Estimating Casualty Numbers

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Abstract

The Directorate of Equipment Capability (Expeditionary Logistics and Support) is responsible for identifying future UK medical support equipment requirements. Estimating the number of casualties that could be sustained on future operations is clearly fundamental. This paper summaries the findings of a review of casualty estimation techniques undertaken recently for DEC(ELS) by Dstl.

Casualty estimation is undertaken in support of both operational planning and long term defence planning. Due to the different requirements and constraints of each a range of approaches have been developed based on both historical analysis and combat simulation.

Due to the difficulty of generating appropriate casualty estimates through simulation alone, validation of the casualty estimates derived from simulations is important. It is increasingly necessary to be able to estimate the number of casualties due to combat accidents and friendly fire. Analysis of medical requirements requires estimation of disease and non-battle injuries as well as battle casualties and the number of wounded enemy prisoners of war and civilians likely to enter the military medical support chain. Also, a clear understanding of the level of uncertainty in the casualty estimates is important.

Introduction

Background

The Directorate of Equipment Capability (Expeditionary Logistics and Support) is responsible for identifying future UK medical support equipment requirements. Estimating the number of casualties that could be sustained on future operations is clearly fundamental. This paper summaries the findings of a review of casualty estimation techniques undertaken recently for DEC(ELS) by Dstl.

Scope

Casualty estimation is undertaken in support of both operational planning and long term defence planning.

Analysis in support of operational planning tends to be undertaken to very short timescales and, particularly in the early stages of the operation, the level of information available on own and enemy forces and capabilities tends to be limited. Both factors tend to limit the level of detail of the analysis that can be conducted.

- Long-term defence planning is undertaken by MoD centre and the timescales for decision making tend to be much longer than for operational planning. As a consequence more detailed analysis can generally be conducted. Analysis in support of long-term defence planning can be broadly categorised into three main types:

- Force Structure Analysis. Evaluation of overall balance required between services and between arms of each service. It is broad in scope but does not generally require a detailed representation of equipment characteristics.
- Equipment Investment Analysis. Analysis generally in support of equipment acquisition that is narrower in scope than Force Structure Analysis but with a more detailed representation of equipment characteristics.

Analysis supporting other long-term defence planning issues including organisation of forces. Analysis to determine the best way to organise forces within a force structure (as distinct from the size of different arms within the structure), balance between active and reserve components, personnel issues etc.

For both operational support and long term defence planning, casualty estimation can be conducted:

- as the final element of an analysis in order to identify the impact of a factor, such as number or type of military forces employed, on a high level measure of merit (ie the number of casualties sustained);
- as a starting point for an analysis of the number or balance of medical capabilities required.

Also both operational support and long term defence planning can require casualty estimation for either the whole campaign or for a single engagement. Analysis of medical requirements requires estimation of Disease and Non-Battle Injuries (DNBI) as well as battle casualties.

As a consequence of these different requirements a wide variety of techniques have been developed. No single technique is likely to be suitable in all circumstances.

Classifying casualties

Introduction

There is no single complete classification system for casualties, nor, because of the inherent complexity of the issues is one likely to be universally adopted. In any analysis it is therefore important to recognise and document the issues of classification and the inherent assumptions in data sources used.

Interpreting historical records of casualty numbers

Casualties are generally divided into Battle Casualties and Disease and Non-battle Injuries (DNBI). UK doctrine[1] defines a casualty as ‘any person who is lost to the organisation by reason of having been declared dead, wounded, injured, diseased, detained, captured or missing’ and battle casualties as those ‘incurred as the direct result of hostile action, [or] sustained in combat or relating thereto or sustained going to or returning from a combat mission’.

The definition of battle casualties is therefore much broader than just those killed or injured by the enemy but includes, among other things, deaths and injuries due to:

[1] Joint Warfare Publication 4-03 Joint Medical Doctrine.

- accidents such as falls or drowning occurring in combat;
- accidents involving vehicles or helicopters taking troops into combat;
- accidental weapon discharge or exploding ordnance;
- incidents of ‘fratricide’, ‘amicide’ or ‘friendly fire’;
- battle stress.

Battle casualties also include not only those killed or injured but also those captured by the enemy. In historical records, when a force is defeated the number captured frequently significantly outnumber those killed or wounded. When estimating casualty numbers to support analysis of medical support requirements it is clearly important not to include casualties who do not enter the medical support chain.

Battle Casualties are frequently categorised as:

- Killed in Action (KIA). Battle casualties who die before entering the medical support chain.
- Died of Wounds (DOW). Battle casualties who die after entering the medical support chain. In practice an upper time limit may also apply, whether formal or *de facto*[2]. Frequently DOW are subsumed within KIA numbers in historical records.
- Wounded in Action (WIA). Generally this only includes wounds serious enough to require admission into, as opposed to attendance at, a medical facility; lighter wounds where the soldier is returned to duty after treatment without admission are frequently not recorded[3]. In a land environment a ‘medical facility’ is generally a field hospital, admission to which is a formal process where the responsibility for the soldier changes from his unit to the hospital. In a maritime environment personnel who cannot return to duty are entered onto the ‘sick list’.
- Missing in Action (MIA). Frequently initial casualty returns include a number of MIA. These may in fact have been killed or captured or may be absent without leave (AWOL). They are usually later re-classified as their actual status becomes known (or at least deduced).
- Captured in Action (CIA). CIA may be unwounded or may have been wounded and hence may also later die of their wounds. While in captivity they may be deliberately wounded or killed or may be injured or die through accident or natural causes.

