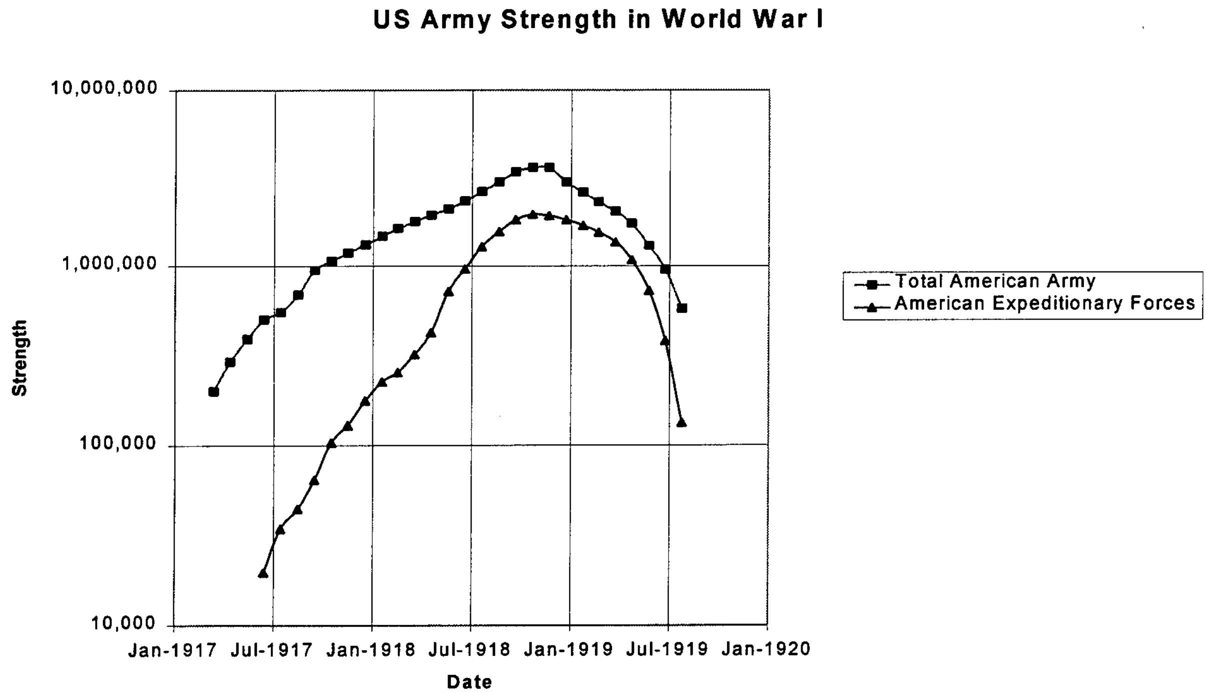

Figure 2-13. Escalation and Deescalation of US Army Strength in World War I

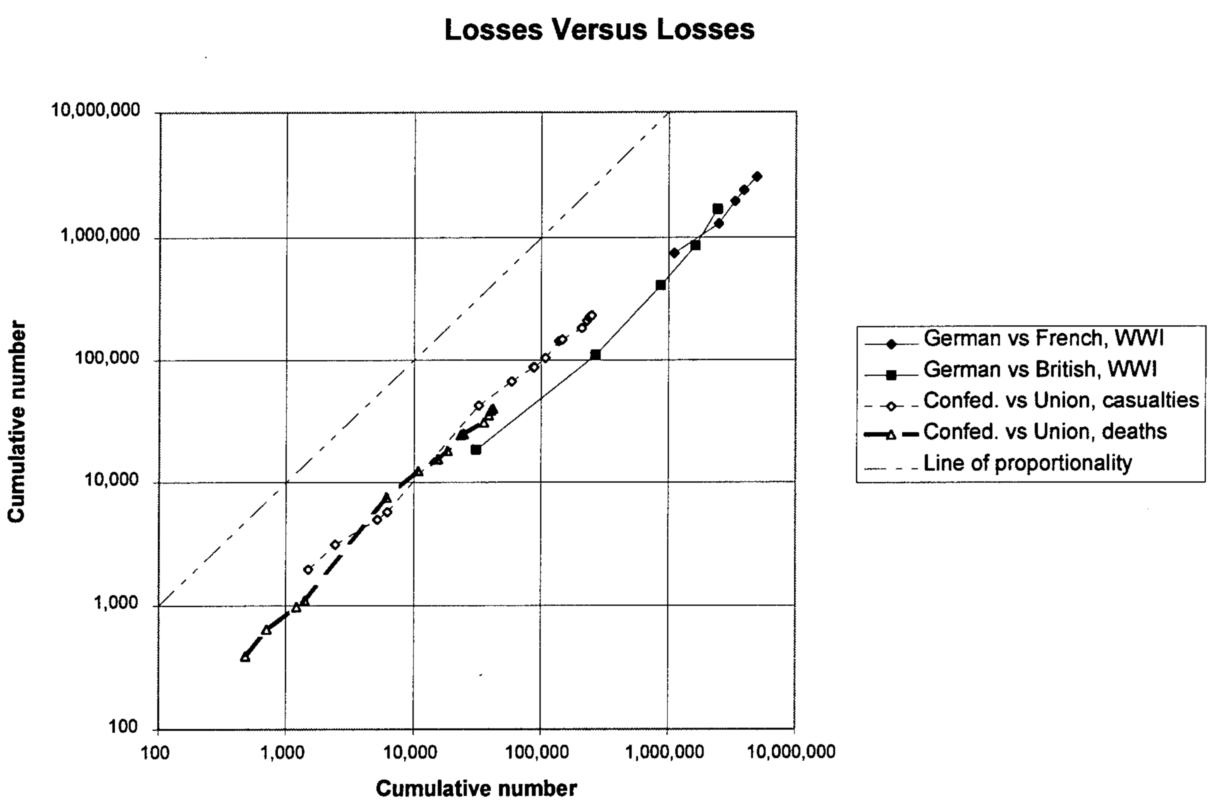

Figure 2-14. Proportionality of Losses in Wars

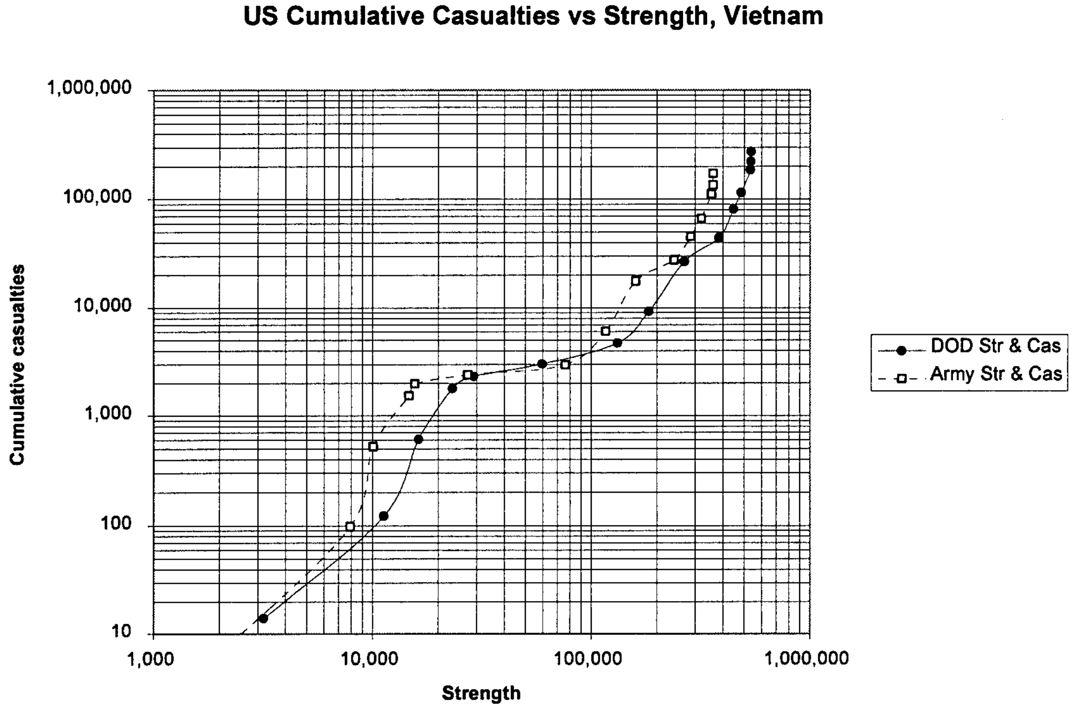

Figure 2-15. Casualties as a Function of Strength

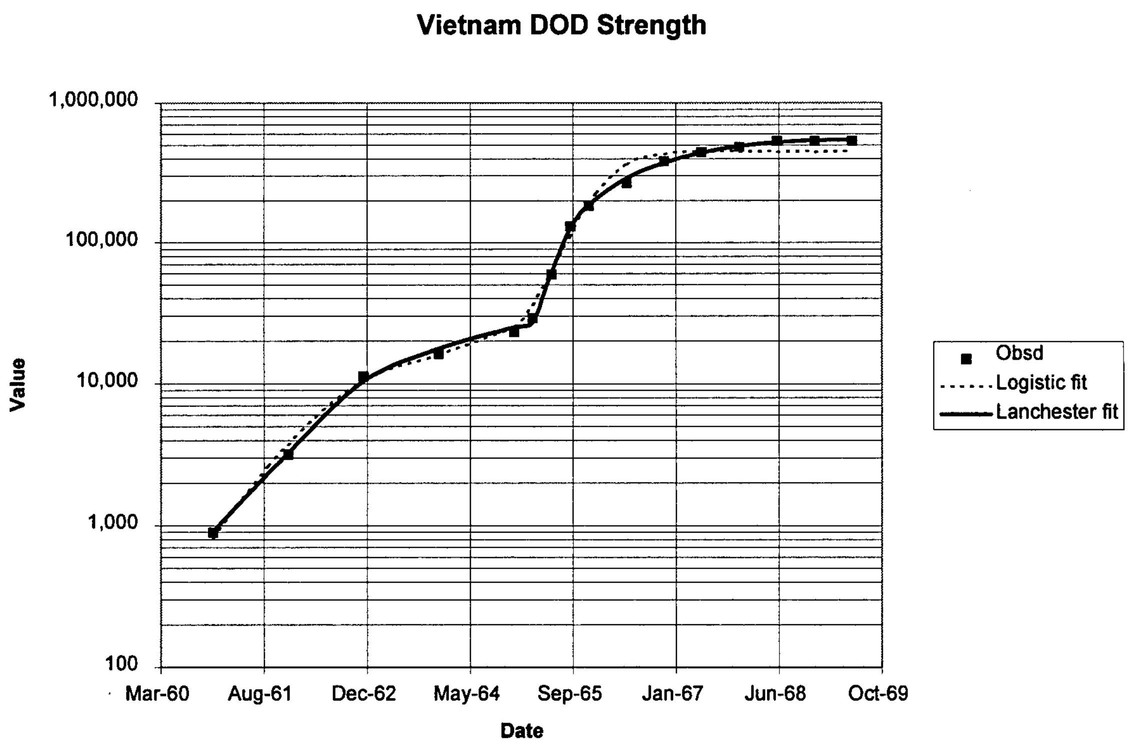

Figure 2-16. Logistic and Lanchester Fits to Vietnam Data

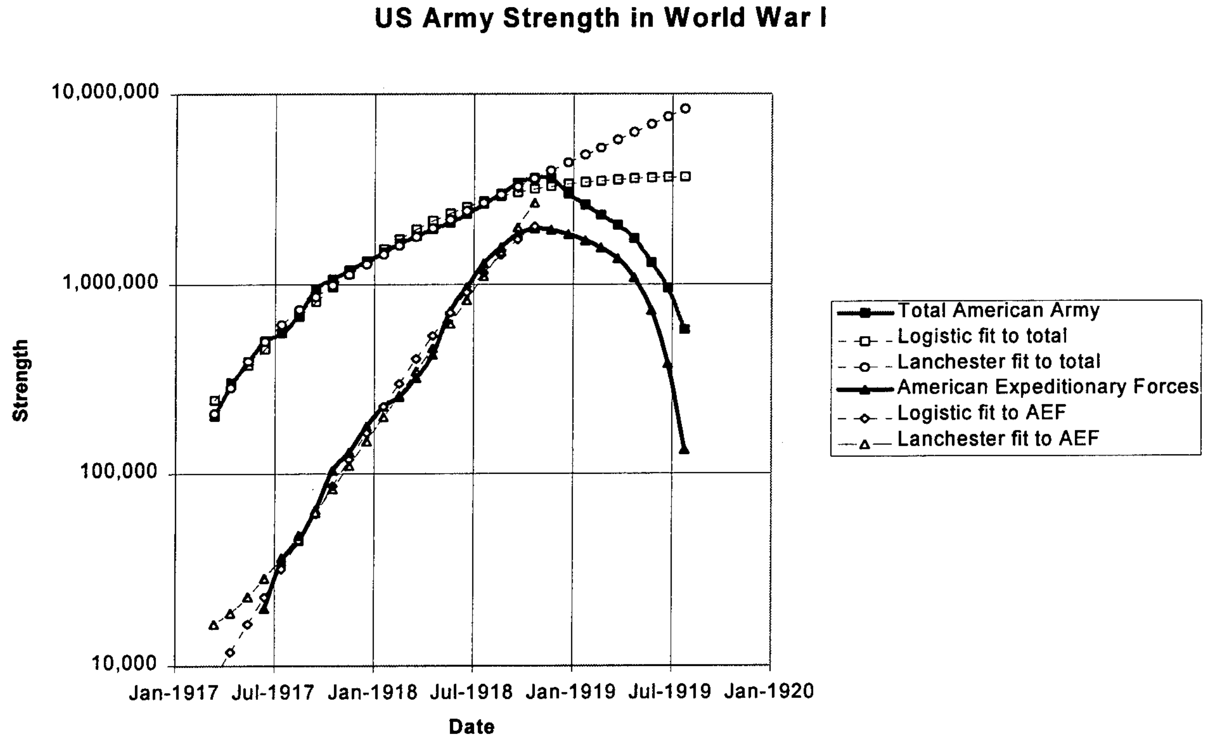

Figure 2-17. Logistic and Lanchester Fits to World War I Data

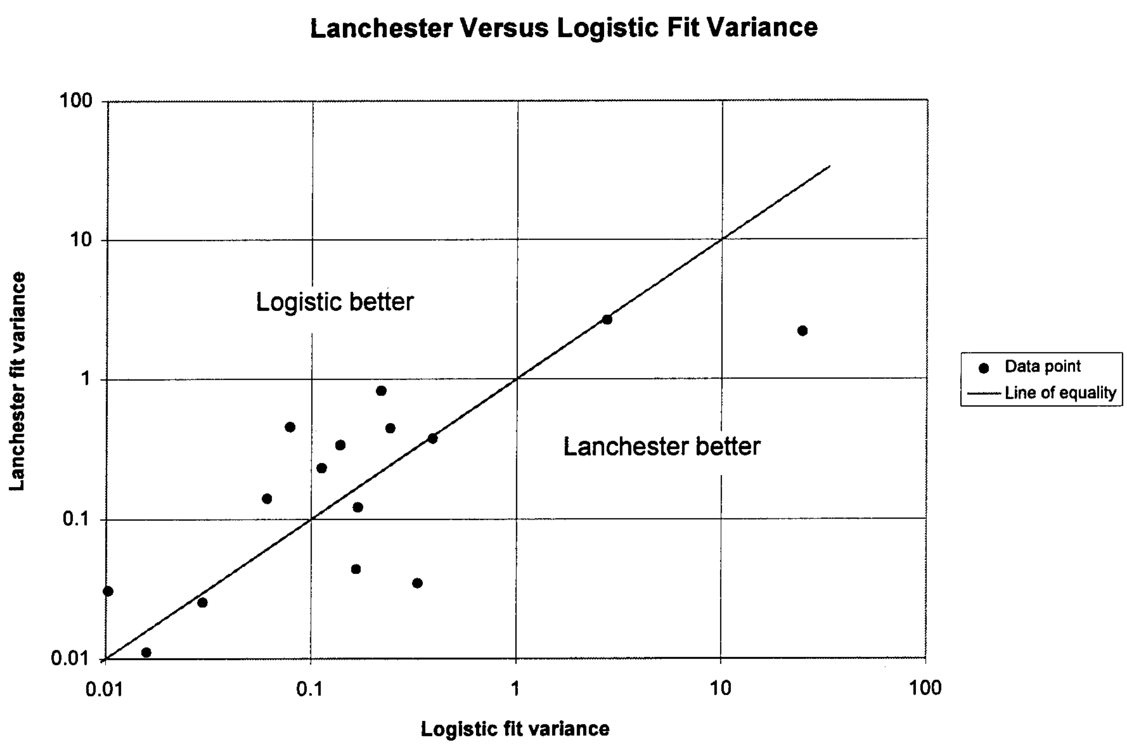

Figure 2-18. Comparison of Logistic and Lanchester Fits to Crisis Wave Data

CHAPTER 3

VARIATION OF LOSSES BY NATIONALITY AND THEATER OF OPERATION

3-1. INTRODUCTION. This chapter examines selected aspects of the variation of losses by nationality, theater, and major operations or campaigns of a war. Because the available data often do not permit a more detailed description of the losses, it deals primarily with either battle deaths (BD) or total battle casualties (TBC). For our purposes, battle deaths (BD) are normally defined as the sum of the (KIA) and the died of wounds suffered in combat (DOW). Also, total battle casualties (TBC) are defined as the sum of the killed in action (KIA), wounded in action (WIA), and captured or missing in action (CMIA). The treatment given here is intended to be illustrative, rather than exhaustive. Thus, we present some examples of loss variations by theater and campaign, but do not attempt a comprehensive review of that subject.

3-2. VARIATION BY NATIONALITY. Nations differ in the extent to which they suffer casualties in a war. This generally depends on the extent of their involvement in combat operations. This is illustrated by Table 3-1, which shows the losses suffered by various nations involved in World War I combat operations. Table 3-2 shows the losses suffered by various nations involved in World War II. As can be seen, there are substantial differences from nation to nation in the scale of involvement and consequently in the number of losses incurred. (Data in this paragraph based on Wright.)

3-3. VARIATION BY THEATER

a. Figure 3-1 shows the total battle losses of the German Army in World War II by theater of operation. Note that there is considerable variation in losses from theater to theater. Also, in World War II, about 77 percent of the German Army's total battle losses were incurred on the eastern front. (Data from HERO, German and Soviet Replacement Systems in World War II, AD-B959-989L, July 1975, UNCLASSIFIED, taken from this source's Table 14, p 50. It is for the German Army Casualties, 1 September 1939 - 20 April 1945, attributed to a table put out by the Organizational Branch, [German] General Staff, 26 April 1945, copy in US Archives as T-78, Roll 414, Frame 638189.)

Table 3-1. Casualties in World War I by Nationality

Belligerent	Population (000)	Total mobilized (000)	Percentage of population mobilized	Percentage of active male population mobilized	Soldiers killed or died of wounds (000)	Fraction of population killed or died of wounds /kp	Fraction of those mobilized killed or died of wounds /kp
Russia	150,000	12,000	8%	30%	1,700	11.33	141.67
France	39,000	8,410	22%	59%	1,363	34.95	162.07
Great Britain	41,000	8,904	22%	39%	908	22.15	101.98
Serbia	3,000	707	24%	70%	45	15.00	63.65
Belgium	7,000	267	4%	12%	14	2.00	52.43
Germany	63,000	11,000	17%	66%	1,774	28.16	161.27
Austria-Hungary	47,000	7,800	17%	54%	1,200	25.53	153.85
Total, original belligerents	350,000	49,088	14%	42%	7,004	20.01	142.68
Turkey (Nov 1914)	26,000	2,850	11%	#N/A	325	12.50	114.04
Italy (May 1915)	33,000	5,615	17%	46%	650	19.70	115.76
Bulgaria (Oct 1915)	4,000	560	14%	#N/A	87	21.75	155.36
Rumania (Aug 1916)	7,000	750	11%	#N/A	336	48.00	448.00
US (April 1917)	92,000	4,355	5%	13%	126	1.37	28.93
Total, later belligerents	162,000	14,130	9%	27%	1,524	9.41	107.86
Grand total	512,000	63,218	12%	36%	8,528	16.66	134.90

Table 3-2. Casualties in World War II by Nationality

Belligerents	Population (000,000)	Mobilization (000)	Soldiers killed or died of wounds (000)	Civilians killed (000)	Total losses in war (000)	Percentage of population mobilized	Fraction of those mobilized killed or died of wounds /kp	Soldiers killed or died of wounds as fraction of population /kp
Germany	71	10,200	3,250	500	3,750	14.4%	318.63	45.77
Italy	44	3,100	149	783	932	7.0%	48.06	3.39
Japan	72	9,700	1,507	672	2,179	13.5%	155.36	20.93
Hungary	9	350	147	UNK.	147	3.9%	420.00	16.33
Rumania	14	1,136	520	UNK.	520	8.1%	457.75	37.14
Bulgaria	7	450	10	UNK.	10	6.4%	22.22	1.43
Finland	4	500	79	UNK.	79	12.5%	158.00	19.75
Total, Axis	221	25,436	5,662	1,955	7,617	11.5%	222.60	25.62
United Kingdom	48	5,896	557	61	618	12.3%	94.47	11.60
France	39	5,000	202	108	310	12.8%	40.40	5.18
USSR	175	22,000	7,500	7,500	15,000	12.6%	340.91	42.86
United States	135	16,113	292	neg.	292	11.9%	18.12	2.16
China	449	17,251	2,200	20,000	22,200	3.8%	127.53	4.90
Total, major United Nations	846	66,260	10,751	27,669	38,420	7.8%	162.25	12.71
India	324	2,394	36	UNK.	36	0.7%	15.04	0.11
Canada	12	1,041	32	UNK.	32	8.7%	30.74	2.67
Australia	7	1,000	27	UNK.	27	14.3%	27.00	3.86
New Zealand	2	194	12	UNK.	12	9.7%	61.86	6.00
South Africa	11	410	7	UNK.	7	3.7%	17.07	0.64
Total, Commonwealth	356	5,039	114	0	114	1.4%	22.62	0.32
Czechoslovakia	15	150	10	490	500	1.0%	66.67	0.67
Poland	35	1,000	64	2,000	2,064	2.9%	64.00	1.83
Belgium	8	625	8	101	109	7.8%	12.80	1.00
Netherlands	9	410	7	242	249	4.6%	17.07	0.78
Denmark	4	25	4	UNK.	4	0.6%	160.00	1.00
Norway	3	75	2	2	4	2.5%	26.67	0.67
Yugoslavia	15	3,741	410	1,275	1,685	24.9%	109.60	27.33
Greece	6	414	73	400	473	6.9%	176.33	12.17
Philippines	17	200	27	91	118	1.2%	135.00	1.59
Brazil	43	40	1	UNK.	1	0.1%	25.00	0.02
Total, lesser United Nations	155	6680	606	4601	5207	4.3%	90.72	3.91
Other Latin American states	87	444	neg.	neg.	0	0.5%	0.00	0.00
Other United Nations	74	1,121	neg.	neg.	0	1.5%	0.00	0.00
Total, United Nations	1518	79544	11471	32270	43741	5.2%	144.21	7.56
Total, Axis	221	25,436	5,662	1,955	7,617	11.5%	222.60	25.62

Table 3-3. US Army Battle Death Rates for World War II by Theater and Year

Year	All areas	CONUS	OCONUS	ETO	MTO	Africa	CBI	SWPA	POA	NAmer	LAmer
All years	9.071	0.000	21.798	32.140	25.987	3.315	12.560	16.687	9.792	2.559	0.100
1942	3.265	0.000	18.072	1.458	34.895	6.616	4.917	13.394	4.048	1.401	0.137
1943	3.219	0.000	13.107	18.905	22.344	5.920	0.995	8.219	6.036	5.544	0.058
1944	16.196	0.000	33.041	51.144	37.807	0.585	10.172	18.589	9.100	0.209	0.186
1945	9.543	0.000	15.935	20.280	10.513	2.162	3.265	17.727	13.845	0.178	0.014

b. Figure 3-2 and Table 3-3 show the variation in battle death rates of US Army forces in World War II by theater of operation and year of the war. In this case, battle deaths include KIA, DOW, died in prison, and declared dead. The theater abbreviations used here are as follows: LAmer = Latin America, NAmer = North America (including Alaska and Iceland), Africa = Africa-Middle East Theater, CBI = China-Burma-India Theater, POA = Pacific Ocean Area, SWPA = Southwest Pacific Area, OCONUS = outside of the continental United States (i.e., an aggregate for all overseas areas), MTO = Mediterranean Theater of Operations, ETO = European Theater of Operations. It is clear that there were substantial theater to theater differences, and that these differences themselves changed from year to year as the global war situation evolved and emphasis shifted from one theater to another. (Data from Reister.)

c. The US data on battle deaths and exposure to risk can be plotted as shown in Figure 3-3. Here, each point represents the theater exposure level (in kpy) and the theater battle deaths that resulted from this exposure for 1 year and theater combination. For example, the highest point, with a theater exposure of 1,677 kilo-person-years or kpy and theater battle deaths of 85,775, is for the ETO in 1944. The trend line is a power function fit to the data points, given by the equation shown on the figure. While the data scatter widely about this trend line, it does seem to represent the general trend of these data. The exponent in the equation suggests that casualties tend to increase faster than linearly with the number of kpy of exposure. That is, doubling the exposure in kpy *more* than doubles the number of casualties incurred. (Data from Reister.)

d. Figure 3-4 shows some World War I theater-level casualty experience. The key to the theater code used for the abscissa of Figure 3-4 is given in Table 3-4. Clearly, there were substantial variations in British casualty rates from theater to theater in World War I. The casualty rates of the US American Expeditionary Force (AEF) were about one-quarter those of British forces operating in France and Flanders. However, this difference is smaller than the fluctuation of British casualty rates from theater to theater. Figure 3-5 shows the casualty *numbers* plotted against the exposure level (measured in kpy of exposure). On this figure, the open square is the US AEF experience, and the open triangle is the British Boer War experience. The trend line is a power function fit to the data points, given by the equation shown on the figure. While the data scatter widely about this trend line, it does seem to represent the general trend of the data shown in this figure. The exponent in the equation suggests that casualties have a tendency to increase faster than linearly with the number of kpy of exposure. That is, doubling the exposure in kpy *more* than doubles the number of casualties incurred. (Data based on Mitchell and Ayres.)

3-4. A NOTE ON THEATER DNBI RATES.

a. Table 3-4 shows the death rates of US Army forces from disease and nonbattle injury for various wars. As can be seen, the death rates from disease have decreased substantially over time and are nowadays but a small fraction of the battle death rate. (Data from Love and Reister.)

Table 3-4. Disease and Battle Death Rates of US Forces in Various Wars

War	Disease death rate/kpy	Battle death rate/kpy
Mexican (1846-1848)	110	15
Civil, North (1861-1865)	65	33
Spanish American	26	5
WWI (1917-1918)	19	53
WWII (1941-1945)	3	9

b. Figure 3-6 and Table 3-5 show the US Army's death rates from disease and nonbattle injury in World War II by theater and year. There are clear differences from theater to theater and from year to year, but the rates generally tend to be around 3/kpy. (Data from Reister.)

Table 3-5. US Army Disease and Nonbattle Injury Death Rates/kpy in World War II

Year	All areas	CONUS	OCONUS	ETO	MTO	Africa	CBI	SWPA	POA	NAmer	LAmer
All years	3.02	2.39	3.90	3.59	4.32	4.86	6.92	4.11	3.62	3.69	4.80
1942	2.77	2.51	3.94	2.87	7.20	4.80	10.18	5.73	3.02	4.19	4.49
1943	2.85	2.45	4.06	3.37	4.83	4.24	8.63	4.22	3.60	3.64	4.75
1944	3.05	2.54	3.58	2.97	4.07	6.36	7.16	4.36	2.80	2.97	6.35
1945	3.24	1.96	4.09	4.13	3.98	3.57	6.33	3.76	4.44	4.44	3.45

c. For comparison, battle injury rates for the Union forces in the US Civil War were 120.5/kpy, and for the US forces in the Philippine Insurrection of 1899-1902 were 16.1/kpy. (Data based on Love.)

3-5. A NOTE ON BALLISTIC AND CRUISE MISSILE THREATS TO THEATER REAR AREAS

a. Concern over the ballistic and cruise missile threat to theater rear areas has increased in recent years. This is largely a result of the Gulf War experience, during which Iraq launched

SCUD missiles, similar to World War II V-2 rockets, against Israel as well as against combat forces in the Gulf theater. While many of the Iraqi missiles that were successfully launched failed to reach their intended targets, some did get through and cause casualties. The US and its allies used cruise missiles as well as aircraft to attack targets deep in enemy territory.

b. The most extensive historical experience bearing on the magnitude of the rear area threat from such weapons was gained during the German V-1 (cruise missile) and V-2 (ballistic missile) attacks in World War II. While many of these weapons were launched against the United Kingdom, a large number were also launched against Antwerp in an obvious attempt to hamper its port operations. In addition, at least five V-2 missiles were launched at the Remagen bridgehead over the Rhine river in an apparent attempt to destroy the bridge. However, the best documentation readily available is for the attacks against the UK. Table 3-7 summarizes the information obtained from various sources.

c. Apparently, in London, the casualty rate (killed and seriously wounded) per impacting missile varied from about 10 to 18. However, Welborn remarks that in the less densely populated areas outside London the casualty rate was much less, being but 0.13 killed and 1.24 seriously injured per impacting missile. This would amount to a total of about 1.37 killed and seriously injured per impacting missile. Because the target density has a major role in determining the number of casualties per impacting missile, the experience of military forces in rear areas can be expected to be closer to that of the less densely populated areas outside of London. This projection will be valid, on the average, unless the enemy is able to locate and target rear area combat targets in a timely and relatively precise manner, while rear area targets have little or no warning and have only relatively ineffective countermeasures against these missile attacks. (Data from Churchill, Jones, Johnson, and Welborn).

d. For comparison, in the Gulf War, a total of 88 SCUDS reached friendly territory—43 in Saudi Arabia, 3 in Bahrain, and 42 in Israel. Israeli casualties were about 7 injured. Other casualties were the 28 US soldiers killed and 100 wounded when a SCUD hit their barracks. The overall casualty rates per SCUD that reached friendly territory, computed from these figures, amount to 0.32 killed per SCUD and 1.22 wounded per SCUD, for a total of 1.53 killed or wounded per SCUD. These rates are comparable to those noted in the preceding paragraph for missile impacts in the UK areas outside London. (Data in this paragraph taken from Sultan.)

Table 3-6. V-1 and V-2 Attacks Against the UK in World War II.

Source	Weapon type	No. of weapons launched at London	No. of weapons successfully launched	No. of weapons that impacted in UK	No. of weapons that impacted in London	London civilians killed	Service personnel killed	UK civilians outside London killed	London civilians seriously injured	Service personnel seriously injured	UK civilians outside London seriously injured	London civilians killed per weapon reaching London	London civilians seriously injured per weapon reaching London
Churchill	V-1	8,564	7,558	NA	2,400	6,184	NA	NA	17,981	NA	NA	2.6	7.5
Jones	V-1	8,617	NA	NA	2,340	5,500	NA	NA	16,000	NA	NA	2.4	6.8
Johnson	V-1	NA	NA	NA	2,419	6,000	2,000	NA	NA	NA	NA	2.5	NA
Welborn	V-1	NA	NA	NA	NA	5,187	NA	369	17,085	NA	1,241	NA	NA
Churchill	V-2	1,359	1,190	NA	500	2,724	NA	NA	6,467	NA	NA	5.4	12.9
Jones	V-2	1,359	1,190	1,115	501	NA	NA	NA	NA	NA	NA	NA	NA
Johnson	V-2	NA	NA	1,054	517	2,700	NA	NA	NA	NA	NA	5.2	NA
Welborn	V-2	NA	NA	1,115	NA	NA	NA	NA	NA	NA	NA	4.8	NA

3-6. CHAPTER SUMMARY.

a. Casualty numbers and rates vary widely from nation to nation, from theater to theater, and from year to year.

b. At the theater level, it appears that casualty numbers tend to increase faster than linearly with exposure in kpy.

c. Theater level battle casualty rates of 50/kpy to 250/kpy are not unusual.

d. The SCUD missile threat the theater rear areas can be expected to produce about one or two killed or seriously injured casualties per impacting missile, unless the enemy is able to locate and target rear area targets in a timely and accurate fashion, while the rear area has no effective countermeasures against them.

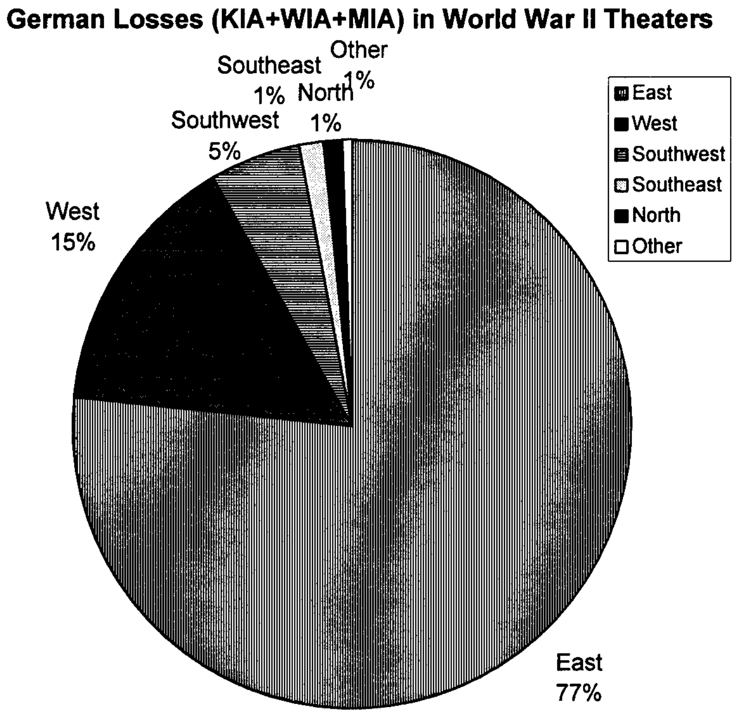

Figure 3-1. German Losses in World War II by Theater

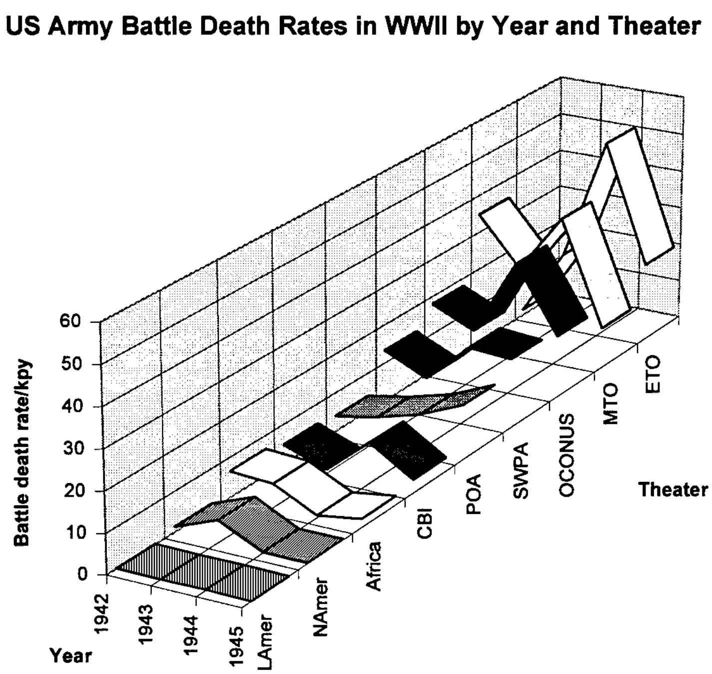

Figure 3-2. US Army WWII Battle Death Rates by Theater and Year

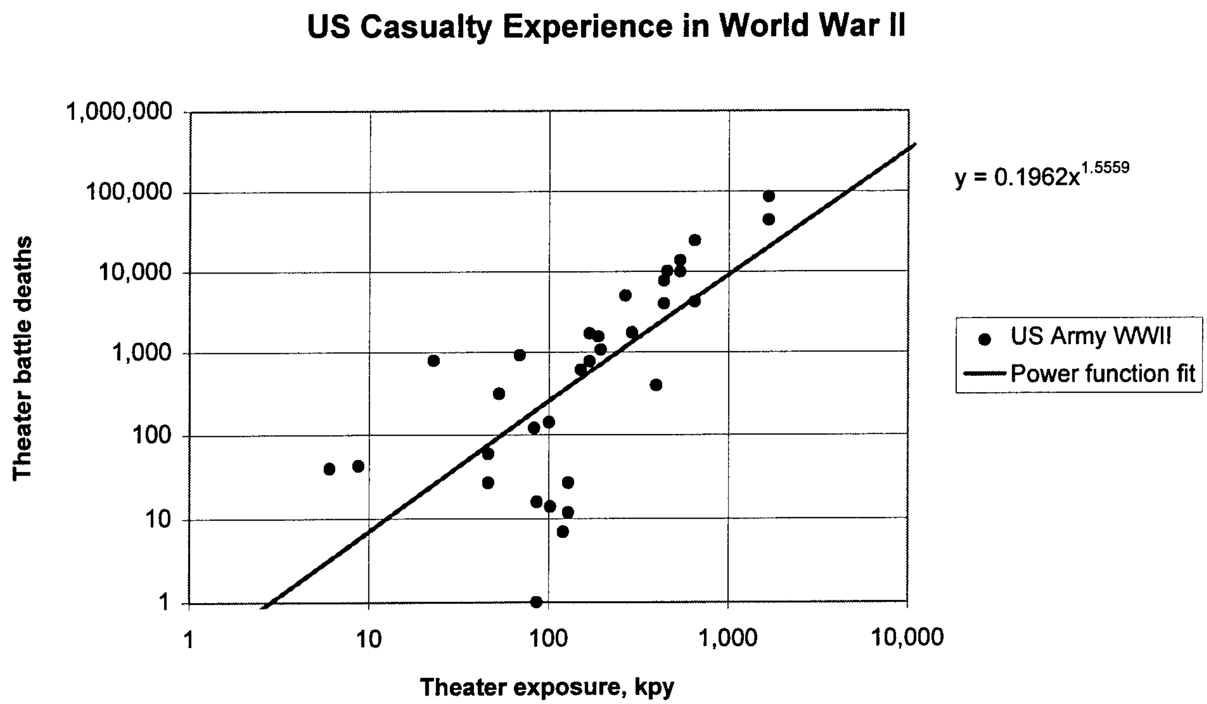

Figure 3-3. US Casualty Experience at Theater Level in World War II

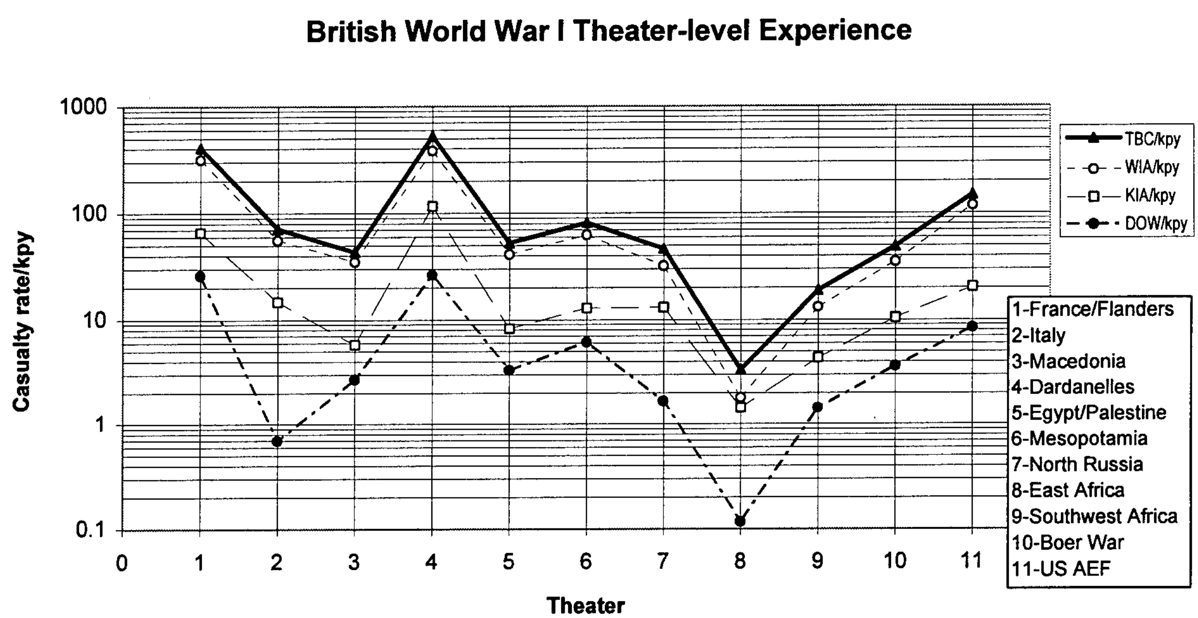

Figure 3-4. Examples of World War I Theater-level Casualty Experience

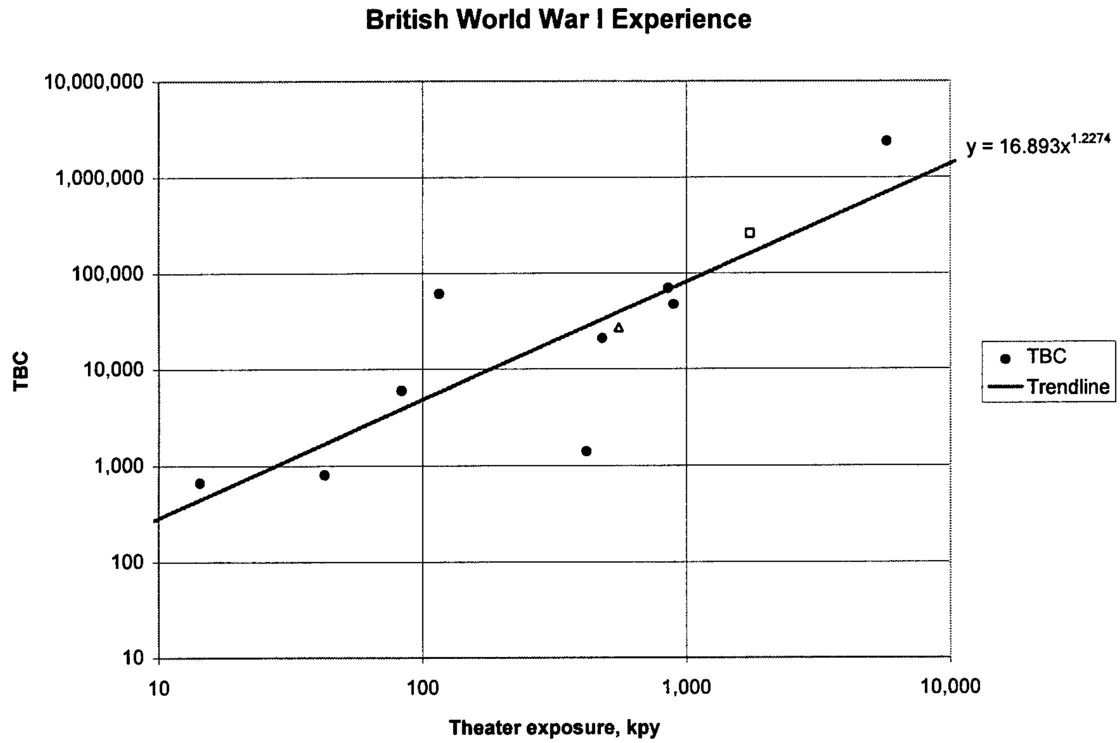

Figure 3-5. Examples of World War I Casualty Experience at the Theater Level

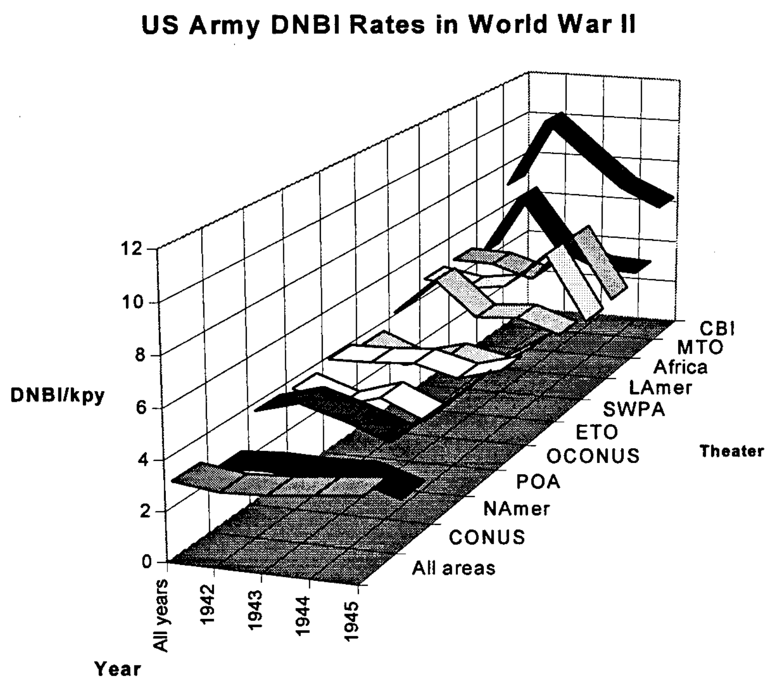

Figure 3-6. US Army Nonbattle Death Rates in World War II

CHAPTER 4

LOSSES OF ARMY GROUPS

4-1. INTRODUCTION

a. This chapter examines selected aspects of the casualty rates of army groups operating in a theater of war. It deals exclusively with the US 12th Army Group because for it we have the most detailed and complete information. This information includes the onhand strength and casualty data (including KIA, WIA, and CMIA) on a daily basis for the US 12th Army Group's operations in Northwest Europe during World War II from 15 June 1944 (shortly after the D-day landings in Normandy on 6 June 1944) through 30 April 1945 (shortly before the surrender of Nazi Germany on 5 May 1945). However, due to gaps in the archival records, no data are available for the following dates: 16 June 1944, 3 July 1944, 6 July 1944, and 11 August through 30 September 1944.

b. For simplicity, we will always refer to the forces included in this data base as the US 12th Army Group. However, during the early period (15 June 1944 through early August 1944), these forces were not of army group size. Instead, they constituted the US First Army and were one of the armies under the British 21st Army Group. By early August 1944, the size of the US forces had increased to the point that they were reorganized as the US 12th Army Group under GEN Omar Bradley. By the time the war in Europe ended, the US 12th Army Group was organized as shown below.

