My Wargaming Urban Conflict Working Papers are short papers that probably don't merit peer review yet, but which contain information which will hopefully be of interest to the wargaming and urban conflict community, and which I can publish in a more timely way than through a journal. Any comments are welcome as are pointers to any errors and omissions. More information on my PhD in Wargaming Urban Conflict is at http://taunoyen.com/wiki/doku.php?id=phd and you can contact me at david@burden.name.

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Derivation of Combat Factors

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"In our view, the DoD does not appreciate that in many cases the models are built on a base of sand. Nor does it appreciate that while replacing the sand with a more nearly solid foundation is feasible, it will be extremely difficult in scientific, intellectual, and managerial terms." (Davis & Blumenthal, 1991)

Introduction

In almost any (rigid) wargame, represented units have "combat factors", a measure of their ability to fight. Such a combat factor (CF) might be homogenous – representing a single weapon type (e.g. against personnel, armour, structures, aircraft, drones etc), or heterogenous – representing a combined arms combat with a mix of capabilities. As a result of combat the combat factors may be reduced, typically in "steps", until such time as the unit is eliminated.

For the purposes of my research, the need to derive combat factors is complicated by the fact that I am interested in urban combat factors. Urban engagements are typically at short range (Collins & Spencer, 2025), existing urban structures can provide solid cover – necessitating more use of direct HE and "anti-structure" weapons and munitions (Dick, 2006), and it is commonly believed that ammunition expenditures are far high than in rural (Spencer & Geroux, 2022). These dichotomies of homogeneous/heterogeneous and rural/urban result in a 2x2 grid which needs to be filled, shown in Figure 1.

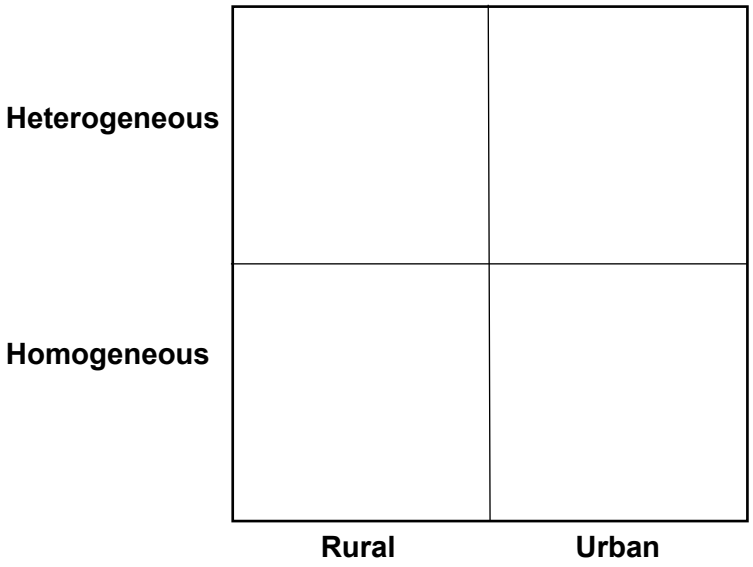

Figure 1: A 2x2 grid of Required Combat Factors

This working paper set out trying to establish a framework for the calculation of combat factors in my urban wargames. Some games, such as OPUC and City & CEMA require a heterogeneous combat factor (i.e. one factor covering multiple weapon types), whereas others, such as Rubble Town and Brick By Bloody Brick require homogenous combat factors (one per weapon type). However, as is discussed below, such a unified framework approach does not seem viable given the discrepancies between sources and the lack of transparency in almost all of them. As a result a more pragmatic approach is considered at the end of the paper.

In order to try and keep this paper readable, all of the detail for each section has been placed in annexes, with only the discussion kept in the main body.

Note that this is just a first step in developing a robust model of the wargame “kill chain”, as once combat factors have been deduced the resulting casualty/damage and attrition rates and mechanics will also need to be developed through similar research.