There is no generally accepted categorisation of DNBI, although on several recent operations medical reporting of DNBI has used a scheme[4] comprising 16[5] disease categories based on the symptoms and 6 injury categories[6] based on the cause.

Key primary records used in developing reports of casualties from land operations are:

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[2] Soldiers who die several years after they received their wounds are unlikely to be captured in historical records.

[3] US practice is to record such casualties under the term ‘Carded for record only’. They represent a significant proportion of all casualties: in the Vietnam War some 25% of all US battle casualties.

[4] Originally developed in the UK as the J95 reporting form the scheme was adopted for NATO operations in Bosnia in 1996 under the name ‘EPINATO’ and later used in East Timor in 2001 and Iraq in 2003 under the name ‘EPIGULF’.

[5] With sub-categories this increase to 18.

[6] Including hostile action, which may therefore not count as DNBI.

- Unit records. Units report daily their strength and the reasons for changes from their previous strength, eg KIA, WIA. However, this may include a number of unresolved MIA and units will not necessarily record if someone WIA later dies of their wounds.
- Medical records. Most WIA enter the medical chain through the regimental aid post (Role 1), pass through a dressing station (Role 2) to a field hospital (Role 3). However, at each role some WIA may be treated and returned to duty and, conversely, some WIA may enter the medical chain at Roles 2 or 3. Consequently, medical records from different roles will show different numbers of WIA. Also, as the circumstances in which the wounds were received are frequently not recorded, it may be difficult to differentiate between WIA and non-battle injuries (NBI). Medical records from deployed medical units may not capture all cases of DOW as some may be repatriated and die much later. Information on the number of wounded enemy prisoners of war and civilian casualties will also be available from medical records.
- Where the enemy abides by the Geneva Conventions the names and status of CIA will be reported via the Red Cross.

Historical records in secondary sources generally rely on a range of primary source material; consolidating primary sources and resolving the inevitable inconsistencies is frequently non-trivial.

The concept of casualties '… sustained in combat or relating thereto or sustained going to or returning from a combat mission' requires interpretation and cannot be expected to have been applied consistently in historical records. Hence injuries received from enemy mines or unexploded ordnance or through accidents may be classified as KIA/WIA or NBI depending on the specific circumstances. In major combat operations such injuries are more likely to be reported as battle casualties when units are close or 'in contact' with enemy forces and more likely to be reported as NBI if they occur in the rear area. In other operations, particularly enduring operations such as peace support operations, injuries are likely to be reported as NBI unless they are directly attributable to hostile action[7].

Casualties 'in combat' caused by 'fratricide', 'amicide' or 'friendly fire' are categorised as battle casualties. Frequently historical records do not distinguish between casualties due to fratricide from those from other sources, either because it was not considered important or because it was not possible due to lack of information. Casualties arising other than 'in combat', for example due to accidental or negligent weapon discharges, are categorised as NBI. There is no clear definition of 'fratricide' as the plethora of terms used demonstrates[8].

[7] Thus injuries arising from mines are likely to be categorised as battle casualties if they occur in a deliberate intervention operation but non-battle injuries if they occur in a peace support operation.

[8] Any categorisation needs to recognise the range of circumstances that can apply including: accidental weapon discharge or ordnance explosion, accidentally entering a minefield laid by friendly forces, intentional use of a weapon accidentally hitting an unintended target, intentional use of a weapon against a target location believed to be occupied by the enemy in fact occupied by friendly forces, intended use of a weapon against a target that has been misidentified. In practice the first is rarely classed as fratricide, and the last usually with the remainder somewhere in between.

WIA can be categorised according to the severity of their wounds, most commonly using the NATO triage system P1, P2, P3. However, it should be recognised that this is a battlefield assessment of the patient's condition at that specific time and may not remain constant. Also, it is not generally logged in medical records and cannot necessarily be assessed after the event. Alternatively, classification can be based on whether or not the patient attends and/or is admitted to hospital or the length of stay in hospital.

The majority of casualties due to Battle Stress (BS) are likely to be unrecorded in historical records as they are treated at Role 1. Even for the more severe cases, those that are admitted to a hospital, it may be difficult from the medical records to distinguish between BS and other mental conditions. As attitudes to BS have changed over time so too has its reporting.

Casualty classification in Operational Analysis studies

When interpreting historical data it is important to consider the records as a whole, and how they were developed, in making judgements as to what is and is not included. If a category of casualty is not listed it may either have been combined with another or may not have been recorded. In general for secondary sources:

- During periods of sustained combat operations nearly all injuries incurred by combat units in contact with the enemy, howsoever caused, will be reported as battle casualties. During other operations only casualties directly attributable to hostile action will be so reported.
- Where DOW are not listed separately it can be assumed that they have been subsumed into the KIA total, apart from a very small proportion who died a long time after being wounded.
- Unless otherwise stated, WIA totals include only those with wounds serious enough to be admitted to a medical facility. This includes cases of battle stress, only a small proportion of which, the most serious cases, will therefore be reported.
- Where casualties arising from fratricide are not identified separately they are subsumed into the battle casualty totals.

When undertaking any analysis it is important to record the assumptions made in developing casualty estimates and therefore what categories of casualty are therefore included in the estimate. It should not generally be necessary to make estimates of the number of additional casualties not otherwise represented (eg accidents, fratricide, battle stress) unless:

- The numbers will be compared to casualty estimates from other sources using different assumptions. Clearly it is important to compare like with like.
- The casualty estimates are to be used as an input to an analysis, eg to determine medical support requirements, and the additional casualties are relevant to the analysis.