- 12th Army Group (Bradley)
  - 3d Army (Patton)
    - 8 Corps (Middleton)
    - 12 Corps (Eddy)
    - 20 Corps (Walker)
  - 1st Army (Hodges)
    - 3 Corps (Van Fleet)
    - 5 Corps (Huebner)
    - 7 Corps (Collins)
    - 18 Abn Corps (Ridgway)
  - 15th Army (Gerow)
    - 22 Corps (Harmon)
    - 23 Corps (Balmer)
  - 9th Army (Simpson)
    - 13 Corps (Gillem)
    - 16 Corps (Anderson)
    - 19 Corps (McLain)

c. This data base uses a category called UNIT to denote the type of basic unit. For divisions, UNIT designations are either INF D, ARM D, or ABN D. For higher echelons, the

UNIT designations are either INF D, ARM D, or ABN D (for individual divisions attached directly to the higher echelon); HQ/SE (for organic and attached "headquarters and service" elements); or OTHER (for other *combat* elements organic or attached to the higher echelon, such as artillery, tank destroyer units, *etc.*, although some of these were often temporarily assigned or attached to divisions for operational control, this data base carries them at the higher echelon).

d. Every data base has some special characteristics of which the user should be aware. Some of the special characteristics of this data base are mentioned here. First, there are the gaps in the available source data, mentioned above. Second, there are no HQ/SE elements listed in the data base for the period prior to 1 October 1944 (although some US corps and Army HQ/SE must have been active prior to that date, the sources used to prepare this data base provide no information on them). Third, the 44th Infantry Division appears only briefly (in 3 Corps of the 9th Army from 1 October 1944 through 10 October 1944 and as attached directly to the 9th Army from 11 October 1944 through 16 October 1944). Throughout its appearance, all of its battle casualties are recorded as zero, and its assigned strength varies from a low of 13,551 to a high of 13,895. This agrees with the information in the sources consulted in preparing the data base. Fourth, for the period 23 January 1945 through 31 January 1945, the 35th Infantry Division in 3 Corps of the 3d Army consisted of a regimental combat team only, which explains its unusually low authorized and assigned strength values. Fifth, at various times from 2 October 1944 through 24 October 1944, the 9th Armored Division in 3 Corps of the 9th Army (later reassigned to 8 Corps of the 3d Army) had one of its combat commands assigned to another division, which explains its occasional unusually low authorized and assigned strength values. Sixth, at various times from 15 June 1944 through 11 July 1944, both the 82d and 101st Airborne Divisions had unusually low assigned strengths, but these have been confirmed by a check against the original source materials used. Seventh, at various times from 19 December 1944 through 6 April 1945, the 106th Infantry Division had unusually low assigned strengths, but these were a direct result of the heavy losses this division took in the early phases of the Ardennes Campaign (Battle of the Bulge). Apparently, this division was never restored to full strength after suffering these losses and was either offline or assigned to a quiet sector thereafter. As in other chapters, our analysis of the data on the US 12th Army Group is intended to be illustrative, rather than exhaustive.

4-2. DISTRIBUTION OF TOTAL BATTLE CASUALTY RATE. Figure 4-1 shows the distribution of daily total battle casualty rates per thousand personnel-days (TBC/kpd) for the US 12th Army Group in World War II. ***Note that here and in the following we have switched from casualty rates/kpy to rates/kpd.*** As is often observed with casualty rate data, this distribution is approximately lognormal (in this case, the mean of the logarithms is 0.476 and their standard deviation is 0.988). (Data in this paragraph based on Kuhn.)

4-3. VARIATION OF TBC RATE BY DATE. Figure 4-2 shows the daily TBC/kpd and KIA/kpd rates of the US 12th Army Group, plotted against the day the casualty rates were experienced. Here the "Day Number" is the number of days since 1 June 1944. Thus, Day Number zero is 1 June 1944, and Day Number 30 is 1 July 1944. The gap in the data from 11 August through 30 September 1944 is shown as a straight line with no data points from Day Number 71 through Day Number 121. The unusually high peak near Day Number 200 occurred during the early phases of the Ardennes offensive (popularly known as the Battle of the Bulge). The relatively low period from Day Number 130 to 160 was occupied by the fall of Aachen and involved extensive preparations for further offensives against the Siegfried Line. The decline starting shortly after Day Number 300 was related to operations in Germany after the Rhine crossing (Germany surrendered on Day Number 338). Although the casualty rate data scatter rather widely, they do appear to follow the exponentially declining trend lines in Figure 4-2. Note that the KIA rate is nearly one-tenth the TBC rate. This is unusual, as most historical data show KIA rates about one-fifth the TBC rate. A possible explanation of this discrepancy is offered in paragraph 4-5b below. (Data based on Kuhn.)

4-4. RELATIONSHIP OF KIA TO WIA RATES. Figure 4-3 shows the relationship of KIA rates to WIA rates for the US 12th Army Group data. Clearly, the power law relationship shown there is a very good fit to the data. (Data based on Kuhn.)

4-5. RELATIONSHIP OF CMIA TO WIA RATES

a. Figure 4-4 shows the relationship of CMIA to WIA rates for the US 12th Army Group data. The power law relationship shown there gives the general trend of this relationship, but there is a good deal of scatter in the data. Note that the general trend line is given by nearly the same equation as for the relationship of KIA to WIA rates exhibited in Figure 4-3.

b. The US 12th Army Group data here were extracted from archival copies of the unit casualty reports made at the time of the action. It is quite possible, therefore, that a large fraction of the number classified on those reports as CMIA were later reclassified under the KIA category. If this is assumed, then the true KIA rate (as well as the true KIA number) would be nearly double the value given in the World War II reports. This would bring the KIA rate as a proportion of the TBC rate more nearly in line with other historical data. (Data based on Kuhn.)

4-6. FITTING THE TBC RATE TIME SERIES.

a. We fitted a time series model to the TBC rate values as a function of time. To do this, we estimated the missing data values by linear interpolation of their logarithms. The time series model fitted to the resulting data consists of a deterministic trend plus an autocorrelated residual. Because the residuals are correlated, conventional regression theory is not applicable. Instead, we used the so-called autoregressive integrated moving average (ARIMA) model that was popularized by Box and Jenkins. The simplest time series model having an acceptable fit to the data was found to be the one given by the following relationships.

$$\ln\left[TBCRate(i)\right] = 1.914684 - 0.007993415 \times i + z(i),$$

where

$\ln\left[TBCRate(i)\right]$ = the natural logarithm of the TBC rate / kpd on Day number i,

$z(i) = 0.8854 \times z(i-1) + \mathrm{N}(0, 0.31261)$, where

$\mathrm{N}(0,\sigma)$ = a normal random variable with mean zero and standard deviation σ.

Thus, the logarithmic residuals, $z(i)$, are given by a simple autoregressive process. The root mean square error (RMSE) of the difference between this model's predictions of $\ln[TBCRate(i)$ and the interpolated data is equal to 0.313. Figure 4-5 shows the original and interpolated data compared to the values generated by this time series model. As can be seen, the fit is quite good. However, it should be remembered that this is a purely statistical and kinematic description of the recorded data. Its main virtue is that it provides a simpler and more readily grasped description of the data than was apparent from the data itself. This description suggests that other casualty data might be governed by a similar process—that is, one with an exponentially declining deterministic trend on which is superimposed a simple autoregressive residual. However, the description does not by itself provide a causal or dynamic model of the casualty generation process.

b. A simulated time series of "army group TBC rates" can be generated from the statistical model. Figure 4-6 shows the results of one such simulation. There is a good "family resemblance" of Figure 4-6 to the actual data shown in Figure 4-5.

4-7. EXPOSURE AND TBC EXPERIENCE OF ARMY GROUP 12. Figure 4-7 shows the TBC number versus exposure in kpd for the US 12th Army Group operating in northwest Europe during World War II. (Here and in similar figures, the trendlines are shown beyond the range of the data to enhance their visibility, and not because any such extrapolation is recommended. As shown in this figure, the TBC number declined with increasing levels of exposure. This trend is opposite to that found in Chapter 3 for theater-level operations. This is probably due to a peculiarity of these data. The lower exposure levels plotted here occurred during the early days of the 12th Army Group operation, when TBC rates were relatively high. The higher exposure levels occurred during the later days, when TBC rates were relatively lower. Whatever the reason for the trend in Figure 4-7, it demonstrates the danger of using the conventional proportionality between casualty numbers and exposure to risk without considering other factors that may bear on the situation.

4-8. CONTRIBUTION OF ARMY FORMATIONS TO ARMY GROUP CASUALTIES. The overwhelming majority of army group casualties are taken by formations at Army level and below. The Kuhn data contain the following results on this score for the US 12th Army Group operations in northwest Europe during World War II. This data base records 337,864 casualties taken by the US 12th Army Group, of which 337,268 (99.82 percent) were taken by formations at army level and below. Of all the casualties taken by formations at army group level and below, only 0.17 percent were taken by army group echelons above army.

4-9. CHAPTER SUMMARY

a. The available data suggest that army group total battle casualty rates (TBC/kpd) generally range from around 0.1/kpd to about 20/kpd.

b. It appears likely that KIA rates are about one-fifth the TBC rate, and that a large fraction of those initially classified as CMIA are later reclassified as KIA.

c. The available data suggest that, when viewed over several weeks or months duration, army group TBC rates tend to decline exponentially. After transforming the data logarithmically, this is a linear trend, and on this general trend is superimposed a residual that can be represented by a simple, one-term autoregressive process having a normal random error.

d. US 12th Army Group TBC values declined as the exposure in kpd increased. This trend is opposite to that for theater forces found in the preceding chapter.

e. Over 99 percent of army group casualties are taken by formations at army level and below.

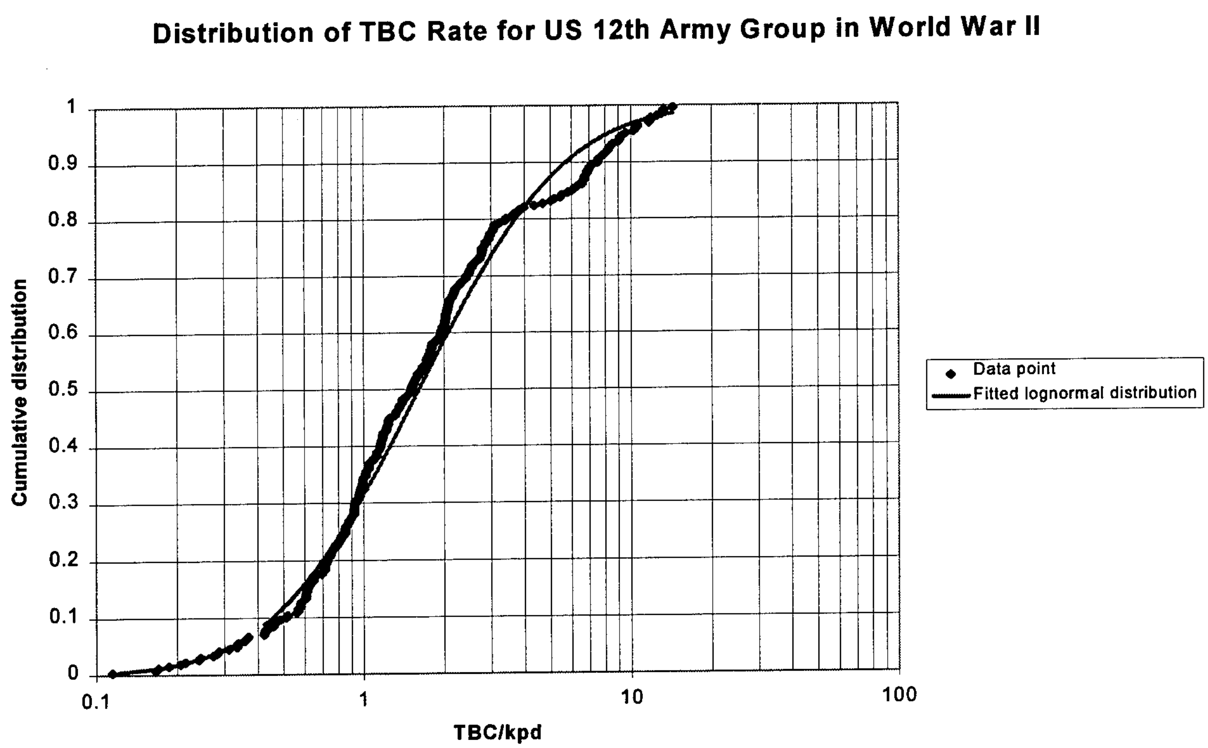

Figure 4-1. Distribution of TBC Rate for US 12th Army Group in World War II

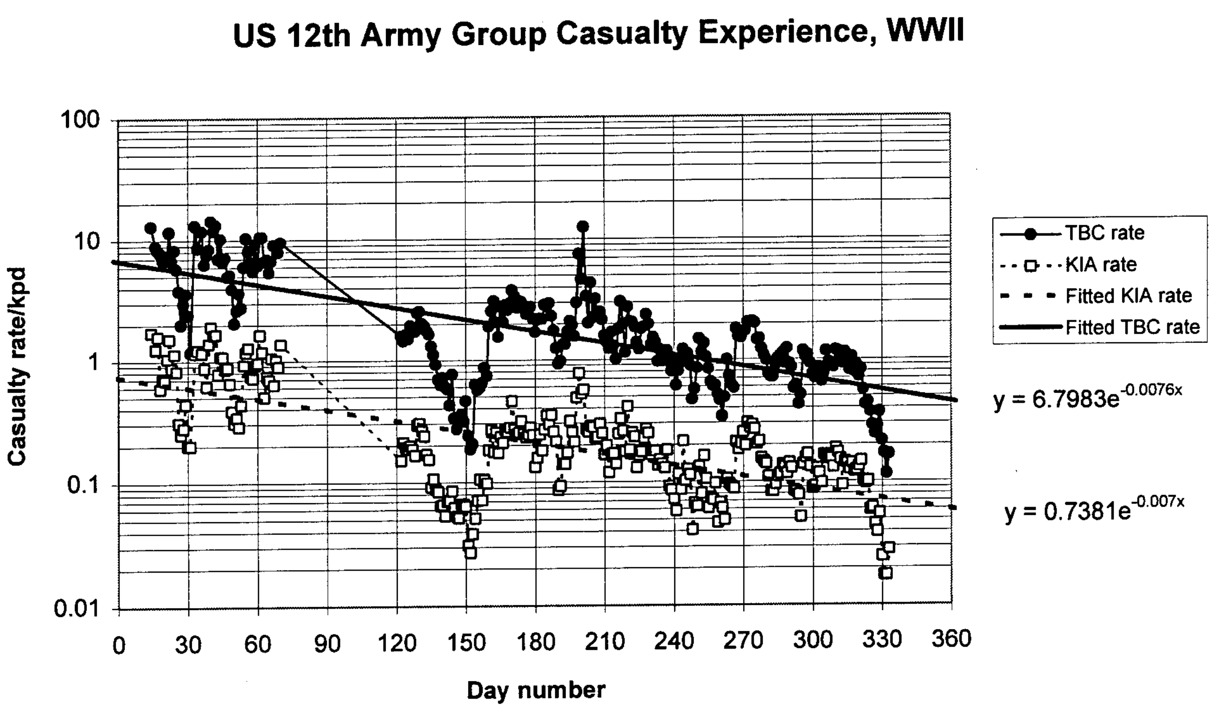

Figure 4-2. Daily Casualty Experience of US 12th Army Group in World War II

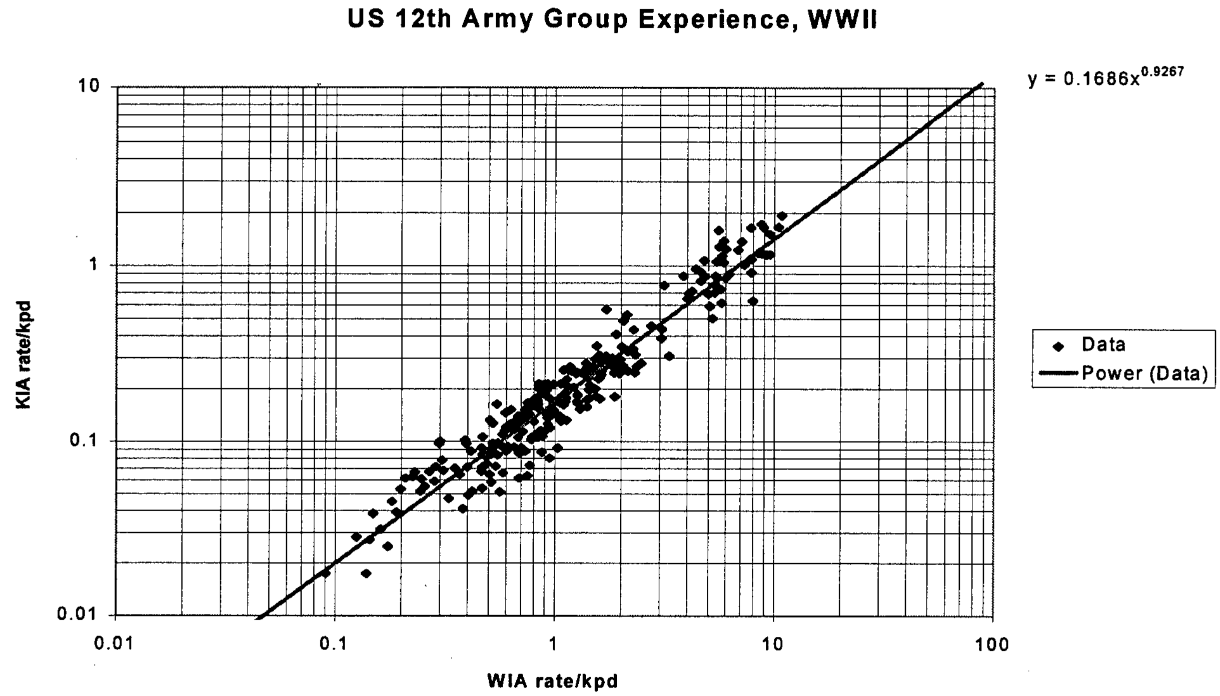

Figure 4-3. KIA Versus WIA Rates for the US 12th Army Group

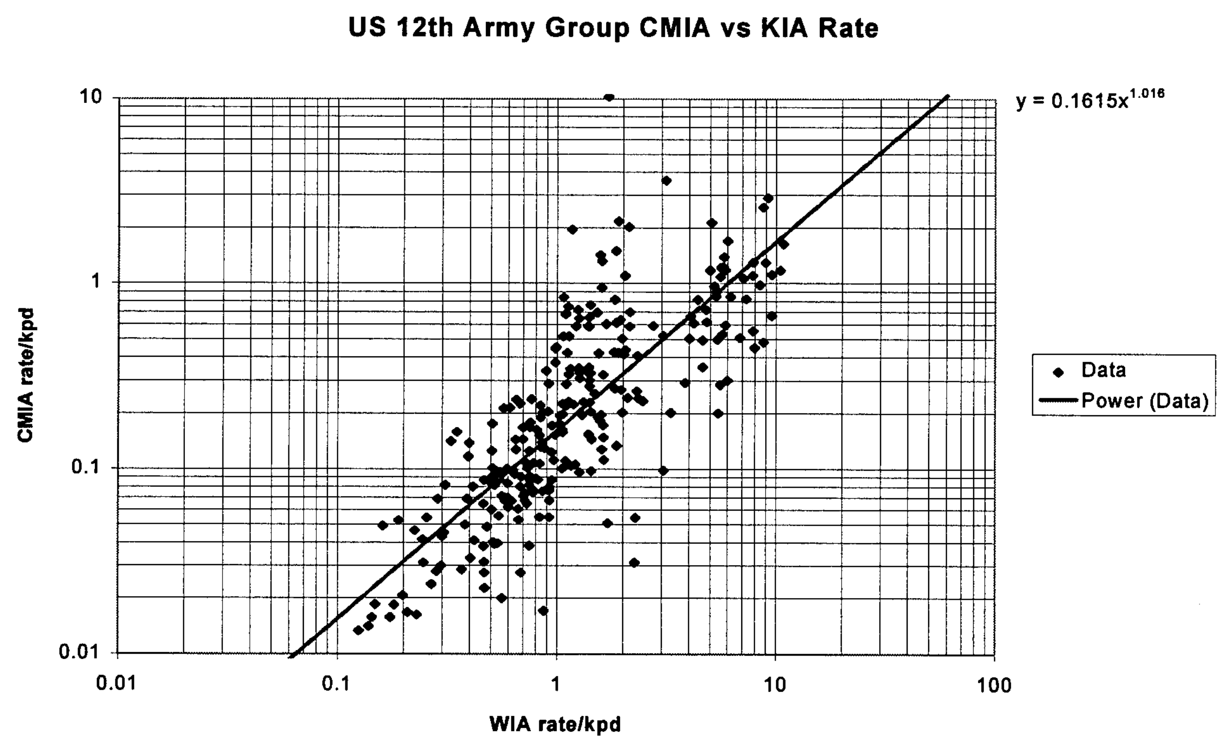

Figure 4-4. CMIA Versus WIA Rate for the US 12th Army Group

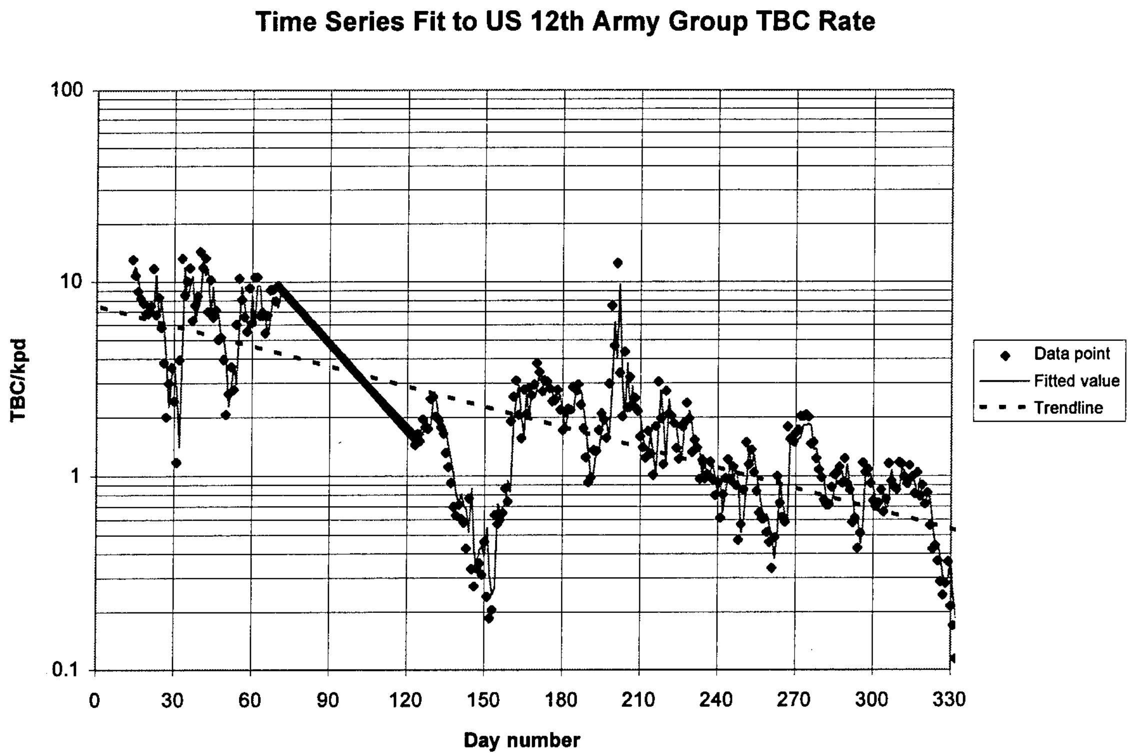

Figure 4-5. Time Series Fit to US 12th Army Group TBC Rate

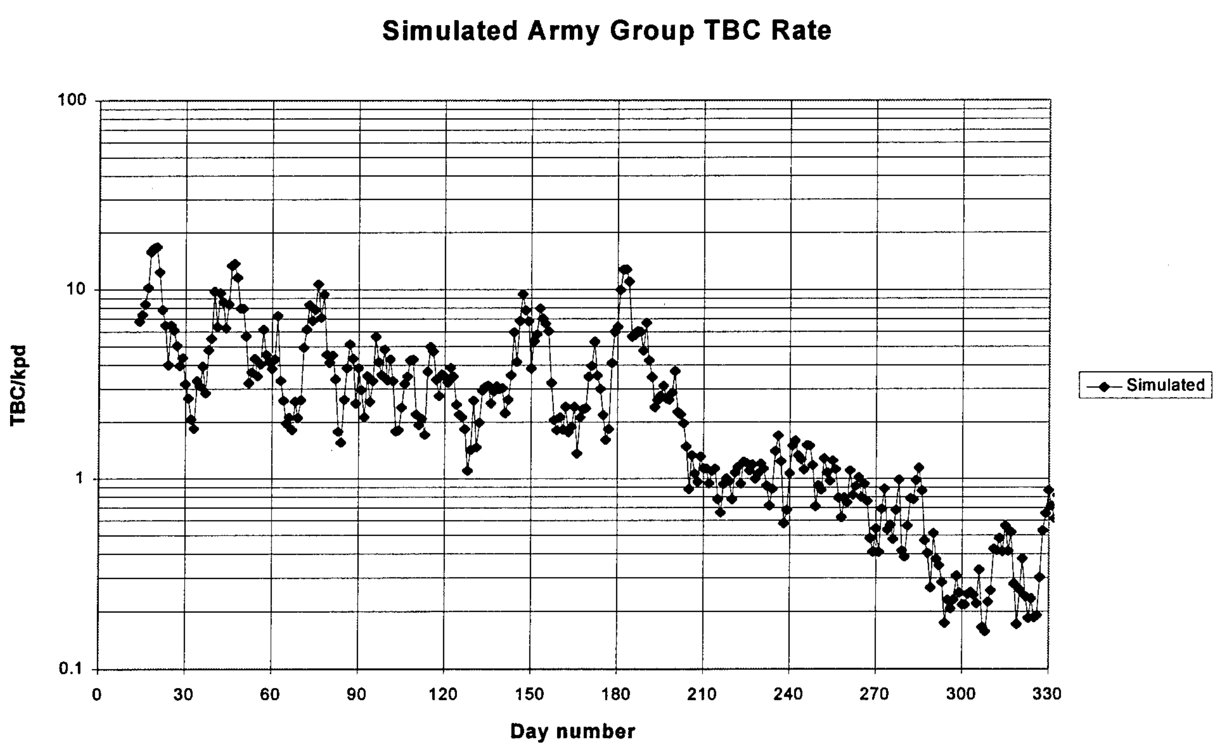

Figure 4-6. Simulated Army Group TBC Rate

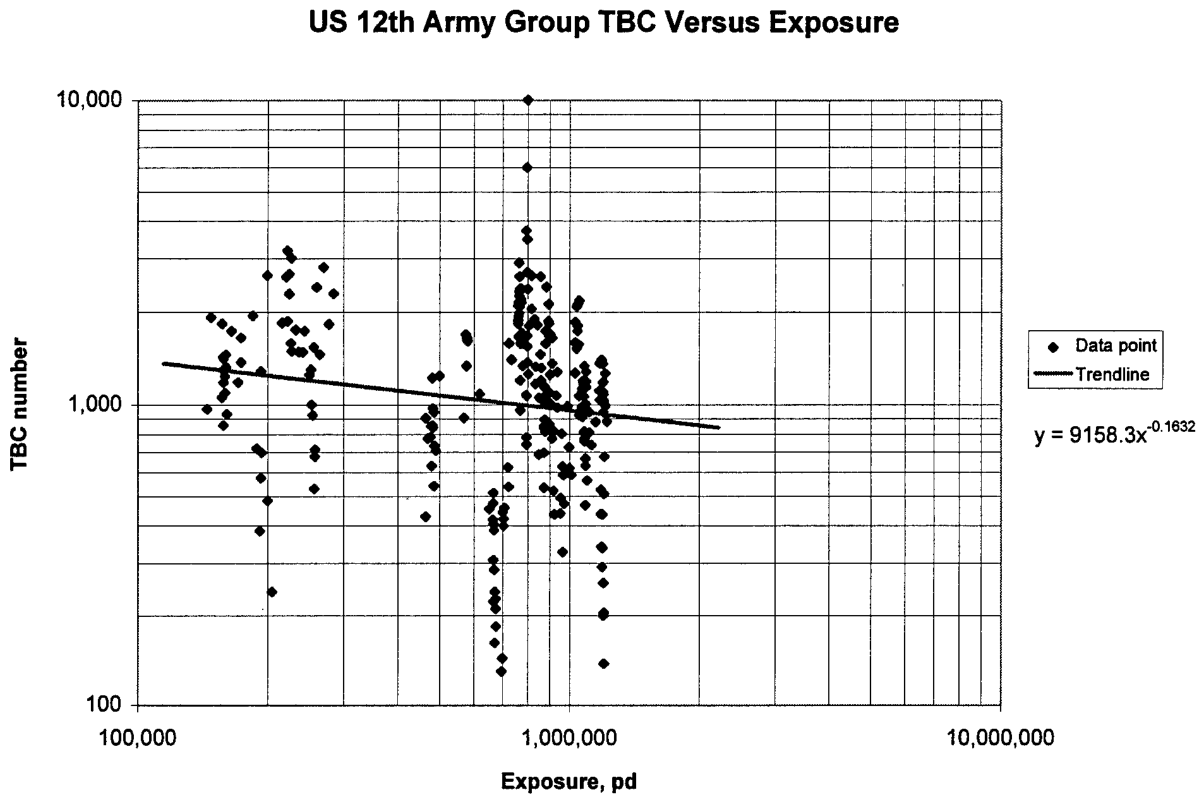

Figure 4-7. US 12th Army Group Experience in World War II

CHAPTER 5

LOSSES OF ARMIES AND ARMY-SIZED FORMATIONS

5-1. INTRODUCTION

a. This chapter examines selected aspects of the casualty rates of armies and army-sized formations operating in a theater of war. It makes considerable use of the data for armies of the US 12th Army Group in northwest Europe during World War II because for them we have the most detailed and complete information. This information includes the onhand strength and casualty data (including KIA, WIA, and CMIA) on a daily basis for each of the US 12th Army Group's armies operating in Northwest Europe during World War II from 15 June 1944 (shortly after the D-day landings in Normandy on 6 June 1944) through 30 April 1945 (shortly before the surrender of Nazi Germany on 5 May 1945). These US armies are listed below.

- 1st Army (Hodges)
- 3d Army (Patton)
- 9th Army (Simpson)
- 15th Army (Gerow)

The comments regarding the characteristics of these data bases given in paragraph 4-1 apply here as well.

b. Additional data on the casualty rates of other armies and army-sized formation has been extracted from a few sources, as described later in this chapter. The number of personnel in an army-sized formation is not specifically defined, and in fact varies rather widely. So the criteria used in this chapter to decide whether a formation was "army-sized" varied. Because most of the data on army-sized formations is for specific operations by such forces, we treat them separately from the US armies.

5-2. DISTRIBUTION OF TOTAL BATTLE CASUALTY RATE FOR US ARMIES

a. Table 5-1 shows some examples of US army casualty rates from World War II, taken from Beebe and DeBakey's Table 16, pg. 69. ***Note that in this chapter we use casualty rates/kpd rather than rates/kpy.*** The original values in casualties per thousand per week (casualties /kpw) have here been converted to casualties /kpd for the sake of uniformity. The TBC/kpd values shown in Table 5-1 were estimated by multiplying the wounded admissions rate /kpd by 1.5, which is a rough approximate ratio of TBC to wounded (see Appendix C). The First, Third, Seventh, and Ninth Armies all fought in northwest Europe toward the end of World War II. The Tenth Army fought in Okinawa, among other campaigns in the Pacific.

Table 5-1. Examples of US Army Casualty Rates/kpd from World War II

Theater	Army	Disease /kpd	Nonbattle injury /kpd	Wounded /kpd	Disease +nonbattle wounded /kpd	Est TBC /kpd
European	First	1.47	0.49	1.71	3.67	2.57
European	Third	1.43	0.39	1.30	3.11	1.95
European	Seventh[a]	2.00	0.53	1.11	3.64	1.65
European	Ninth	1.07	0.30	0.60	1.97	0.90
Mediterranean	Seventh (Sicily)	4.06	0.39[a]	2.33[b]	4.06	3.50
Mediterranean	Fifth	2.39	0.39	0.79	3.56	1.14
Pacific	Sixth (Leyte)	3.16	0.41	1.00	4.57	1.50
Pacific	Sixth (Luzon)	3.76	0.34	1.03	5.13	1.54
Pacific	Tenth	1.10	1.04	2.97	5.11	4.46

[a]--Including period in Southern France when army was assigned to MTO.
[b]--Estimated from reported 19.0 per thousand per week for both WIA and nonbattle injury.

b. Wainstein gives somewhat different values for the armies in Europe, as shown in Table 5-2.

Table 5-2. US Army in Europe Casualties/kpd

			Average battle casualties			
Army	**Entered combat**	**Average strength**	**Daily**	**Percent of strength**	**Number of campaign days**	**TBC/kpd**
First	6-Jun-1944	318,851	616	0.19	334	1.93
Third	1-Aug-1944	299,614	497	0.17	281	1.66
Ninth	5-Sep-1944	209,322	149	0.07	246	0.71

c. Figures 5-1 through 5-5 show the distribution of daily total battle casualty rates per thousand personnel-days (TBC/kpd) for the US 1st Army in the Meuse-Argonne campaign of World War I, and for the US 1st, 3d, 9th, and 15th Armies operating in northwest Europe during World War II. (The data for the US 1st Army in the Meuse-Argonne campaign is characterized as "casualties," but appears to represent total battle casualties.) As is often observed with casualty rate data, these distributions are approximately lognormal. (Data in this paragraph based on Love, Kuhn.).

5-3. TBC RATE TIME SERIES FOR US ARMIES

a. We fitted a time series model to the TBC rate values as a function of time. Where necessary, we estimated missing data values by linear interpolation of their logarithms. The time series model fitted to the resulting data consists of a deterministic trend plus an autocorrelated residual. Because the residuals are correlated, conventional regression theory is not applicable. Instead, we used the so-called autoregressive integrated moving average (ARIMA) model that was popularized by Box and Jenkins. The simplest time series model having an acceptable fit to the data was found to be the one given by the following type of relationship.

$$\ln[TBCRate(i)] = \beta_0 + \beta_1 \times i + z(i),$$

where

$\ln[TBCRate(i)]$ = the natural logarithm of the TBC rate / kpd on day number i,

β_0, β_1 = parameters of an exponential trend in TBC rate,

$z(i) = \gamma \times z(i-1) + \mathrm{N}(0, \sigma)$, where

γ = an autoregressive coefficient, and

$\mathrm{N}(0, \sigma)$ = a normal random variable with mean zero and standard deviation σ.

Thus, the logarithmic residuals, $z(i)$, are given by a simple autoregressive process. There are four parameters to be estimated from the time series data on TBC rates: β_0, β_1, γ, and σ. Parameter values for the cases treated here or in the previous chapter are shown in Table 5-3.

Table 5-3. ARIMA Parameter Values

Case	β_0	β_1	γ	σ	Notes
US 12th Army Group	1.915	−0.0080	0.885±0.03	0.313	From Chapter 4
US 1st Army (Meuse-Argonne, WWI)	1.713	−0.0260	0.413±0.13	0.349	From Love
US 1st Army (WWII)	1.884	−0.0069	0.853±0.03	0.435	From Kuhn
US 3d Army (WWII)	0.626	−0.0022	0.863±0.04	0.444	From Kuhn
US 9th Army (WWII)	−0.779	−0.0006	0.827±0.04	0.662	From Kuhn

Figures 5-6 through 5-9 show the original and interpolated data on armies as well as its comparison to the predicted values generated by this time series model. The “Day number” convention is the same as explained in the preceding chapter. The data on the Meuse-Argonne campaign is characterized as "casualties," and is interpreted here as total battle casualties. The US 15th Army's employment history in World War II is too brief for an adequate ARIMA analysis. For those US army cases with enough data, the ARIMA fit is quite good. However, this is a purely statistical and kinematic description of the recorded data that provides a simpler and more readily grasped description of the data than was apparent from the data itself. However, the description does not by itself provide a causal or dynamic model of the casualty generation process. (Data in this paragraph from Love, Kuhn.)

5-4. EXPOSURE AND TBC EXPERIENCES OF US ARMIES. Here we are concerned with the number of total battle casualties (TBC) as a function of the army's exposure in kilo personnel days (kpd). Figures 5-10 through 5-13 show this relationship for the US 1st, 3d, 9th, and 15th Armies, operating in northwest Europe during World War II. The trend lines are shown beyond the range of the data to enhance their visibility, and not because any such extrapolation is recommended. Oddly enough, some of these data have upward sloping trend lines, while others have downward sloping trend lines. The values shown as exposure in kpd are actually daily strengths. Observe that the 1st Army's daily strength varied from 114,641 to 355,732, but most of the time was fairly close to its average value of 249,002. On the other hand, from the tendency of the points shown on Figures 5-11 and 5-12 to appear in two separated vertical bands, the 3d and 9th Armies tended to have either a "low" or a "high" strength. On several days, the 9th Army's strength was considerably lower than the average strength of either the 1st or the 3d Army (249,002 and 245,864, respectively). On most days, the 15th Army's strength was below that of the 1st or 3d Army's average strength. Because of the few days on which the 15th Army took casualties, no trend line is shown for its experience. No experience chart is shown for the US 1st Army experience in the Meuse-Argonne campaign of World War I because the source consulted (Love) does not provide separate daily strength and casualty values for it, but only their ratio, the daily casualty rate. (Data in this paragraph from Kuhn.)

5-5. CONTRIBUTION OF CORPS ECHELON FORMATIONS TO US ARMY CASUALTIES. The overwhelming majority of army casualties are taken by formations at corps level and below. The Kuhn data contain the following results on this score for the US 12th Army Group operations in northwest Europe during World War II. This data base records 337,268 casualties taken by Armies and their subordinate echelons, of which 336,061 (99.64 percent) were taken by formations at corps level and below. In other words, of all the casualties taken by formations at army level and below, only 0.36 percent were taken by army echelons above corps. (Data in this paragraph from Kuhn.)

5-6. DISTRIBUTION OF TOTAL BATTLE CASUALTY RATE FOR ARMY-SIZED FORMATIONS

a. Table 5-4 shows some examples of casualty rates for US army-sized formations from World War II, taken from Beebe and DeBakey. The estimated TBC rate shown in the last column is obtained by multiplying the number of WIA by 1.5, which is a rough approximation to the usual ratio of TBC to WIA (see Appendix C). The estimated TBC rates vary from a low of 0.30 TBC/kpd to a high of 4.5 TBC/kpd. These rates are generally consistent with those found for the armies of the US 12th Army Group.