Sources

In putting this Research Note together I have consulted a number of sources from the literature. These include:

- Lanchester (Lanchester, 1956), and related work;
- Dupuy (Dupuy, 1987) and related work;
- Lawrence’s *War By Numbers* (Lawrence, 2017), a derivative of Dupuy’s work;
- Helmbold’s The Key to Victory (Helmbold, 2021) and related work;
- Rowland (Rowland, 2006) and related work;
- Hogg’s *Correlation of Forces* (Hogg, 1993) and related works;
- Official sources, such as Cold War Era Fighting Exercise (FTX) umpire handbooks (US and UK), and Staff Officer Handbooks; and
- Existing wargame rules where they have well documented sources for their combat factors.

Others no doubt exist and as identified will be used to enhance further versions of this paper. The paper will look at each of the currently identified sources, considering both their general view on combat factors and any urban specific observations, before comparing the different approaches

to form the basis of Combat Factor derivation for homogenous and heterogenous wargame factors to support my wargames.

Wargames as a Theory of Combat

In *Understanding War* Dupuy talks about the importance of developing a Theory of Combat – and through the Quantified Judgment Model (QJM) that is what he seeks to present (Dupuy, 1987). Dupuy notes that such a model should:

- Identify the major elements of combat and the combat processes through which they operate and patterns in interactions and relationships among them;
- Describe combat, structures, and patterns of interactions and relationships of variable factors that constantly shape or determine the outcome of combat;
- Express in quantitative terms, the patterns so identified and described.

It strikes me that that is also what every wargame is trying to do, and as such every wargame is a theory of combat, either that of the wargame's designer, or a manifestation of someone else's.

Combat Models

Five types of combat mode were identified by Lawrence (Lawrence, 2017)(Ch.18), which accounted for 85% of the 150 models he examined:

- Historical data based one-sided look up tables;
- Monte-Carlo simulations;
- Force ratio/Firepower score models;
- Lanchester type models; and
- A hierarchy of models (e.g. RAND's JICM).

A similar typology is in Farmer (Farmer, 1980). Most of those discussed below fall within the Force ratio/Firepower score category, with some examples of one-sided look-up tables (particularly in the military manuals), although Lanchester is also considered. Monte-Carlo and Lanchester are both best suited to computer simulation rather than wargaming. The hierarchy of models approach, whilst attractive has faced ongoing problems with getting the models at each level to interact correctly (Lawrence, 2017)(p.295).

Christian notes the issues that many force ratio systems failed to account for specialist weapons (e.g. the difference in performance of ATGWs vs armour and vs infantry), emphasising the need for "two-sided" tables, and was of the opinion that "*The Army must differentiate force ratios from correlation of forces models. Force ratios should be abandoned as invalid heuristics. Correlation of forces models, with some effort, may provide utility to planners if they can be separated from force ratios and altered to present the results of its comparison in terms of anticipated effects and expenditures. By continuing to present results in the form of a force ratio that is not valid to begin with, the tool will lack utility*." (Christian, 2019)

The Combat Potential and the Sum Product Approach

Many of the methods examined below use some variation of the combat potential and sum product approach – a subset of Lawrence's Firepower score model – so it is useful to describe the common features up front. In this approach each weapon/system type is given a rating (the combat potential) relative to a reference (e.g. an M1A2), and then the number of weapons/systems of each type in a unit are multiplied by the rating for the relevant type, and the numbers simply summed. The equation is shown in Figure 2. As described by Reach (Reach et al., 2020)(p.32)

"where X_i is the number of friendly assets or formations of type i, of I total possible types of friendly weapons or assets (forces). X_j is the number of enemy assets or formations of type j, of J total possible types of friendly weapons or assets (forces). C_i is the combat potential of a friendly type i asset or formation. Similarly, C_j is the combat potential of an enemy type j asset or formation."

$$COFM = \frac{P_A}{P_B} = \frac{\sum_{i=1}^{i=I} X_i C_i}{\sum_{j=1}^{j=J} X_j C_j}$$

Figure 2: The standard Combat Potential/Sum-Product equation (after Reach et al, 2020)

Lanchester (1914)

Frederick W Lanchester is considered to be one of the founding fathers of operational research (McCloskey, 1956). His initial OR work was on air combat, and from that he developed his two laws of attrition – although equivalent equations were also being developed in parallel by the Russian M. Osipov (Helmbold, 1993; Wrigge et al., 1995) and Americans B.A. Fiske and Lieutenant (later Rear Admiral) Jehu Valentine Chase (Priska et al., 2022).