Where casualty estimates are derived from the output of campaign level combat models, which typically represent only attrition arising directly from enemy activity, it may be necessary to make estimates of the number of casualties arising from accidents during combat[9] and from friendly fire and the number of cases of battle stress requiring hospitalisation. However, if the casualty estimates derived from the combat models have been validated by comparison with historical data this may not be necessary as these will have been included in the historical data and therefore can be considered to have been subsumed within the validation. If estimates of additional casualties are made then any validation work may need to be revisited to ensure it remains consistent.

Battle Casualty Estimation Techniques

Introduction

In common with most military operational analysis there are two basic approaches to estimation of battle casualties: statistical analysis of historical data and *ab initio* simulation of combat operations.

The advantages of historical analysis based approaches are that they naturally include a range of human factor and organisational effects that are generally (at best) poorly represented in simulations. Also they are generally much quicker and simpler to use. Their disadvantages are that, being based on past conflicts, they may not be able to represent the changing nature of combat, such as the trend over time for the tempo of combat to increase. Also, since the data set is naturally limited, particularly if it is constrained to more recent conflicts, it is generally only possible to rigorously establish the effects of the most significant factors.

In general, only simulations can represent the impact of proposed changes to the composition or equipment of future forces on the outcome of an operation and thus inform Force Structure and Equipment Investment decisions. Shortcomings in simulations in representing human factors[10] and organisational effects should wherever possible be overcome by validation against historical analysis[11].

As a result generally in operational analysis historical analysis based approaches are most widely used in analysis in support of operations and simulations are most widely used in support of long term defence planning. A similar trend exists in battle casualty estimation techniques.

In a very limited number of cases, where no other method is available and where there is no historical precedent judgmental methods have been used, for example to estimate casualties from an unconventional BW attack.

Maritime Environment

The nature of maritime combat means that the time profile of casualties is likely to be highly peaked as individual ships are sunk. Different analytical approaches are therefore necessary when assessing average casualty numbers (for example when casualty levels

[9] Since the Falklands War, helicopter crashes have been a significant source of battle casualties in many UK operations. This is particularly true of battle deaths since the proportion of killed to wounded from such incidents is higher than the average.

[10] For a summary of the quantitative analysis of the impact of human factors issues on battle outcome see Dstl/WP/09987/1.0. *Differences between performance in real wars compared to simulators, trials and exercises*, dated March 2004.

[11] D/DG(S&A)/7/18/7. *Guidelines for the Verification and Validation of Operational Analysis*, dated Dec 2002.

are an output of the analysis) and assessing peak casualty numbers for analysis of medical capability requirements.

Maritime battle casualty estimation is generally conducted in two phases, estimation of the frequency with which ships are lost or damaged, usually through the use of a combat simulation, and analysis of the number of casualties arising when a ship is lost or damaged, whether from historical analysis or simulation.

The significant advances in maritime warfare since World War II and the paucity of data from maritime conflicts subsequently mean that historical analysis based approaches are little used in prediction of maritime battle casualties at the campaign level. Also, historical analysis[12] indicates that even during World War II the rate at which ships were hit in different combat operations varied by several orders of magnitude. Notwithstanding this, the UK Naval Manual of Logistics for Operations[13] includes flat casualty rates, and casualty breakdowns, for planning maritime and amphibious operations.

Maritime combat simulations, such as the UK models COMAND[14] and MCP[15] at the campaign level and ANSWER[16] and THREEDIM[17] at the engagement level, are typically stochastic. Consequently their output typically comprises average numbers of ships lost or damaged and probability distributions of ship losses over a number of replications, or chronologies of ship losses in individual replications. Where the output considers only ship losses it may be necessary to estimate the number of ships damaged but not lost.

Both historical analysis and simulation methods have been used to assess the number of casualties arising when a ship is lost or damaged. Historical analysis[12, 18, 19] is generally preferred. Estimates are available, expressed as the proportion of the ship's complement who become casualties when a ship is lost or damaged according to the type of attack (bomb/missile, torpedo, multiple attacks) and air superiority situation.

Simulations can also be used to assess the number of casualties arising when a ship is lost or damaged and may better represent future ship designs but are unlikely to represent all the mechanisms by which casualties arise. The SURVIVE model has been used, in the UK, to estimate battle casualties from blast effects[20] but it does not yet represent fire and smoke, nor does it represent the recovery of survivors in the water following the loss of a ship.

Calculation of average battle casualties from the average numbers of ships lost or damaged in a number of replications of the combat model is straightforward. Estimating peak casualties from the output from a stochastic model, for example for establishing the medical capability required, is more problematic. It is generally most appropriate to estimate the probability that casualties in a period of time do not exceed given levels by

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[12] Naval Health Research Center Report 95-13. *Casualty incidence during naval combat operations a matter of medical readiness*, dated 1996.
[13] CB 2002 *Naval Manual of Logistics for Operations Vol 2* dated Oct 2001.
[14] DSTL/LB09098/1.0. *COMAND Version 2.5 Model Validation Log Book*, dated July 2004.
[15] DSTL/LB09170/1.0. *Model validation logbook for the Maritime Campaign Program (MCP)*, dated December 2003.
[16] DERA/CDA/SEA/AIR/WP980088/3.0. *ANSWER Validation Log Book*, dated Jan 2001.
[17] CDA/NAVY/PN/WP960137 V4.0. *THREEDIM validation log book: THREEDIM version 9*, dated August, 2003.
[18] DERA/CDA/HLS/WP980186. *Review of SAG casualties by Historical Analysis*, dated Jan 1999.
[19] Naval Health Research Center. *Casualty Sustainment During Naval Warfare: Adjustments to World War II- Based Projections*, dated Dec 1995.
[20] See, for example, Dstl/CR02780/1.0. PCRC Novel explosives Study, dated Feb 2002.

considering the types of ship loss, singly or in combination, and the level of casualties that each would produce.