Table 5-4. Sample Casualty Data for Army-sized Formations in World War II (page 1 of 2 pages)

Theater	Campaign	Force(s)	Start date	End date	Duration (days)	Estimated average strength	Number KIA	Number WIA	Number CMIA	TBC	KIA /kpd	WIA /kpd	CMIA /kpd	TBC /kpd	Estimated TBC /kpd
Mediterranean	North Africa	All	8-Nov-1942	13-May-1943	187	277,300	2,767	10,469	5,796	19,032	0.05	0.20	0.11	0.37	0.30
Mediterranean	Sicily/Armies	Army	10-Jul-1943	17-Aug-1943	39	183,500	1,439	5,236	1,116	7,791	0.20	0.73	0.16	1.09	1.10
Mediterranean	Italy/Fifth Army/Salerno	Army	9-Sep-1943	20-Sep-1943	12	94,900	509	1,847	1,112	3,468	0.45	1.62	0.98	3.05	2.43
Mediterranean	Italy/Armies	Army	9-Sep-1943	8-May-1945	608	182,800	19,488	80,576	9,637	109,701	0.18	0.72	0.09	0.99	1.09
Mediterranean	Italy/Fifth Army/Naples-Foggia	Army	21-Sep-1943	6-Oct-1943	16	180,300	293	996	116	1,405	0.10	0.35	0.04	0.49	0.52
Mediterranean	Italy/Fifth Army/Volturno	Army	7-Oct-1943	15-Nov-1943	40	201,500	1,399	5,186	267	6,852	0.17	0.64	0.03	0.85	0.97
Mediterranean	Italy/Fifth Army/Winterline	Army	16-Nov-1943	15-Jan-1944	61	200,600	1,642	6,962	253	8,857	0.13	0.57	0.02	0.72	0.85
Mediterranean	Italy/Fifth Army/Gustav Line	Army	16-Jan-1944	10-May-1944	116	227,200	4,415	16,281	4,199	24,895	0.17	0.62	0.16	0.94	0.93
Mediterranean	Italy/Fifth Army/May Offensive	Army	11-May-1944	4-Jun-1944	25	240,500	3,205	13,876	1,045	18,126	0.53	2.31	0.17	3.01	3.46
Mediterranean	Italy/Fifth Army/Pursuit Northward	Army	5-Jun-1944	13-Jul-1944	39	208,700	1,424	6,324	306	8,054	0.17	0.78	0.04	0.99	1.17
European	1st Army/Opening Phases	Army	6-Jun-1944	31-Jul-1944	56	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	3.30	#N/A	#N/A	4.95
Mediterranean	Italy/Fifth Army/Arno Valley	Army	14-Jul-1944	15-Aug-1944	33	152,900	537	2,469	270	3,276	0.11	0.49	0.05	0.65	0.73
European	1st Army/Exploitation of St. Lo	Army	1-Aug-1944	12-Sep-1944	43	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.97	#N/A	#N/A	2.96
European	3d Army/Avranches to Moselle	Army	1-Aug-1944	24-Sep-1944	55	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.53	#N/A	#N/A	2.30
Mediterranean	Southern France	Army	15-Aug-1944	31-Oct-1944	78	122,700	#N/A	14,000	#N/A	#N/A	#N/A	1.46	#N/A	#N/A	2.19
Mediterranean	Italy/Fifth Army/Gothic Line	Army	16-Aug-1944	20-Dec-1944	127	142,400	3,663	16,254	1,628	21,545	0.20	0.90	0.09	1.19	1.35
European	9th Army	Army	5-Sep-1944	8-May-1945	246	229,700	#N/A	34,500	#N/A	#N/A	#N/A	0.61	#N/A	#N/A	0.92
European	1st Army/Battle of Germany	Army	13-Sep-1944	15-Dec-1944	94	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.45	#N/A	#N/A	2.18
European	3d Army/Forcing the Moselle	Army	25-Sep-1944	7-Nov-1944	44	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.61	#N/A	#N/A	0.92

Table 5-4. Sample Casualty Data for Army-Sized Formations in World War II (page 2 of 2 pages)

Theater	Campaign	Force(s)	Start date	End date	Duration (days)	Estimated average strength	Number KIA	Number WIA	Number CMIA	TBC	KIA /kpd	WIA /kpd	CMIA /kpd	TBC /kpd	Estimated TBC /kpd
Southwest Pacific	Leyte-Samar/Central Visayan	Sixth Army	19-Oct-1944	25-Dec-1944	68	140,400	2,381	9,128	#N/A	#N/A	0.25	0.96	#N/A	#N/A	1.43
Southwest Pacific	Leyte-Samar/Central Visayan	All	19-Oct-1944	30-Jun-1945	255	145,700	2,968	10,235	#N/A	#N/A	0.08	0.28	#N/A	#N/A	0.41
European	7th Army	Army	1-Nov-1944	8-May-1945	189	252,300	#N/A	51,000	#N/A	#N/A	#N/A	1.07	#N/A	#N/A	1.60
European	3d Army/Metz and Saar	Army	8-Nov-1944	18-Dec-1944	41	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.04	#N/A	#N/A	3.06
European	1st Army/German Counteroffensive	Army	16-Dec-1944	2-Jan-1945	18	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.88	#N/A	#N/A	2.82
European	3d Army/Bastogne-St. Vith	Army	19-Dec-1944	28-Jan-1945	41	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.69	#N/A	#N/A	2.54
Mediterranean	Italy/Fifth Army/Northern Apennines	Army	21-Dec-1944	13-Apr-1945	114	165,100	1,142	5,226	372	6,740	0.06	0.28	0.02	0.36	0.42
European	1st Army/Roer River Offensive	Army	3-Jan-1945	22-Feb-1945	51	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.12	#N/A	#N/A	1.68
Southwest Pacific	Philippines/Luzon	Army	9-Jan-1945	30-Jun-1945	173	180,200	7,142	27,708	#N/A	#N/A	0.23	0.89	#N/A	#N/A	1.33
Southwest Pacific	Philippines/Luzon	All	9-Jan-1945	30-Jun-1945	173	265,400	7,375	29,008	#N/A	#N/A	0.16	0.63	#N/A	#N/A	0.95
European	3d Army/Eifel to Rhine-Trier	Army	29-Jan-1945	12-Mar-1945	43	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.26	#N/A	#N/A	1.89
European	1st Army/Closing Phases	Army	23-Feb-1945	8-May-1945	75	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.06	#N/A	#N/A	1.59
European	3d Army/Koblenz and Palatinate	Army	13-Mar-1945	21-Mar-1945	9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.39	#N/A	#N/A	2.09
European	3d Army/Forcing the Rhine-Mulde	Army	22-Mar-1945	21-Apr-1945	31	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.74	#N/A	#N/A	1.11
Mediterranean	Italy/Fifth Army/Spring Offensive	Army	14-Apr-1945	8-May-1945	25	174,900	1,259	5,155	69	6,483	0.29	1.18	0.02	1.48	1.77
European	3d Army/Danube, Czechoslovakia, Austria	Army	22-Apr-1945	8-May-1945	17	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.35	#N/A	#N/A	0.53

b. Figure 5-14 shows the distribution of estimated TBC rates for the data of Table 5-4. Its median TBC/kpd value is 1.33. This distribution as a whole is consistent with those for the Armies given in previous paragraphs. (Date in this paragraph from Beebe & DeBakey.)

c. Figure 5-15 shows the distribution of TBC rates in selected Soviet large Front operations of World War II. This distribution, with a median value close to 7.8 TBC/kpd, represents substantially higher TBC rates than for the preceding data on US army and army-sized formations. However, the Soviet data give initial strengths only, and in the calculations it was assumed that these initial strengths were a fair estimate of the average personnel strength. In addition, these may be relatively unattenuated rates. (Data in this paragraph from Krivosheyev.)

d. Figure 5-16 shows the distribution of TBC rates for the major named Soviet strategic land operations in World War II. This distribution, with a median value close to 5.6 TBC/kpd is intermediate between the distributions for Soviet large Front operations in Figure 5-15 and for selected US operations shown in Figure 5-14. Nearly all of the relatively low values (that is, those below 1.0 TBC/kpd) are for Soviet operations near the end of the war against collapsing German forces or weak Japanese resistance in Manchuria. For these Soviet data, it was necessary to assume that initial strengths fairly represented average strengths. In addition, these may be relatively unattenuated rates. (Data in this paragraph from Krivosheyev.)

5-7. TBC RATES VERSUS TIME FOR ARMY-SIZED FORMATIONS. It is not appropriate to fit a time series to these TBC rate data on army-sized formations because the available data do not give the TBC rates of a given formation for an extended series of consecutive time periods. However, it is of some interest to consider the TBC rates of army-sized formations over a span of time, such as over the course of a war or long campaign. Figures 5-17 through 5-19 show plots of the TBC rate for the data of Table 5-4, for selected Soviet large Front operations of WWII, and for major named Soviet strategic operations of WWII. Both the Soviet trend lines lie well above that for the US operations. The first trend line slopes upward, the second stays nearly constant, and the third slopes downward. Also, near the end of the war, it seems that the US and Soviet TBC rates in major named land operations became approximately equal. As in previous paragraphs, for the Soviet data it was necessary to assume that initial strengths fairly represented average strengths, and these rates may be relatively unattenuated. Figure 5-20 shows data on the average TBC rates of Soviet operational Fronts and independent armies, by quarter of the year for World War II. These data, taken from Krivosheyev, appear to use average (rather than initial) strengths. For comparison, an exponentially decreasing trend line is superimposed on the data of Figure 5-20. The trend line in Figure 5-20 falls roughly parallel to the trend line of Figure 5-19, but above it by a factor of about 1.5. The general agreement of the data in Figure 5-20 with that in Figure 5-19 suggests that the use in Figure 5-19 of initial strengths as an approximation to average strengths is not too far from the truth. (Data in this paragraph from Beebe & DeBakey and Krivosheyev.)

5-8. EXPOSURE AND TBC EXPERIENCES OF ARMY-SIZED FORMATIONS. Here we are concerned with the number of TBC as a function of the formation's exposure in kpd. Figure 5-21 shows this relationship for the data of Table 5-4. Figures 5-22 and 5-23 show it for Soviet large Front operations and for major named Soviet strategic operations. The trend line for Soviet large Front operations in Figure 5-22 lies roughly parallel to, but above that for US operations. The trend line for Soviet major strategic operations in Figure 5-23 also lies roughly parallel to, but below that for US operations. As in previous paragraphs, for the Soviet data it was necessary to assume that initial strengths fairly represented average strengths. (Data in this paragraph from Beebe & DeBakey and Krivosheyev.)

5-9. THE RELATION BETWEEN CASUALTY RATES AND WINNING AND LOSING FOR ARMY-SIZED FORMATIONS

a. Here we are concerned with the relation between the casualty rates of the winning and losing sides for army-sized formations. Unfortunately, the data available to us on US armies and discussed in paragraphs 5-2 through 5-5 is entirely one-sided and so provides no information on the relation of casualty rates for both the winner and loser. However, for some other army-sized formations, we are able to obtain a relation of casualty rates to winning and losing. It seems reasonable to suppose that about the same relation applies to US armies.

b. Figure 5-24 shows the distribution of casualty rates for 27 army-sized formations (personnel strengths over 100,000) in the CDB90DAT data base. Data for the attacker, defender, winner, and loser are shown separately. Clearly the winner suffers fewer total battle casualties than the loser. Although the attacker also *appears* to suffer fewer TBC than the defender, this is almost certainly due to the fact that the attacker won 19 (70 percent) of these 27 battles. All but one of the 27 battles were fought between 1812 and 1943. They include battles from the Napoleonic wars, the American Civil War, the Franco-Prussian War of 1870, World War I, and World War II.

c. Figures 5-25 shows the casualty rates for the attacker and defender versus the year in which the battle was fought. Figure 5-26 shows them for the winner and loser. Quadratic trend lines are also shown on these figures in order to guide the eye to the main trends, despite the broad scatter in the data values. The tendency of the winner to have the lower TBC rate has persisted at least since the early 1800s through World War II, despite the considerable change in weapons and tactics between the Napoleonic era and that of the two World Wars.

d. Figure 5-27 shows the experience of army-sized formations in the CDB90DAT data base. The attacker's and defender's data are shown separately. The trend line for the attacker practically coincides with that of the loser, considering the scatter in the data. Hence, the attacker's and the defender's experiences are very similar regarding the relation of TBC numbers to exposure in kpd. In other words, for army-sized forces, the trend line or average relation of TBC number to exposure in kpd is about the same for the defender as for the attacker.

e. Figure 5-28 shows the experience of army-sized formations in the CDB90DAT data base. The winner's and loser's data are shown separately. The trend line for the loser is practically parallel to that of the winner. However, the loser's trend line represents TBC values about twice those of the winner. So we expect that the typical fractional exchange ratio favoring the winner, defined by

$$FER(FavoringWinner) = \frac{TBCRate(Loser)}{TBCRate(Winner)}$$

to also be approximately equal to 2. This is confirmed by Figure 5-29, which shows the distribution of FER values favoring the winner for army-sized formations in the CDB90DAT data base. The median FER value favoring the winner indeed turns out the be approximately equal to two. It is also clear from this figure that none of these battles have an FER value favoring the winner less than one. In fact, its minimum value for these battles is about 1.6. The conclusion is inescapable—for battles between army-sized forces the FER values are strongly associated with victory.

f. Figure 5-30 shows the distribution of FER values favoring the winner for army-sized formations in the PARCOMBO data base. The median FER value favoring the winner again turns out the be approximately equal to 2. For this data base, the minimum FER value is less than one. Nevertheless, for battles between army-sized forces the FER values are strongly associated with victory.

5-10. CHAPTER SUMMARY

a. The available data suggest that US army total battle casualty rates (TBC/kpd) generally range from around 0.1/kpd to about 20/kpd, with median values ranging from about 0.5/kpd to 8/kpd.

b. The available data suggest that, at least when viewed over several weeks or months duration for a basically successful offensive campaign, army-level TBC rates tend to decline exponentially. On this general exponential trend is superimposed a residual that often can be represented (after a logarithmic transformation of the data) by a simple, one-term autoregressive process having a normal random error.

c. The relation of TBC numbers and exposure in kpd is obscure. The available data usually show trends in TBC numbers with increasing exposures, but some exceptional data bases show a decrease rather than an increase. In either case, the relationship is not necessarily one of simple proportionality. Instead doubling the exposure may *more* than double the TBC number, or it may *less* than double it. These findings demonstrate that it is hazardous to apply a simple proportionality without considering other important factors.

d. Over 99 percent of army casualties are taken by formations at corps level and below.

e. Winners have about half the TBC rate of losers.

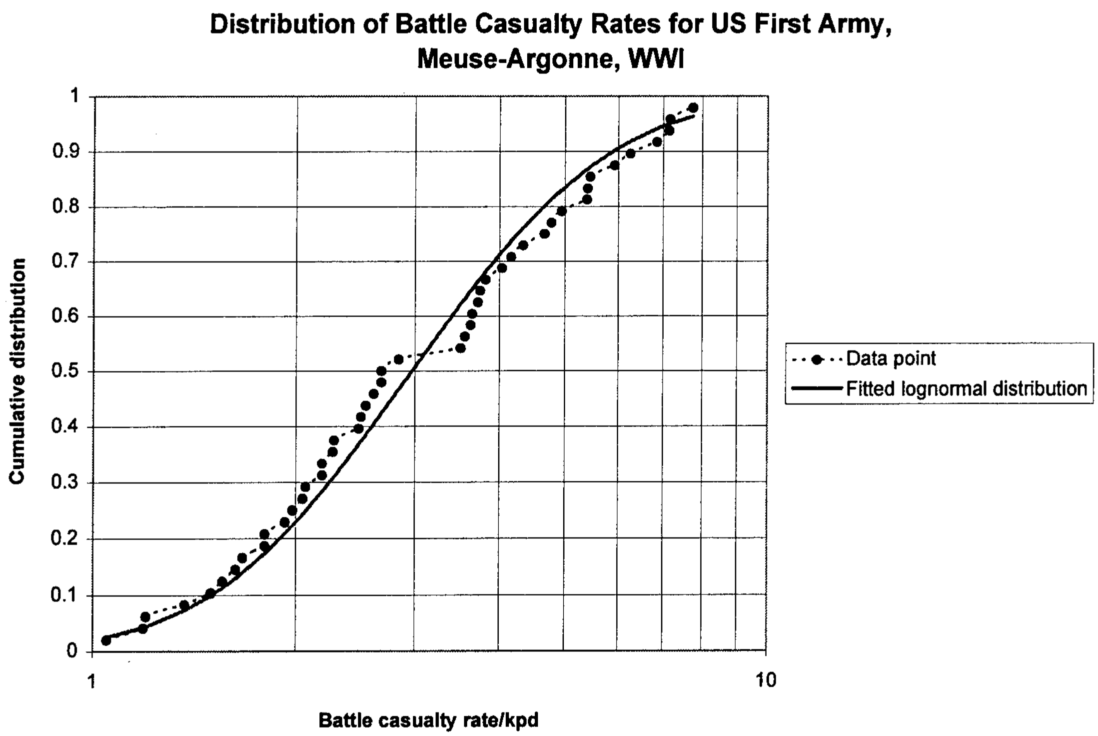

Figure 5-1. Distribution of Battle Casualty Rates for US First Army, Meuse-Argonne, WWI

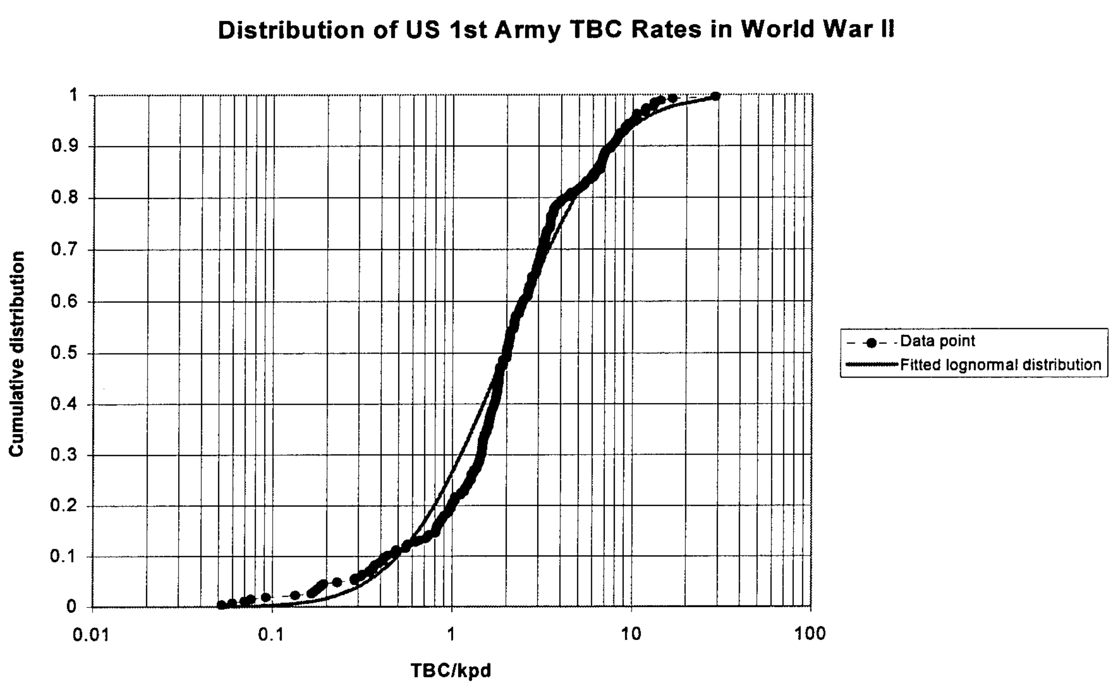

Figure 5-2. Distribution of US 1st Army TBC Rates in World War II

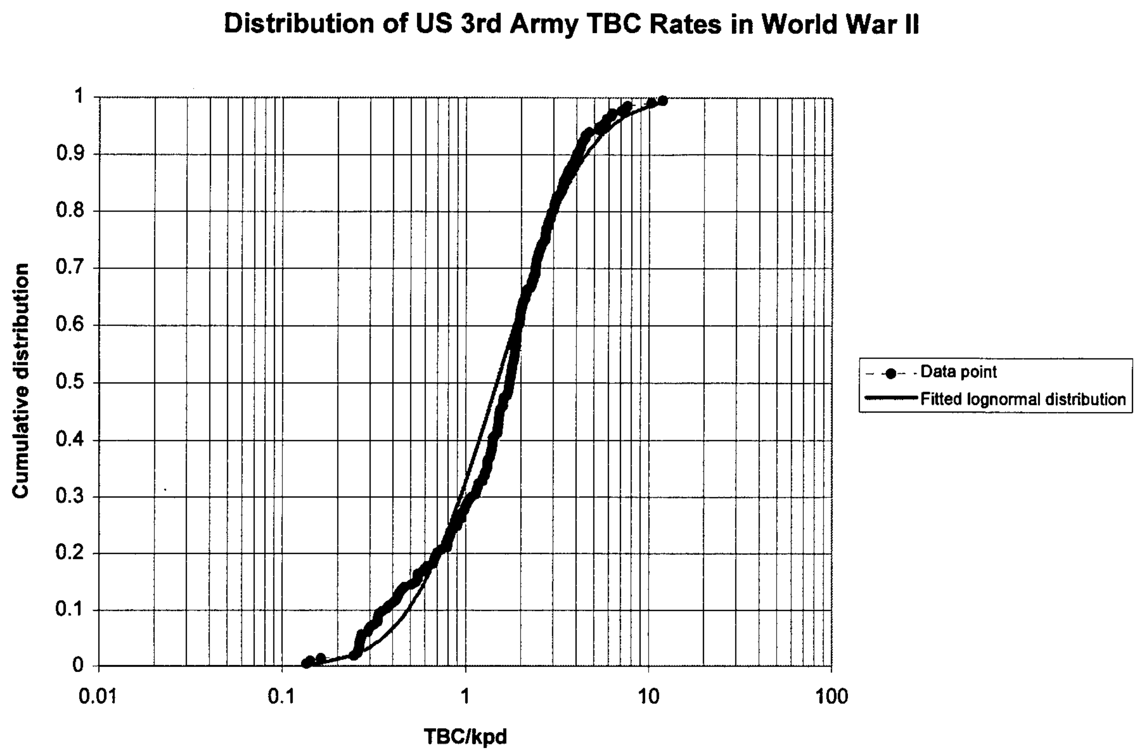

Figure 5-3. Distribution of US 3rd Army TBC Rates in World War II

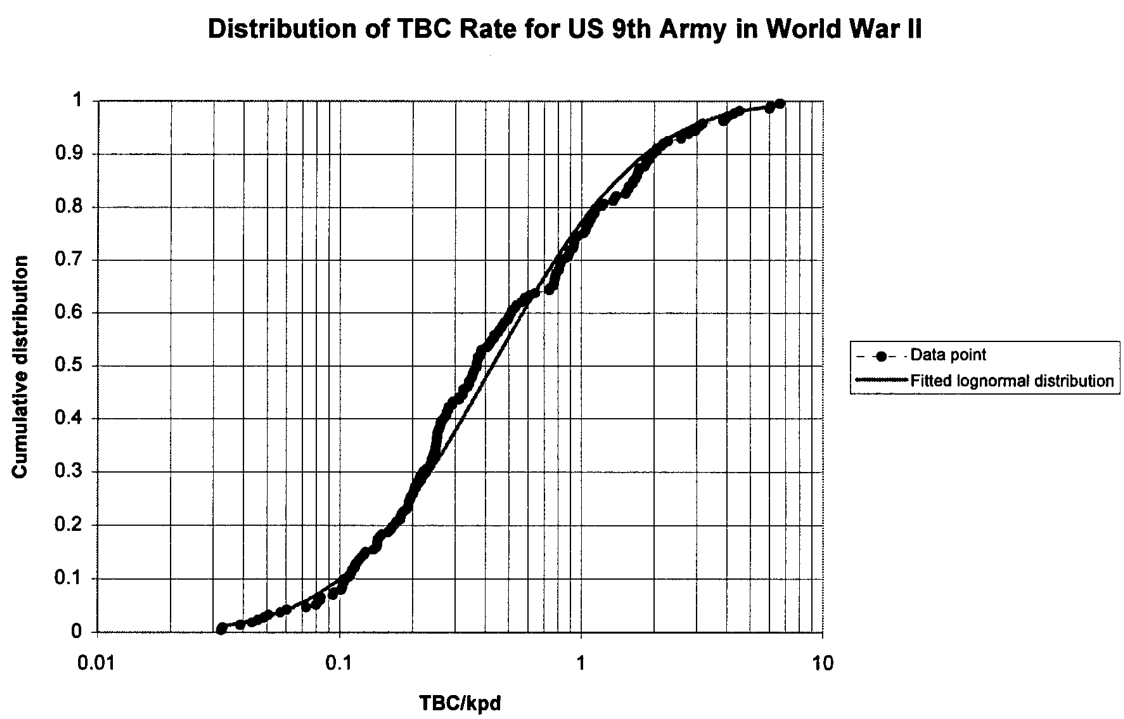

Figure 5-4. Distribution of TBC Rates for US 9th Army in World War II

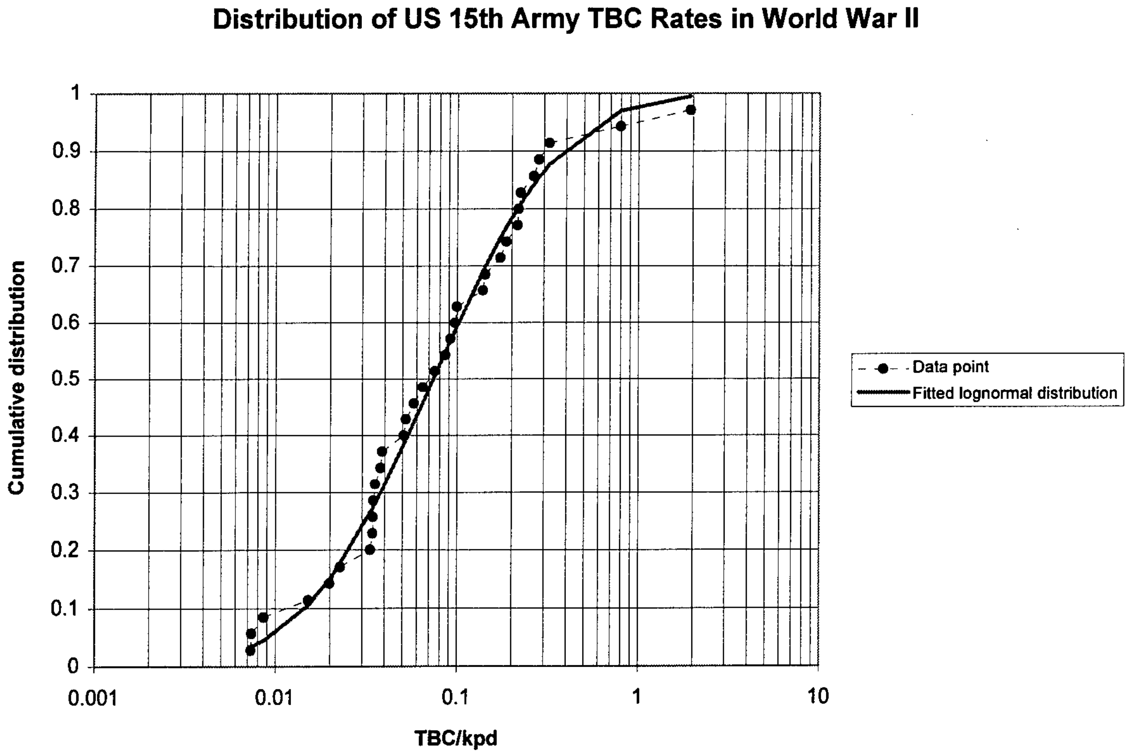

Figure 5-5. Distribution of US 15th ArmyTBC Rates in World War II

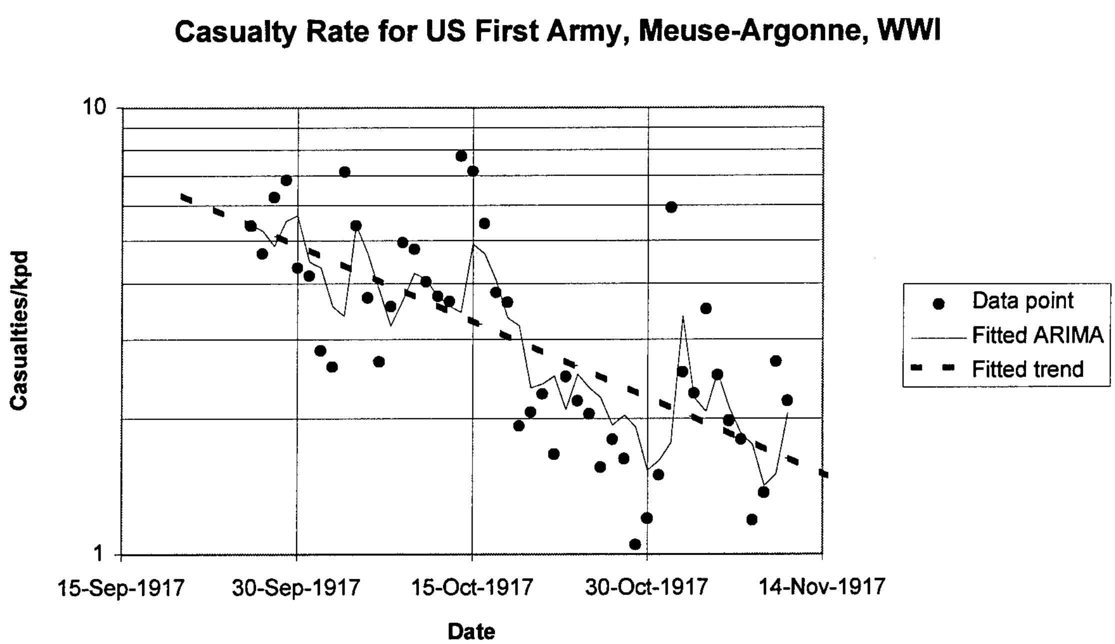

Figure 5-6. Casualty Rate for US 1st Army in the Meuse-Argonne Campaign

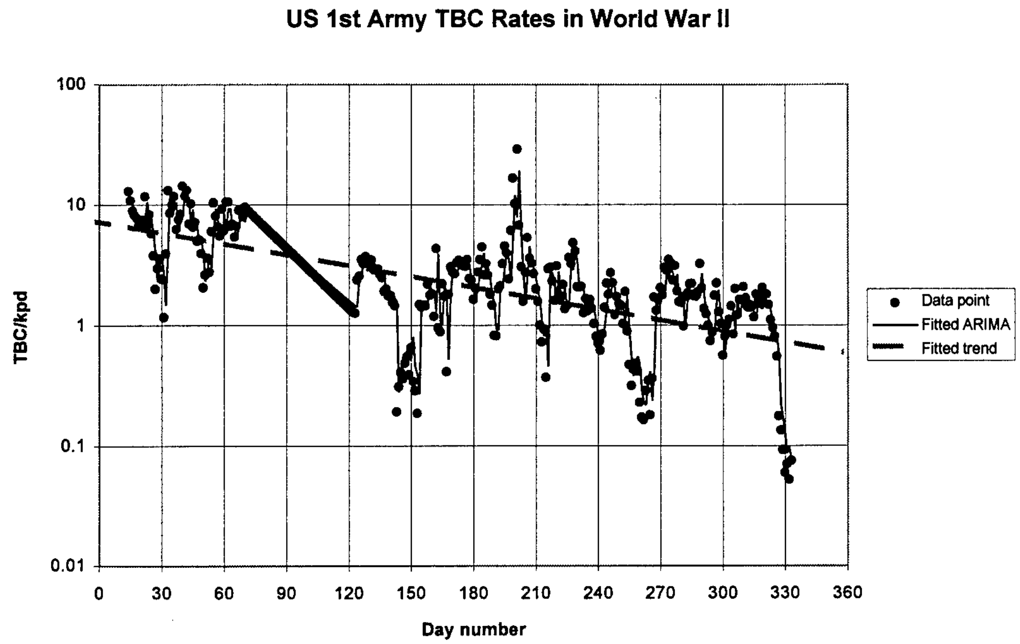

Figure 5-7. TBC Rate for US 1st Army in World War II

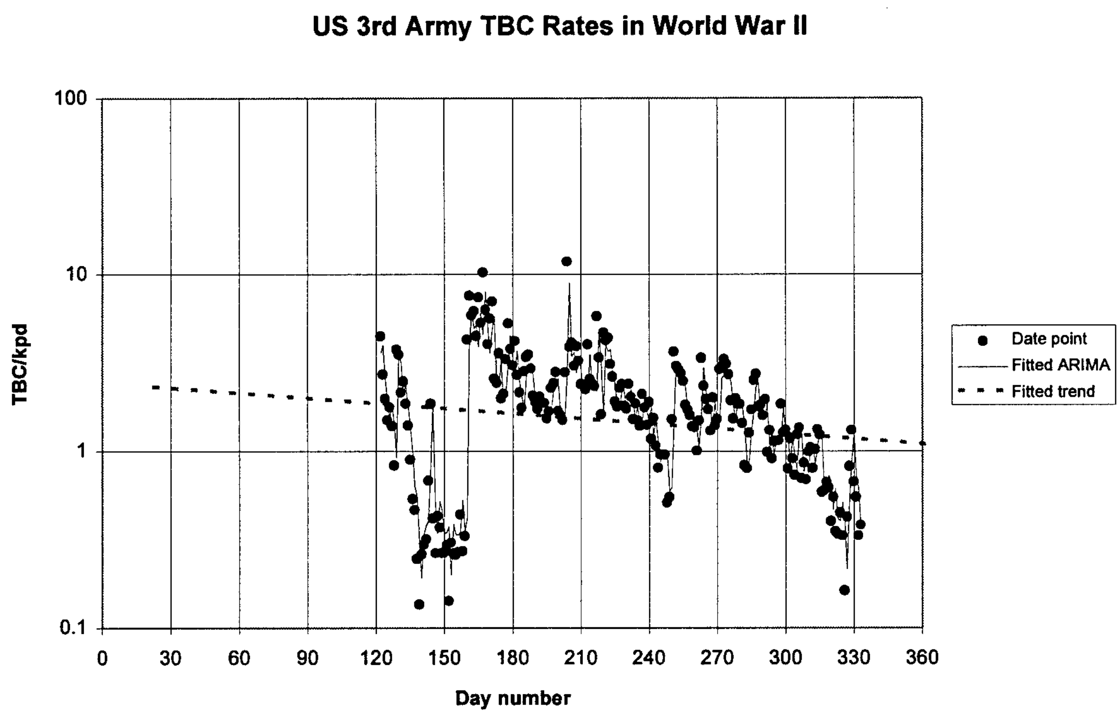

Figure 5-8. TBC Rate for US 3rd Army in World War II

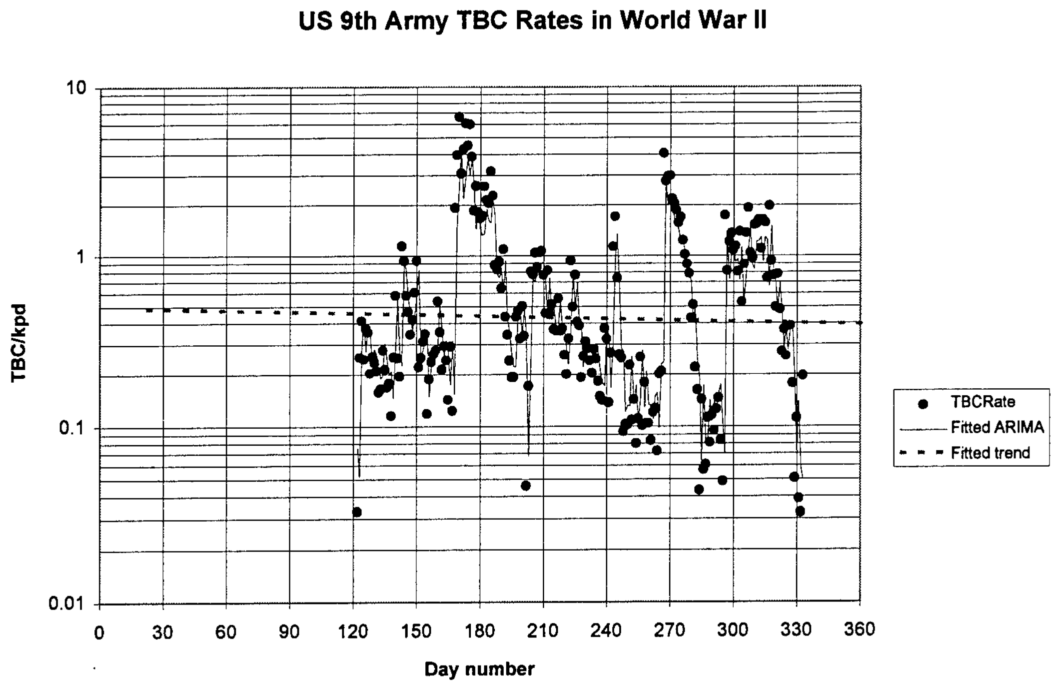

Figure 5-9. TBC Rate for US 9th Army in World War II

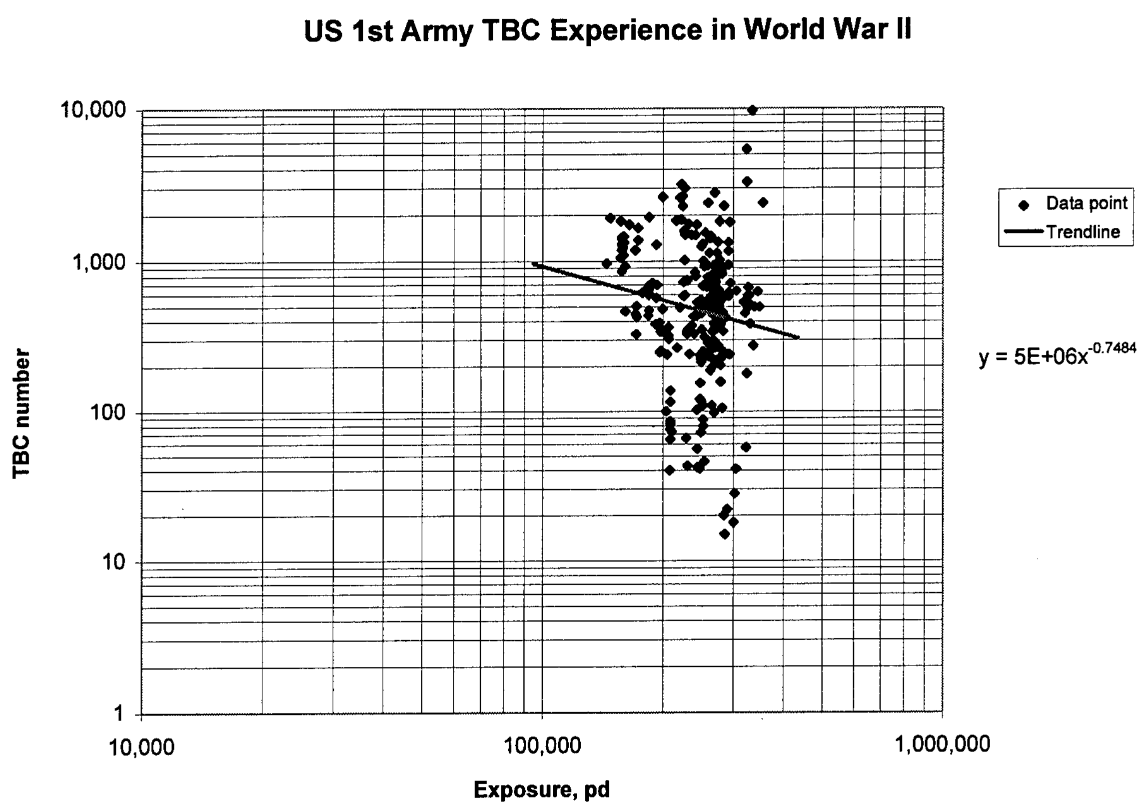

Figure 5-10. US 1st Army Experience in World War II

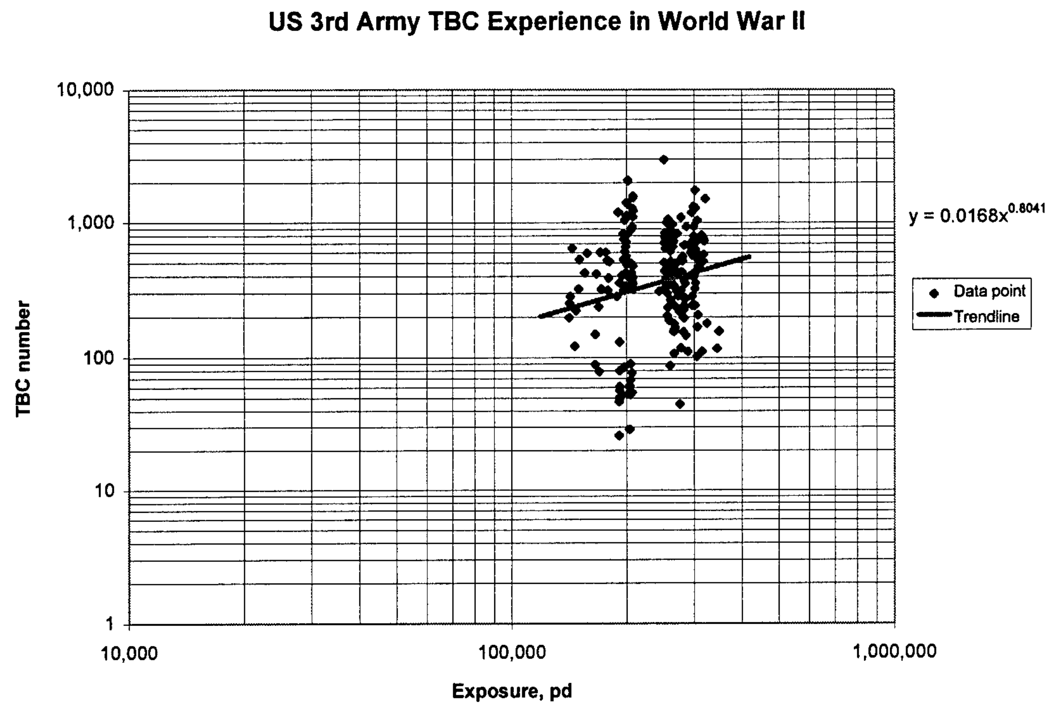

Figure 5-11. US 3rd Army Experience in World War II

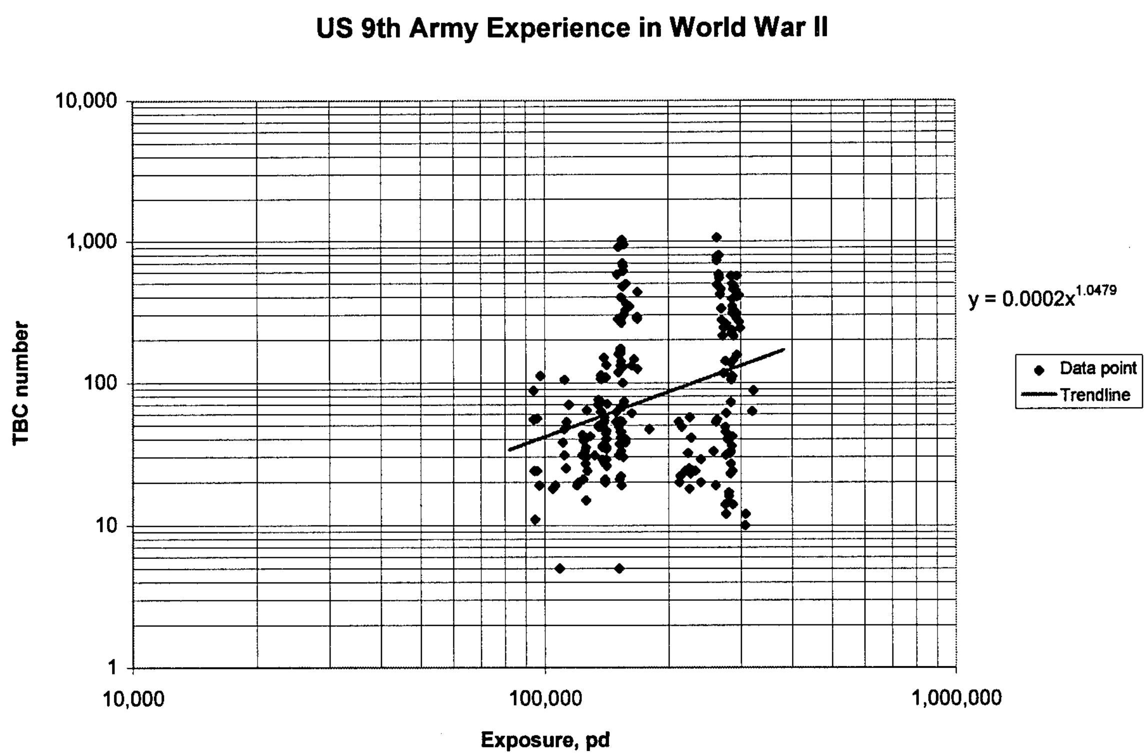

Figure 5-12. US 9th Army Experience n World War II

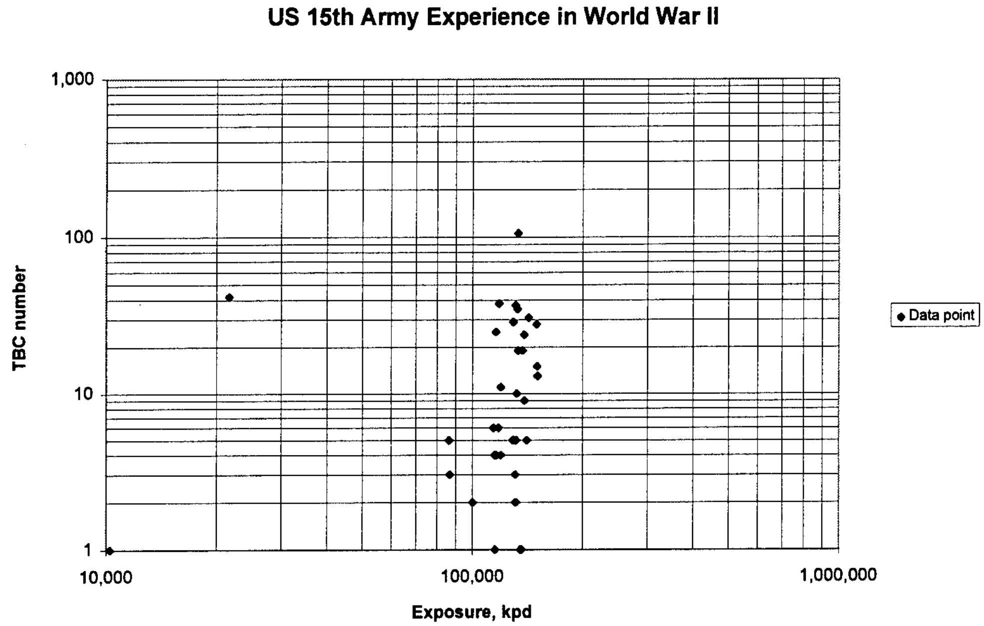

Figure 5-13. US 15th Army Experience in World War II

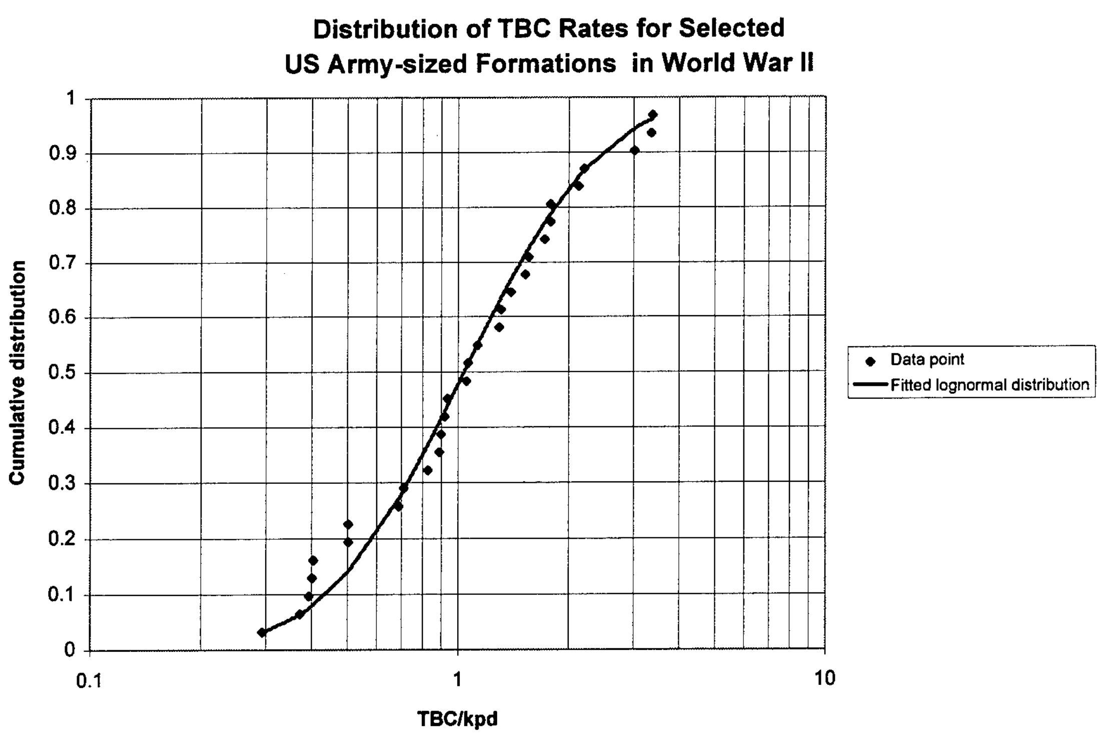

Figure 5-14. Distribution of TBC Rates for Selected US Army-sized Formations in World War II