Figure 3: A plaque on Frederick Lanchester's House, 200m from where I live!

Lanchester presented two differential equations to assess the rate of casualties inflicted by two sides fighting, one for aimed fore (known as the square law), and one for unaimed fire (e.g. from fragmentation). From the square law the fighting strength of a force can be expressed as:

$$\text{Fighting Strength} = PN^2$$

Where P= efficiency and N = number fighting (Christian, 2019; Flanagan et al., 2024).

For heterogenous forces (i.e. comprised of a mix of different weapons) the equations were then extended to the sum-product model described above (Farmer, 1980)

$$\text{Fighting Strength} = \left(\sum_{i=1}^{n} \sqrt{P_i}\, N_i\right)^2$$

Where P = probability of hit for weapon type i, and N the number of weapons of type i. Note that P is square-rooted before being squared with N so as to maintain the square law effect on numbers not efficiency. However is has been noted that such a breakdown potentially invalidates the core assumptions and expression of the Lanchester equations (Lepingwell, 1987).

More detail of the equations is shown at Annex A, which also presents some of the challenges to Lanchester's equations. For the current task, Lanchester does not seem appropriate as the intended wargames are a) manual and b) involve the chaotic terrain of the urban battle (not the relatively sterile environment of air or sea warfare). However, several of the methods below are influenced by Lanchester, although it is interesting to note that the squaring of numerical strengths appears to be lacking from all of them – but perhaps returns when actual loss rates are calculated?

Dupuy (1979)

Trevor Dupuy served in the Second World War, in SHAPE and the US War Department, and after moving into military education set up his consultancy, Historical Evaluation and Research Organization (now the Dupuy Institute) in 1962. His aim was to develop a theory of war, ultimately manifest as the Quantified Judgement Method (QJM), and documenting his work in several works, including *Numbers, Predictions and War* (Dupuy, 1979), *Understanding War: History of Theory of Combat* (Dupuy, 1987) and *Attrition: Forecasting Battle Casualties and Equipment Losses in Modern War* (Dupuy, 1990). His own theory of combat grew out of the 1977 Leesburg conference, and an invitation to work on the problem from SRI and the US Navy Post-Graduate School. He describes it as an inductive approach, and one that is closely mirrored by the Soviet approach of Correlation of Forces and Means (as described below). (Dupuy, 1987)(Ch. 5 & 6).

Dupuy briefly considers the history of the 3:1 attack ratio, noting that from historical data whilst attacks at 3:1 result in near certain victory for the attacker, and attacks at a 1.5:1 ratio near certain defeat, most attacks are stages at odds within that range (e.g. 2:1) making pure force numbers ratios often useless (Dupuy, 1987)(Ch. 4). The diminishing returns beyond 2:1 are also noted.

The main components of QJM are (Dupuy, 1987)(Ch. 8):

- `Theoretical Lethality Index (TLI) = Rate of Fire x Reliability x Accuracy x Targets per Strike x Range`
  - TLI is assessed for 6 classes of weapon: Infantry, Artillery, Armor, Air Support, Air Defence, Anti-Armour
- `Operational Lethality Index (OLI) = TLI / Dispersion Index (DI)`
  - Where the Dispersion Index reflects the increased dispersion on the battlefield – and hence ability to bring weapons to bear on a target, and which has risen from 3000 in WW2 to 4000 in 1970s, to 5000 in 1980s. There is no explicit derivation for DI, but is seems to come out that DI = sqm per man. (from Lawrence Ch 13 DI of 3000 = 333 men per sq km, Sqrt(3000) = 55m
- `Force Strength (S) = SumProduct of all OLI x Weapon Effect Factor (V or` V_w`) x Number of Weapons per category`
  - Weapon Effect Factors are not explicitly explained, but probably include environmental and operational factors, incl terrain and posture

- Combat Power (P) = Force Strength (S) x Variable Factors (V_f) x Combat Effectiveness Value (CEV)
    - Where:
        - S = W x V_w and W = SumProduct (OLI x Number of Weapons per category)
        - Vf includes environmental and posture effects (so some overlap with V_w?)
        - CEV is a quality/morale of troops measure, derived by the difference between theoretical and actual outcome (!)