Land Environment[21]

Historical analysis based approaches

Historical analysis based approaches are widely used in the prediction of land battle casualties. There are a number of techniques currently in use. These can be subdivided into two types as follows:

- rate based approaches;
- more complex approaches using a number of factors to represent the nature of the operation identified as significant by statistical analysis of the historical data.

All historical analysis based approaches must balance between drawing data from the very limited number of recent conflicts and therefore being very constrained in the statistical analysis that can be undertaken, or, drawing from a much larger set of earlier operations which are less likely to reflect the nature of future warfare. The largest body of operational data remains that from World War II and this remains the basis of many historical analysis based approaches.

The use of historical analysis to predict casualty rates in future conflicts is sometimes criticised on the assumption that changes in the nature of combat have been too significant to make the past a reasonable guide to the future. Conversely, it has been demonstrated[22] that no significant increase in divisional casualty rates occurred between World War II and the 1967 and 1973 Arab-Israeli conflicts. Clearly, in more recent conflicts, such as the Gulf Wars in 1991 and 2003, UK casualty rates have been very low in comparison with earlier conflicts. While this may appear to invalidate historical analysis based approaches, in particular simple rate based approaches, equally such low rates are generally better predicted by the more sophisticated historical analysis based tools than by most combat simulations.

Rate based historical analysis approaches

In rate based approaches casualties are calculated as a daily percentage of the force, generally expressed as the Population At Risk (PAR) from a set of rates derived from historical analysis.

Both the UK and US historical analyses indicate that battle casualty rates are strongly correlated with the size of a formation, with smaller formations, when committed to combat, suffering much higher battle casualty rates as a proportion of their strength than larger formations. At each level a formation commits only a fraction of its sub-elements; consequently the rate across the formation is the average of the peak rate for the fraction of the elements committed and a very low rate for those elements not committed. Also that casualty rates vary significantly over time with significant peaks reflecting intense combat and longer periods of less intense activity. Typically the higher the peak rate the shorter the duration of the peak.

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[21] For a review of casualty calculators for operational support of land operations see DERA/CDA/CR010006/1.1. *Review of Land Force Casualty Calculators*, dated 2001.
[22] G Kuhn, Report FP703TR1. *Ground Force Casualty Rate Patterns – The Empirical Evidence*. Dated Sept 1989.

When using rate based approaches it is therefore important to select the appropriate rate:

- Rates should be applied to the appropriate size of formation for which they were derived and cannot be scaled up or down. In practice it can be non-trivial to equate current or future formations with those considered in the historical analysis as the size and structure of formations bearing the same name can change significantly over time (and between nations).
- Peak rates should only be applied for the appropriate duration. Wherever possible the duration of a peak should be drawn from the same historical analysis as the casualty rate, however, these data have not always been recorded. It is therefore common practice[23] to take the details of the planned operation and assign rates to different phases of the operation, however, this frequently leads to a significant overestimate of the total battle casualties as the duration of the peak is overestimated.

Examples of rate based approaches are the UK War Office rates incorporated in the PJHQ Joint Casualty Calculator[24], and the NATO casualty estimation methodology[25,26].

The UK War Office rates[27], developed by the Evett Committee during WWII and developed by the Army Operational Research Group (AORG) during the 1950's, identify casualty rates for divisions, and breakdown by arm, for 3 levels of intensity of combat (high, normal and quiet).

The NATO casualty estimation methodology is based on analysis by Kuhn of historical casualty rates from World War II, Korea and Arab Israeli conflicts in 1967 and 1973 together with US exercise data[22, 28]. It identifies peak one day casualty rates for formations from battalion to army size to be used for medical planning. Kuhn's original papers also provide an analysis of the duration of peak rates.

Factor based historical analysis approaches

This methodology is based on combining a series of factors that have been demonstrated to be significant by historical analysis. This method is typified by the work of Rowland[29] in the UK and Dupuy[30] and Hartley III[31] in the US. CHALICE[32] is a more recent UK approach.

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[23] See for example ACDS(L)/OMST/552/50. *Report of the Operational Medical Study Team*, dated June 1997.

[24] Goodman &Young, CORDA Report CR1025/3/TN/1 dated May 1997.

[25] ACE Directive Number 85-8. *ACE Medical Support Principles, Policies and Planning Parameters*, dated Oct 1993.

[26] SHAPE Report 2105.05/SHOLM/042/93. *Capability-Related Medical Support Planning*, dated 22 Feb 1993.

[27] Goodman & Richardson. DSc(Land) Note 5/95, CORDA Report CR3047/11/TR.2. *Casualty Estimation in Open and Guerrilla Warfare*, dated 1995.

[28] G Kuhn. *Ground Force Battle Casualty Rate Patterns. Uses in Casualty Estimation and Simulation Evaluation*, published in Proceedings of the 60th Military Operations Research Society Symposium, June 1992.