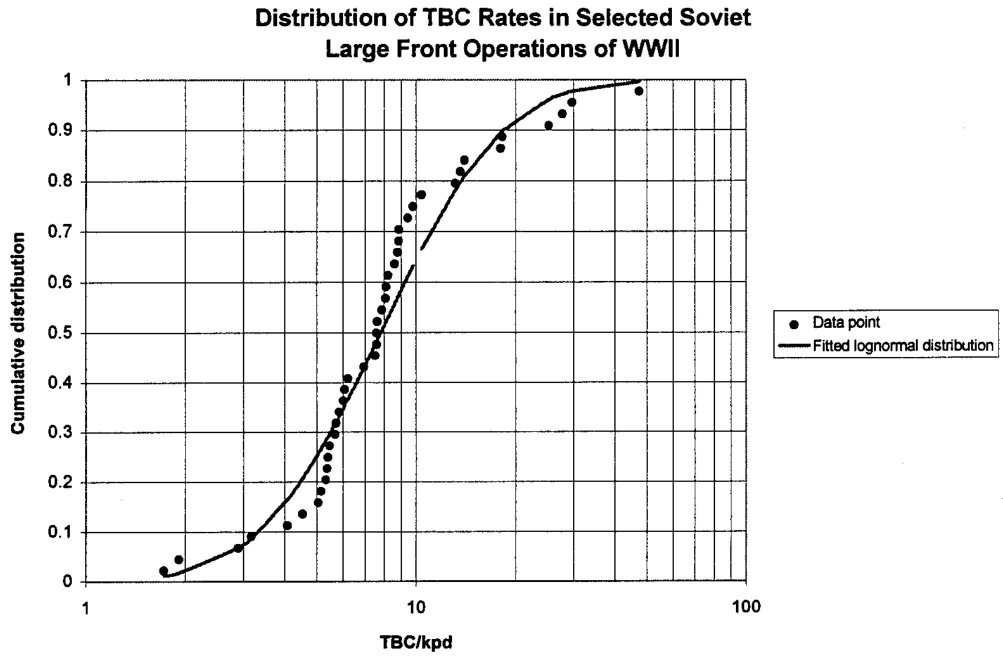

Figure 5-15. Distribution of TBC Rates in Selected Soviet Large Front Operations of WWII

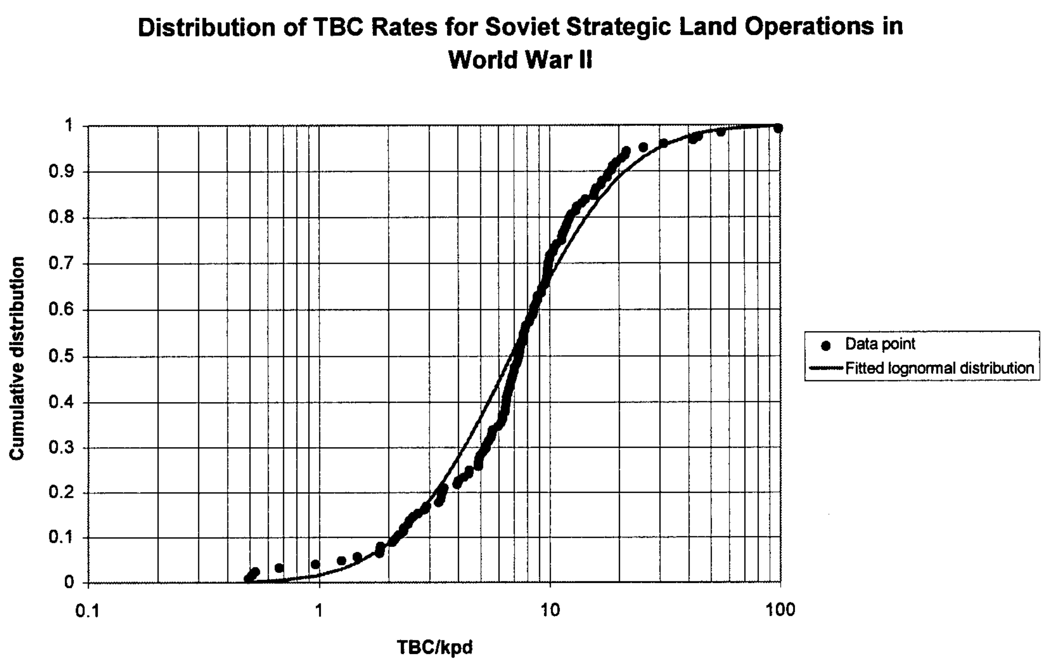

Figure 5-16. Distribution of TBC Rates for Soviet Strategic Land Operations in World War II

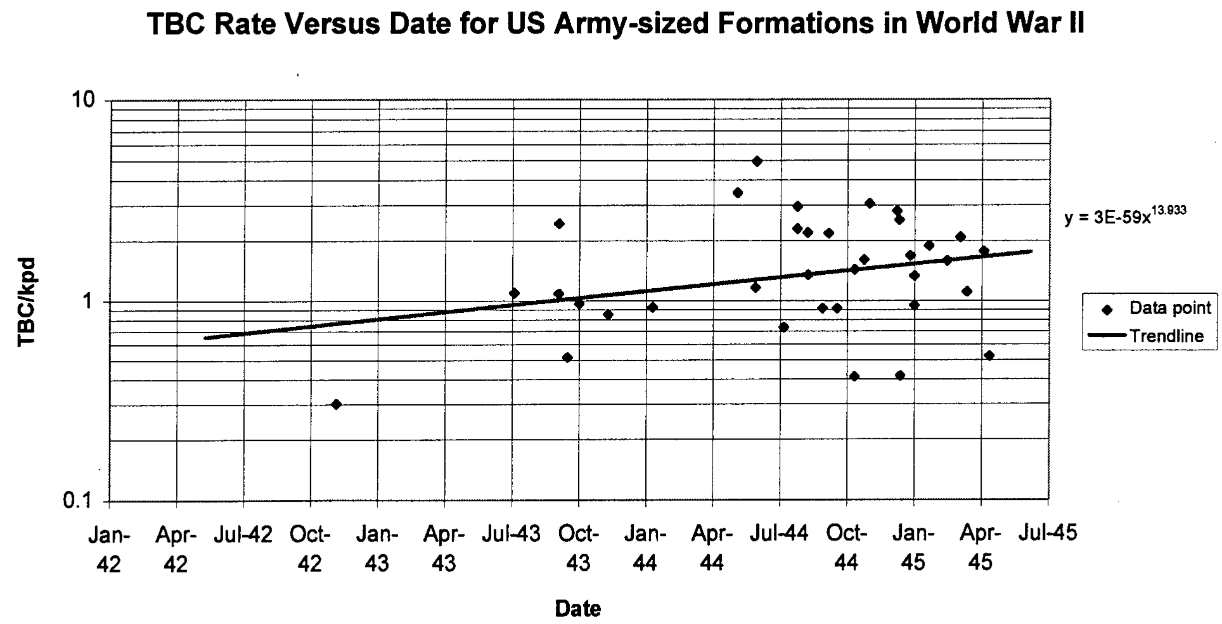

Figure 5-17. TBC Rate versus Date for Selected US Army-sized Formations in World War II

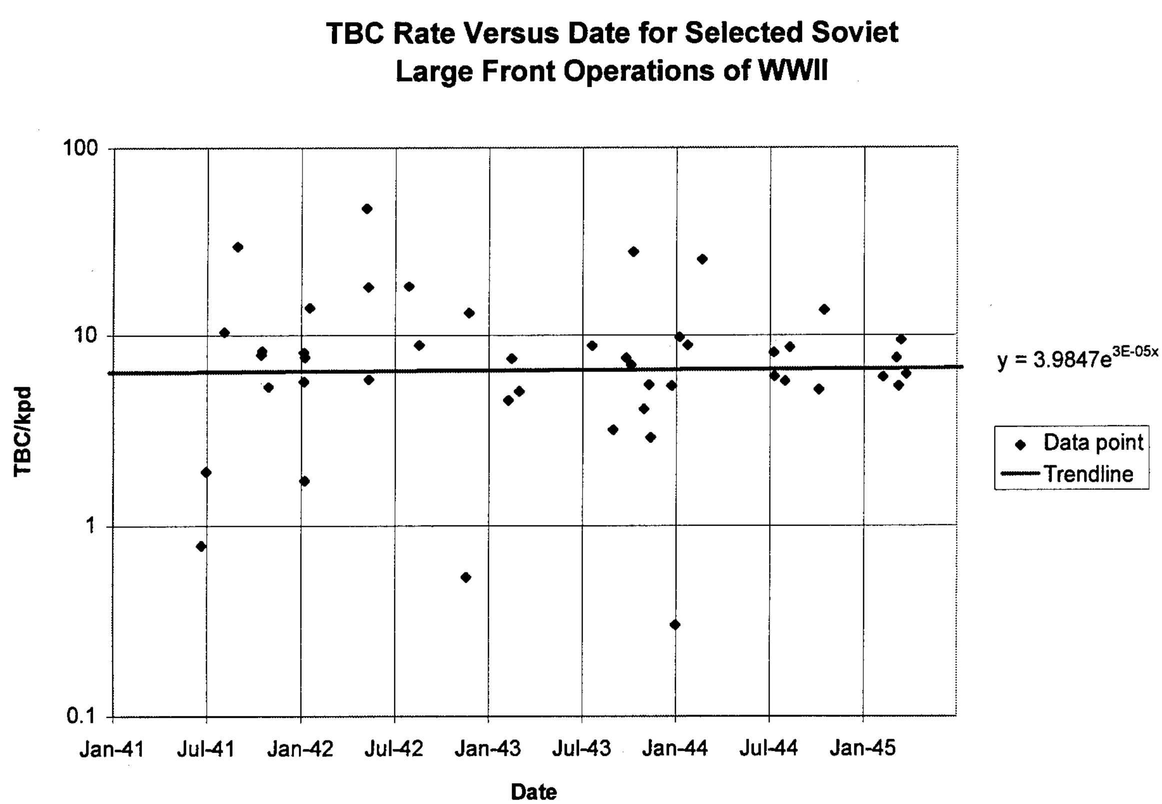

Figure 5-18. TBC Rate versus Date for Selected Soviet Large Front Operations of WWII

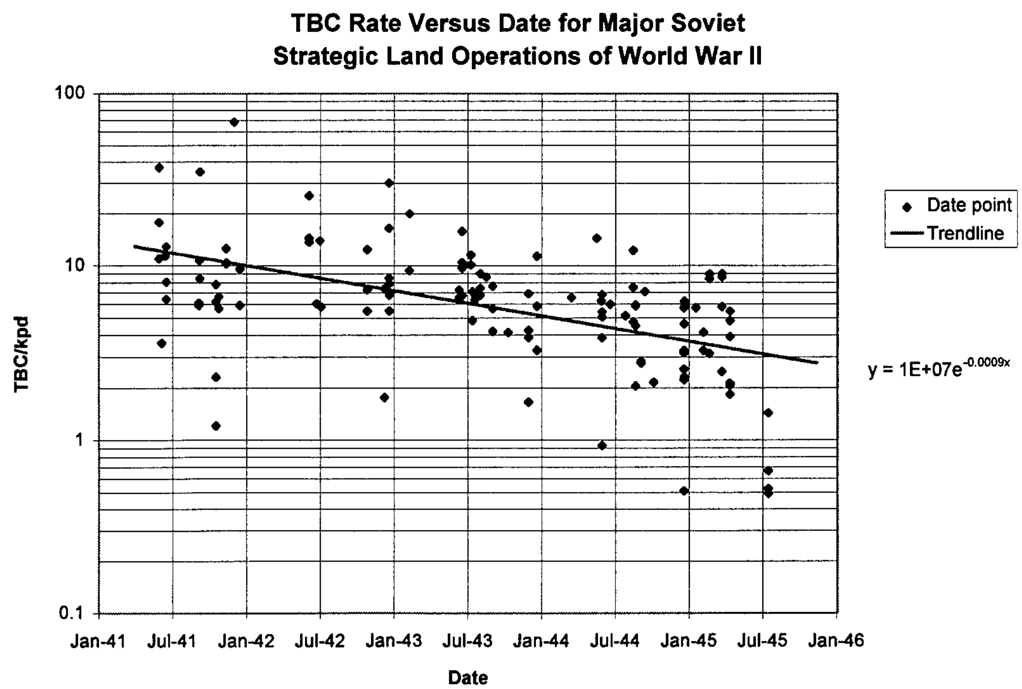

Figure 5-19. TBC Rate versus Date for Major Soviet Strategic Land Operations of World War II

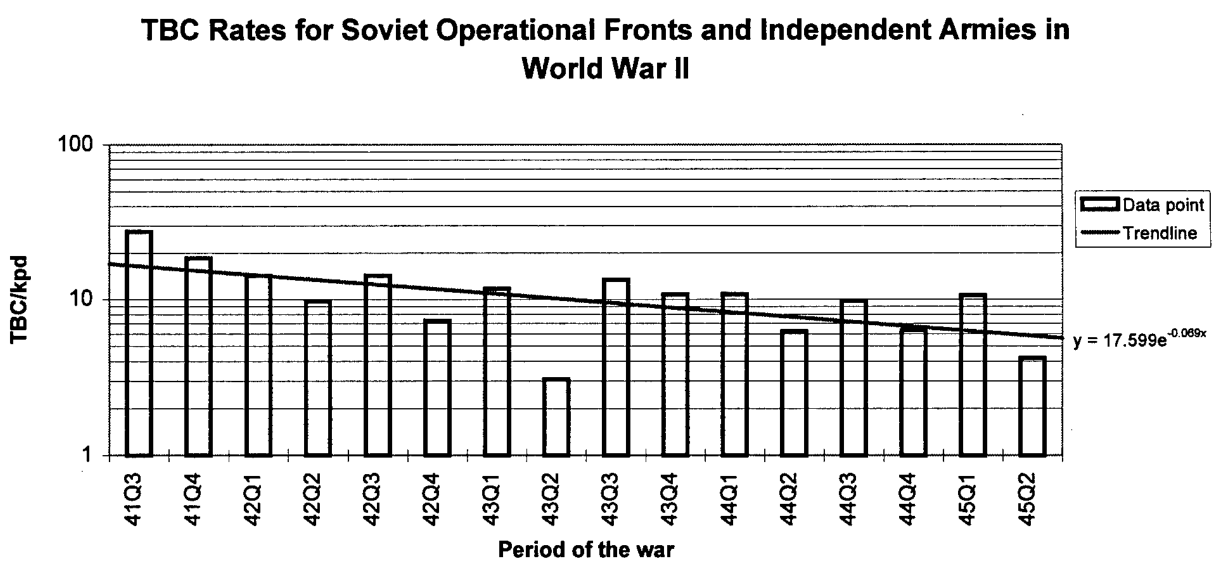

Figure 5-20. TBC Rates for Soviet Operational Fronts and Independent Armies in World War II

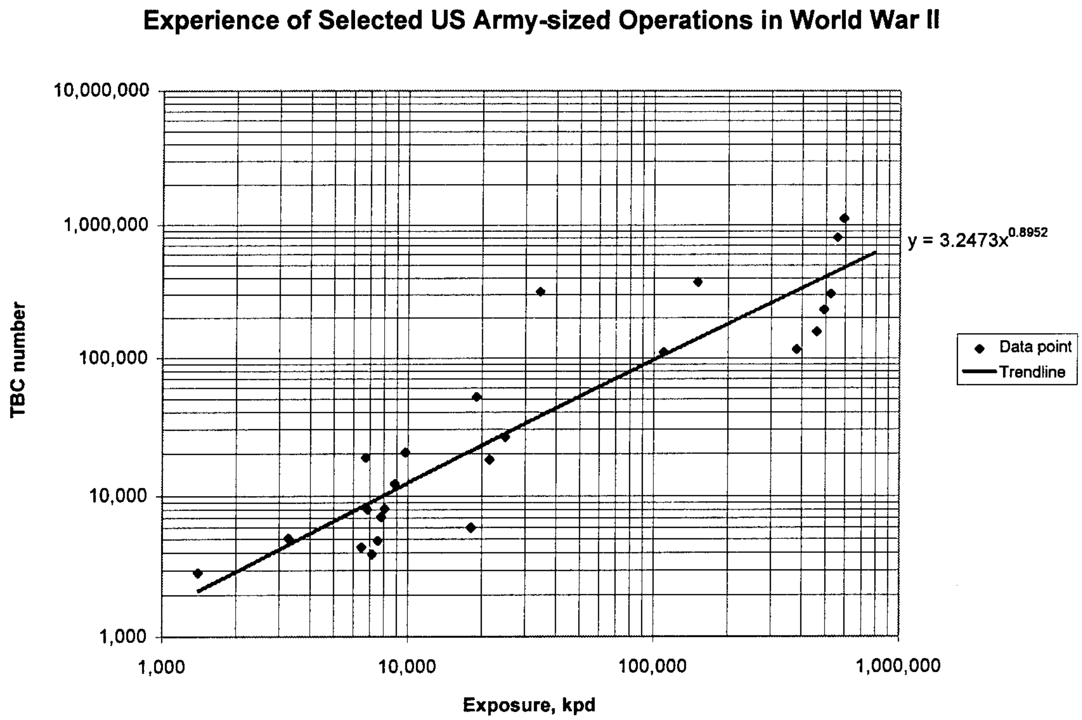

Figure 5-21. Experience in Selected US Army-sized Operations of World War II

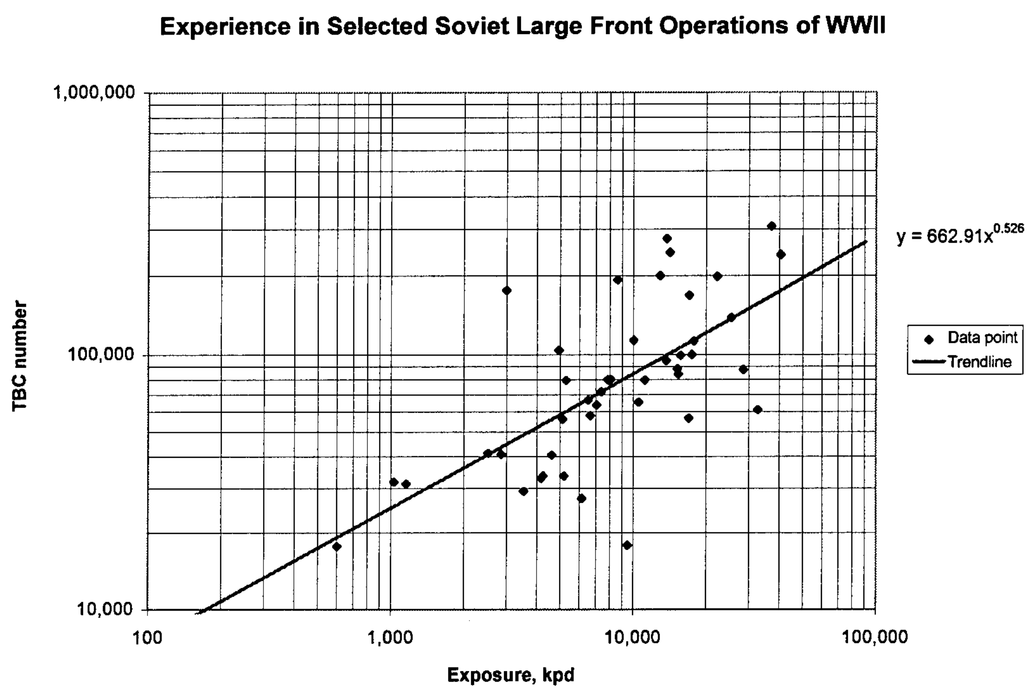

Figure 5-22. Experience in Selected Soviet Large Front Operations of WWII

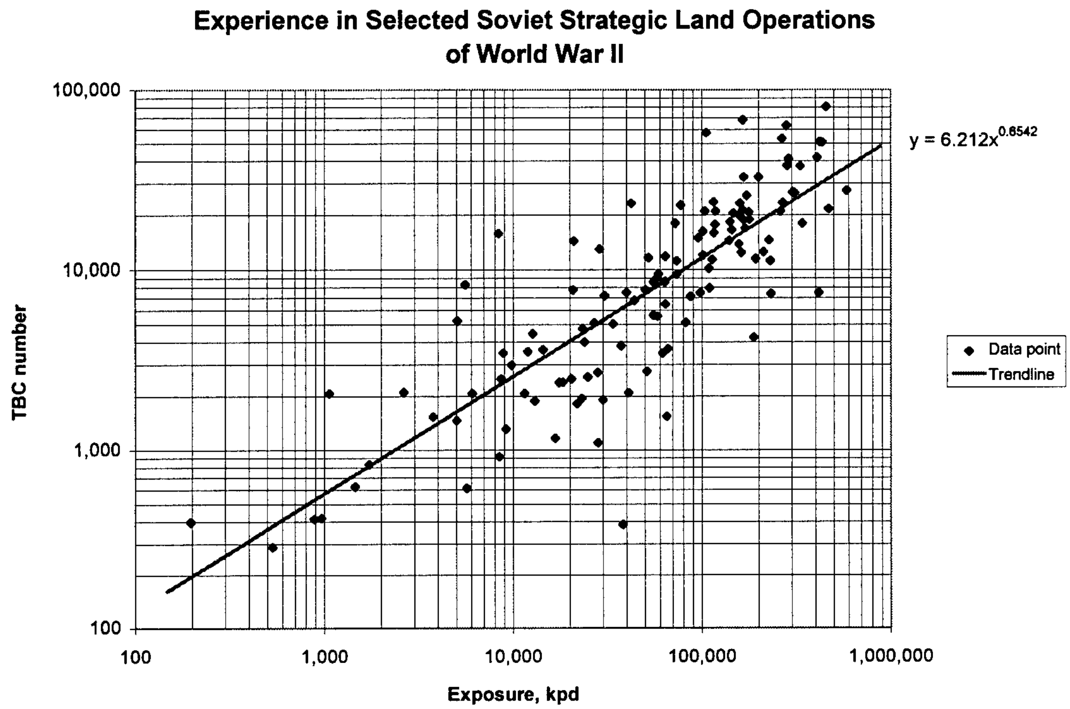

Figure 5-23. Experience in Soviet Strategic Land Operations in World War II

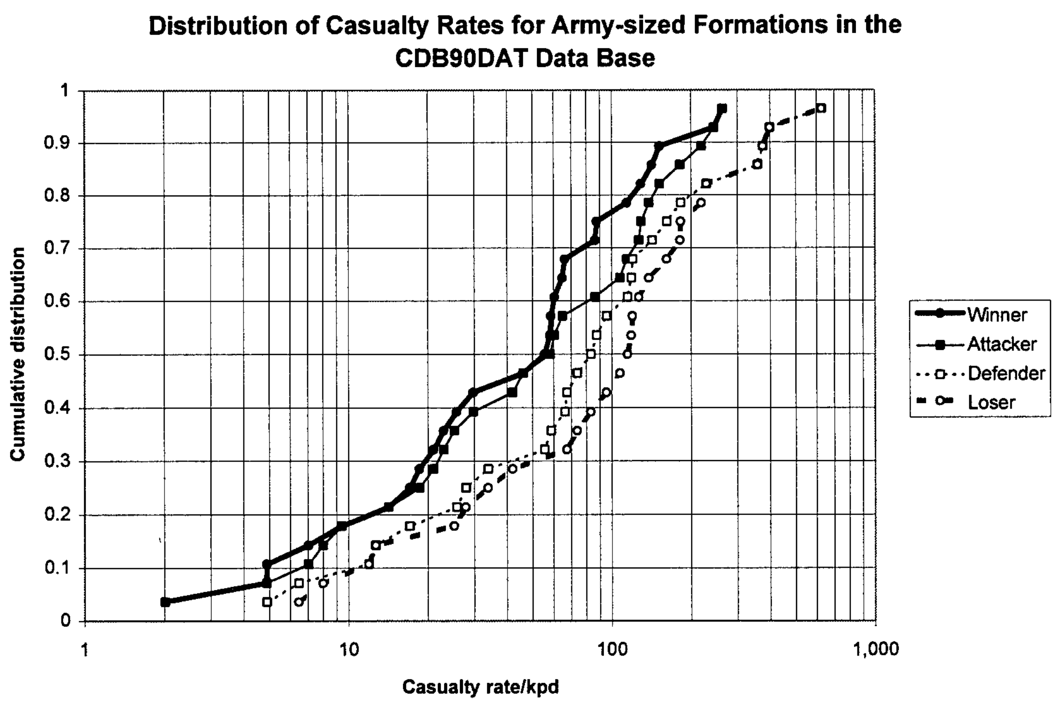

Figure 5-24. Distribution of Casualty Rates for Army-sized Formations in the CDB90DAT Data Base

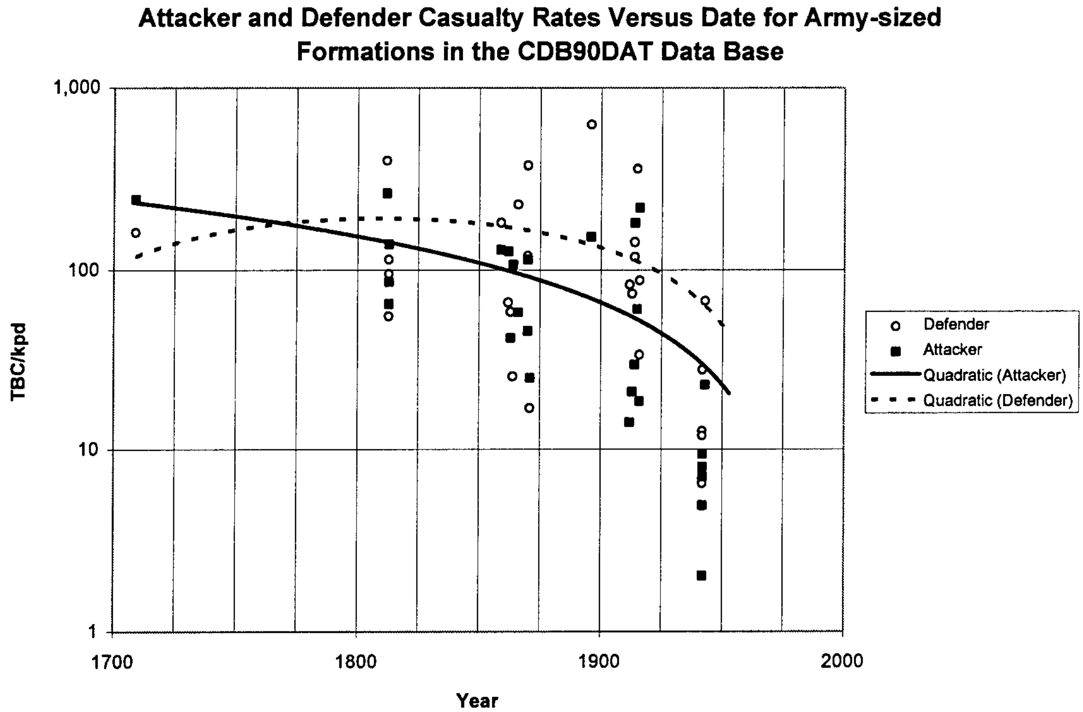

Figure 5-25. Attacker and Defender Casualty Rates versus Date for Army-sized Formations in the CDB90DAT Data Base

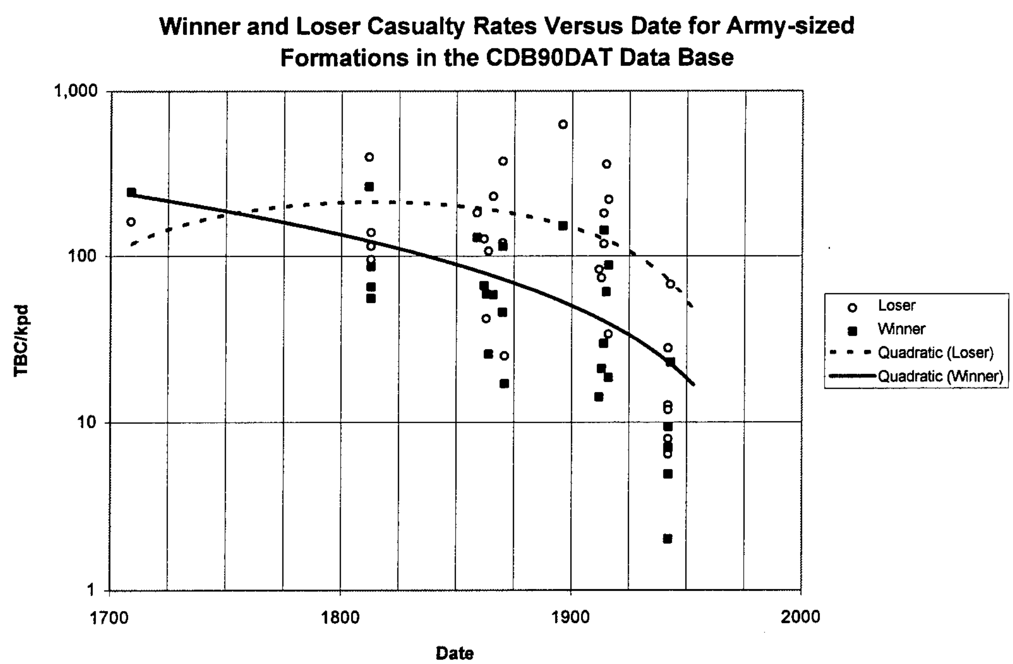

Figure 5-26. Winner and Loser Casualty Rates versus Date for Army-sized Formations in the CDB90DAT Data Base

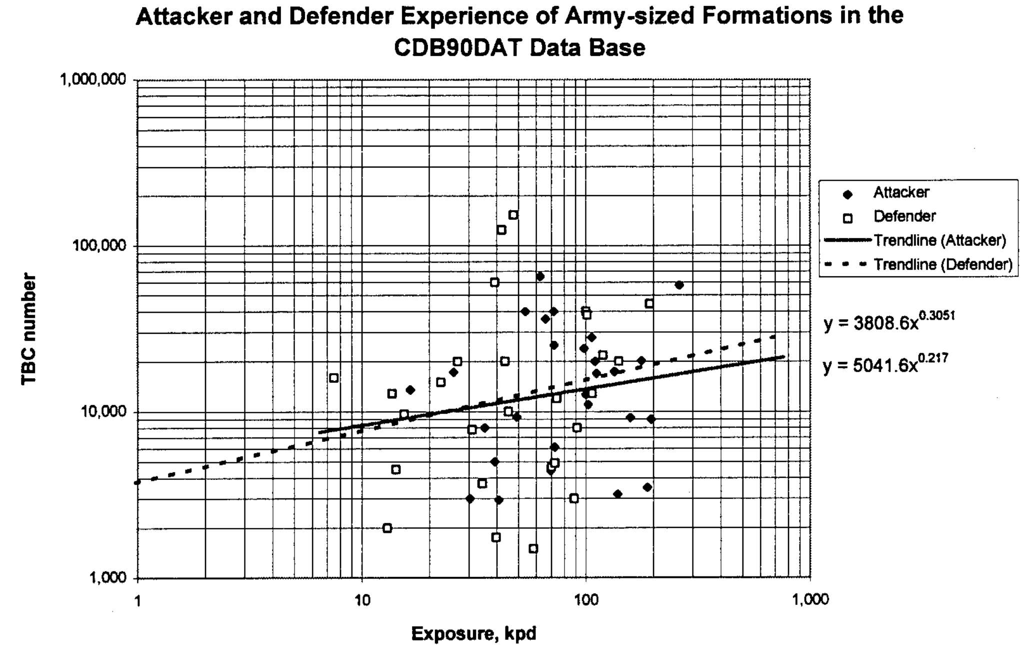

Figure 5-27. Attacker and Defender Experience of Army-sized Formations in the CDB90DAT Data Base

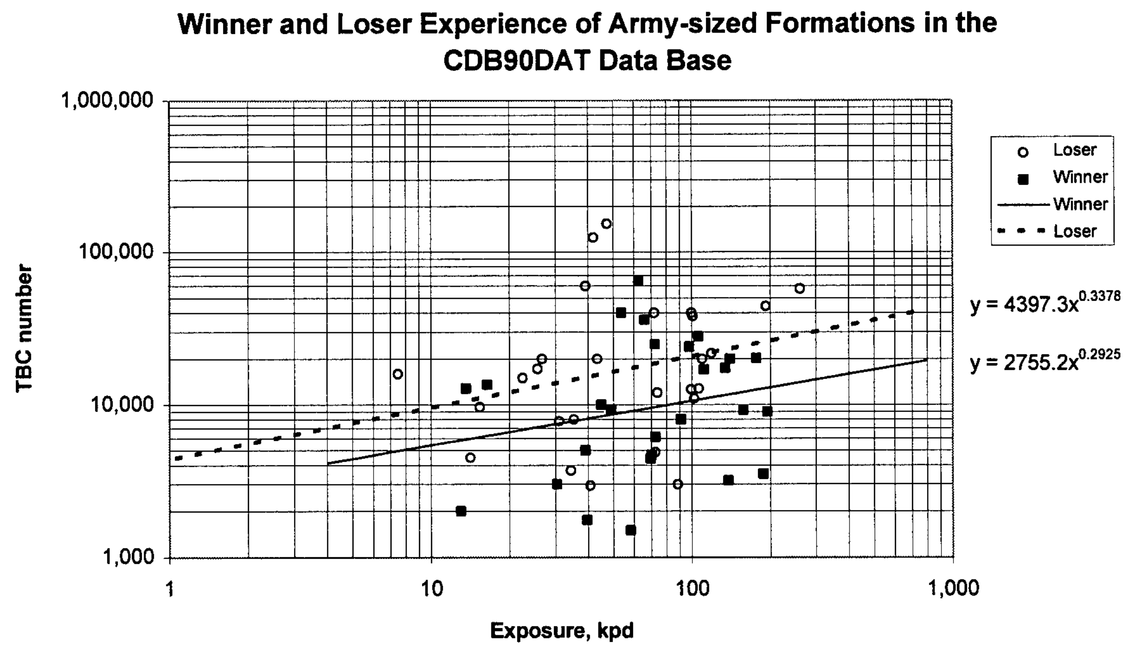

Figure 5-28. Winner and Loser Experience of Army-sized Formations in the CDB90DAT Data Base

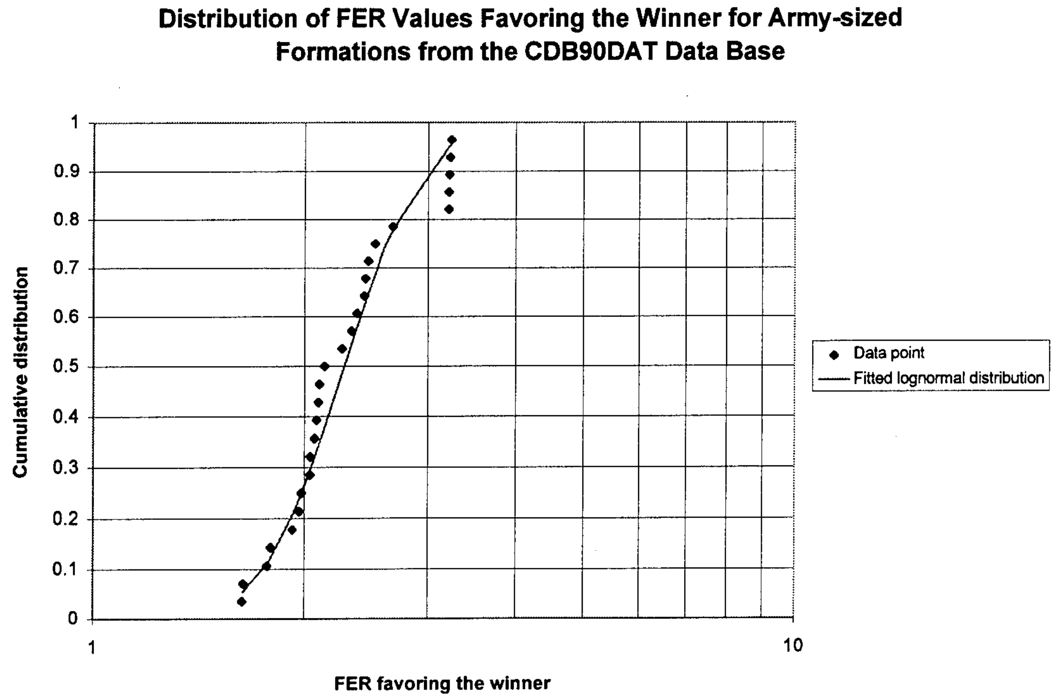

Figure 5-29. Distribution of FER Values Favoring the Winner for Army-sized Formations in the CDB90DAT Data Base

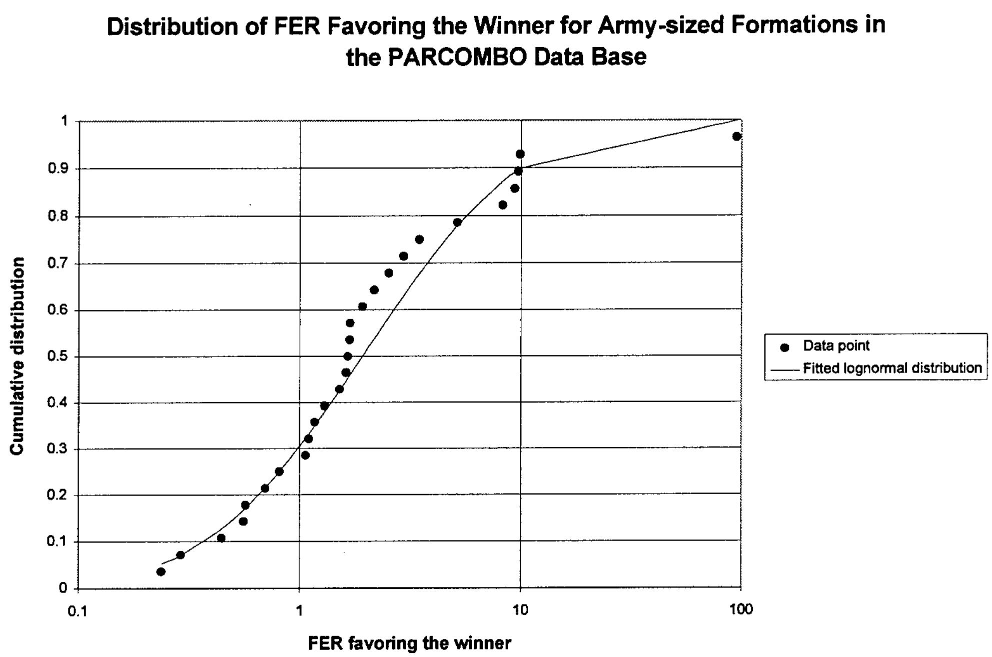

Figure 5-30. Distribution of FER Values Favoring the Winner for Army-sized Formations in the PARCOMBO Data Base

CHAPTER 6

LOSSES OF CORPS AND CORPS-SIZED FORMATIONS

6-1. INTRODUCTION

a. This chapter examines selected aspects of the casualty rates of corps and corps-sized formations operating in a theater of war. It makes considerable use of data on the corps of the US 12th Army Group in northwest Europe during World War II because for them we have the most detailed and complete information. This information includes the onhand strength and casualty data (including KIA, WIA, and CMIA) on a daily basis for each corps of the US 12th Army Group, which fought in Northwest Europe during World War II from 15 June 1944 (shortly after the D-day landings in Normandy on 6 June 1944) through 30 April 1945 (shortly before the surrender of Nazi Germany on 5 May 1945). These US corps are the 3d, 5th, 7th, 8th, 12th, 13th, 16th, 18th, 19th, 20th, 22d, and 23d. The comments in paragraph 4-1 regarding the characteristics of these data bases apply here as well.

b. Additionally, data on the casualty rates of other corps and corps-sized formation were extracted from a few sources, as described later in this chapter. The number of personnel in a corps-sized formation is not specifically defined, and in fact varies rather widely. So the criteria used in this chapter to decide whether a formation was "corps-sized" varied. Because most of the data on corps-sized formations is for specific operations by such forces, we treat them separately from the US corps.