Whilst Dupuy presents Defence Factors (in V_f?) for a variety of situations none of these are urban specific.

Other useful information from *Understanding War* includes:

- Casualty rates lower for victor (but may have more absolute casualties due to higher troop numbers)
- Improvements in lethality being offset by increased dispersion
- Typical 4:1 wounded to killed ratio
- Suppression is more determined by ROF not calibre (so faster 105mm better than slower 155mm), and can possibly be represented as a temporary reduction in CEV.

For the current task there are 4 potential uses of Dupuy that I can see at the moment:

- For the homogenous case the TLI/OLI values and calculation might be a way of deriving per weapon system combat factors;
- For the heterogeneous case Force Strength (S), or Force Strength x CEV could provide the basis for unit factors;
- The various variable factors (V_f) could be of use in guiding wargame values; and
- The other Dupuy metrics could be useful to validate wargame models/rules against.

Dupuy's comments on force ratios are particularly interesting from a (board) wargame standpoint as they seem to completely invalidate the classic ratio Combat Results Table (CRT) which may have odds ranging from 1:5 to 5:1 (or higher). Rather the CRT should focus on the 1:1 to 2:1 region, but within that specific ratios aren't a good guide to success.

Annex B provides more detail on Dupuy and QJM, but the underlying databases and the real detail of QJM are the Dupuy Institutes "crown jewels" and so are not available to independently verify or to check derivations (such as what is in V_w and what is in V_f). Annex B also provides a summary of the criticism of Dupuy. From my reading of Dupuy I also have a feeling that some of the numbers is are bit soft (despite all being to 2 decimal places), and that there are often fudge factors, which are set so that the equation outputs them match the battles they were derived from. As noted above the best use of Dupuy may be in seeing whether wargames produce the sort of metrics he sees when examining historic battles, rather than in trying to use QJM itself.

McQuie provided an independent analysis of 260 battles between 1937 and 1982 using the Dupuy data for the US Army Concepts Analysis Agency (McQuie, 1988). The aim was to determine ranges and medians of various characteristics in order that "they may serve as criteria of credibility for the results of wargames and combat simulations". Only 1% of the battles were urban. McQuie highlights the problems with skewedness (asymmetry), a homogeneity in the data and a wide range of variability. The report presented two main tables – medians and bounds for "plausible" battles, and medians and bounds for "central" (i.e. most likely) battles, as shown in

Characteristic		Criteria		
		Lower	Median	Upper
INITIAL CONDITIONS				
Force ratio (atkr:dfdr)	-Men	.57:1	1.9:1	6.3:1
	-Mortars	.21:1	1.6:1	13:1
	-Guns	.24:1	1.7:1	15:1
Troop density (men/meter)	-Atkr	.45	2.5	9.3
	-Dfdr	.30	1.3	5.7
Weapon system density ("systems"/km)	-Atkr	24	82	600
	-Dfdr	3.7	71	610
Rifle squad density (squads/km)	-Atkr	1.1	30	120
	-Dfdr	1.3	6.7	80
Mortar density (weapons/km)	-Atkr	.76	13	110
	-Dfdr	.63	7.2	38
Antitank weapon density (weapons/km)	-Atkr	1.5	9.8	82
	-Dfdr	.59	4.2	75
Tank density (tanks/km)	-Atkr	2.9	18	80
	-Dfdr	1.3	6.9	45
Artillery density (weapons/km)	-Atkr	1.7	16	110
	-Dfdr	1.5	8.9	50
Air defense density (weapons/km)	-Atkr	2.2	7.1	35
	-Dfdr	1.1	5.0	36
Close air support density (sorties/km/day)	-Atkr	.31	5.5	43
	-Dfdr	.2	2.6	29
OUTCOMES				
Casualty rate (%/day)	-Atkr	0.2%	0.93%	5.5%
	-Dfdr	0.3	2.8	22
Casualty ratio	-(Atkr-Dfdr)	.08:1	.68:1	7.0:1
Tank loss rate (%/day)	-Atkr	0%	4.3%	44%
	-Dfdr	.5	12	53
Advance rate	-(km/day)	0	1.7	21
Combat intensity	-(hours/day)	3	10	19