[29] DERA/CDA/HLS/CR990014 /1. *PJHQ Casualty Estimation*, dated March 2000.

[30] Historical Evaluation and Research Organisation Report Number 118. *Casualty Estimates for Contingencies*, dated 15 November 1985.

T N Dupuy, *Attrition: forecasting battle casualties and equipment losses in modern war*, Hero Books, Fairfax Virginia 1990.

[31] Dean S. Hartley III. *Predicting Combat Effects*. ISBN 1-877640-16-6, 2001.

Factor based approaches can represent much of the operational context and thus should give a much better estimate of battle casualty levels than simpler rate based approaches. Their sophistication is limited by the availability of historical data. Typical factors considered are the relative sizes of the opposing forces and their quality, type of operation and the environment.

The, often complex, calculations of casualties of factor based approaches can be combined into spreadsheets or simple computer models. UK models, based on Rowland's work, are SLAM[33] (brigade and above level), PJHQ Tac (company to battalion level) and SMICC[34]/GIT (fire team to company level). US models include:

- ACE, a spreadsheet version of the Dupuy's Quantified Judgmental Method (QJM), developed at the US Army Force Structure & Analysis Branch, Fort Sam Houston, San Antonio.
- The Oak Ridge Spreadsheet Battle Model[31] based on the analysis of Hartley III.
- FORECAS[35] and SLICECAS[36] based on the analysis of Blood.

Simulation

Complex computer based combat simulations are used in operational analysis to address a very wide range of issues and exist at both the engagement and the campaign level. Simulations require detailed orders of battle for each side in the conflict together with their operational plans. They can take weeks or months to set up and are therefore not often appropriate for supporting operational planning. They are however widely used to support long term defence planning.

Simpler simulations such as the Wartime Planning Tool (WPT)[37] have much shorter setup times and are used to support operational headquarters.

Few such models directly calculate battle casualties; however the attrition measures they typically output (equipment losses or reduction in strength of units) can generally be converted to casualty estimates by using data on the expected numbers of casualties per equipment lost drawn from historical analysis[18].

Models used in this manner in the UK include:

- Campaign level: CLARION[38];
- Formation/Brigade level: WISE[39], SIMBRIG[40], CLASS[41], WPT[37];

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[32] DSTL/PCS/SMC/5/1. *CHALICE Model Logsheet* dated 21 Feb 2005.
[33] Dstl/FLD/MWC/534650/TTAG/1.1. *SLAM Validation Log Book*, dated April 2003
[34] CDA/HLS/R9719/1.0. *SMICC Model Validation Log-Book*, dated April 1997
[35] Naval Health Research Centre Report 97-39. *Using the ground forces casualty forecasting system (FORECAS) to project casualty sustainment*, dated Sep 1997.
[36] Zouris JM and Blood CG. *Medical Resource Planning for Combat Operations: Utilizing Percentile Estimates as an Alternative to the Mean*. Journal of Medical Systems, Vol 24, No 6 2000.
[37] 1410.13/ARCSOA/94. *The Wartime Planning Tool a Description and User Guide*, dated January 1994.
[38] Dstl/LB07695. *CLARION v3.0 Model Validation Log Book*, dated July 2003.
[39] Dstl/LSD/104/21/17 V2.0a. *Wargame Infrastructure and Simulation Environment – Formation Wargame (WISE-FW) Validation Log Book*, dated July 2003.
[40] Dstl/LSD/104/21/25/1.0. *Simple Brigade Model Version 2 (SIMBRIG V2) Validation Log Book*, dated May 2004.

▪ Battlegroup level: JANUS[42], ATLAS[43], SIMBAT[44].

It is important to ensure a consistent approach between the historical analysis from which the estimate of casualties sustained per equipment lost is derived and the simulation output.

The focus of many combat simulations on combat equipment can make derivation of personnel losses problematic as, historically, the majority of personnel casualties are infantry. Also, in developing estimates of casualties from combat simulations it is frequently necessary to make assumptions about in what circumstances during the battle infantry are mounted in their vehicles or dismounted.

Many combat simulations do not represent all the elements of the force, such as logistics, artillery observers and headquarters, which may suffer casualties. In some cases casualties suffered by such elements are estimated from scaling factors derived from historical analysis.

Because of these difficulties, *ab inito* calculations of casualties from combat simulations should be wherever possible validated against historical data, particularly if the casualty estimates are to be used as an input to analysis of medical support requirements[45]. In the UK, models used to support MoD decision-making are subject to DG(S&A) guidelines on validation[46,], however, work supporting model validation[47] has not generally had validation of casualty estimates as a specific aim.

In analysis at the campaign level, UK forces are frequently operating as part of a coalition. The assumptions made about the role the UK forces undertake within the coalition plan significantly affect the estimate of the likely number and time profile of UK casualties. It can therefore be useful to compare the estimate of UK casualties with the overall coalition casualties. The number of UK casualties can be compared with the number of casualties that would have occurred if the total coalition casualties were evenly spread across the force, often known as 'fair share' casualties, to determine if the UK forces casualties were higher or lower than the average. Alternatively, casualty estimates can be developed for a set of cases in which UK forces undertake different roles within the coalition plan to understand the likely range of casualty numbers.