6-2. DISTRIBUTION OF TOTAL BATTLE CASUALTY RATE FOR US CORPS

a. Figure 6-1 shows the distribution of reported daily total battle casualty rates per thousand personnel-days (TBC/kpd) for US corps operating in the Meuse-Argonne, Aisne, Marne, and Somme during 205 corps battle days. Here the casualties are characterized as battle casualties including wounds by war gases, gunshot missiles, and also the killed in action. As is often observed with casualty rate data, these distributions are approximately lognormal. In this case, the obviously excellent fit to the reported values is due in large part to the fact that the source does not give the actual raw data—instead it gives values that have already been smoothed by fitting them to a distribution curve. (Data in this paragraph based on Love.)

b. Figures 6-2 through 6-9 show the distribution of daily TBC/kpd for the US 3d, 5th, 7th, 8th, 12th, 13th, 19th, and 20th Corps operating as part of the US 12th Army Group in northwest Europe during World War II. The data on the other corps is not sufficient to plot a sensible TBC rate distribution. These World War II data indicate a TBC rate that, by and large, is less than that represented in Figure 6-1 for World War I. The following reasons for this may be suggested. First, the World War I data are for corps known to have been in battle, while those for World War II have their TBC rates attenuated by days where they were not heavily engaged. Second, the long-term historical trend is toward lower TBC rates. Third, the US corps TBC rate in World

War I may, in fact, have systematically higher than in World War II, although we have no specific quantitative data to demonstrate this effect.

c. We also observe that Figures 6-2 through 6-9 show the TBC rate distribution for nonzero TBC rate values. This was necessary because the logarithm of zero is not defined. In order to limit TBC rates to nonzero values, any zero TBC rate values were stripped from the data. Table 6-1 shows the number of zero values that were stripped from the data for this purpose. In addition, for the 13th Corps, only those data points with strengths of at least 30,000 were used. (Corps strengths typically are in the 30,000 to 100,000 range). So the total number of TBC rate values shown in Table 6-1 for the 13th Corps count just for those days on which the 13th Corps is recorded as having a strength of at least 30,000 personnel.

Table 6-1. Zero and Nonzero TBC Rate Values

Corps number	Number of zero TBC rate values	Number of nonzero TBC rate values	Total number of TBC rate values
3	72	140	212
5	2	263	265
7	15	250	265
8	3	252	255
12	0	206	206
13	1	171	172
19	2	129	131
20	0	131	131

(Data in this paragraph based on Kuhn .)

6-3. TBC RATE TIME SERIES FOR US CORPS. We fitted a time series model to the TBC rate values as a function of time. Where necessary, we estimated missing data values by linear interpolation of their logarithms. The time series model fitted to the resulting data consists of a deterministic trend plus an autocorrelated residual. Because the residuals are correlated, conventional regression theory is not applicable. Instead, we used the ARIMA model popularized by Box and Jenkins. The simplest time series model having an acceptable fit to the data was found to be the one given by the following type of relationship.

$$\ln[TBCRate(i)] = \beta_0 + \beta_1 \times i + z(i),$$

where

$\ln[TBCRate(i)]$ = the natural logarithm of the TBC rate / kpd on day number i,

β_0, β_1 = parameters of an exponential trend in TBC rate,

$z(i) = \gamma \times z(i-1) + N(0, \sigma)$, where

γ = an autoregressive coefficient, and

$N(0, \sigma)$ = a normal random variable with mean zero and standard deviation σ

Thus, the logarithmic residuals, $z(i)$, are given by a simple autoregressive process. There are four parameters to be estimated from the time series data on TBC rates: β_0, β_1, γ, and σ. Parameter values for the cases treated here are shown in Table 6-2.

Table 6-2. ARIMA Parameter Values for Some US Corps in the ETO

Corps number	β_0	β_1	γ	σ	Data based on
3	+2.993	–0.00998	0.747±0.06	0.779	Kuhn
5	+1.145	–0.00506	0.777±0.04	0.633	Kuhn
7	+2.166	–0.00802	0.793±0.04	0.688	Kuhn
8	+0.140	–0.00421	0.844±0.03	0.726	Kuhn
12	+0.967	–0.00277	0.787±0.04	0.626	Kuhn
13	+0.510	-0.00546	0.767±0.05	0.849	Kuhn
19	+0.568	-0.00639	0.858±0.15	0.859	Kuhn
20	-1.063	+0.00335	0.693±0.06	0.749	Kuhn

Figures 6-10 through 6-17 show the original and interpolated data points for the 3d, 5th, 7th, 8th, 12th, 13th, 19th, and 20th Corps. The other corps have insufficient data to support a sensible ARIMA analysis. Figures 6-10 through 6-17 also show the fitted values based on this time series model. The "Day number" convention is the same as explained in the preceding chapter. For the US corps cases with enough data, the ARIMA fit is quite good. However, this is a purely statistical and kinematic description of the recorded data. Its advantage is that it provides a simpler and more readily grasped description of the data than is apparent from the data itself. However, this description by itself does not provide a causal or dynamic model of the casualty generation process. (Data in this paragraph based on Kuhn.)

6-4. EXPOSURE AND TBC EXPERIENCES OF US CORPS.

a. Here we are concerned with the number of TBC as a function of the corps's exposure in kpd. Figures 6-18 through 6-27 show this relationship for the US 3d, 5th, 7th, 8th, 12th, 13th, 16th, 18th, 19th, and 20th Corps. The other corps do not have enough data to generate satisfactory trend lines of TBC number versus exposure in kpd. Nearly all of these data have upward sloping trend lines. No experience chart is shown for the US corps experience in World War I because the source consulted (Love) does not provide separate daily strength and casualty values for it, but only their ratio, the daily casualty rate. (Data in this paragraph based on Kuhn .)

b. Table 6-3 shows the total exposure, total TBC, and average TBC/kpd for each corps in this data base. Here, Sum1 gives the sum for all corps; Sum2 gives the sum for all corps except the 22d and 23d Corps, which obviously had less exposure than the other corps; Sum3 gives the sum for all corps except the 16th, 19th, 22d, and 23d Corps, which had relatively low average TBC/kpd rates.

Table 6-3. Average TBC Rates for US Corps in WWII

Corps number	Total exposure, kpd	Total TBC, number	Average TBC rate /kpd
3	9,960.4	23,003	2.31
5	18,748.2	38,206	2.04
7	21,244.1	76,068	3.58
8	17,572.4	58,833	3.35
12	18,041.1	40,434	2.24
13	11,118.9	12,282	1.10
16	8,183.2	5,781	0.71
18	5,576.0	14,133	2.53
19	10,518.6	9,067	0.86
20	9,259.7	12,493	1.35
22	2,248.1	409	0.18
23	433.0	4	0.01
Sum1	132,903.8	290,713	2.19
Sum2	130,222.7	290,300	2.23
Sum3	111,520.9	275,452	2.47

6-5. CONTRIBUTION OF DIVISION ECHELON FORMATIONS TO US CORPS CASUALTIES.

a. The overwhelming majority of corps casualties are taken by formations at division level and below. The Kuhn data contain the following results on this score for the US 12th Army Group operations in northwest Europe during World War II. This data base records 336,061 casualties taken by corps and their subordinate echelons, of which 310,730 (92.46 percent) were taken by formations at division level and below. In other words, of all the casualties taken by formations at corps level and below, only 7.54 percent were taken by corps echelons above division. In considering these values, it should be remembered that these data count casualties to "OTHER" combat units organic or attached to corps as casualties to echelons above division. However, in the operations considered, these "OTHER" combat units include many corps combat or combat support elements (such as antitank guns, tanks, antiaircraft units, combat engineers, and so forth) which were more or less permanently assigned or attached to divisions, *especially* when these divisions were committed to combat. Indeed, this practice was so widespread and so consistently followed that many of these corps elements became, in operational practice, permanently assigned to and fought with a specific division. Hence, these results should be interpreted as "at least" 92.46 percent of corps total battle casualties were taken by divisions and "OTHER" combat units operating in the division area, and "at most" 7.54

percent of corps casualties were taken by corps units operating outside the division area. (Data in this paragraph based on Kuhn .)

b. Table 6-4 shows divisional and nondivisional casualties for the American Expeditionary Force (AEF) in World War I. Here the nondivisional casualties are less than 2 or 3 percent of the aggregate number of casualties to the AEF. This is true regardless of whether the aeronautical units (indicated in Table 6-4 as "Aero") are included or not. (Data in this paragraph based on Anonymous-1926.)

Table 6-4. Divisional and Nondivisional Casualties for the American Expeditionary Force in World War I

Item	KIA, number	DOW, number	Wounds not mortal	KIA+WIA
Divisional totals	36,770	12,729	190,809	240,308
Nondivisional totals	771	205	2,802	3,778
Aggregate totals	37,541	12,934	193,611	244,086
Ratio divisional/ aggregate	97.9%	98.4%	98.6%	98.5%
Nondiv total (excl Aero)	547	184	2,648	3,379
Aggregate (excl Aero)	37,317	12,913	193,457	243,687
Ratio divisional/ aggregate (excl Aero)	98.5%	98.6%	98.6%	98.6%

c. Figures 6-28 and 6-29 show the proportion of casualties attributed to divisions and to nondivisional elements of the two corps (one a US Army corps and the other a US Marine corps) during the Okinawa campaign of World War II. They both show casualties to corps elements above division of around 1 or 2 percent. Observe also that casualties fall unevenly upon the several divisions involved. Presumably, this is due to their differing missions and tactical situations. (Data in this paragraph based on Appleman.)

d. Figure 6-30 shows the proportion of casualties attributed to divisions and to nondivisional elements of the 5th US Marine Amphibious Corps during the Iwo Jima operation. As for Okinawa, corps elements above division account for about 1 percent of the total corps battle casualty numbers. (Data in this paragraph based on Bartley.)

Table 6-5. Sample Casualty Data for Corps-sized Formations in World War II

Theater	Campaign	Force(s)	Start Date	End Date	Duration (days)	Estimated Average Strength	Number KIA	Number WIA	Number CMIA	TBC	KIA /kpd	WIA /kpd	CMIA /kpd	TBC /kpd	Estimated TBC /kpd
Pacific Ocean Areas	Guadalcanal	Marines	7-Aug-42	17-Nov-42	103	32,650	1,190	2,753	28	3,971	0.35	0.82	0.01	1.18	1.19
Pacific Ocean Areas	Bougainville	Army	19-Nov-43	30-Apr-44	164	38,200	511	2,569	62	3,142	0.08	0.41	0.01	0.50	0.60
Pacific Ocean Areas	Saipan	Marines	15-Jun-44	23-Jul-44	39	40,000	2,116	10,419	247	12,782	1.36	6.68	0.16	8.19	9.72
Pacific Ocean Areas	Tinian	Marines	24-Jul-44	9-Aug-44	17	40,200	295	1,554	0	1,849	0.43	2.27	0.00	2.71	3.31
Pacific Ocean Areas	Iwo Jima	Marines	19-Feb-45	26-Mar-45	36	40,000	5,435	14,893	53	20,381	3.77	10.34	0.04	14.15	15.06
Pacific Ocean Areas	Ryukus	Marines	1-Apr-45	30-Jun-45	91	51,200	2,779	13,609	119	16,507	0.60	2.92	0.03	3.54	4.25
Pacific Ocean Areas	Ryukus	Army	1-Apr-45	30-Jun-45	91	69,200	4,468	17,821	81	22,370	0.71	2.83	0.01	3.55	4.12
Southwest Pacific	Philippines	Army	7-Dec-41	10-May-42	155	33,000	1,638	1,813	31,156	34,607	0.32	0.35	6.09	6.77	0.52
Southwest Pacific	Morotai	Army	15-Sep-44	4-Oct-44	20	31,200	30	80	1	111	0.05	0.13	0.00	0.18	0.19
Southwest Pacific	Philippines/ Mindanao	Army	10-Mar-45	30-Jun-45	113	41,700	682	3,523	#N/A	#N/A	0.14	0.75	#N/A	#N/A	1.09
Mediterranean	Italy/Divisions	Army	9-Sep-43	8-May-45	608	90,500	14,375	63,360	8,370	86,105	0.26	1.15	0.15	1.56	1.68
Mediterranean	Italy/Fifth Army/ Salerno	Army	9-Sep-43	20-Sep-43	12	94,900	509	1,847	1,112	3,468	0.45	1.62	0.98	3.05	2.36
European	Ground Phase/ Divisions-Armored	Army	6-Jun-44	8-May-45	337	96,500	9,748	40,753	6,842	57,343	0.30	1.25	0.21	5.06	1.46

6-6. DISTRIBUTION OF TOTAL BATTLE CASUALTY RATE FOR CORPS-SIZED FORMATIONS

a. Table 6-5 shows some examples of casualty rates for US corps-sized formations from World War II, taken from Beebe and DeBakey. The estimated TBC rate shown in the last column is obtained by multiplying the number of WIA by 1.5, which is a rough approximation to the usual ratio of TBC to WIA. As can be seen, the estimated TBC rates vary from a low of 0.19 TBC/kpd to a high of 15.06 TBC/kpd. Most of these rates are consistent with those found for the corps of the US 12th Army Group. However, those for Saipan and Iwo Jima are substantially higher than those generally experienced by US Army corps in Europe. (Data in this paragraph based on Beebe and DeBakey.)

b. Table 6-6 shows some additional casualty rates for US corps from World War II, taken from Blood. In this table, "NR" indicates that this information is not reported by Blood. The rates shown in Table 6-6 are obviously much higher than those reported for US corps in the ETO. The contrast indicates the sensitivity of TBC rates to the tactical situation (amphibious operations against well-prepared, fanatical Japanese defenders versus weakened German troops in the closing months of World War II), and perhaps to the time period covered being one of high operational tempo, so that attenuation effects are minimal. Note that in these operations the first day TBC rates are substantially higher than the overall rates. This may in part be due to the tendency for TBC rates of winning forces to decline approximately exponentially during the course of a successful operation. (Data in this paragraph based on Blood.)

c. Figures 6-31 through 6-33 show the distribution of TBC rates for the corps-sized formations in the CDB90DAT, PARCOMBO, and Bodart-Willard-Schmieman-Helmbold (BWSH) data bases. In each of these cases, a corps-sized formation is considered to have an initial strength of 30,000 to 100,000 personnel. To the extent that data are available, Figures 6-31 through 6-33 show separate distributions of TBC rates for the winner (WIN), attacker (ATK), defender (DEF), and loser (LOS). In general, TBC rates are highest for the loser, and successively lower for the defender, attacker, and winner. To a large extent, the relative ranking of the attacker and defender is due to the fact that most of the battles in these data bases were won by the attacker. Observe that Figures 6-31 through 6-33 all indicate TBC rates roughly an order of magnitude or more higher than those shown in Figures 6-1 through 6-9 for US corps in World War I or II. The reasons for this presumably lie in the fact that the data used in Figures 6-31 through 6-33 are for the forces most directly involved in battles of relatively brief duration (generally from 1 to 2 or 3 days) and so are substantially less subject to the dilution and attenuation effects mentioned in paragraph 2-2e. (Data in this paragraph based on Bodart, CAA, and Helmbold.)

Table 6-6. Additional Examples of US Corps TBC Rates in World War II

Operation	Overall start date	Overall end date	Overall duration	Overall WIA rate /kpd	Overall KIA rate /kpd	First day date	First day WIA rate /kpd	First day KIA rate /kpd	Overall TBC /kpd	First day TBC /kpd
Tarawa	NR	NR	NR	54.63	25.92	NR	NR	NR	80.55	NR
Kwajalein	NR	NR	NR	14.83	9.01	NR	NR	NR	23.84	NR
Eniwetok	NR	NR	NR	17.99	7.99	NR	47.43	24.29	25.98	71.72
Saipan	15-Jun-1944	10-Jul-1944	26	11.20	4.12	15-Jun-1944	73.00	27.00	15.32	100.00
Tinian	NR	NR	NR	9.82	1.88	NR	14.42	0.96	11.70	15.38
Peleliu	15-Sep-1944	14-Oct-1944	30	9.39	2.29	15-Sep-1944	60.07	14.00	11.68	74.07
Iwo Jima	19-Feb-1945	26-Mar-1945	36	9.52	3.22	19-Feb-1945	58.50	18.87	12.74	77.37
Okinawa	1-Apr-1945	30-Jun-1945	91	2.90	0.81	1-Apr-1945	1.34	0.43	3.71	1.77
Guam	21-Jul-1945	15-Aug-1945	26	6.63	1.94	21-Jul-1945	24.94	7.06	8.57	32.00

6-7. TBC RATES VERSUS TIME FOR CORPS-SIZED FORMATIONS

a. It is not appropriate to fit a time series to the TBC rate data on corps-sized formations because the available data do not give the TBC rates of a given formation for an extended series of consecutive time periods. However, it is of some interest to consider the trend of TBC rates for corps-sized formations with the passage of years. Figures 6-34 through 6-38 show plots of the TBC rate for the CDB90DAT, PARCOMBO, and BWSH data bases versus the date of the battle. The trend lines generally slope downward, indicating that the TBC rates have declined with battle date over the course of the last 400 years or so. (Data in this paragraph based on CDB90DAT, PARCOMBO, and BWSH.)

b. Figures 6-39 through 6-44 show attrition rates for corps-sized forces over consecutive but shorter periods of time. Figure 6-39 shows the estimated daily TBC rates for US and Japanese forces in the battle of Iwo Jima. Here the Japanese attrition rate is estimated based on an assumed Lanchester square law relationship and information on US force strengths based largely on Bartley. The procedure used for estimating Japanese strengths and losses is analogous to that used by Engel. Note that US TBC rates are comparatively very high during the first few days of the operation, which is an effect already noted in connection with Table 6-6. However, they soon become lower than those of the Japanese (losers). Figure 6-40 shows the US and German TBC rates during the Westwall battle near Aachen in World War II. This figure shows a quasi-diurnal pulsation in TBC rates as active periods were interspersed with periods of rest, reorganization, and resupply. However, active periods were interspersed with periods of rest, reorganization, and resupply. However, German (loser) TBC rates were appreciably higher than US (winner) TBC rates during the active periods. Figure 6-41 shows daily TBC rates for US and German forces for a portion of the Saar Campaign of World War II. Here again, the US's (winner's) TBC rates are consistently much lower than the German's (loser's). Figure 6-42 shows daily TBC rates for US and German forces for a portion of the operations conducted from LeMans to Metz during World War II. Here again, the US's (winner's) TBC rates are usually much lower than the German's (loser's). Figures 6-43 and 6-44 show the daily TBC rates of the German XLVII Corps and XL Panzer Corps for some operations in the first period of World War II. The source consulted does not provide the Soviet TBC rates for these operations, but data from other sources (such as Krivosheyev) indicate that Soviet (loser) TBC rates for these operations must have been about an order of magnitude higher than those of the German (winner) forces. A comparison of Figures 6-39 through 6-44 with those of 6-10 through 6-17 shows that corps can frequently have TBC rates in excess of 10 TBC/kpd, even when conducting successful offensive operations. When conducting losing defensive operations, their TBC rates can often be an order of magnitude higher. Because Figures 6-39 through 6-44 cover relatively short time spans, it is not appropriate to attempt a time series fit to their data. (Data in this paragraph based on Bartley, Engel, Helmbold, HERO, HERO-DMSI, Krivosheyev, and Morehouse.)

6-8. EXPOSURE AND TBC EXPERIENCES OF CORPS-SIZED FORMATIONS. Here we are concerned with the number of TBC as a function of the formation's exposure in kpd. Figures 6-45 through 6-49 show this relationship for the CDB90DAT, PARCOMBO, and BWSH data bases. The slopes are sometimes up and sometimes down, indicating that the relationship of

TBC number to exposure in kpd is unstable and unpredictable. It may be that other factors not included in these graphs influence the slope of the relationship of TBC number to exposure in kpd. Even when the trend lines slope upward, the relationship of TBC number to exposure is often nonlinear and far from simply proportional. (Data in this paragraph based on CAA, Helmbold, and Bodart.)

6-9. THE RELATION BETWEEN CASUALTY RATES AND WINNING AND LOSING FOR CORPS-SIZED FORMATIONS

a. Here we are concerned with the relation between the casualty rates of the winning and losing sides for corps-sized formations. Unfortunately, the data available to us on US corps and discussed in paragraphs 6-2 through 6-5 is entirely one-sided and so provides no information on the relation of casualty rates for both the winner and loser. However, for some other corps-sized formations, we are able to obtain a relation of casualty rates to winning and losing. It seems reasonable to suppose that about the same relation applies to US corps.

b. Figure 6-50 shows the distribution of FER favoring the winner for 85 corps-sized engagements (personnel strengths from 30,000 to 100,000) in the CDB90DAT data base. As before, the FER favoring the winner is defined to be

$$FER(FavoringWinner) = \frac{TBCRate(Loser)}{TBCRate(Winner)}.$$

Figures 6-51 and 6-52 show the distribution of FER favoring the winner for 102 corps-sized engagements in the PARCOMBO data base and for 194 engagements in the BWSHALL data base. These figures show that the value of FER favoring the winner tends to be greater than one, and typically is about equal to 2. The conclusion is inescapable—for battles between corps-sized forces the FER values are strongly associated with victory. (Data in this paragraph based on CAA, Helmbold, and Bodart.)

6-10. CHAPTER SUMMARY

a. These data suggest that US corps total battle casualty rates (TBC/kpd), when taken over an extended period of time covering a variety of combat situations, but typically associated with conducting a successful offensive operation, generally range from around 0.1/kpd to about 20/kpd, with median values ranging from about 0.7/kpd to 7/kpd. These values apply to the nonzero casualty days. Zero casualty days can range from zero to about 33 percent for a corps, depending on its sector of the front, mission, and so forth.

b. These data suggest that the TBC rates of corps conducting part of a winning offensive campaign, when viewed over several weeks or months duration, tend to decline exponentially. On this general exponential trend is superimposed a residual that (after a logarithmic transformation of the data) can often be represented by a simple, one-term autoregressive process having a normal random error.

c. For short, intense battles, corps TBC rates can be substantially higher than their long-term averages or values affected by attenuation and dilution, and typically amount to about 100 TBC/kpd.

d. The relation of TBC numbers to exposure in kpd is obscure. The data available for use in this paper usually show increasing trends in TBC numbers with increasing exposures, but some data bases show a decrease rather than an increase. However, even when the TBC number increases with exposure in kpd, the relation is often nonlinear and far from simply proportional.

e. Well over 90 percent of corps casualties are taken by formations at division level and below.

f. Winners typically have about half the TBC rate of losers, although this ratio can vary substantially from battle to battle.