(a) Plausibility Criteria

Characteristic		Criteria		
		Lower	Median	Upper
INITIAL CONDITIONS				
Force ratio (atkr:dfdr)	-Men	1.1:1	1.9:1	3.0:1
	-Mortars	.67:1	1.6:1	4.6:1
	-Guns	.87:1	1.7:1	3.7:1
Troop density (men/meter)	-Atkr	1.3	2.5	4.6
	-Dfdr	.72	1.3	1.9
Weapon system density ("systems"/km)	-Atkr	54	82	130
	-Dfdr	30	71	150
Rifle squad density (squads/km)	-Atkr	7.6	30	71
	-Dfdr	1.9	6.7	21
Mortar density (weapons/km)	-Atkr	5.0	13	36
	-Dfdr	3.2	7.2	13
Antitank weapon density (weapons/km)	-Atkr	4.6	9.8	19
	-Dfdr	2.2	4.2	13
Tank density (tanks/km)	-Atkr	9.7	18	31
	-Dfdr	3.5	6.9	14
Artillery density (weapons/km)	-Atkr	7.6	16	31
	-Dfdr	4.8	8.9	16
Air defense density (weapons/km)	-Atkr	4.5	7.1	14
	-Dfdr	2.9	5.0	12
Close air support density (sorties/km/day)	-Atkr	1.6	5.5	14
	-Dfdr	1.0	2.6	7.5
OUTCOMES				
Casualty rate (%/day)	-Atkr	.57%	.93%	2%
	-Dfdr	1.2	2.8	5.7
Casualty ratio	(atkr-dfdr)	.26:1	.68:1	1.8:1
Tank loss rate (%/day)	-Atkr	1.7%	4.3%	14%
	-Dfdr	4.9	12	27
Advance rate	(km/day)	.40	1.7	5
Combat intensity	(hours/day)	7.3	10	13

(b) Centrality Criteria

Table 1: Plausible and Centrality Criteria (after McQuie, 1988)

The report warns that a) the data is far from perfect and b) the next war is unlikely to be like the previous ones. There is no separate analysis for urban criteria, which is reasonable given that they represent 1% (so 2-3 battles) of the database. The report provides a proforma for use after a wargame to compare each of these criteria to its centrality in order to help validate the wargame.

Urban Effects

Dupuy has little specific on urban in *Understanding War*. His factors for QJM for hasty, prepared or fortified defence don't specify whether there is any difference between rural and urban defence. *Opposed Rates of Advance of Large Forces in Europe (ORALFORE)* (Dupuy & Hayes, 1972), whilst reiterating the defence factors above only lists "urban areas" as "exceptional terrain" and third in the list of environmental factors affecting rates of advance (after general terrain and weather), with all environmental factors rating below force ratios, force mixes, postures and military tasking.

Lawrence (2017)

Lawrence's *War By Numbers* (Lawrence, 2017) declares in its dedication that it is a "*continuation of his [Dupuy's] life's work*". In particular it has a further development of QJM, called the Tactical Numerical Deterministic Model (TNDM), which incorporates the passage of time (and so returns to differential equations as in Lanchester). No real detail on TNDM is presented (again one assumes as it's the commercial life-blood for the Dupuy Institute), and much of the book refines and extends information in Dupuy, looking at metrics derived from historical analysis. As with Dupuy the best of Lawrence may be in validating (rural) wargames, and in informing some combat factors (e.g. force multipliers from different postures). There is also some useful information on how different weapon types contribute to the casualty mix. Annex C provides more information, along with some of the criticism of Lawrence and TNDM – which reflect many of the same issues as for Dupuy.