Other battle casualties

When estimating casualty numbers, particularly as part of an analysis of medical support capability, it may be necessary to consider:

▪ wounded enemy prisoners of war (EPW);

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[41] DSTL/LB01238/3.0. *PC CLASS version 5: Validation log book*, dated Jun 2004.
[42] *JANUS UK version 2.00.00 model validation log book*, dated Jan 2003.
[43] DERA/CDA/LAND/CR/97067/2.30. *ATLAS Model Validation Log Book (V 7.23KC)*, dated September 2002.
[44] DSTL/LB/0436/5.0. *SIMBAT Model Validation Logbook Version 5.0*, dated Apr 2004.
[45] See for example, DSTL/TR18195. *Validation of casualty estimates from the CLARION land campaign model,* dated Jan 2006.
[46] UK Ministry OF Defence, Deputy Chief Scientist (Scrutiny & Analysis). *Guidelines for the Verification and Validation of Operational Analysis Modelling Capabilities*, dated 2002.
[47] For example:

- DERA/CDA/HLS/CR980180/1.0. *CLARION Validation Exercises FY98/99*, dated Jan 1999;
- DERA/CDA/LAND/AIR/CR000001. *Battlegroup Level Validation Study – (BATUS / SIMBAT)*, dated Feb 2000.

- civilian casualties;
- battle casualties arising other than from direct hostile action including accidents and ‘fratricide’, ‘amicide’ or ‘friendly fire’ casualties.

A limited body of historical analysis exists for the incidence of wounded EPW[48], civilian[49] and friendly fire casualties[50].

Estimates of the incidence of wounded EPW, civilian and friendly fire casualties are frequently made by assessing the ratio of the number of these casualties to the number of battle casualties in historical operations and deriving scaling factors to apply to estimates of battle casualties derived from simulations. However, there is not necessarily any *a priori* reason to assume the number of wounded EPW, civilian and friendly fire casualties are correlated with the number of casualties incurred as a direct result of hostile action and thus that such an approach is valid. Analysis of friendly fire incidents[50] has indicated a great variation in the proportion of total battle casualties represented by friendly fire in different campaigns, suggesting no such correlation exists[51]. Similarly, there appears a strong case for the number of casualties arising from accidents in combat being related to the population at risk, as with NBI, rather than the number of casualties sustained.

Even where such an approach proves appropriate in developing estimates of total casualties over a campaign, it is unlikely to be appropriate to use it in the calculation of peak daily rates as the ratio is likely to vary significantly over the phases of the operation. For example, in Op TELIC, whilst over the whole operation UK Field Hospitals treated significantly more EPW and civilian battle casualties than UK and coalition battle casualties, this ratio was reversed during the peak period of warfighting[52].

Estimates of EPW casualties can also be made from analysis of combat simulation runs by estimating enemy casualty numbers, in the same manner as friendly casualty numbers, and making assumptions about the proportion of such casualties that might be expected to be taken prisoner based on the tactical circumstances.

Air Environment

There has been little analysis of battle casualty rates from air operations, largely due to the small number of casualties expected relative to maritime and, particularly, land operations.

Both historical analysis[53] and air combat simulations, such as COMAND[54], can be used to estimate aircraft attrition rates. The NATO casualty estimation methodology[25] includes

48 Dstl/CR06221/1.0. *A further review of Prisoner of War Proportions*, dated Feb 2003.

49 Dstl/TR051 69/1 .0. *The Effects of Rubble on Urban Close Combat*, dated Feb 2003.
Dstl/CR13135. *Historical Analysis of Collateral Damage*, dated Dec 2004.

50 Dstl/CR03804/1.0. *Land Fratricide and IFF OA Review,* dated May 2002. See also Dstl/WP08280. *A catalogue and analysis of amicidal incidents*, dated August 2004.

51 It may be possible, through a full statistical analysis of friendly fire casualties, to identify an alternative parameter, such as Blue force size or the number of Red casualties, which is correlated with the number of friendly fire casualties. This would be useful both in making casualty estimates and in assessing the effectiveness of developments in IFF processes and technologies.

52 Academic Department of Military Emergency Medicine at the Royal Centre for Defence Medicine. *Operational Surgical Services Review - Final Report,* Dec 2004.

53 DERA/CDA/HLS/CR990047/1.0. *PJHQ Air Casualty Calculator*, dated Jul 2004.

54 DSTL/LB09098/1.0. *COMAND Version 2.5 Model Validation Log Book*, dated July 2004.

peak casualty rates, and casualty breakdowns, for planning air operations, although, unlike the equivalent land operation casualty rates, these do not appear to be based on historical analysis.

Estimates of the casualty rate per aircraft lost are available from historical analysis[18].

Estimates of civilian casualties caused by air operations have been derived from historical analysis and through analysis of weapon effects[55]. Casualty estimates from the Collateral Damage Model[56] can be used to support operational planning.

Estimation of Casualties from Chemical, Biological, Radiological and Nuclear Weapons

Estimation of casualties from chemical weapons (CW), biological weapons (BW), Radiological weapons (RW) and Nuclear Weapons (NW) relies almost exclusively on simulation, although some historical data exist on the effects of CW from World War 1[57].

HPAC[58] is a detailed simulation of the dispersion and effects of CW, BW, RW and NW. In addition, the aggregated effects of CW, non-infectious BW and NW can be modelled in CLARION[38].

Due to the limitations of combat simulations in supporting operational planning, the output of systematic runs of detailed simulations has been analysed to inform NATO planning guidelines on the effects of CW, BW and NW[59]. CREST is a software support tool for planning using these guidelines.