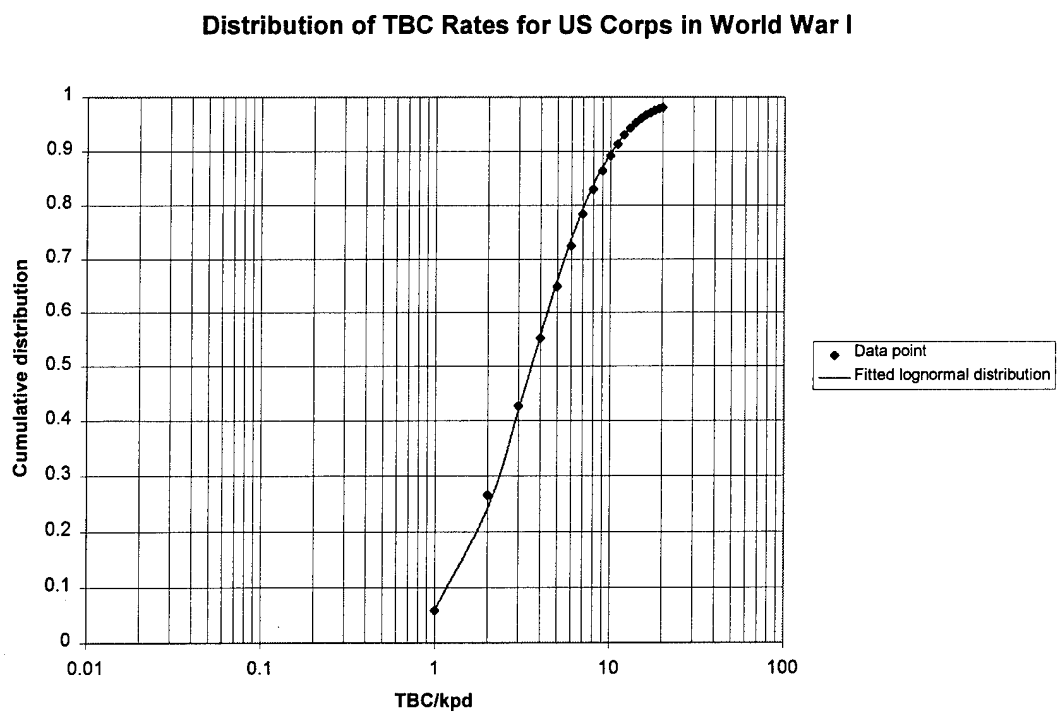

Figure 6-1. Distribution of TBC Rates for US Corps in World War I

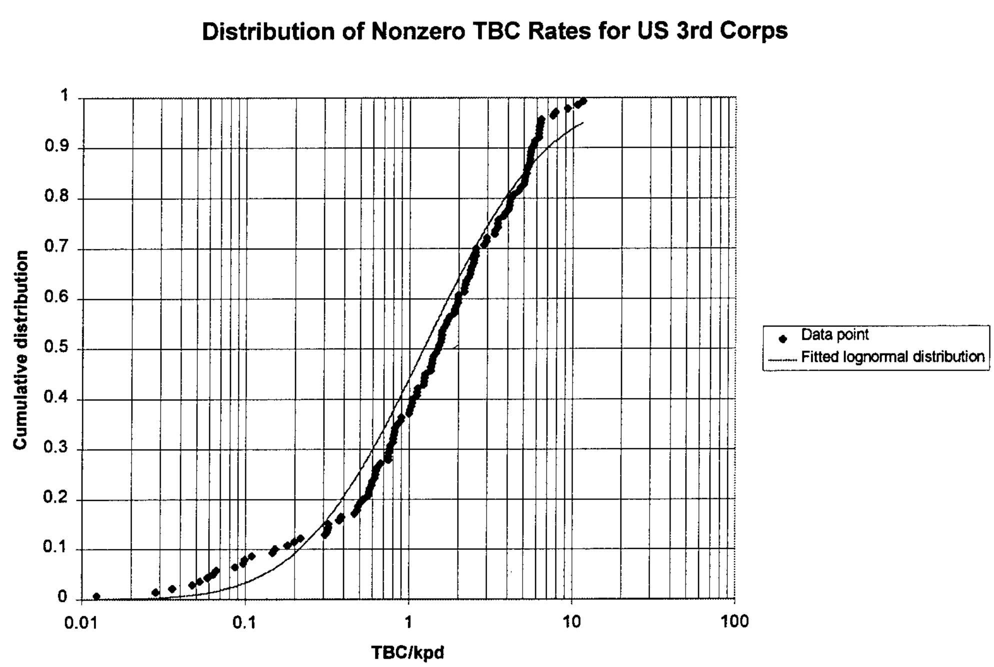

Figure 6-2. Distribution of Nonzero TBC Rates for US 3d Corps in World War II

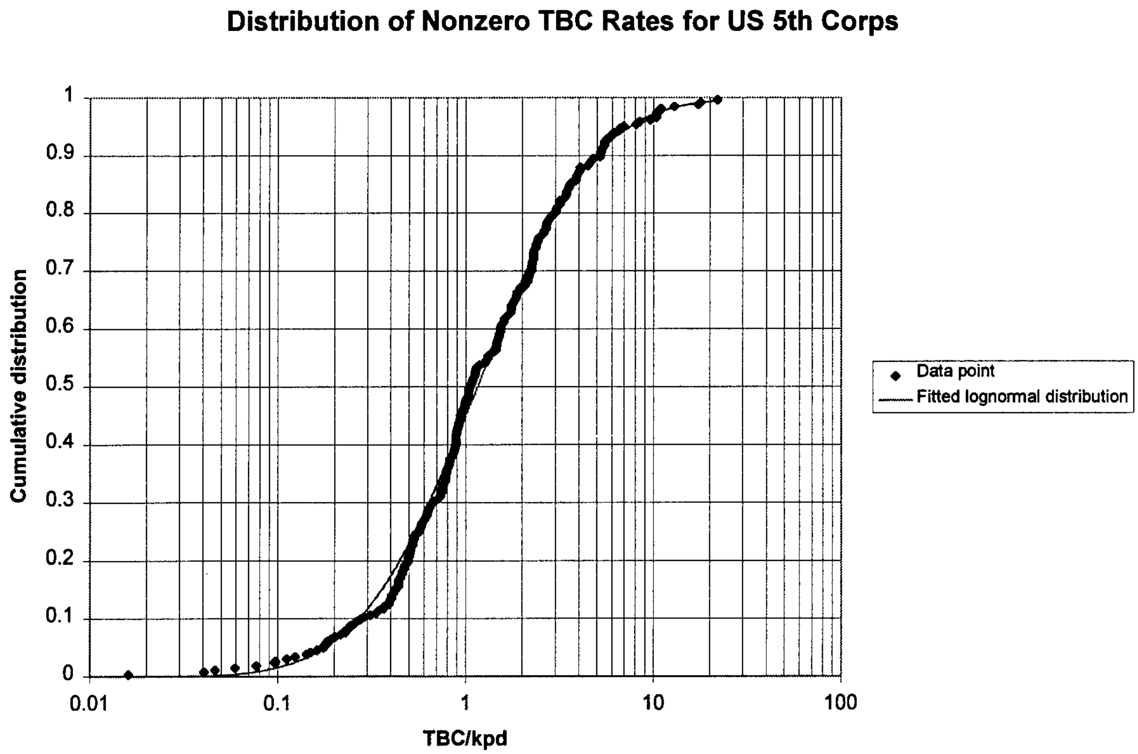

Figure 6-3. Distribution of Nonzero TBC Rates for US 5th Corps in World War II

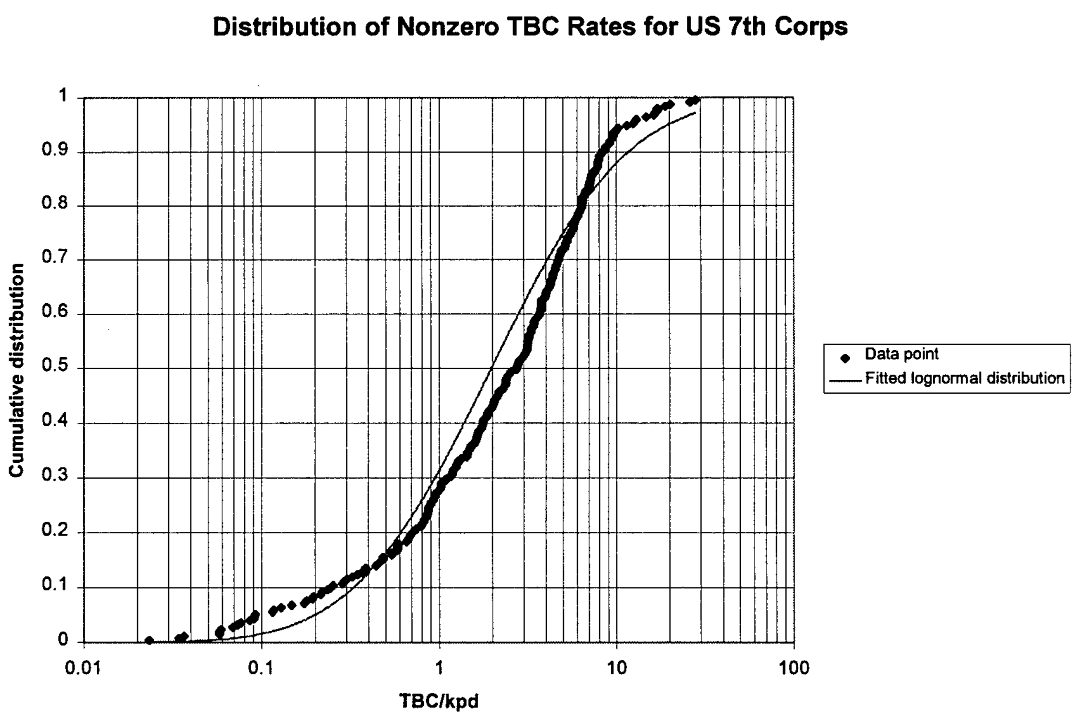

Figure 6-4. Distribution of Nonzero TBC Rates for US 7th Corps in World War II

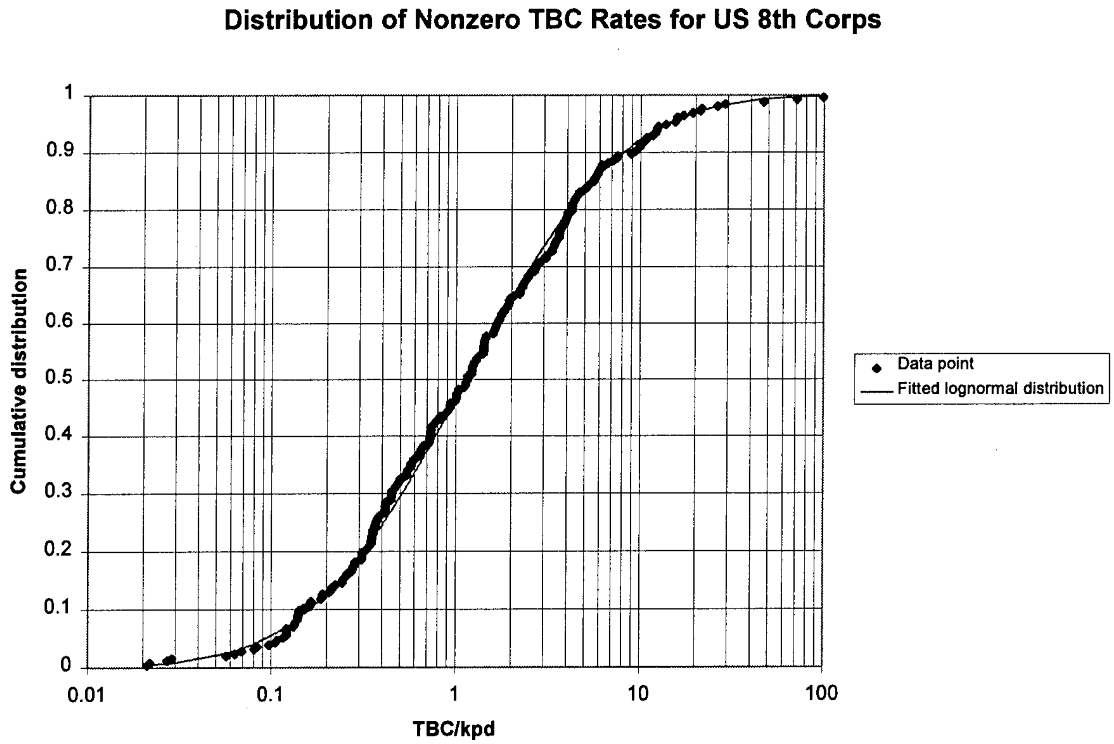

Figure 6-5. Distribution of Nonzero TBC Rates for US 8th Corps in World War II

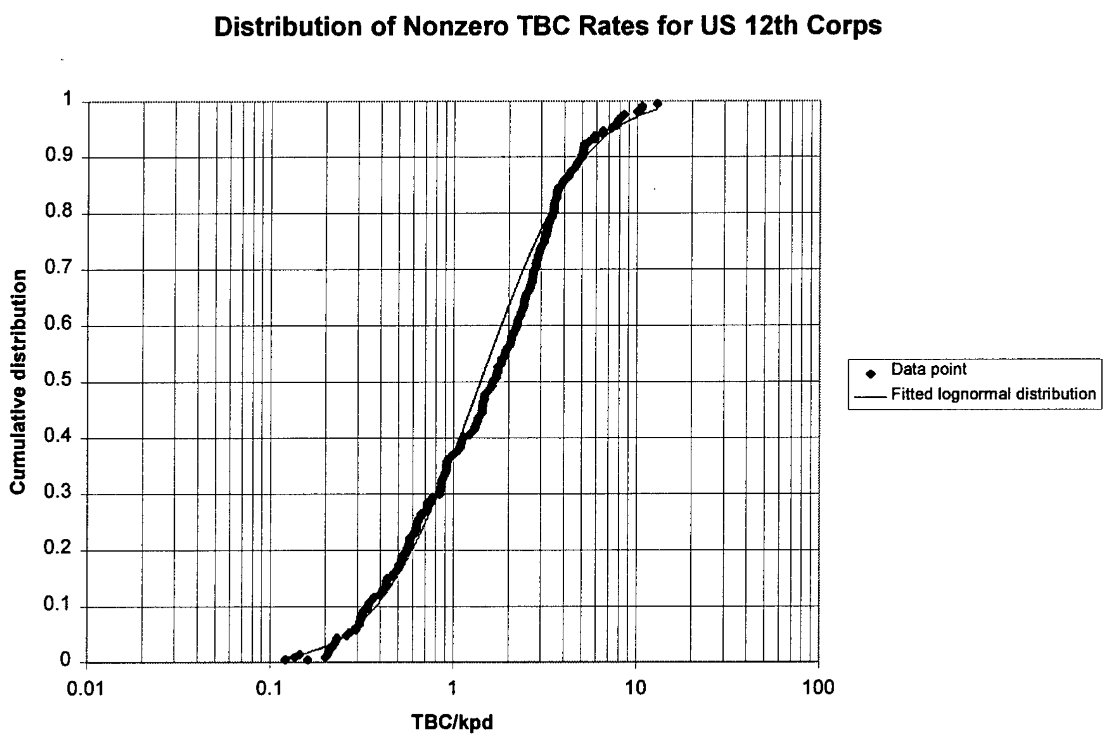

Figure 6-6. Distribution of Nonzero TBC Rates for US 12th Corps in World War II

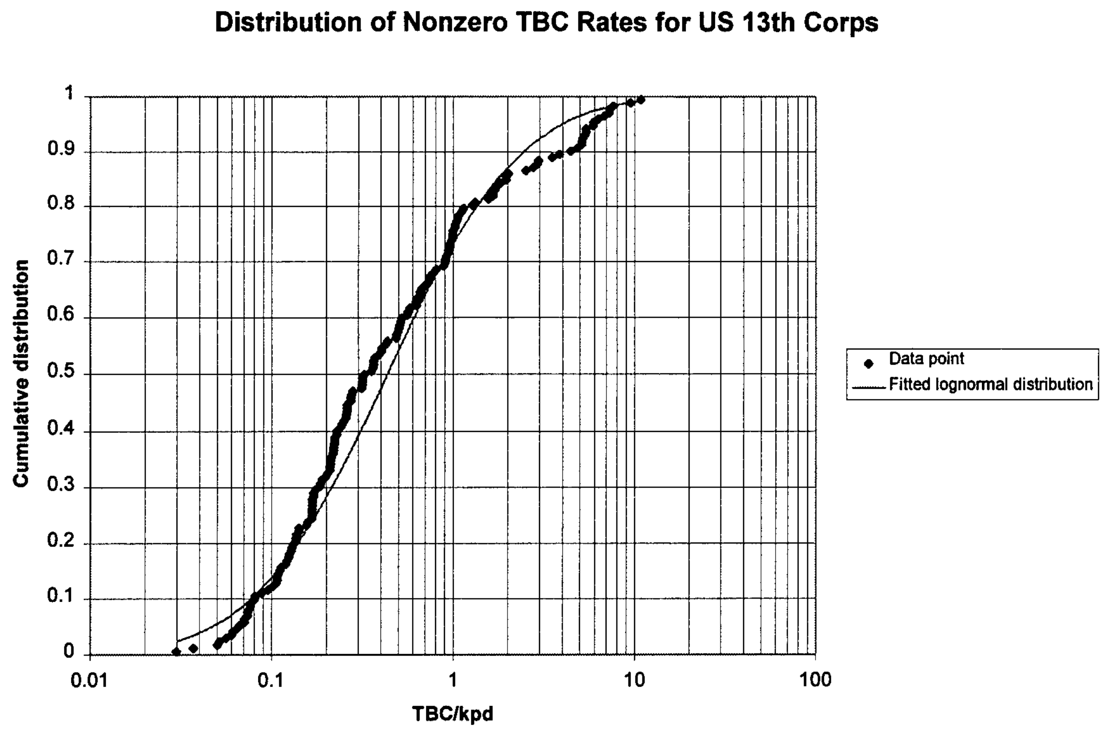

Figure 6-7. Distribution of Nonzero TBC Rates for US 13th Corps in World War II

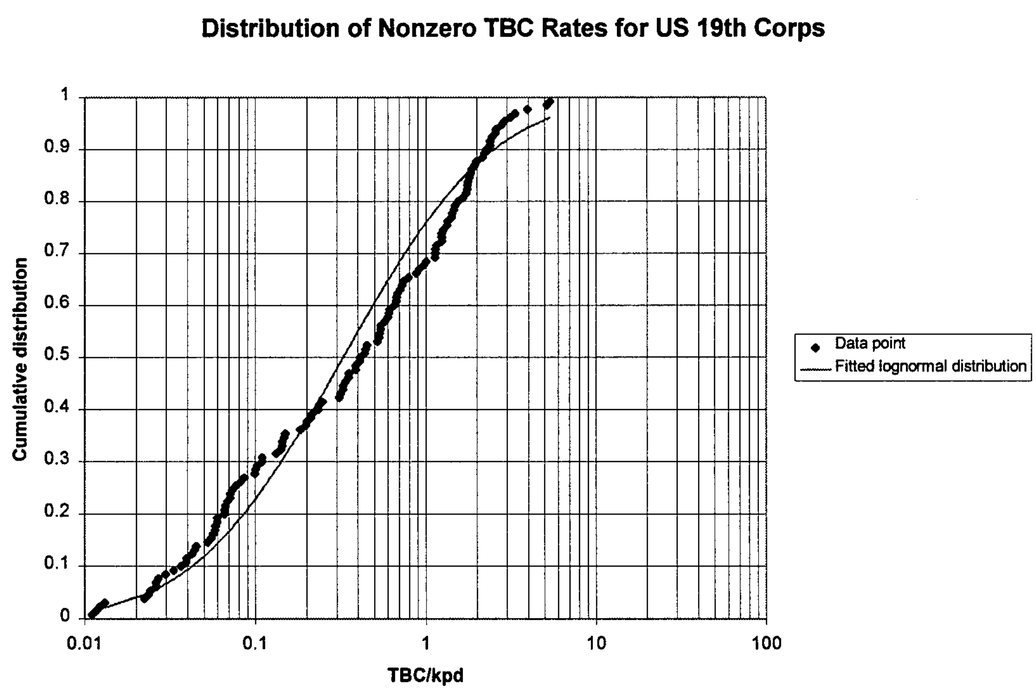

Figure 6-8. Distribution of Nonzero TBC Rates for US 19th Corps inWorld War II

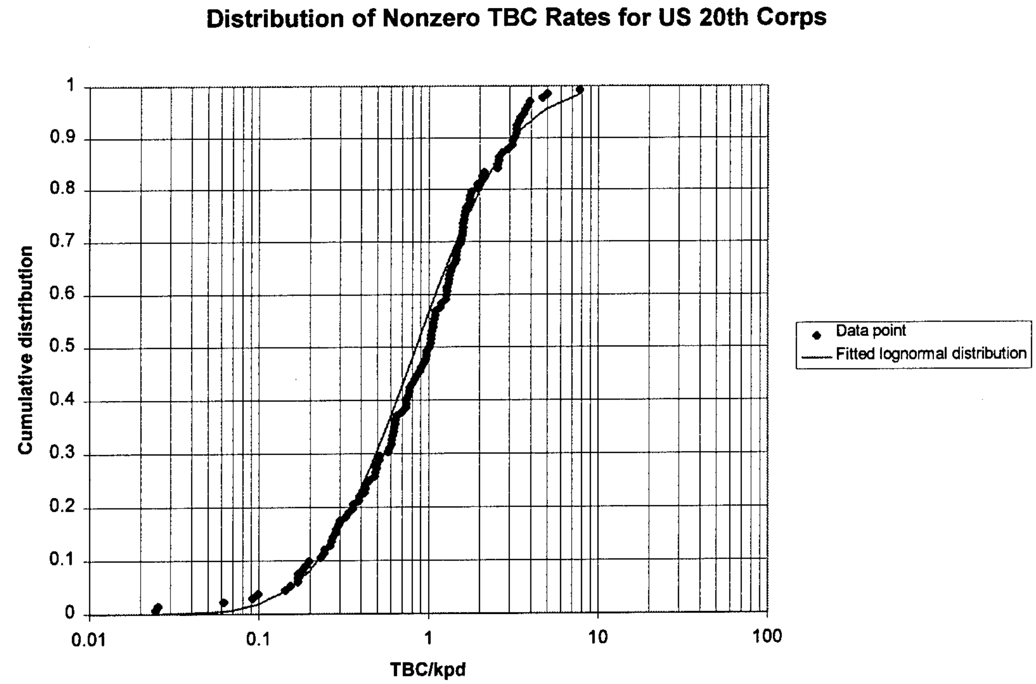

Figure 6-9. Distribution of Nonzero TBC Rates for US 20th Corps in World War II

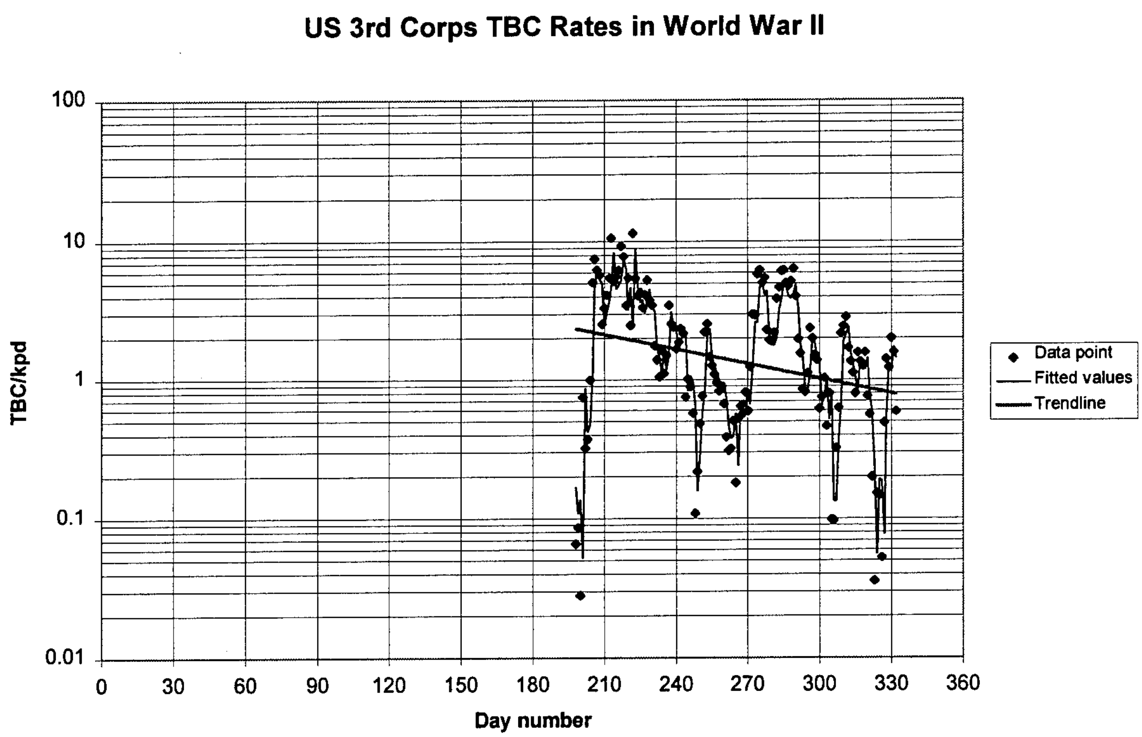

Figure 6-10. US 3d Corps TBC Rates in World War II

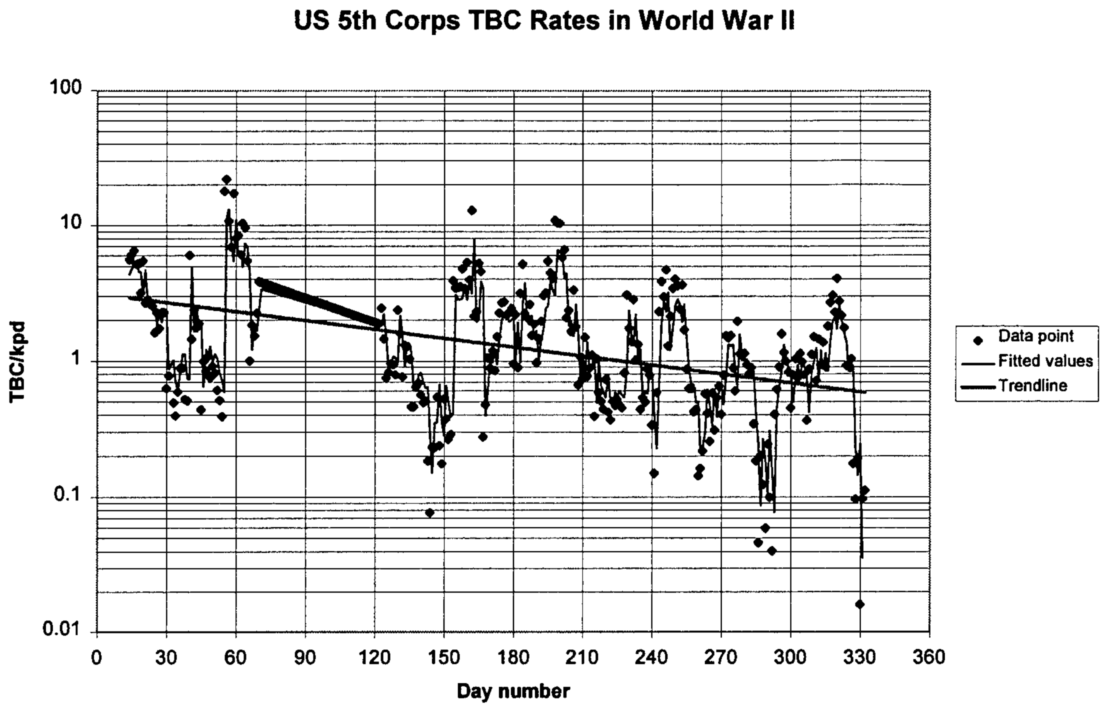

Figure 6-11. US 5th Corps TBC Rates in World War II

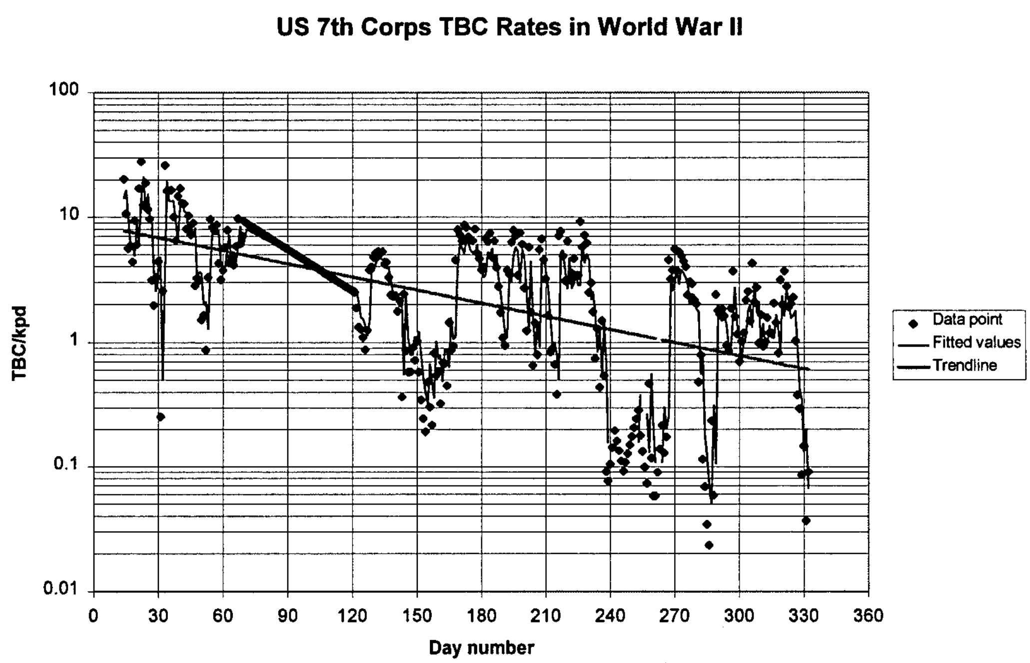

Figure 6-12. US 7th Corps TBC Rates in World War II

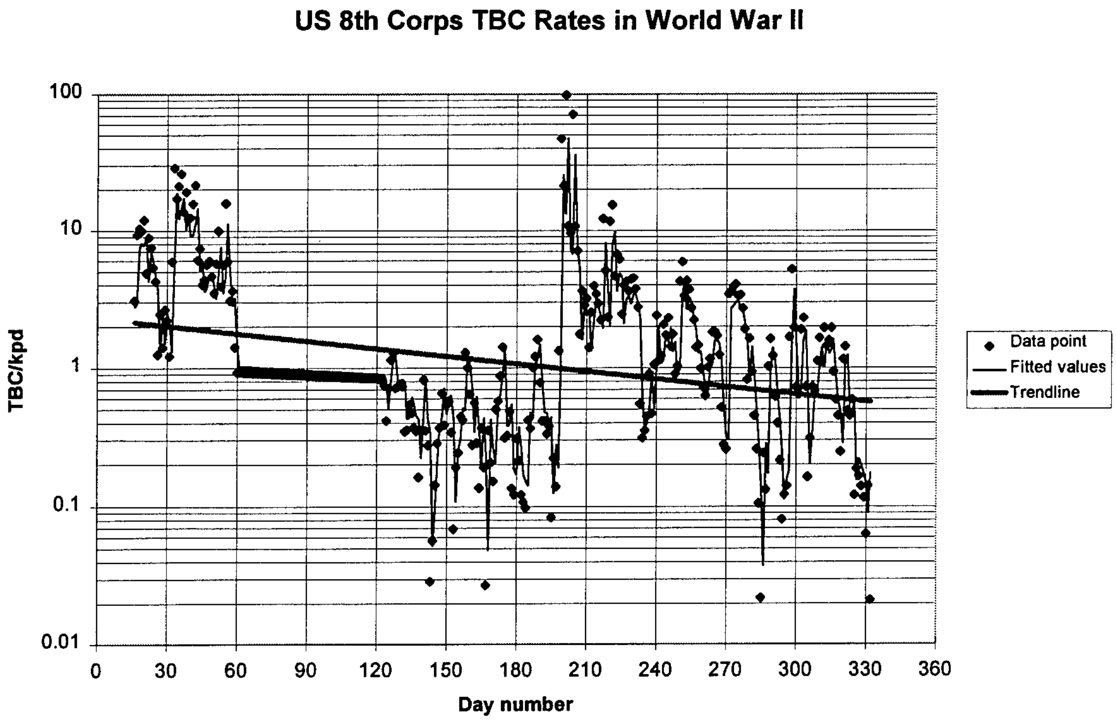

Figure 6-13. US 8th Corps TBC Rates in World War II

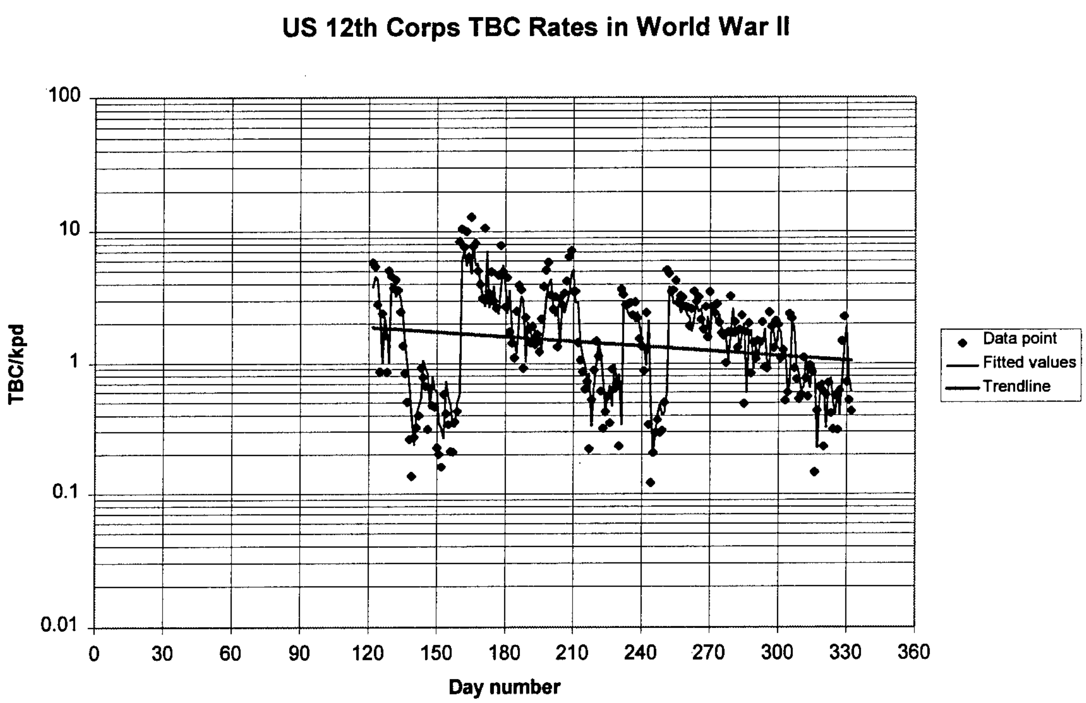

Figure 6-14, US 12th Corps TBC Rates in World War II

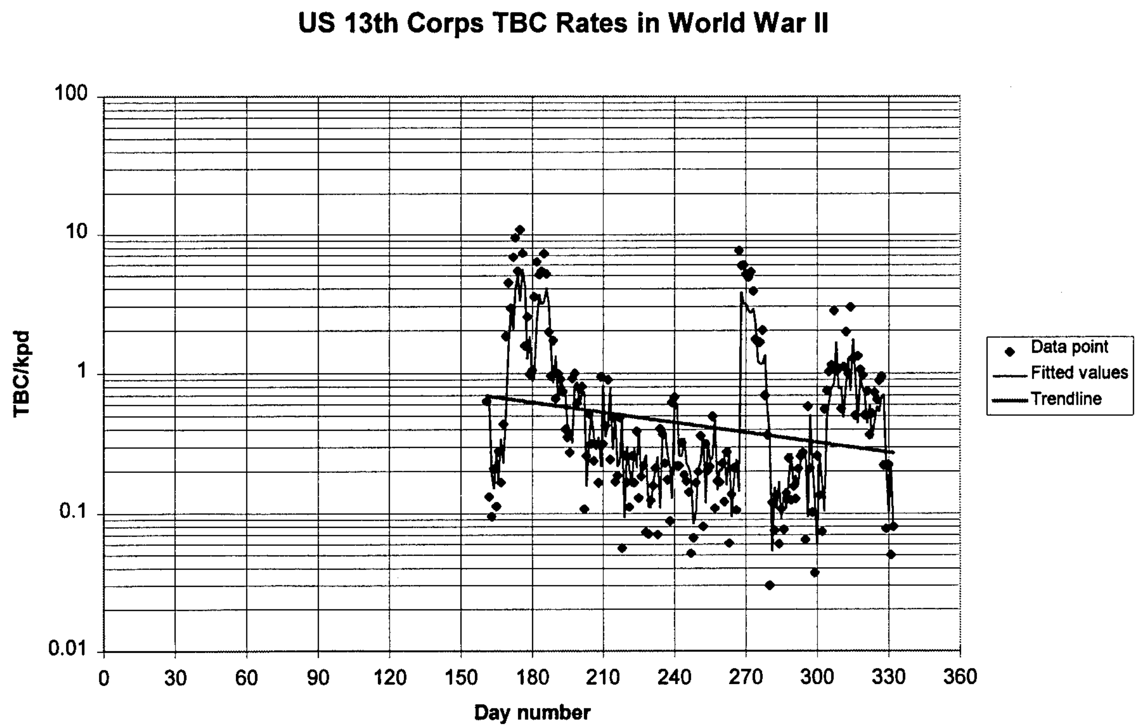

Figure 6-15. US 13th Corps TBC Rates in World War II

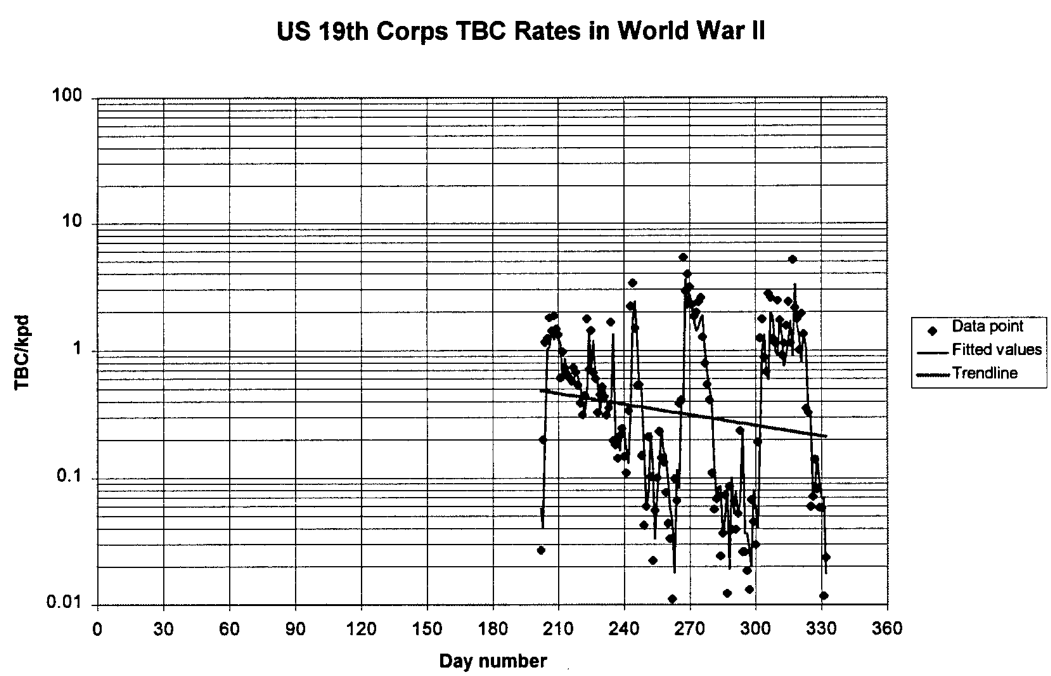

Figure 6-16. US 19th Corps TBC Rates in World War II

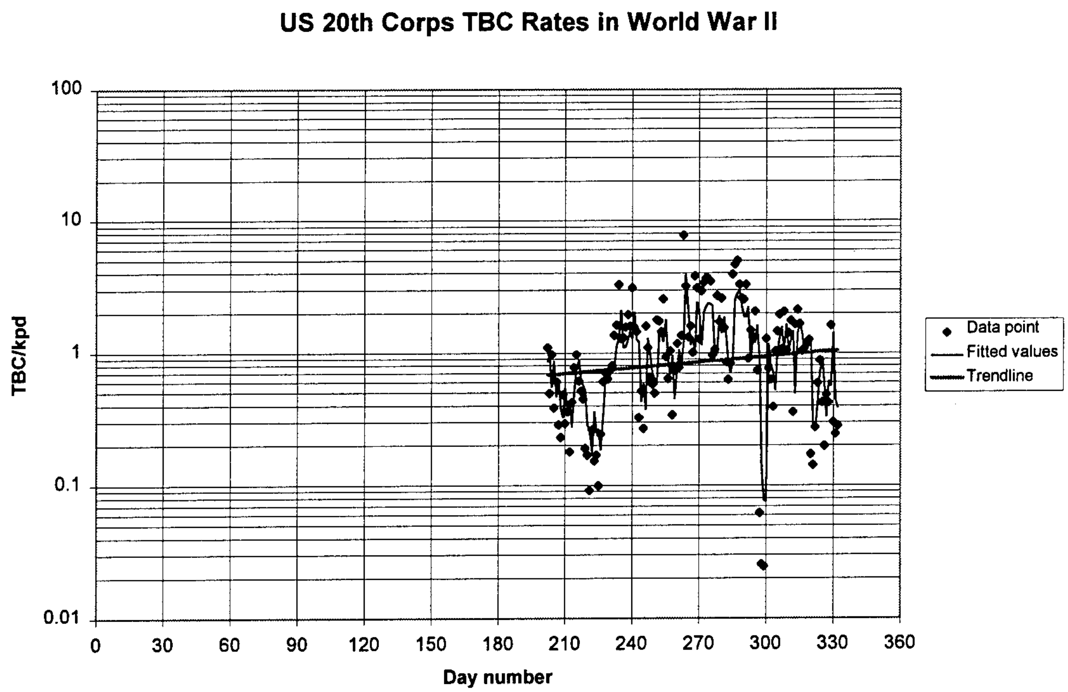

Figure 6-17. US 20th Corps TBC Rates in World War II

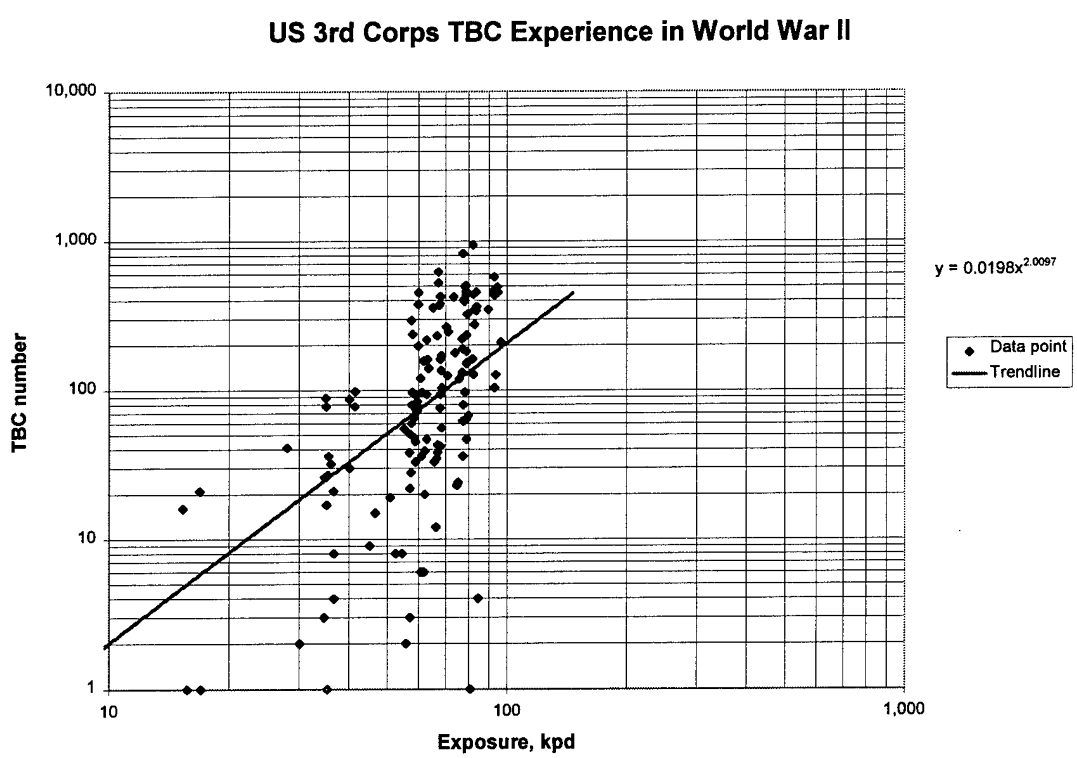

Figure 6-18. US 3d Corps TBC Experience in World War II

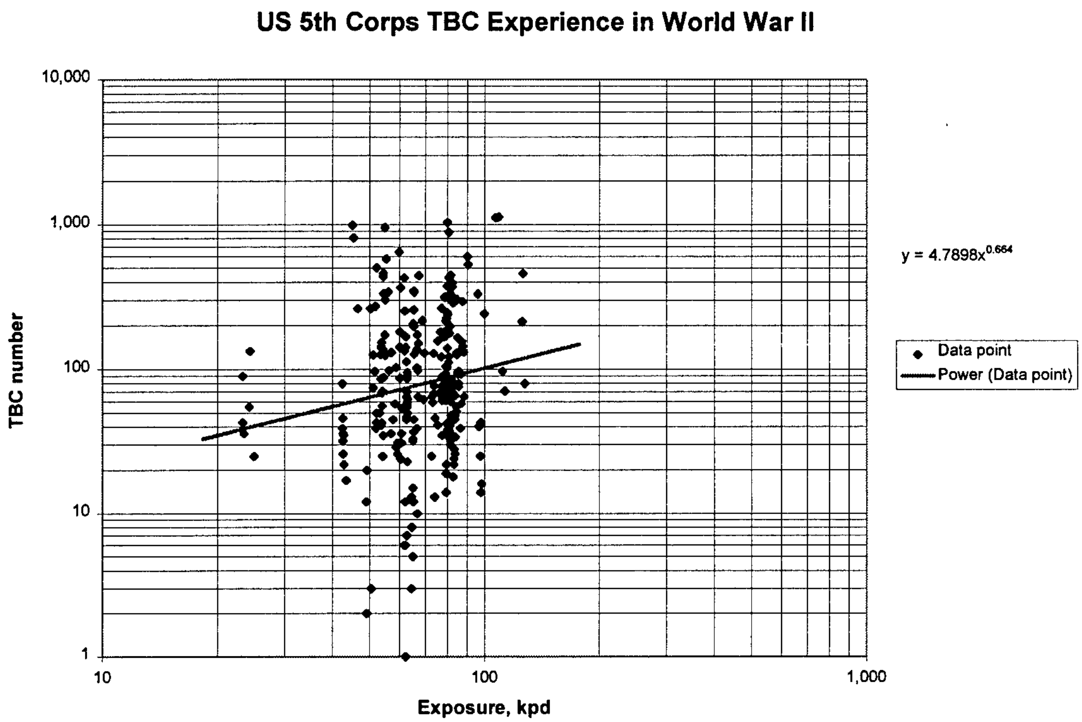

Figure 6-19. US 5th Corps Experience in World War II

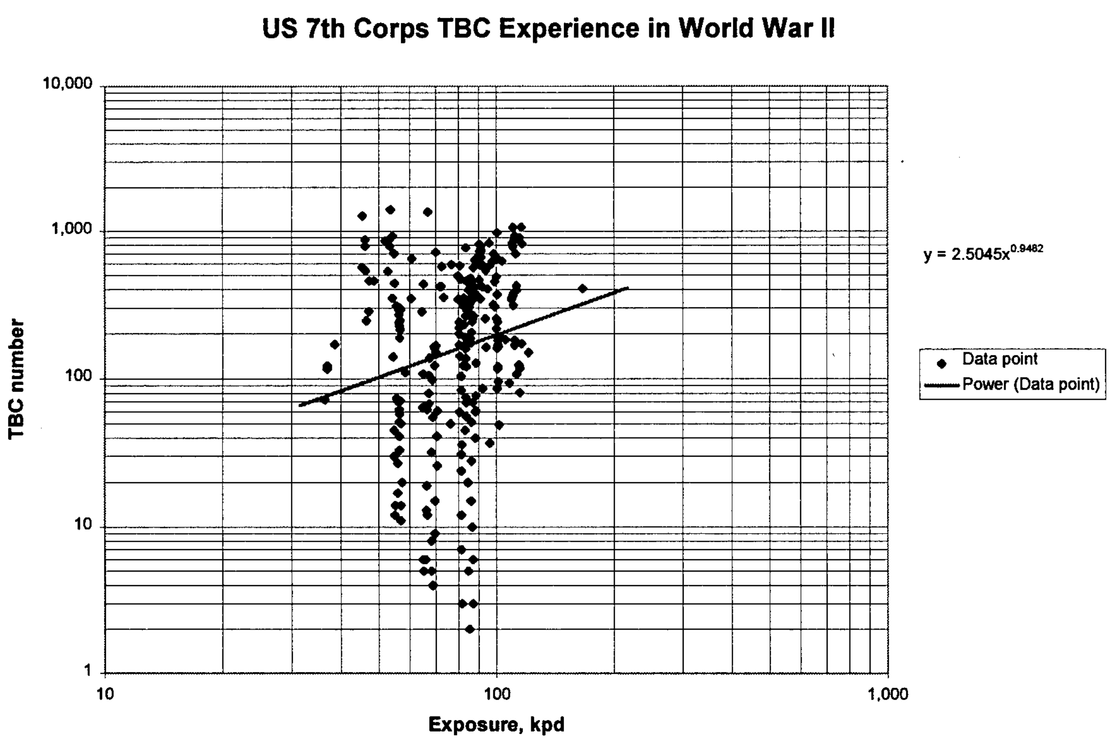

Figure 6-20. US 7th Corps Experience in World War II

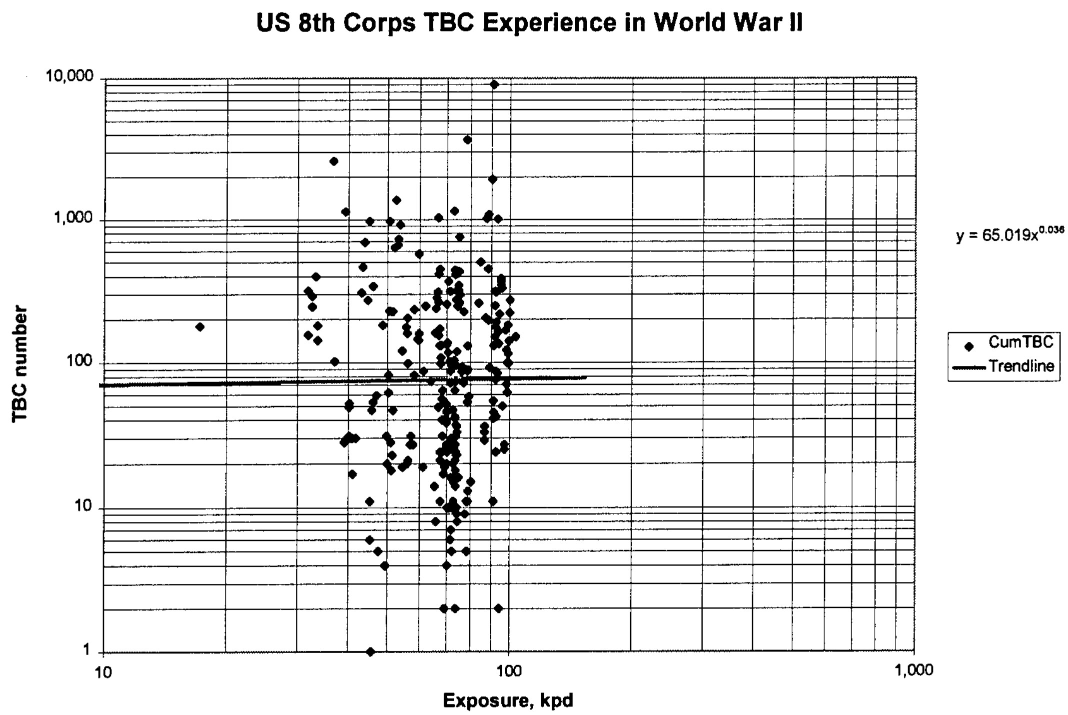

Figure 6-21. US 8th Corps Experience in World War II

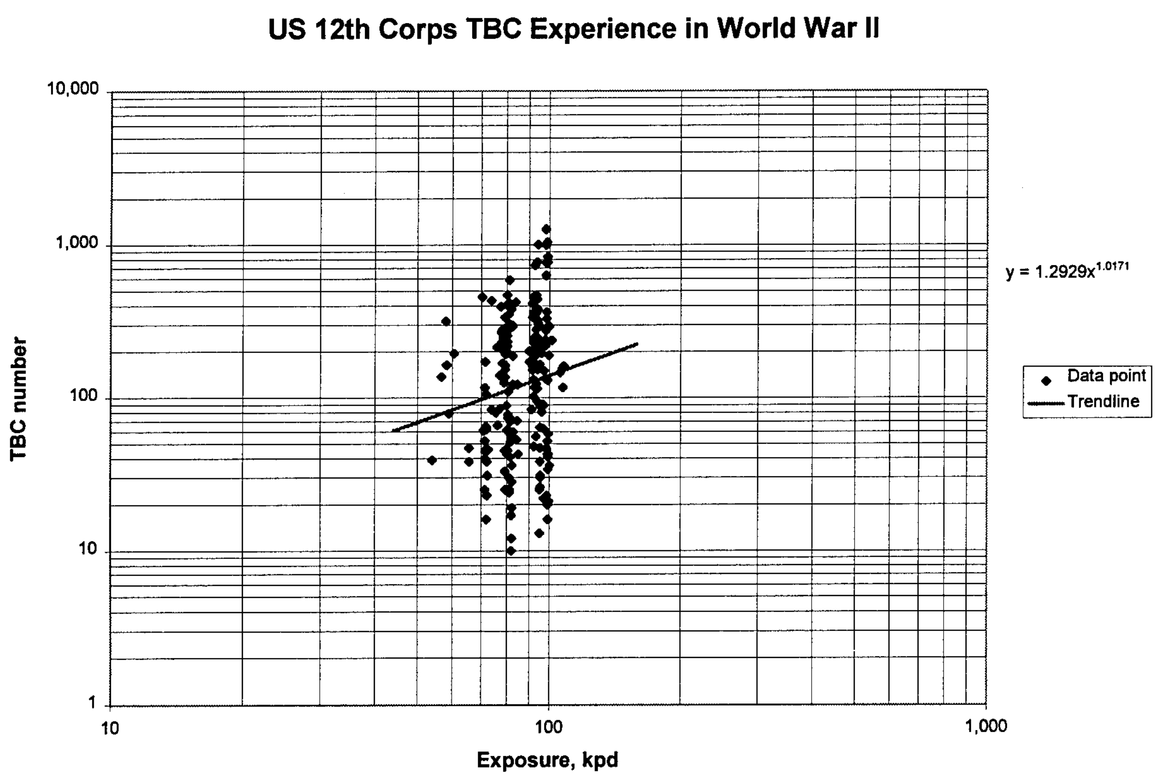

Figure 6-22. US 12th Corps Experience in World War II

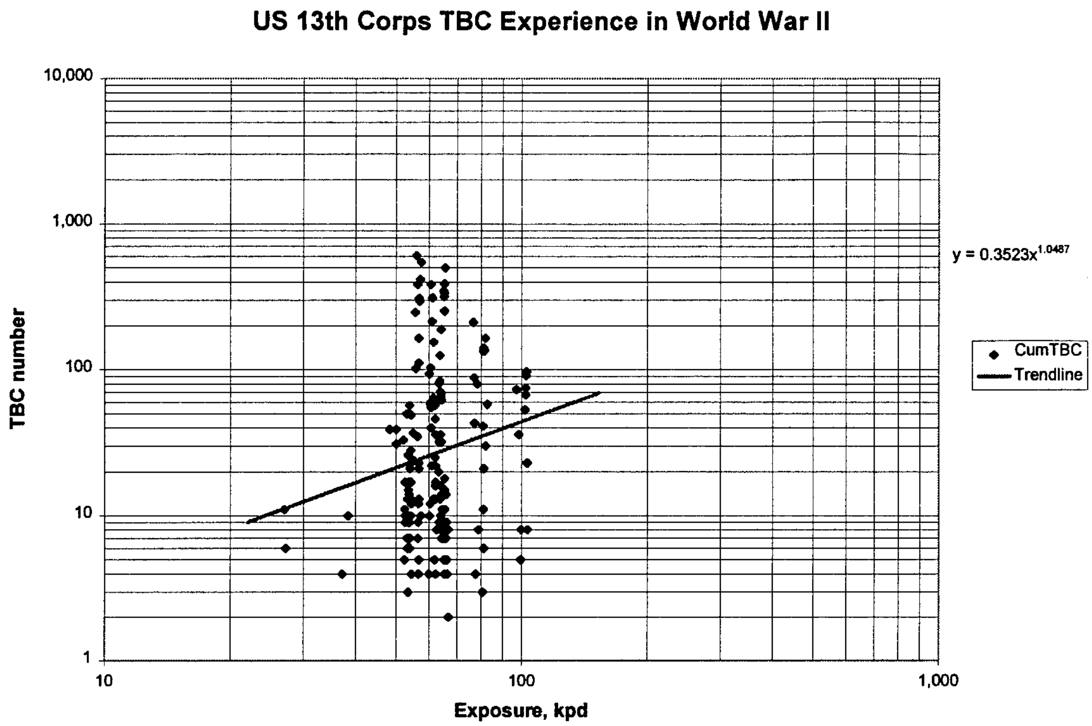

Figure 6-23. US 13th Corps TBC Experience in World War II

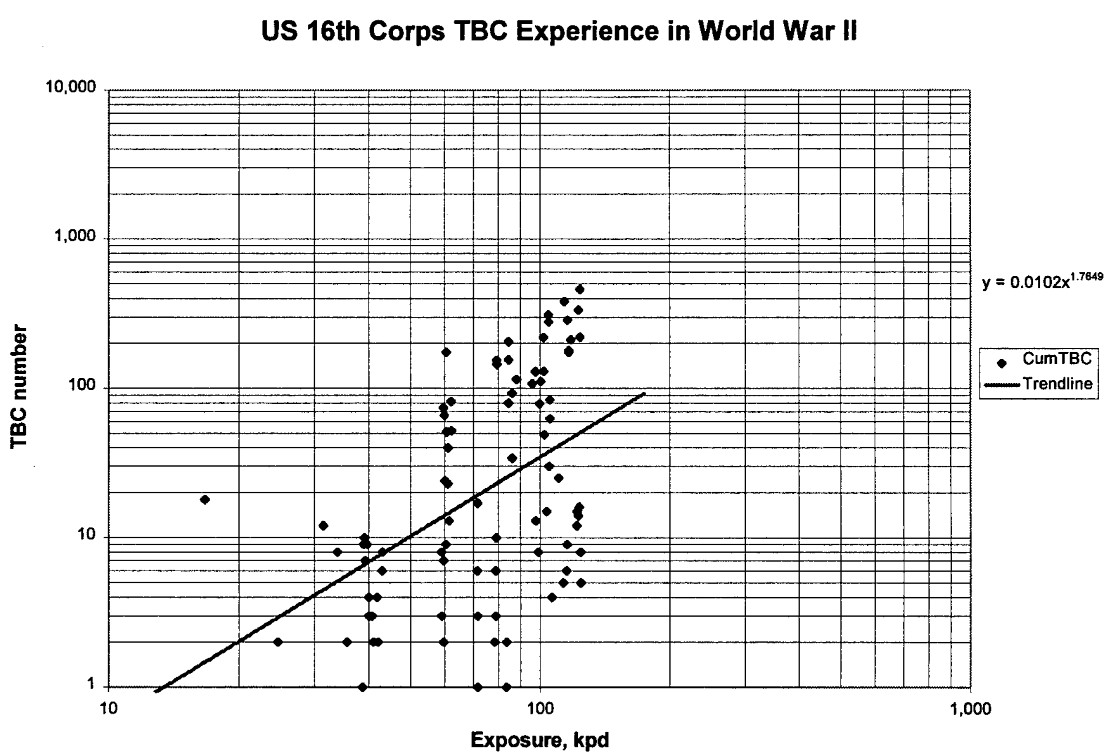

Figure 6-24. US 16th Corps Experience in World War II