Urban Effects

Lawrence devotes two chapters to urban (Lawrence, 2017)(Ch 16 & 17). His view (pointing the

finger at Russell Glenn) is that "*The fear of the effects of fighting in cities, or urban warfare, was one of these recent trends. I'm not sure where this trend got started, but it was certainly promulgated by RAND, whose reputation is such that even their bad ideas are given credence.*" p.206. Dupuy Institute produced a 3 part study on urban warfare in 2001 "*with an open mind*", most of which is summarised in *War By Numbers*. Key findings are:

- Average force ratio was twice as high in urban (1944 ETO, c. 140 engagements, 44 urban/conurban)
- All at < 1:1 failed in urban
- None at > 2.56:1 failed (but 20% of rural at that ratio did)
- Force ratio is main predictor of outcome (and outcome is the main driver of casualties)
- Attacker loss rate lower than rural (but higher force ratios, so absolute casualties may be higher) (see Figure 4)
- Lower advance rates (by around 66%, in cases where attacker advances)
- Conurban and urban similar
- "armor losses were fairly low in most of the urban operations examined" {but cause and effect?}
- There didn't seem to be a link between combat exhaustion and urban (e.g. Brest 4.53% vs average of 11%), more likely due to poor battle inoculation
- Artillery and small arms data do not show increases in urban (Brest 78x105mm/d cf 242, 43x155mm/d cf 161, 29k small arm at Brest cf 28k/mo). Only big uplift was in 0.5" MG (x4!), grenade projectors (78 cf 17) and 60mm mortar (826 vs 512)
- No mention in battle diaries or data/logs of issues with food and water.

Extending the analysis to both Eastern Front and post WW2 engagements did not contradict, but also did not clarify and if anything made more complex.

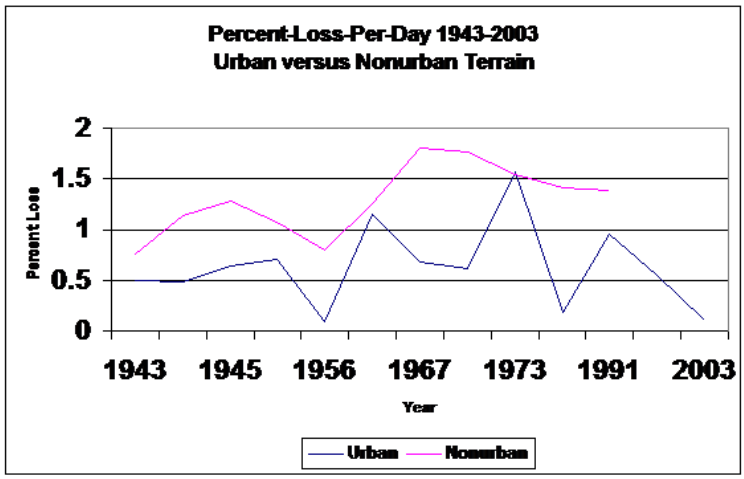

Figure 4: Loss per Day for Urban and Non-Urban Terrain (after Lawrence, 2017)

His summary of urban was that:

- "*the primary result of urban terrain, according to the data derived from the analysis, is to reduce advance rates significantly, reduce casualties to some extent, and so to extend the duration of the combat.*" p.251
- "*terrain [urban or rural type] has no significantly measurable influence on the outcome of the battle*"
- "*the ratio of attacker to defender casualties is more favourable to the attacker in urban warfare*" - may be driven by selection (and force ratios)
- "*the tendency is to weigh one or both flanks and not bother to attack the city until it is enveloped*" p.251
- Lack of unbypassable cities results in few urban combats

- Future impact of more effective weapons may result in more dispersal, less time in less protected conurban
- Bigger, taller, denser cities may not lead to a lot of changes, if anything may even have lower PV (eg metal/glass cf stone)
- The revolution in military affairs/information warfare might rebalance attacker advantage, and may allow more rapid isolation, so urban becomes mop-up

Weapon Effectiveness Index and Weighted Unit Value (1970s)

In the early 1970s the US Army Concepts Analysis Agency developed the Weapon Effectiveness Index (WEI) and Weighted Unit Value (WUV) methodology (also known as WEWV?) (Raymond, 1991)(Reach et al., 2020). This gave each weapon system a Weapon Effective Index (WEI) which was then sum-producted with the quantity and a category weight – to provide a total score for the unit - the Weighted Unit Value (WUV). The total for an Armoured Division then in turn became a reference so that comparable units could be described in terms of the Armoured Division Equivalent (ADE). Unfortunately even now a full description, and more importantly data, for WEI/WUV is not available, and the derivation of the WUV is particularly unclear, but some sample tables shown in Table 2 (Lussier, 1988). The ultimate source document is apparently *U.S. Army Concepts Analysis Agency, Weapon Effectiveness Indices/Weighted Unit Values III (WEI/WUV III) (November 1979, also 1974).* Note that WEI is normalised per category, with WUV then providing the inter-category weight – but also note that papers on WEI/WUV sometime show WUV as the sum-product value for a unit as a whole, and sometimes as the Category Weight.