Judgmental methods

Judgmental methods rely on the views of military officers, scientists or other experts either individually, by interview or questionnaire, or collectively, at a Military Judgement Panel (MJP) or similar. The resulting casualty numbers are thus highly subjective. Such methods have been used for casualty estimation where no other method is available and where there is no historical precedent, for example to estimate the casualties from a BW attack on a military catering facility[60].

Since casualty estimates are necessarily quantitative there is significant benefit in sampling individually as the level of uncertainty can be ascertained. Conversely, a MJP can bring individuals with different expertise together to synthesise a judgement (in the example above it could bring together individuals with expertise in military catering, terrorist operations and medical officers). A MJP is often viewed as a good method of getting acceptance of the output of a study in the stakeholder community. If this is all that is required it could be held to review the results of the individual data collection exercise.

When soliciting judgements it is useful to structure the questioning so as to elicit the mental model underlying the judgement. This can both improve the quality of the

[55] *Research into collateral risk from air-to-surface weapons*. Journal of Defence Science, Volume 7, Number 1, Jan 2002.
[56] Dstl/LB09714/1.0. *UK Collateral Damage Model (CDM) v2 Model Validation Logbook*, dated Mar 2004.
[57] DERA/CDA/HLS/CR971028/1.0. *Historical Analysis of Chemical Warfare*, dated 1998.
[58] Dstl/CR04076. *Verification and validation of SCIPUFF model of atmospheric dispersion: Final report*, dated Jun 2002.
[59] NATO STANNAG 2475 *Medical Planning Guide of NBC Battle Casualties* AMedP-8(A).
[60] DERA/CDA/HLS/CR000194/1.0..*Casualties project - additional BW modelling*, dated Jan 01.

judgement and help the judgement to be defended against criticism. In the study above the operation of the catering facility, numbers of customers and hygiene procedures and the method by which the attack could be made need to be discussed before an estimate of casualties is developed. Asking an individual to make a quantitative judgement outside his direct personal experience without this type of preparation is likely to result in a poor quality estimate.

Guidelines for Selecting Appropriate Casualty Estimation Techniques

Analysis involving casualty estimation is conducted in support of both operational planning and long term defence planning. Also the casualty estimate may be an output of the analysis and be considered as one of the measures of effectiveness[61], for example in Course of Action selection in operational planning or in balance of investment analysis in long term defence planning. Alternatively it may be an input to further analysis of the medical capability required, whether it is deciding what should be deployed in operational planning or what should be procured in long term defence planning.

When deciding whether a casualty estimation technique is appropriate to be used in a particular analysis, a key issue is the balance between accuracy and sensitivity. In general, for analysis in support of Course of Action selection in operational planning and for balance of investment analysis in long term defence planning it is not necessary to have the best possible estimate of the casualty levels, rather, it is essential that the approach is sensitive to changes in the options under consideration even if it only gives an indication of relative casualty levels. In contrast, for analysis supporting decisions about the level of medical capability required, whether in operational planning or long term defence planning, it is important to have the best absolute estimate of casualty numbers. Thus, in general:

- Analysis in support of Course of Action selection in operational planning uses both simulation based approaches and factor based historical analysis approaches, although the latter tend to be preferred due to the short timescales on which such analysis is typically conducted which can constrain the use of complex simulation models.
- Analysis supporting decisions about the level of medical capability required in operational planning uses historically based approaches almost exclusively.
- Balance of investment analysis in long term defence planning uses simulation based approaches. Only these allow the necessary discrimination between options.
- Analysis supporting decisions about the level of medical capability required in long term defence planning typically uses simulation based approaches because:
    - casualty estimates from combat simulations are frequently available from past studies for a range of planning scenarios;
    - combat simulations provide not only the number of casualties but also the time profile of casualties and their locations.

[61] More properly as a measure of merit. See, for example, RTO Technical Report AC/323(SAS-027)TP/39. *Handbook on the Analysis of Smaller-Scale Contingency Operations in Long Term Defence Planning*, dated July 2004 for a discussion of the hierarchy of measures of merit and guidelines for establishing appropriate measures of merit for an analysis.

As such approaches on their own do not give the best absolute estimate of casualty numbers it is important that the casualty estimates the simulations produce are appropriately validated against historical events.

Where analysis is supporting decisions about the level of medical capability required, whether for operational planning or long term defence planning, it is important that all sources of casualties that will require treatment are considered, including battle casualties suffered by non-combat arms, DNBI, fratricide, EPW and civilians.

Estimation of Disease and Non-Battle Injury (DNBI) Casualty Rates

Disease and Non-Battle Injuries (DNBI) casualty rates are exclusively estimated from historical analysis. Uniform daily rates are widely used. UK planning rates for maritime operations are detailed in the Naval Manual for Logistics for Operations[13]. UK planning rates for land and air operations[62] are taken from NATO guidelines[25] based on historical rates from World War II, Korean and Vietnam. Mean DNBI rates from more recent operations are often also used[63].

In practice, DNBI rates are known to be non-uniform during an operation and are also believed to vary significantly between theatres[24]. To date there has been little systematic evaluation of these factors for UK forces. Dstl Policy and Capability Studies, under funding from PJHQ J5(OA), is currently collating all the UK DNBI data available from recent operations and exercises for the Medical Operational Planning Tool[64]. In the US, Blood has undertaken significant analysis of US Navy Data[65, 66] while Kuhn is developing a new DNBI calculation methodology for land forces[67].