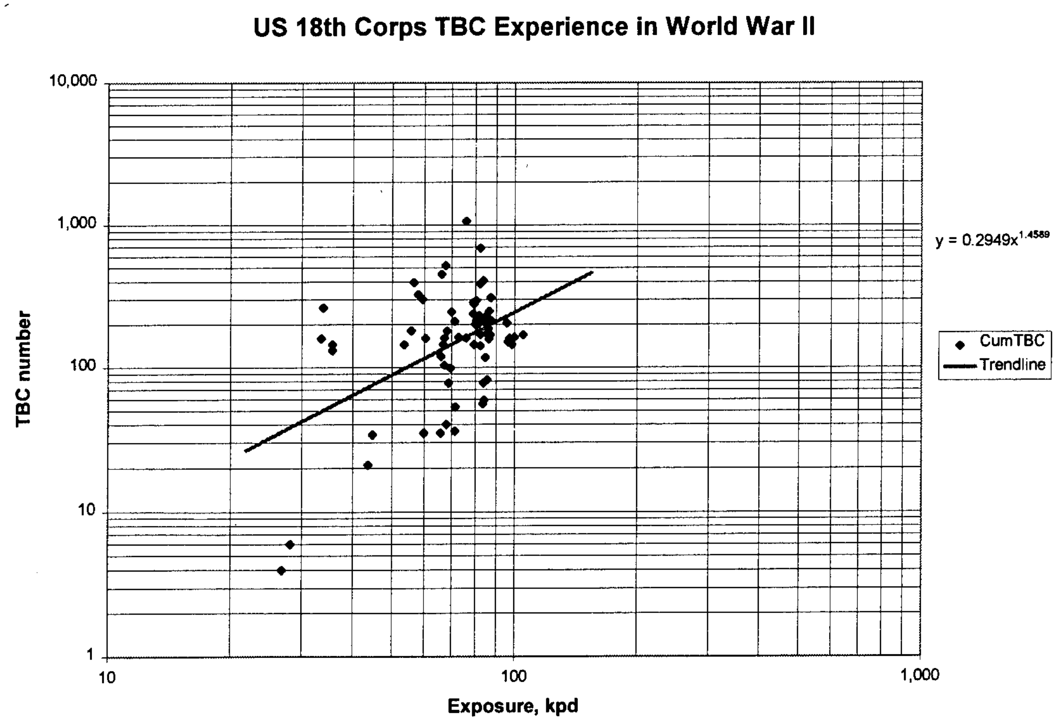

Figure 6-25. US 18th Corps Experience in World War II

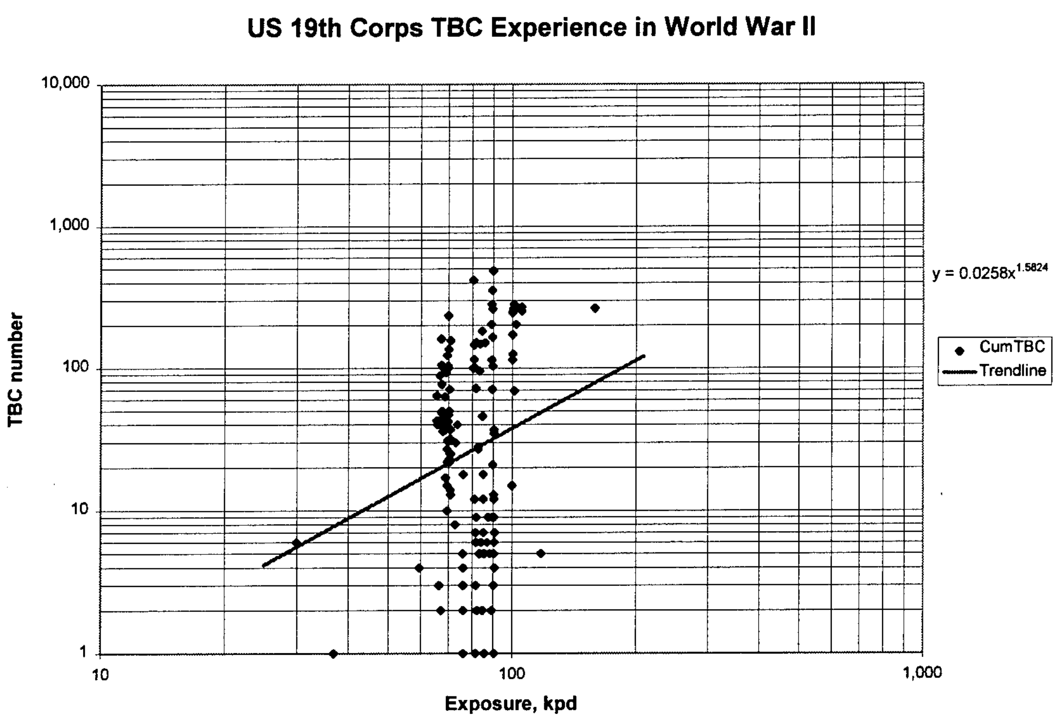

Figure 6-26. US 19th Corps Experience in World War II

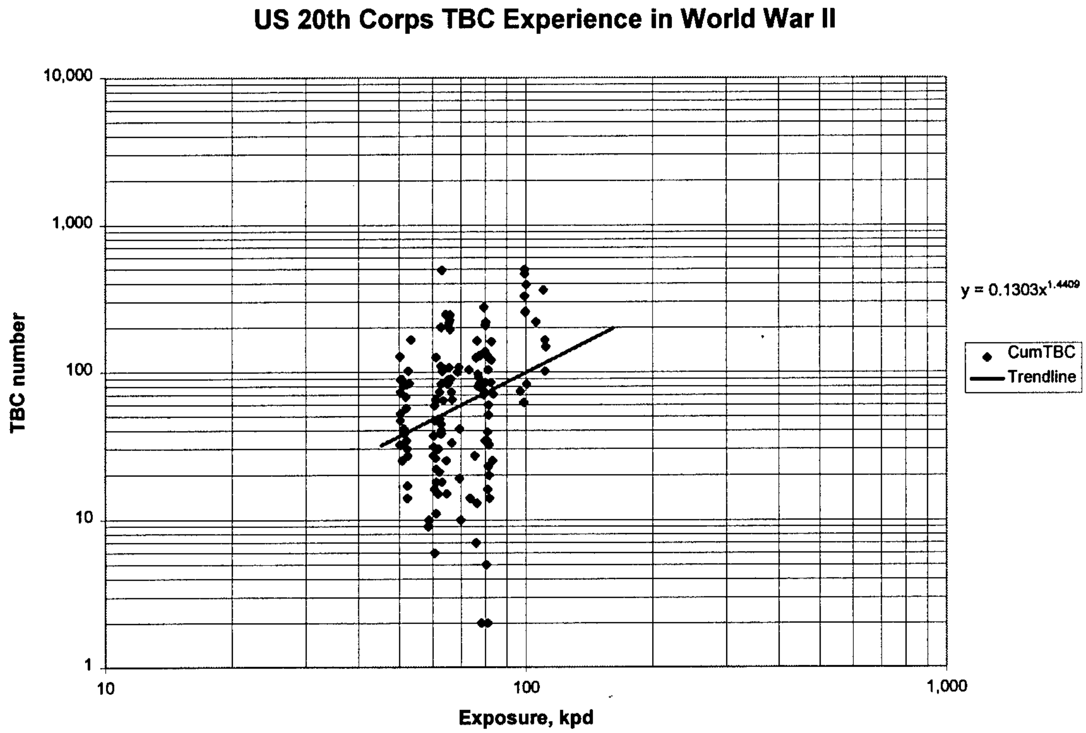

Figure 6-27. US 20th Corps Experience in World War II

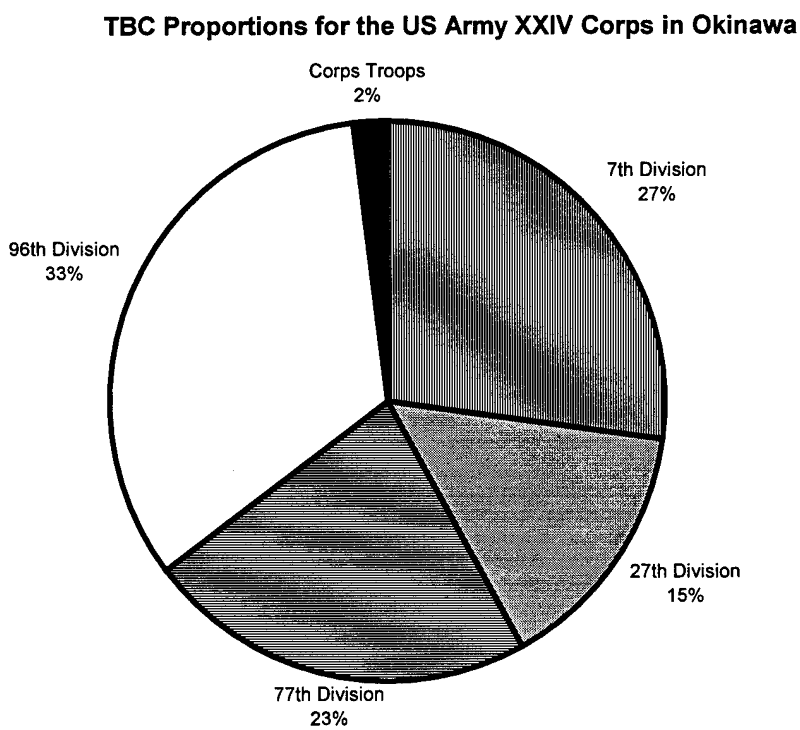

Figure 6-28. TBC Proportions for the US Army's XXIV Corps at Okinawa

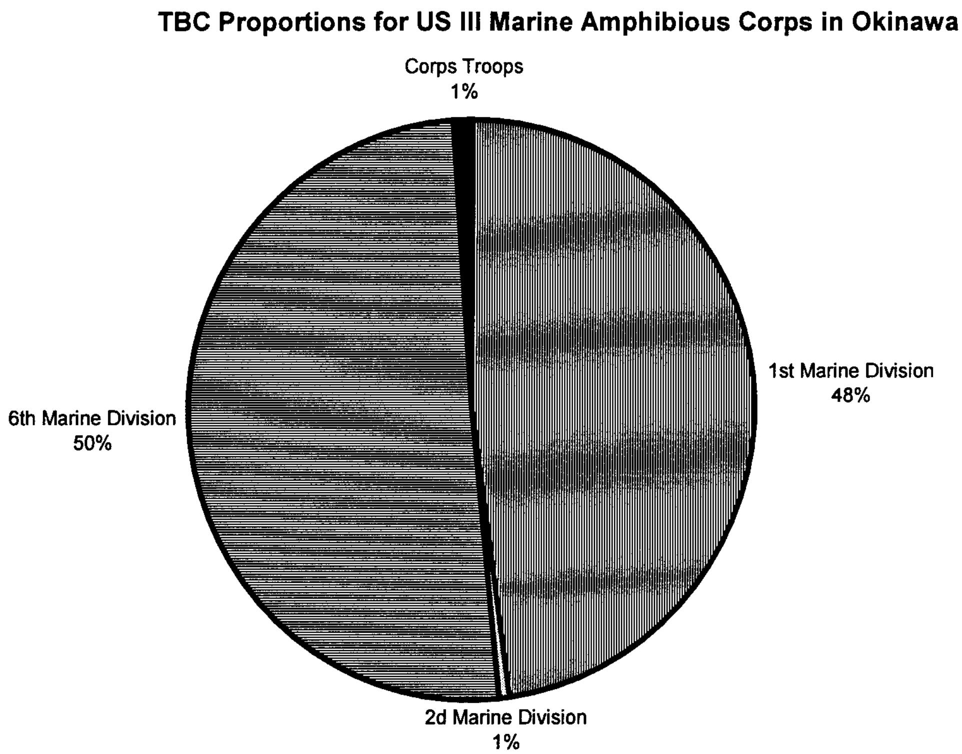

Figure 6-29. TBC Proportions for US III Marine Amphibious Corps at Okinawa

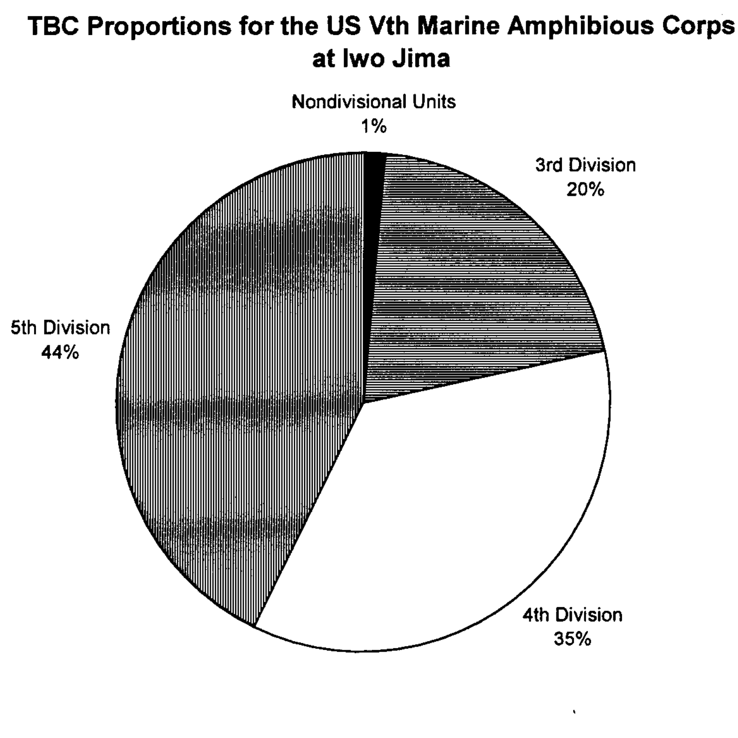

Figure 6-30. TBC Proportions for the US V Marine Corps at Iwo Jima

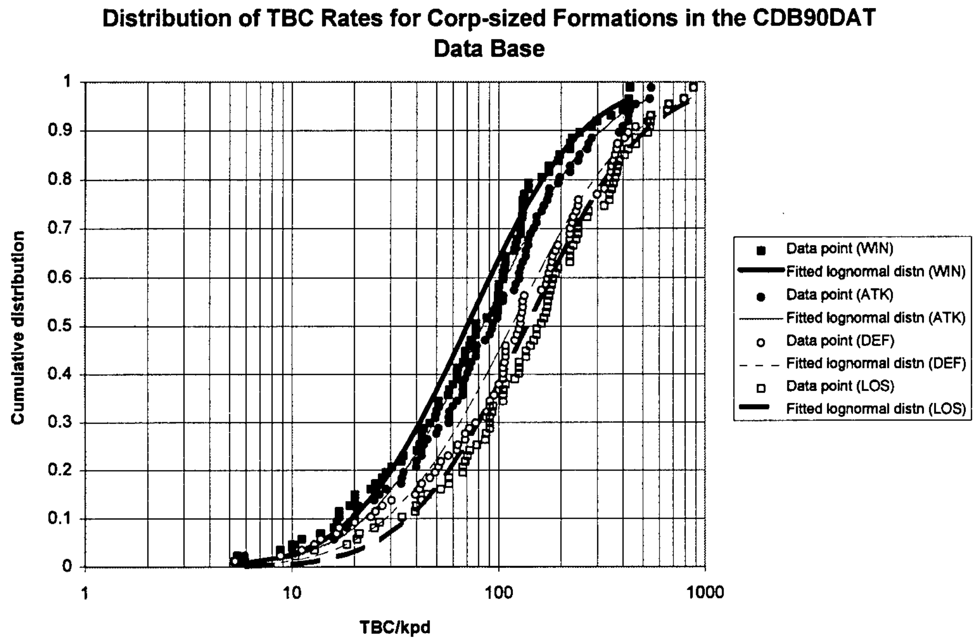

Figure 6-31. Distribution of TBC Rates for Corps-sized Formations in the CDB90DAT Data Base

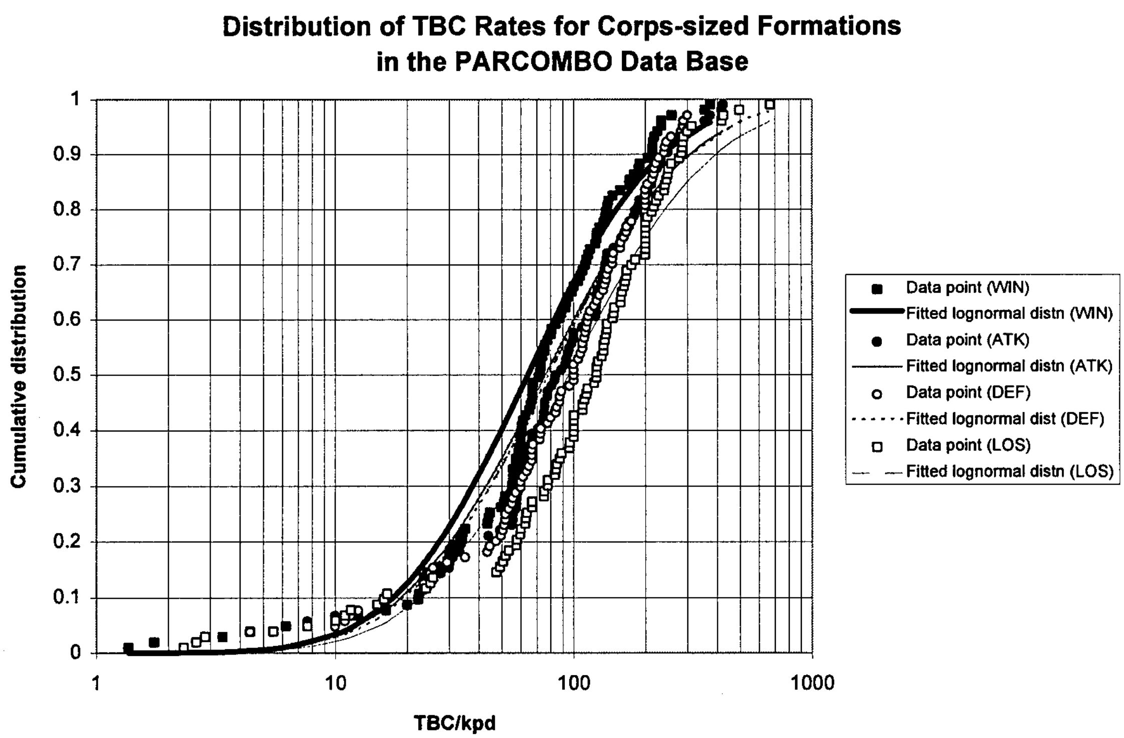

Figure 6-32. Distribution of TBC Rates for Corps-sized Formations in the PARCOMBO Data Base

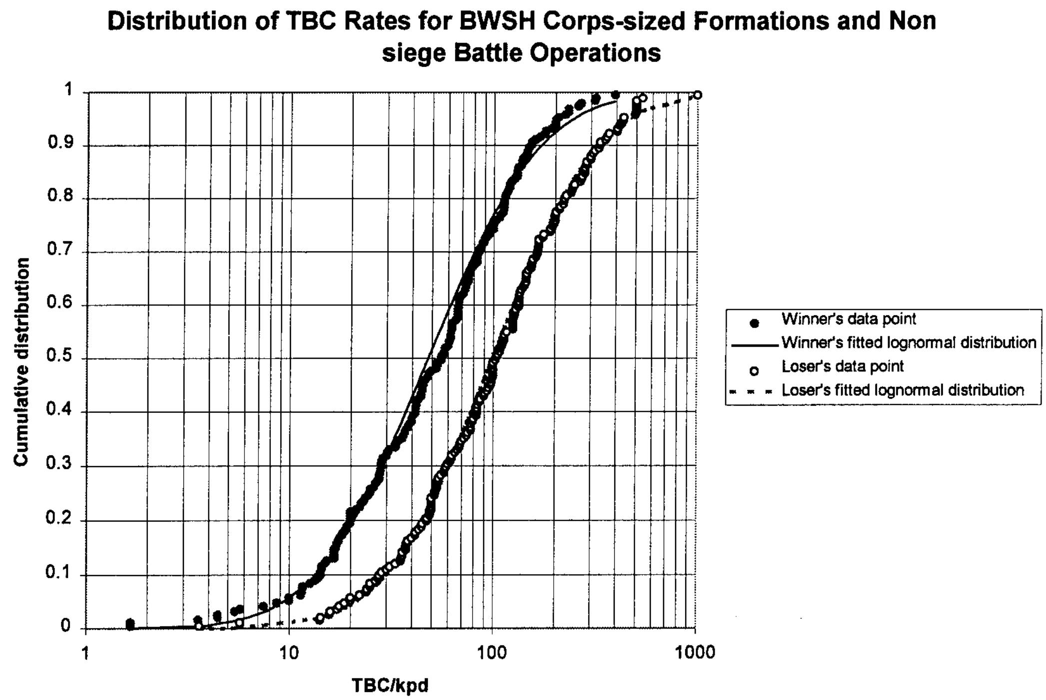

Figure 6-33. Distribution of TBC Rates for Corps-sized Formations in the BWSH Data Base

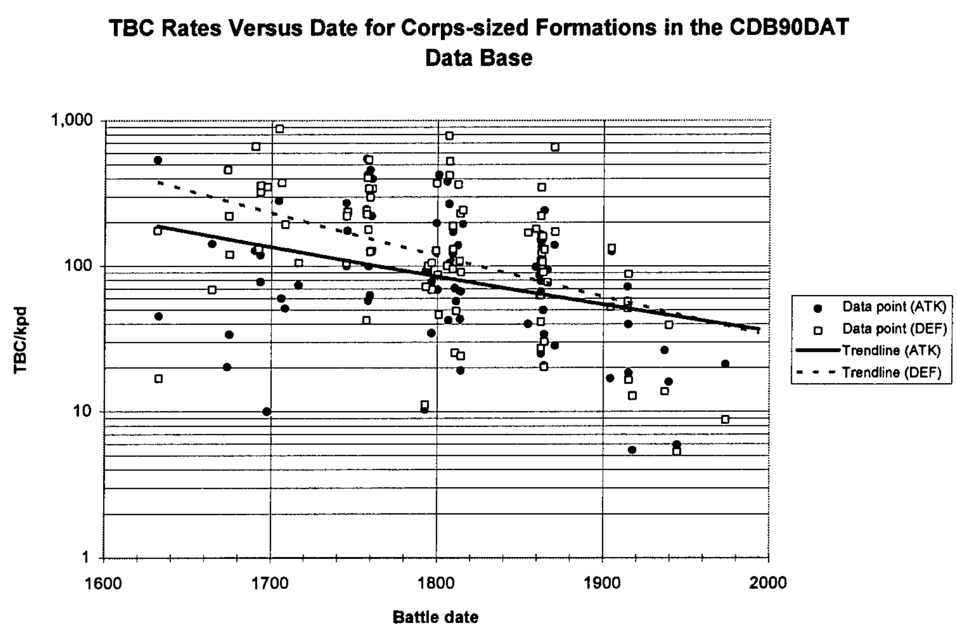

Figure 6-34. TBC Rates versus Date of the Attacker and Defender for Corps-sized Formations in the CDB90DAT Data Base

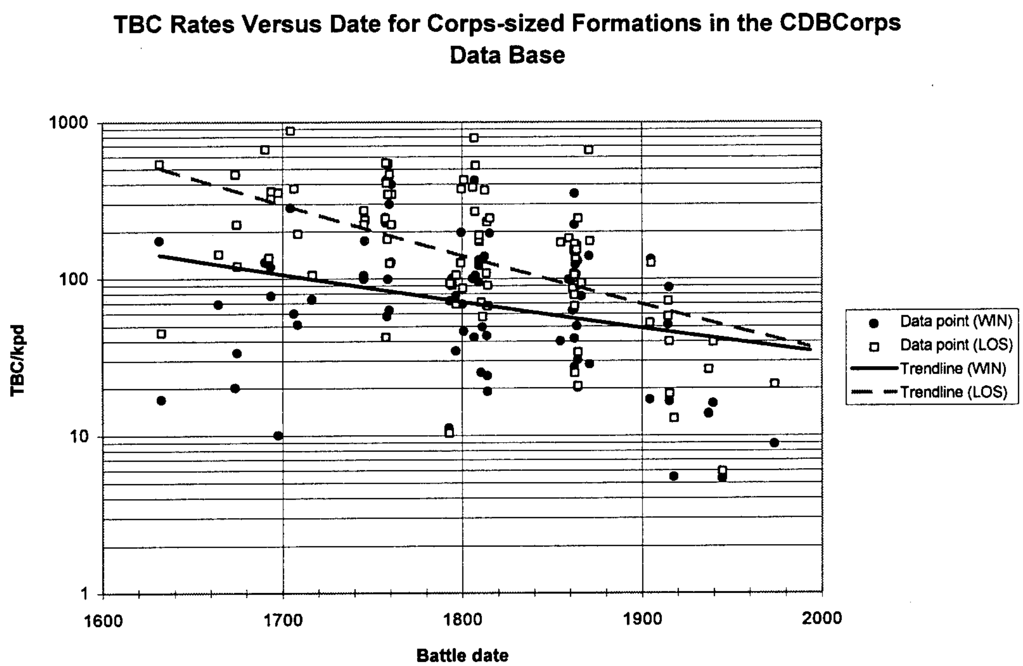

Figure 6-35. TBC Rates versus Date of the Winner and Loser for Corps-sized Formations in the CDB90DAT Data Base

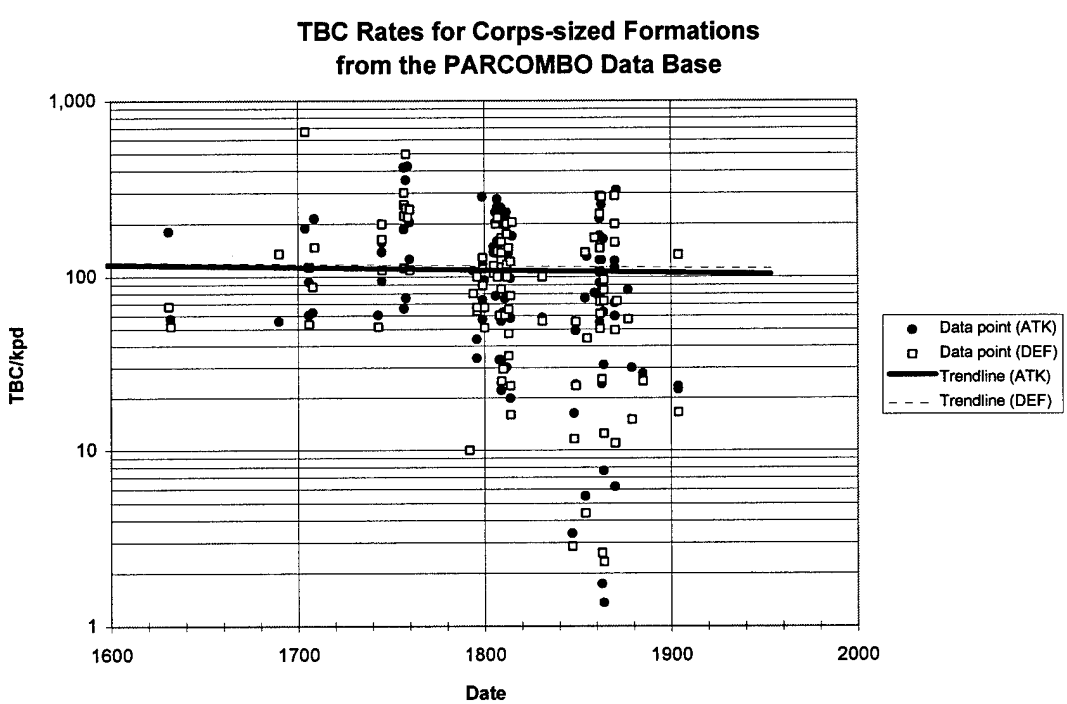

Figure 6-36. TBC Rates versus Date of the Attacker and Defender for Corps-sized Formations in the PARCOMBO Data Base

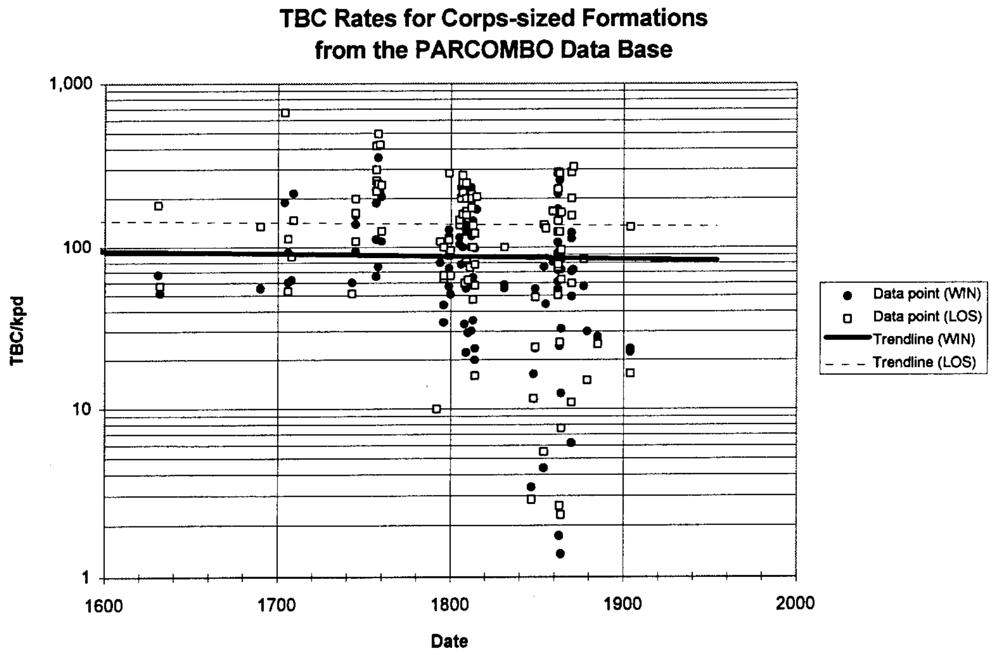

Figure 6-37. TBC Rates versus Date of the Winner and Loser for Corps-sized Formations in the PARCOMBO Data Base

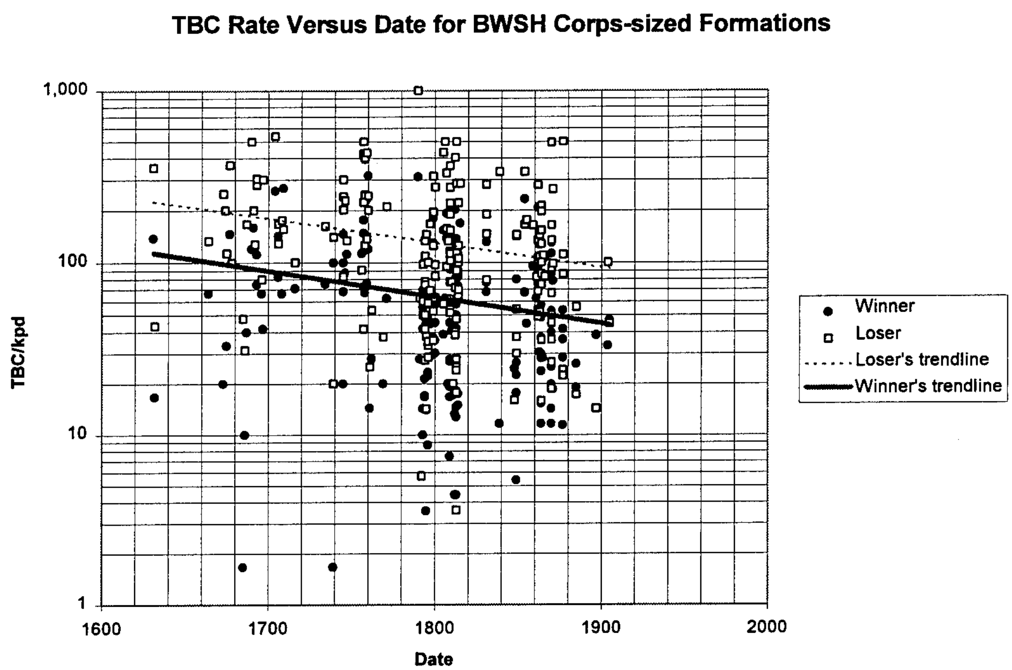

Figure 6-38. TBC Rates versus Date for the Winner and Loser for Corps-sized Formations in the BWSH Data Base

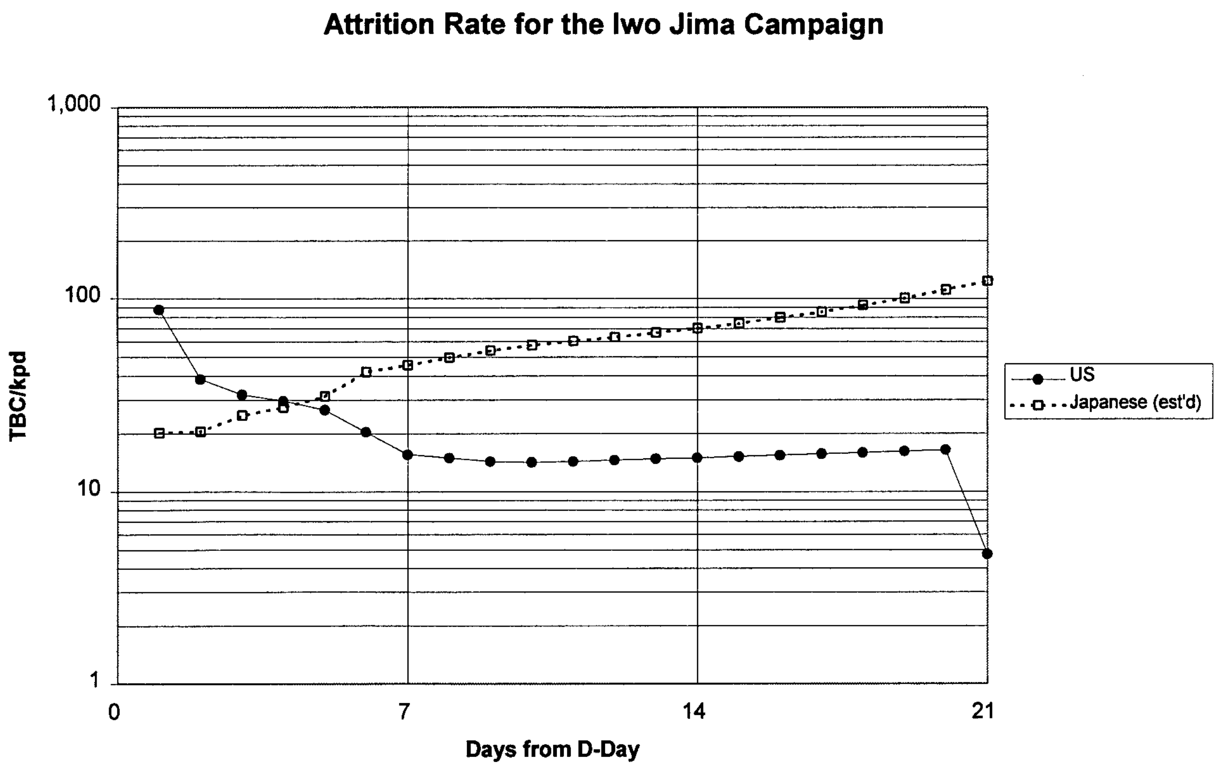

Figure 6-39. Estimated Attrition Rates for the Iwo Jima Campaign

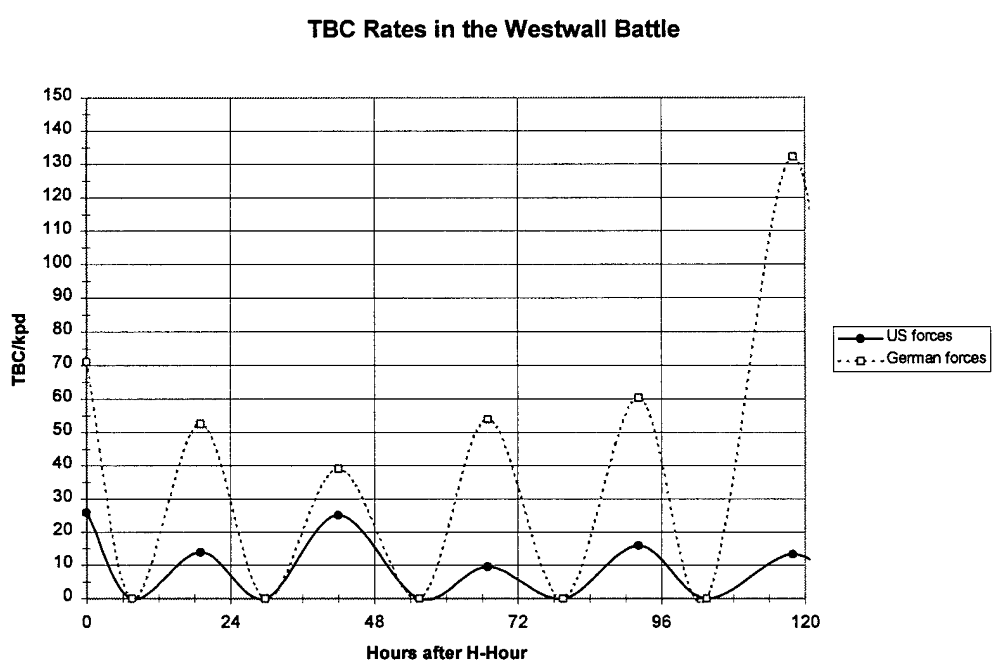

Figure 6-40. Estimated Attrition Rates in the Westwall Battle

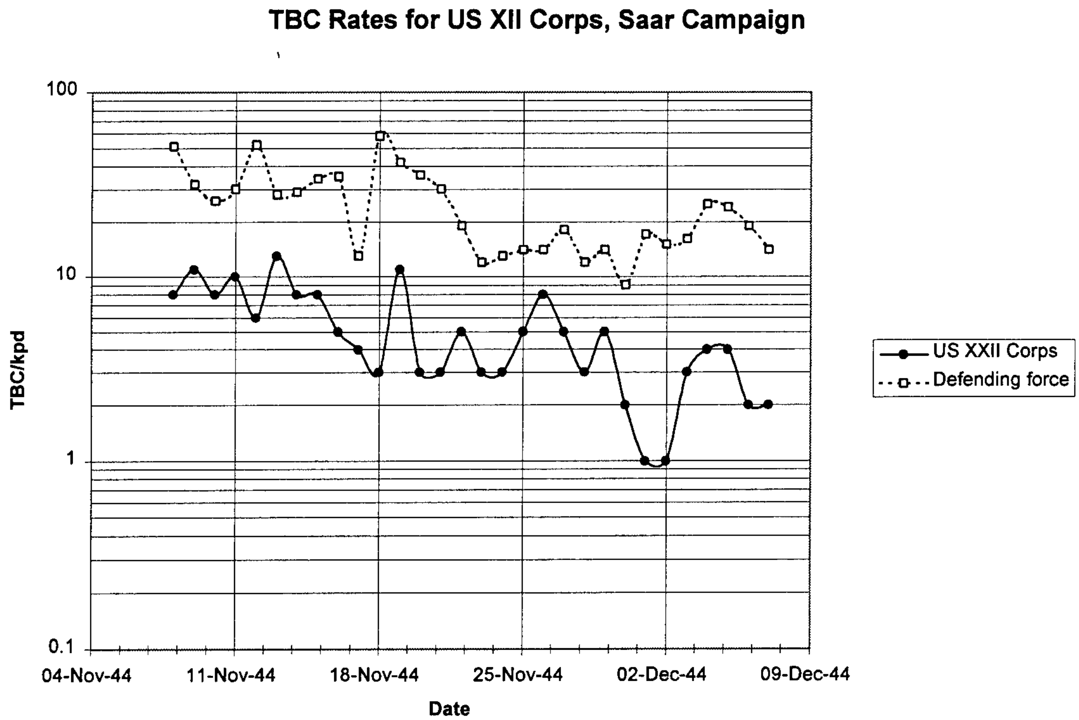

Figure 6-41. Estimated TBC Rates for the US XII Corps, Saar Campaign

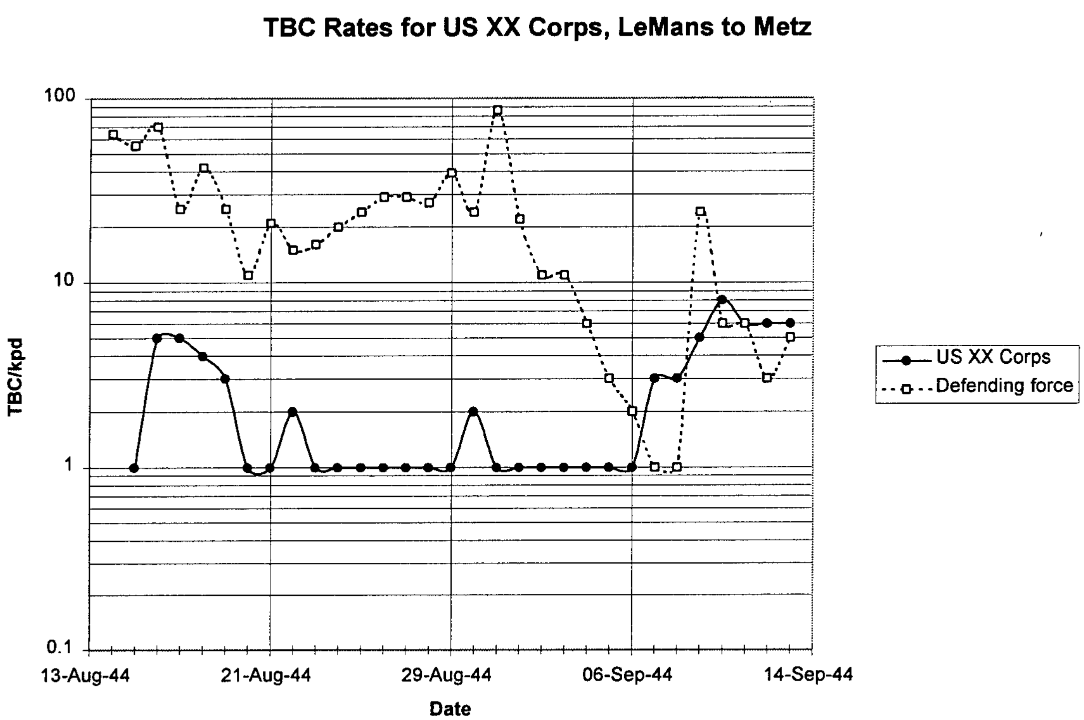

Figure 6-42. Estimated TBC Rates for the US XX Corps, LeMans to Metz

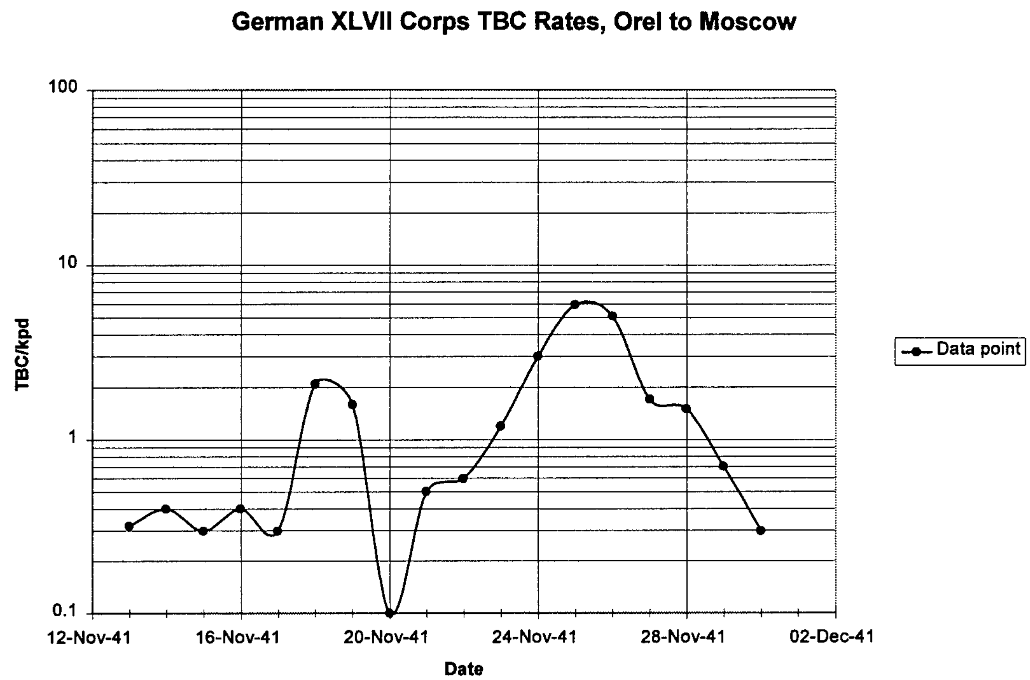

Figure 6-43. Estimated TBC Rates for the German XLVII Corps, Orel to Moscow

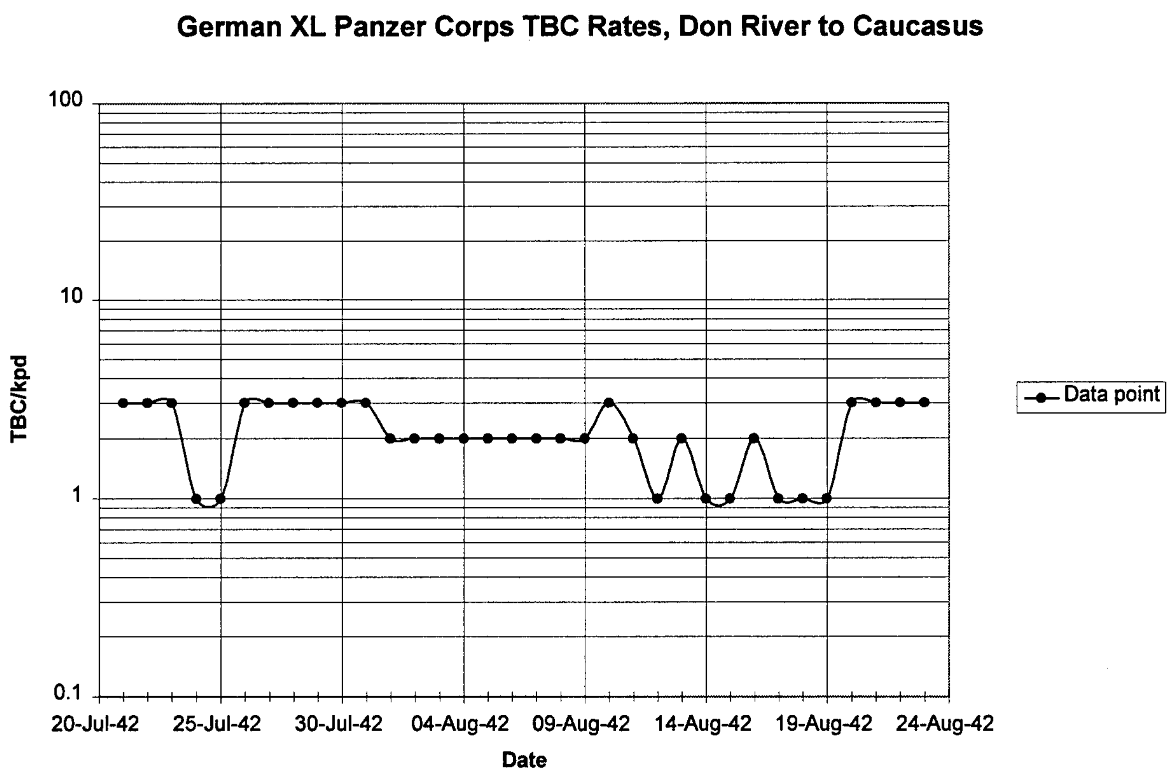

Figure 6-44. Estimated TBC Rates for the German XL Panzer Corps, Don River to Caucasus