Weapon System	Weapon Effectiveness Index	Category Weight	WEI x CW
M60A3	1.11	94	104
M1	1.31	94	123
M2 Bradley	1	71	71
M113 APC	1	30	30
M16	1	4	4
M60 MG	1.77	4	7
TOW	0.79	73	58
Dragon	0.69	73	50
LAW	0.2	73	15
155mm Howitzer	1.02	99	101
8” Howitzer	0.98	99	97
MLRS	1.16	99	115
81mm Mortar	0.97	55	53
AH-1S	1	109	109
AH64	1.77	109	193
Vulcan LLAD	1	56	56

Table 2: Sample WEI and WUV Values (Lussier, 1988)

Zanella (Zanella, 2012) gives the definition for WEI as:

$$WEI = c_f F + c_m M + c_s S$$

Where:

- c_x is the weighting coefficient of each index
- F = firepower index

- M = mobility index
- S = survivability index

Each index in turn was derived from:

$$Index = \sum_{i=1}^{n} Q_i C_i$$

Where:

- Q_i = quality of engineering characteristics with a value range between 1 and 0;
- Ci = the weighting factor for the value of the characteristic relative to the others.
- n = the total number of characteristic considered in evaluating a weapon system.

A Delphi approach was used to define the weighting coefficients.

Lussier highlights several limitations of the WEI/WUV approach (and which also apply to similar ones here):

- Lack of recent (then 1988) WEI/WUV data, relying on applying the original 1979 methodology to what information was available on modern (then 1988) equipments;
- It should hence only be used to assess relative strength and trends, not absolute military capability or conflict outcome;
- It ignores many other attributes such as quality and training of personnel, support and logistics, and interplay between weapon categories.
- It also ignores other decisive variables such as terrain, strategy, manoeuvre, attrition etc – although this is less of an issue where the wargame itself models these elements;
- It assumes a linear impact of increasing numbers, although in reality there is likely to be a law of diminishing returns (and certainly not a Lanchester type square-law).

There are a number of papers that critique, address deficiencies in, or extend the WEI/WUC model (Ben-Haim, 2018; Hillestad & Juncosa, 1995; Krondak et al., 2007; Murray, 2002; Woodford, 2017; Zanella, 2012).

Maj Raymond of the US Army produced a monograph on *Assessing Combat Power: A Methodology For Tactical Battle Staffs* as part of his studies at the US Staff College (Raymond, 1991) which provides a modified version of WEI/WUV, based on an earlier study for the Office of the Secretary of Defense Program Analysis and Evaluation. A key feature of the study was a survey of "*109 NATO field grade officers to obtain their collective judgment of the relative worths of different categories of weapons systems*". This gives an interesting insight as to how soldiers, as against OR analysts, perceived the relative strengths of different weapon systems Table 3.

1 tank = 2.49 IFVs
1 tank = 3.63 APCs
1 tank = 3.49 mortars
1 tank = 2.42 artillery
1 tank = 0.74 MLRS
1 tank = 0.6 AH
1 tank = 2.05 ATGMs

1 tank = 1.76 infantry platoons
1 tank = 3.39 armd recce vehs

Table 3: Perceived Relative Combat Values (Raymond, 1991)

The survey also asked the extent to which systems were degraded by terrain, based on combat types, as shown in Table 4.

	Rural/Rolling		Urban	
	Offence	Defence	Offence	Defence
Tanks	97.7	97.7	36.1	41.9
Inf/IFVs	98.9	97.3	46.1	54.0
Arty	97.0	93.3	45.6	56
Mortars	89.2	91.3	63.7	66.5

Table 4: Perceived Effectiveness (1/degradation) by Terrain and Combat Stance (Raymond, 1991)

The original study then used this to derive new category weights (CW) for use with WEI/WUV as shown in Table 5. His original tables also include values for desert, mountain and forested terrain.