Casualty rate confidence levels

Introduction

In planning medical support requirements it is necessary to take appropriate account of the uncertainty inherent in any estimate of peak battle casualty numbers. Where it is possible to do so, usual UK practice, drawn from NATO guidelines[25], is to base medical support requirements on the 75th percentile of the distribution of peak battle casualty estimates, as a reasonable worst case, rather than the mean or median.

Maritime Environment

In the maritime environment the profile of battle casualties is highly peaked as ships are lost. Distributions of peak casualties can be calculated for individual ships being lost or for several ships being lost within a short period of time.

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[62] Army Code 71038. *Land Component Handbook (SOHB) Issue 1*, dated July 2002.
[63] See for example *PJHQ J5(OA) Casualty Estimation Web-Site Version 1.0*, dated May 2003.
[64] *Medical Operational Planning Tool (MOPT) Log Book*. To be published.
[65] Naval Health Research Center Report 88-42. *Navy Medical Resource Planning : Rates Of Illness For Various Operational Theaters*, dated 1998.
[66] Naval Health Research Center Report 93-12. *Comparisons of disease and nonbattle injury incidence across various military operations,* dated 1993.
[67] Minutes of international meeting on casualty figure generation methodology held 5th July 2004 at Dstl Farnborough.

For a single ship being hit the distribution of casualty numbers observed in historical analysis[68] indicates the 75th percentile is approximately 1.5 times the mean figures.

The probability that two or more ships will be hit within a short period of time (that is such that the casualties from the second event compete for resources with the casualties from the first) can be estimated from the output of multiple replications of a stochastic combat simulation. If the probability of this occurring is significant, several ships being lost with the mean number of casualties may replace a single ship being lost with higher than average casualties as an appropriate basis for medical planning.

Land Environment

The NATO peak daily battle casualty rates[25] are drawn from historical analysis[22, 28] and represent the 75th percentile of daily rates observed. However, days for which the divisional total battle casualty rate was less than <0.5% were excluded from the analysis on the assumption that this figure represented a lower boundary of significant combat intensity. If all combat days are included then the proportion of the most intense days is reduced and level of assurance given by the planning figure is actually more than the 90th percentile, that is a higher rate is likely to occur less than one day in 10[69, 70].

UK peak daily battle casualty rates are usually derived from OA combat modelling, which in the land environment is frequently deterministic, particularly at the operational level. Estimating the 75th percentile casualties for medical planning in this case is therefore problematic.

Factors have been developed to estimate the 75th percentile casualties from the output of deterministic combat models, taken to represent the median, from the distributions of peak casualty rates observed from historical data[68]. Statistical analysis of historical data showed that:

- for the operational-level data the 75th percentile is approximately 2 times the median;
- for the tactical-level data the 75th percentile is approximately 1.3 times the median.

These factors have been used to estimate the 75th percentile casualties from the output of deterministic combat models for use in planning medical support requirements.

An alternative approach to estimating the distribution of casualty rates for a formation is to consider the distribution of rates among all formations of that size within the campaign (for example a UK division operating within a coalition comprising several divisions)[45]. This approach recognises that judgements made in the development of a planning scenario, such as the role a formation plays within the campaign, can have a significant affect on the estimate of casualties. This approach may also be appropriate when using a stochastic model as the resultant distribution of casualty rates may be greater than that caused by the stochastic processes in the modelling.

Where it has not been possible to estimate the distribution of battle casualty rates an alternative has been to consider the worst single case of those modelled as representing a reasonable case for planning medical support provision[71].

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[68] Dstl/CR14209/1.0. *Guide to Casualty Estimation*, dated March 2005.
[69] CDA/HLS/R9709/1.0. *Support to OMST Phase 1*, dated June 1997.
[70] DCS(S&A)4/2/3 (63-98), 19 March 1998.
[71] DMSD/32.12. *The Future Manpower Requirement of the Defence Medical Services - A Paper for PPSG, AD/1* circulation*, dated 18 May 2006.

Air Environment

No analysis of the distribution of casualty rates in the air environment has been undertaken in the UK.

Summary and Conclusions

Casualty estimation is undertaken in support of both operational planning and long term defence planning. Analysis in support of operational planning tends to be undertaken to very short timescales and, particularly in the early stages of the operation, the level of information available on own and enemy forces and capabilities tends to be limited. Both factors tend to limit the level of detail of the analysis that can be conducted. Long-term defence planning is undertaken by MoD centre and the timescales for decision making tend to be much longer than for operational planning. As a consequence more detailed analysis can generally be conducted.

For both operational support and long term defence planning casualty estimation can be conducted as the final element of an analysis, as a high level measure of merit or as a starting point for an analysis of the medical capabilities required. Analysis of medical requirements requires estimation of Disease and Non-Battle Injuries (DNBI) as well as battle casualties.

As a consequence of these different requirements a wide variety of techniques have been developed. No single technique is likely to be suitable in all circumstances.

Techniques for casualty estimation can be broadly categorised as either historical analysis based or simulation based, although elements of both approaches are frequently combined. Due to the difficulty of generating appropriate casualty estimates through simulation alone, validation of the casualty estimates derived from simulations is important.

In planning medical support requirements it is necessary to take appropriate account of the uncertainty inherent in any estimate of peak battle casualty numbers. The method by which this is done needs to be appropriate to the analysis and, again, no single technique is likely to be suitable in all circumstances.