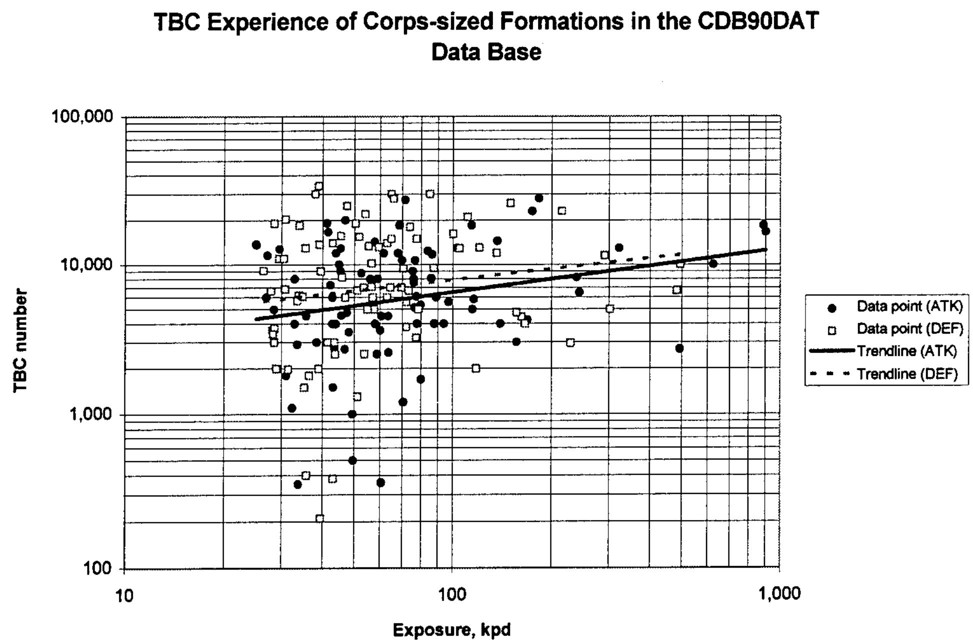

Figure 6-45. TBC Experience of the Attacker and Defender for Corps-sized Formations in the CDB90DAT Data Base

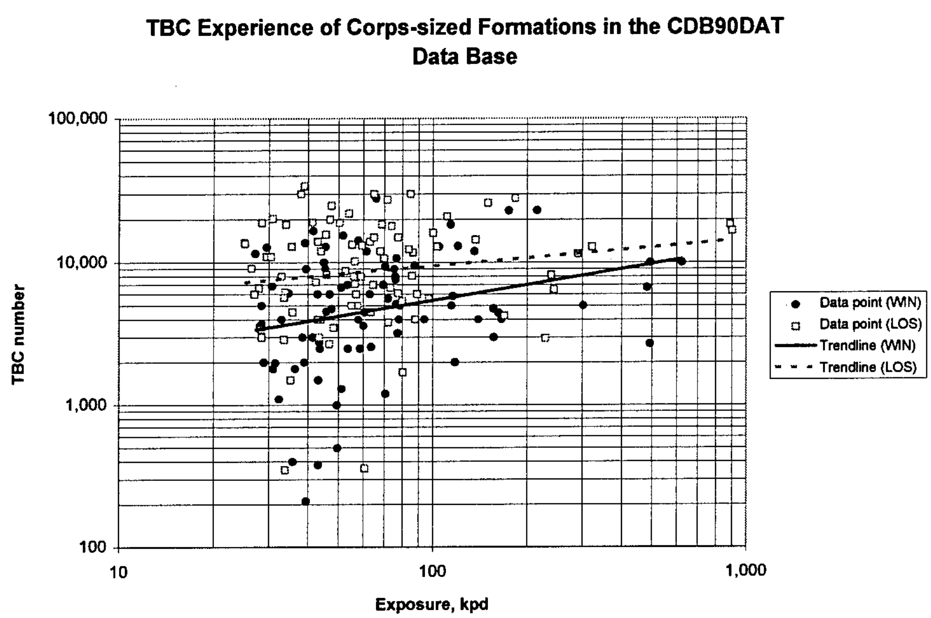

Figure 6-46. TBC Experience of the Winner and Loser for Corps-sized Formations in the CDB90DAT Data Base

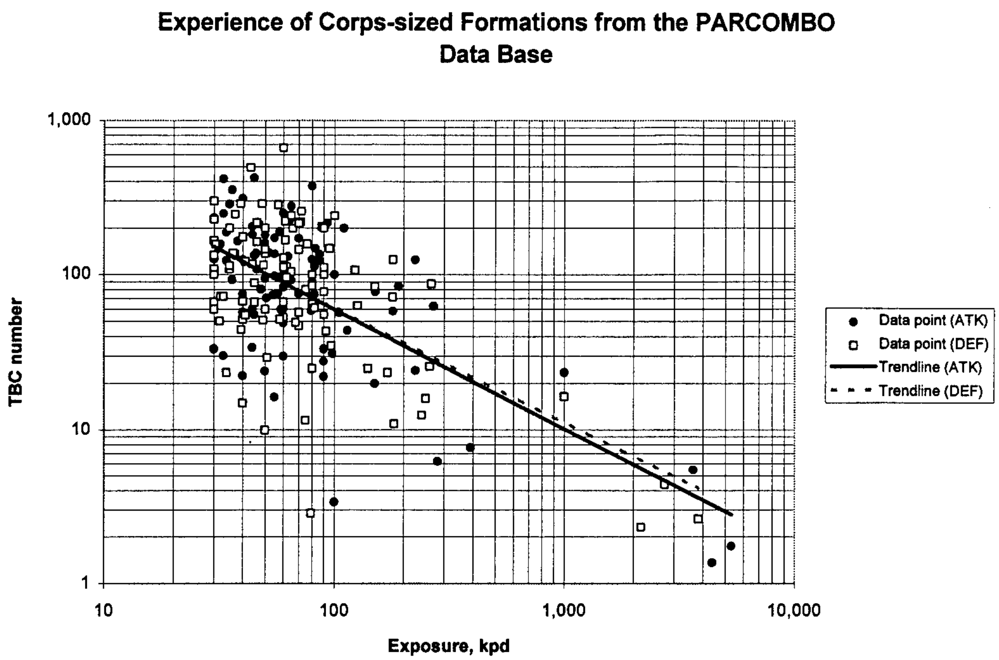

Figure 6-47. TBC Experience of the Attacker and Defender for Corps-sized Formations in the PARCOMBO Data Base

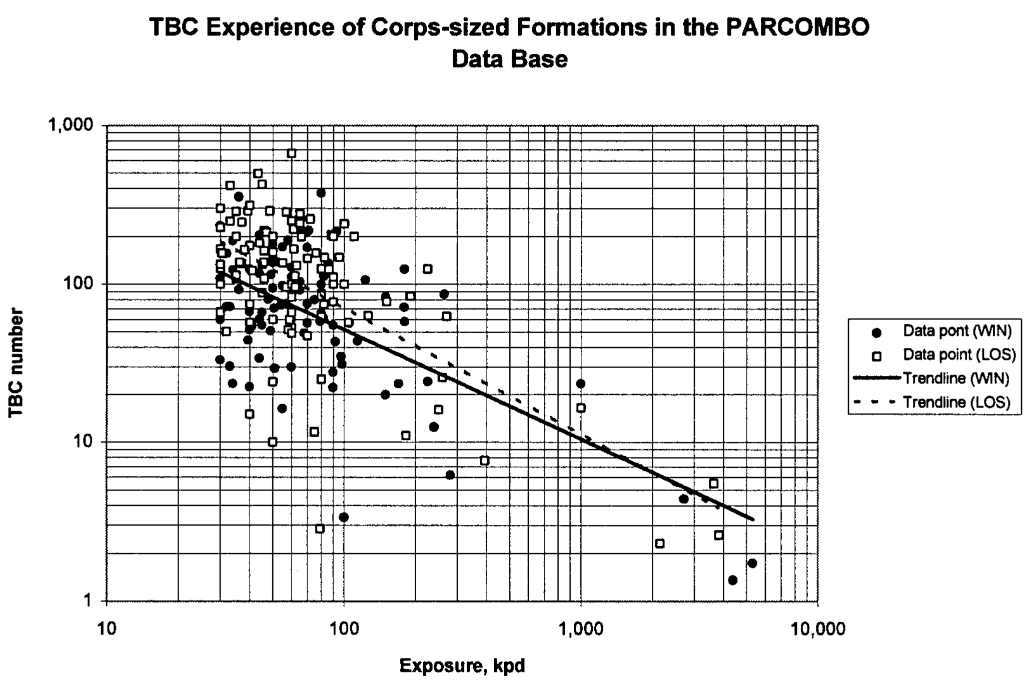

Figure 6-48. TBC Experience of the Winner and Loser for Corps-sized Formations in the PARCOMBO Data Base

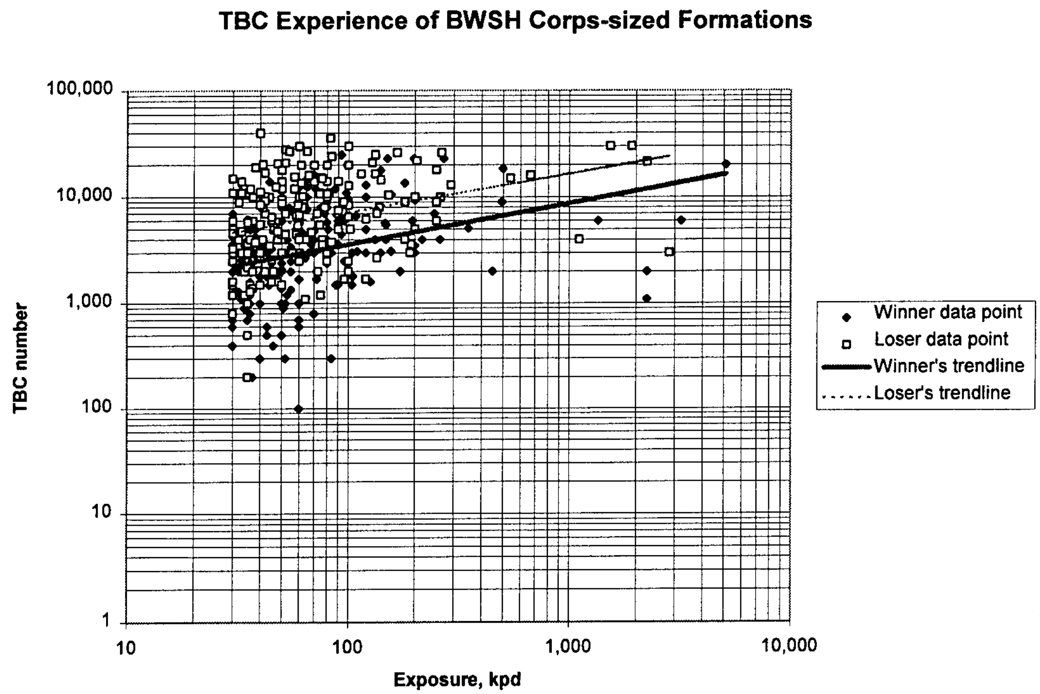

Figure 6-49. TBC Experience of the Winner and Loser for Corps-sized Formations in the BWSH Data Base

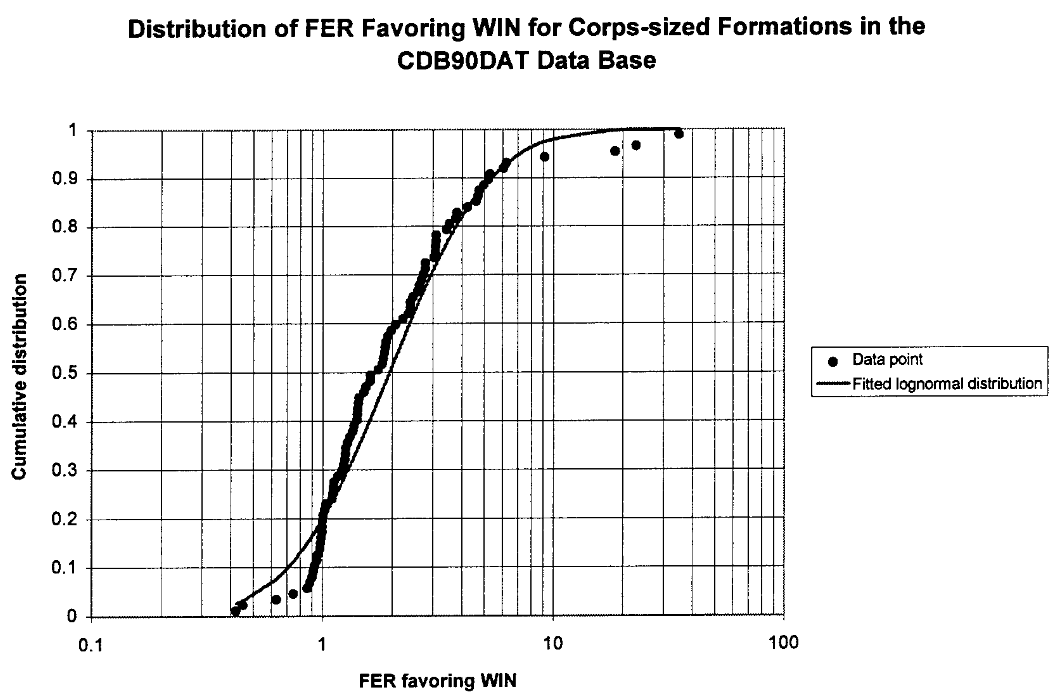

Figure 6-50. Distribution of FER Favoring the Winner for Corps-sized Formations in the CDB90DAT Data Base

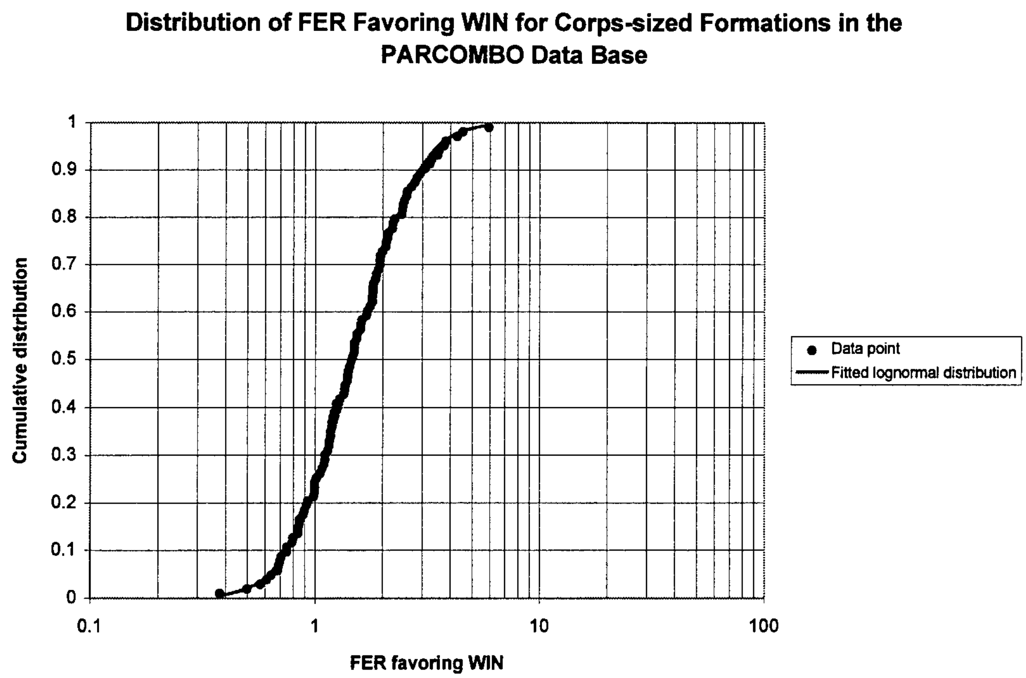

Figure 6-51. Distribution of FER Favoring the Winner for Corps-sized Formations in the PARCOMBO Data Base

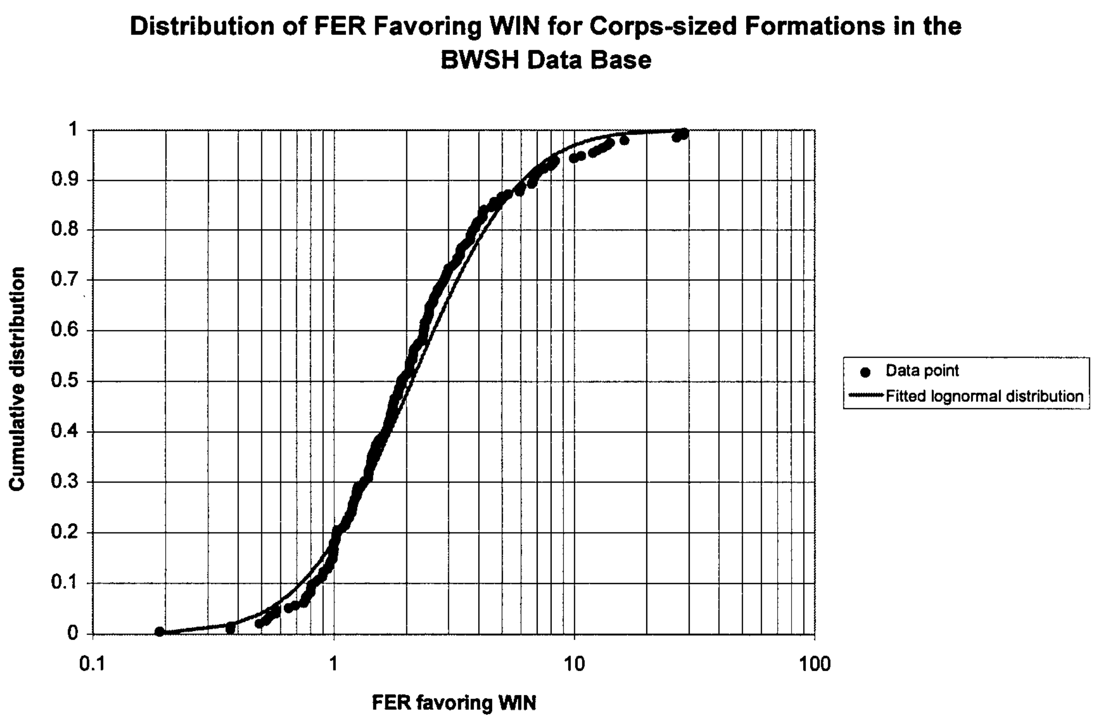

Figure 6-52. Distribution of FER Favoring the Winner for Corps-sized Formations in the BWSH Data Base

APPENDIX A

CONTRIBUTORS

A-1. TEAM

a. Research Director

Dr. Robert L. Helmbold, Tactical Analysis Division

A-2. PRODUCT REVIEW BOARD

Mr. Ronald J. Iekel, Chairman

Mr. Stanley H. Miller

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APPENDIX B

STUDY DIRECTIVE

MEMORANDUM FOR CHIEF, TACTICAL ANALYSIS DIVISION

SUBJECT: Personnel Attrition Rates in Historical Land Combat Operations, Phase 3 (PAR-P3)

1. PURPOSE OF THE STUDY DIRECTIVE. This Directive provides tasking and guidance for the conduct of the Personnel Attrition Rates in Land Combat Operations, Phase 3 (PAR-P3) study effort, which has the objectives of (i) publishing a CAA Research Paper documenting and summarizing selected historical data on personnel losses of army forces engaged in large-scale land combat operations, (ii) publishing a CAA Research Paper providing an Addenda to the previously published CAA Research Paper CAA-RP-93-2, Personnel Attrition Rates in Historical Land Combat Operations: An Annotated Bibliography, June 1993, AD-A268-787, and (iii) planning for the conduct of Phase 4 of PAR.

2. BACKGROUND

a. The results of US Army models and war games of combat are continually being challenged to demonstrate their validity. One of the key features of military combat is the infliction and suffering of personnel attrition. To provide an adequate basis for assessing the validity of US Army war games and models of combat, it is necessary that the reported data and past studies of personnel attrition rates in historical large scale combat operations be summarized and documented

b. PAR is limited to studying personnel strengths and battle casualties of land combat forces. Other types of attrition (non-battle losses, losses to equipment, casualties to other services, and so forth) are outside PAR's scope. PAR is concerned only with historical data on actual combat operations; it will not deal with personnel losses in models, simulations, war games, field experiments, or training exercises (like those of the National Training Center). PAR will focus mainly on either original or translated works in English, although the most important works in other languages should be included. Studies of personnel attrition are also included, provided they contain cogent analyses of a publicly available, non-proprietary body of tabulated data on attrition in actual combat operations. Since trends in attrition over long periods of time are of interest, data on ancient as well as recent battles are solicited. However, as no contract support is anticipated and in-house resources are limited, no systematic effort will be made to extract data from the archives or primary source materials, and no original archival research will be conducted. Thus, PAR will rely almost exclusively on secondary works that contain data in readily usable tabulated form.

c. Phase 1, or PAR-P1, was devoted to assembling the available data and past studies on personnel strengths and attrition rates in land combat operations, preparing a comprehensive annotated bibliography of it, and planning the approach to subsequent phases. It provided an annotated bibliography of over 200 relevant works, with several different types of indexes to aid retrieval.

d. Phase 2, or PAR-P2, was devoted to converting some of the most important data to electronic form in order to facilitate its analysis, and to performing selected analyses of the attrition data to derive information useful in US Army war games, studies, and analyses. As of this writing, the following documents have been published during Phase 2, or are in preparation:

- Personnel Attrition Rates in Historical Land Combat Operations: Susceptibility and Vulnerability of Major Anatomical Regions, CAA Research Paper CAA-RP-93-3, August 1993, AD-A270 766.

- Personnel Attrition Rates in Historical Land Combat Operations: A Catalog of Attrition and Casualty Data Bases on Diskettes Usable With Personal Computers, CAA Research Paper CAA-RP-93-4, September 1993, AD-A279 069 (report), AD-M000 344 (diskettes).

- Personnel Attrition Rates in Historical Land Combat Operations: A Note on the Probability of Readmissions and Multiple Wounds, CAA Research Paper, CAA-RP-94-2, April 1994, AD-280-498.

- Personnel Attrition Rates in Historical Land Combat Operations: Some Empirical Relations Among Force Sizes, Battle Durations, Battle Dates, and Casualties, CAA Research Paper, CAA-RP-95-1, 1 March 1995.
-

3. STUDY SPONSOR AND SPONSOR'S STUDY DIRECTOR. The Director, US Army Concepts Analysis Agency (CAA) will sponsor this study. The Sponsor's Study Director will be Dr. Robert L. Helmbold of the Tactical Analysis Division (CSCA-TCT).

4. STUDY AGENCY. CAA's Tactical Analysis Division will conduct this study. Augmentation and assistance will be provided as outlined in Paragraph 6 of this Study Directive.

5. TERMS OF REFERENCE.

a. Scope. This study directive is intended to provide for PAR-P3, the third phase of the Personnel Attrition Rates (PAR) study.

b. Objectives. The main objectives of PAR-P3 are to (i) publish a CAA Research Paper documenting and summarizing selected historical data on personnel losses of army forces engaged in large-scale land combat operations, (ii) publish a CAA Research Paper providing an Addenda to the previously published CAA Research Paper CAA-RP-93-2, Personnel Attrition Rates in Historical Land Combat Operations: An Annotated Bibliography, June 1993, AD-A268-787, and (iii) plan for the conduct of Phase 4 of PAR.

(1) A major objective of PAR-P3 is to publish a CAA Research Paper documenting and summarizing selected historical data on personnel losses of army forces engaged in large-scale land combat operations. The criteria for inclusion of a database are as follows (roughly in order of importance). The database must be:

(a) In the public domain, so that copies can be made available to Governmental agencies and others without restriction and for (at worst) a nominal cost. However, for the sake of completeness, some important proprietary databases can be described, even if their data cannot be made available through DTIC.

(b) In data base form (i.e., consist primarily of tabulations rather than narratives).

(c) Such as to contain information on large-scale military operations and their personnel losses.

(d) Available on diskettes usable with personal computers.

(e) Useful to many military operations analysts; developers, users, and assessors and validators of the inputs and/or outputs of war games and analogous combat simulations; military historians; students of military art and science; and others with similar interests.

(2) The combat databases are envisioned to possibly include those listed below.

ACSDB-1990, Ardennes Campaign Simulation Data Base (ACSDB).
BERNDT, Data from Berndt's Zahl im Kriege.
CRETE, CNA's database of Crete.
INCHON, Busse's data on the Inchon-Seoul campaign.
IWOJIMA, Various interpretations of the Iwo Jima casualty experience.
LMI-1990, Logistics Management Institute database of Twelfth Army casualty experience, collected by George Kuhn.
POGOGORO, Data on the Pogoroloye-Gorodische battle.
SINGER, Extracts from Singer's data on wars.
SMALL, Extracts from Small's data on wars.
WESTWALL, Data on the Westwall battle of World War II.

(3) Additional data will be sougth from other sources. Potential sources may include the following:

Bodart's Kriegs-lexicon on battles, wars, and campaigns from 1600 to 1900.
Livermore's monograph on losses in the US Civil War.
The Kursk Combat Simulation Data Base.

c. Timeframe. Not applicable.

d. Assumptions. Not applicable.

e. Essential Elements of Analysis for PAR-P3.

(1) What databases are or can be made available to support research into personnel attrition in large-scale land combat operations?

(2) What research topics will these materials support?

(3) What would be an efficient way to conduct such research?

f. Environmental and Threat Guidance. Not applicable.

g. Estimated Cost Savings or Other Benefits.

(1) It is important that the validity (or range of validity) of US Army war games and models of combat be assessed as accurately as possible. This can only be done through the application of the scientific method to historical data. This study is a necessary step in that process.

(2) US Army studies and analyses often need summary quantitative relationships applicable throughout a broad range of combat situations. It would be costly and inefficient to have each study review the literature, assemble the applicable information, convert it to electronic form, and make its own analyses of the reported data on personnel attrition. Making the results of this study available to a wide audience will help avoid unnecessary duplication of effort.

6. RESPONSIBILITIES. CAA's Tactical Analysis Division will conduct the study. Administrative support will be provided by CAA's Management Support Division.

7. LITERATURE SEARCH. A detailed annotated bibliography of sources was prepared during PAR-P1. While no formal literature search is specifically planned for subsequent phases of the PAR studies, we intend to continue informal efforts to identify and acquire additional relevant data.

8. REFERENCES

a. Administrative and Procedural.

b. Substantive.

"Personnel Attrition Rates in Land Combat Operations: An Annotated Bibliography," US Army Concepts Analysis Agency Research Paper, CAA-RP-93-2, August 1993.

9. ADMINISTRATION

a. Funding. Funding will be provided by CAA.

b. Administrative Support. Administrative support will be provided by CAA's Management Support Division.

c. Cost Limitations. Not applicable.

d. Contract Studies. Not applicable.

e. Automatic Data Processing Equipment (ADPE) Support. Personal computers and associated equipment (such as monitors, printers, etc.) will be required, as will appropriate software systems for databases, spreadsheets, word processing, statistical analyses, and programming languages such as BASIC. No need is currently anticipated for other ADPE support.

f. Milestone Schedule. The published Research Papers describing the large-scale operations results and the addenda to the annotated bibliography, together with the draft Study Directive for Phase 4 and its supporting ARB presentation, are to be completed by 1 April 1996.

g. Sponsor's Study Director (SSD) & Study Advisory Group (SAG). Not applicable.

h. Responsibility for DD Form 1498. Tactical Analysis Division.

i. Study Format. The results will be documented in the form of CAA Research Papers. An outline approach to subsequent phases is to be presented as a draft Study Directive and supporting ARB.

j. Action Documents. Written evaluation of study results will be provided by the sponsor in accord with AR 5-5.

E. B. VANDIVER III
Director

APPENDIX C

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APPENDIX D

TECHNICAL NOTE

D-1. ON THE RELATION OF TBC TO WIA. Throughout the main body of this paper we use total battle casualties (TBC) as the basis for most of our comparisons. Here TBC is defined to be the sum of the KIA, WIA, and CMIA. Unfortunately, a few of our data sources provided figures for the WIA and/or KIA, but not for the TBC. Accordingly, in a few places in the main body, we used an estimated number of TBC. For the purposes of this paper we used the estimating relationship $TBC = 1.5 \times WIA$. This technical note provides some of the rationale for this procedure.

D-2. US WORLD WAR II EXPERIENCE. We relied most heavily on the US experience in World War II, as documented in Table 15 on pages 48 through 57 of Beebe and DeBakey. Figure D-1 shows a plot of TBC versus WIA for those data. As can be seen, the relationship inferred from this figure is $TBC \approx 1.46 \times WIA$. For simplicity, and because other data may differ from that presented by Beebe and DeBakey, we elected to round this off to 1.5.

D-3. A CAUTIONARY NOTE. We did not attempt an in-depth study, using a variety of data set, of the relationship of TBC to WIA. However, we do note that the ratio of TBC to WIA was somewhat lower for US 12th Army Group operations in northwest Europe during World War II. Those data give estimates of the TBC/WIA ratio that vary from about 1.3 to 1.4, depending on what statistical model is assumed for the deviations from trend. Accordingly, the figure of 1.5 TBC for every WIA should be considered as an initial rough estimate subject to further refinement and analysis.

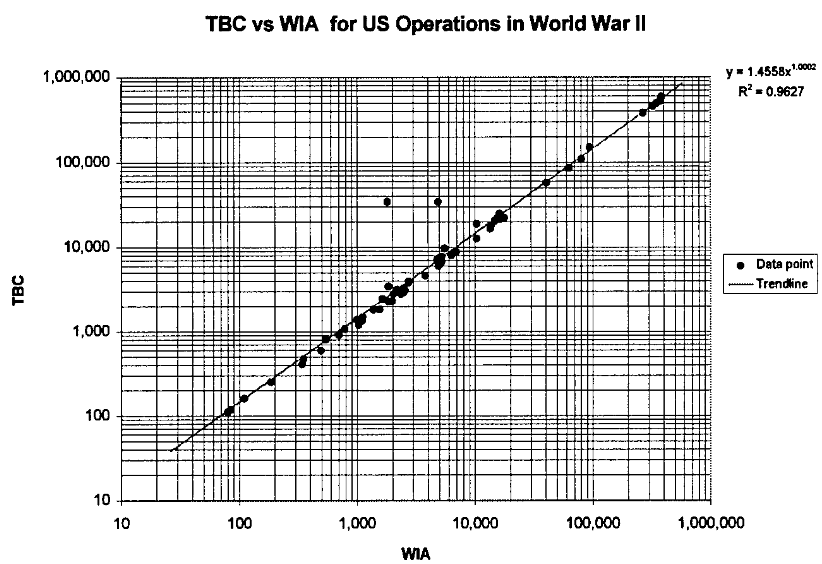

Figure D-1. TBC versus WIA for various forces

APPENDIX E

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GLOSSARY

1. INTRODUCTION. Some of the abbreviations and special terms used in this document are listed below. If the definition given is an official one, the organizations that have adopted it are given in parentheses; otherwise, no indication of its adoption are given. Note that the definitions used by other countries or by the US in earlier times may differ more or less from those given below and may be interpreted in various ways even within the US Department of Defense.

2. DEFINITION OF TERMS

Battle casualty - (DOD) Any casualty incurred in action. "In action" characterizes the casualty status as having been the direct result of hostile action, sustained in combat or relating thereto, or sustained going to or returning from a combat mission provided that the occurrence was directly related to hostile action. Included are persons killed or wounded mistakenly or accidentally by friendly fire directed at a hostile force or what is thought to be a hostile force. However, not to be considered as sustained in action and thereby not to be interpreted as battle casualties are injuries due to the elements, self-inflicted wounds, and, except in unusual cases, wounds or death inflicted by friendly forces while the individual is in absent without leave or dropped from rolls status or is voluntarily absent from a place of duty. See also died of wounds received in action; nonbattle casualty; wounded.

Bloody losses - The sum of the KIA and WIA.

Casualty - (DOD, IADB) Any person who is lost to the organization by reason of having been declared dead, wounded, injured, diseased, interned, captured, retained, missing, missing in action, beleaguered, besieged or detained; see also battle casualty; nonbattle casualty; wounded.

CMIA - Captured or missing in action. See POW and MIA.

CRO - Carded for record only. (Adapted from Beebe, Gilbert W.; and De Bakey, Michael E., *Battle Casualties: Incidence, Mortality, and Logistic Considerations,* Charles C. Thomas (publisher), 1952.) Basically, admissions to a medical treatment facility include all cases admitted for medical care and not returned to duty on the same calendar day as that on which first seen. Cases which are treated on an outpatient (duty) status, are designated as carded for record only (CRO).

DNBI - Disease and nonbattle injury. Personnel treated for diseases and for injuries not received in action. See Nonbattle casualty.

DOW - Died of wounds received in action (DOD, NATO). A battle casualty who dies of wounds or other injuries received in action, after having reached a medical treatment facility. See also killed in action.

DTIC - Defense Technical Information Center.

KIA - Killed in action (DOD, NATO, IADB). A battle casualty who is killed outright or who dies as a result of wounds or other injuries before reaching a medical treatment facility. See also died of wounds received in action.

Losses - (Adapted from FM 101-10-1/2, Staff Officers' Field Manual Organizational, Technical, and Logistical Data Planning Factors, October 1987). A personnel loss is any reduction in the assigned strength of a unit. Personnel losses are recorded in three general categories: battle, nonbattle, and administrative.

- Battle losses are those incurred in action. They include wounded or injured in action (including those who died of wounds and died of injuries received in action), killed in action, and missing in action or captured by the enemy.

- Nonbattle losses are those not directly attributable to action regardless of when sustained. They include nonbattle dead, nonbattle accident/injury, nonbattle missing, and illness/disease.

- Administrative losses are those resulting from transfer from the unit, absence without leave, desertion, personnel rotation, and discharges.

LWIA - Lightly wounded in action (see Slightly wounded).

MIA - (adapted from FM 101-10-1/2, Staff Officers' Field Manual Organizational, Technical, and Logistical Data Planning Factors, October 1987). Missing in action describes battle casualties whose whereabouts or fate cannot be determined and who are not known to be in an unauthorized absence status (desertion or absence without leave). Missing in action (MIA) casualties are not usually included in medical statistical records or reports received by The Surgeon General, but are reportable to The Adjutant General.

NFW - Nonfatal wound. A person who is wounded in action (WIA), but who does not die of wounds (DOW).

Nonbattle casualty - (DOD, NATO, IADB) A person who is not a battle casualty but who is lost to his organization by reason of disease or injury, including persons dying from disease or injury, or by reason of being missing where the absence does not appear to be voluntary or due to enemy action. See also battle casualty; wounded.

Nonbloody loss - Battle casualties other than KIA and WIA; include (for example) MIA, POW, absent without leave, stragglers, and deserters.

NP - Neuropsychiatric.

POW - Prisoner of war. Detainee (DOD). A term used to refer to any person captured or otherwise detained by an armed force. (According to FM 101-10-1/2, Staff Officers' Field Manual Organizational, Technical, and Logistical Data Planning Factors, October 1987, captured describes all battle casualties known to have been taken into custody by a hostile force as a result of and for reasons arising out of any armed conflict in which US armed forces are engaged.

Captured casualties are not usually included in medical statistical records or reports received by The Surgeon General but are reported to The Adjutant General.)

Seriously wounded - (DOD, IADB) A stretcher case. See also WIA.

Slightly wounded - (DOD, IADB) A casualty that is a sitting or walking case. See also WIA.

SWIA - Seriously wounded in action (see Seriously wounded).

TBC - Total battle casualty. The sum of the KIA, WIA, and CMIA casualties.

WIA - Wounded in action (DOD, NATO, IADB). A battle casualty other than "killed in action" who has incurred an injury due to an external agent or cause. The term encompasses all kinds of wounds and other injuries incurred in action, whether there is a piercing of the body, as in a penetrating or perforated wound, or none, as in the contused wound; all fractures, burns, blast concussions, all effects of biological and chemical warfare agents, the effects of exposure to ionizing radiation, or any other destructive weapon or agent.

3. TERMS AND MATHEMATICAL SYMBOLS UNIQUE TO THIS STUDY

ARIMA - Autoregressive moving average, used to describe a certain kind of time series.

Attenuation - The tendency for casualty rates averaged over an extended period of time to be less than the casualty rates associated with relatively intense combat activity.

BD - Battle deaths, the sum of the KIA and DOW.

Dilution - The tendency for casualty rates averaged over a large force to be less than the casualty rates associated with relatively heavily engaged elements of the force.

FER - Fractional exchange ratio, the ratio of the percentage losses on one side to the percentage losses to the other side.

kp - Kilo personnel, that is, 1,000 personnel.

kpd - Kilo personnel-days, that is, 1,000 personnel-days (used as a level of effort or exposure to risk).

kpy - Kilo personnel-years, that is, 1,000 personnel years. Used as an index of exposure to risk.

/kpd - Used as an abbreviation for the phrase "per thousand per day." Thus, the statement that "the attrition rate amounted to 10 per thousand per day" is abbreviated to "the attrition rate amounted to 10/kpd."

/kpy - Used as an abbreviation for the phrase "per thousand per year." Thus, the statement that "the attrition rate amounted to 10 per thousand per year" is abbreviated to "the attrition rate amounted to 10/kpy."

RMSE - Root mean square error, a measure of the scatter of data points about a trendline.

WNM - Wounded not mortal, the difference between WIA and DOW.