Weapon System	**Rural/Rolling**	**Urban**
Tank	10.00	4.00
IFV inc section	4.02	6.35
APC inc section	2.76	3.87
Mortar	2.86	4.12
Artillery	4.13	6.22
MLRS	13.50	9.01
AH	16.71	8.24
AT Wpn	4.96	2.10
Inf Pl	5.68	13.71
Recce Veh	2.96	2.52

Table 5: Modified Category Weights for WEI/WUV (Raymond, 1991)

Selected examples of Raymond's full modified WEV and CV values are shown in Annex D. In his tables Raymond combines the Category Weight and Terrain Modification into a single value, to then be applied against the Weapon Value (WEI) for each terrain type, with the aim of simplifying the process for users.

Urban Effects

Whilst urban effects are not included in the original WEI/WUV model, they are included in Raymond's version. What are notable are which weapon systems have higher Category Weights in

urban, and which have lower:

- Higher weighted weapons in urban are: IFV (158%), APC (140%), Mortars (144%), Artillery (151%), Infantry (241%)
- Lower weighted weapons in urban are: MBT (40%), MLRS (67%), AH (49%), AT (42%), Recce (85%)

Helmbold (1986)

Robert L Helmbold, who worked at RAND and the US Center for Army Analysis (CAA) wrote a number of papers and books on combat models. His general papers on historical analysis take a similar approach to Dupuy, also working with whole battle numeric statistics and quite old battles (Helmbold, 1990; Helmbold & Khan, 1986), whilst his papers on the "advantage parameter" take a very Lanchester style approach, looking at the necessary and sufficient conditions for Lanchester's Square Law to be valid and the derivation of a relatively abstract "advantage parameter".

His most recent book *The Key to Victory: Machine Learning the Lessons of History* (Helmbold, 2021) further develops the "advantage parameter" idea, and also defines "objective and quantitative measures" of "advantage", "bitterness" and "intensity". The work is of particular interest since this triad was cited as part of the inspiration for a new operational level manual wargame by Dstl called the *Generic Low Operational Wargame (GLOW)* system (Rougier, 2025) – covering similar ground to, but with more detail than, my own OPUC game. Figure 5 shows how each element of the triad is defined (A and D used instead of X and Y for defender for clarity).

A_0 = Attacker Start Strength (simple headcount) CA = Attacker losses
D_0 = Defender Start Strength (simple headcount) CD = Defender losses

FR = force ratio = A_0/D_0
CER = casualty exchange ratio = CA/CD = attacker cas / defender cas
FA = Fractional (percentage) losses to Attacker = CA/A_0
FD = Fractional (percentage) losses to Defender = CD/D_0

FER = Fractional Exchange Ratio = FA/FD
μ (mu) = **Defender Advantage** $\approx \sqrt{FER} = \sqrt{FA/FD}$

(So defender advantage is how much faster attacker is taking casualties as a proportion of its start strength than the defender. If $\mu > 1$ then attacker run out of troops first)

ε (eps) = **Bitterness** $\approx \sqrt{FX \times FY}$ = geometric mean of attacker and defender fractional losses (i.e. how bloody as a proportion of those involved)
λ (lam) = **Intensity** = ε / τ (τ = duration), i.e. proportional losses her hour etc

Figure 5: Helmbold's Advantage, Bitterness and Intensity Triad

Whilst interesting (and possibly obvious) Helmbold's equations suffer, for my purposes, from being an *a posteriori* analysis – they can tell you what happened once you have the data, but cannot predict success from the start state. In fact, Helmbold encourages the development of staff procedures and reporting that can give commanders near real-time capture of mu, lam and eps so that they can get a better idea of whether they are going to win or not, and also of using mu as the key assessment criteria for unit exercises at the National Training Centres. Helmbold also identifies that "*Unfortunately, the current state of the military sciences offers no generally accepted method for assigning a simple numerical value that adequately represents the strength of a force [of mixed weapons and troop types]*" (p. 43). It would be interesting to see the results of applying the advantage, bitterness and intensity metrics to the outcomes of wargames.

Allen (1992) and Situational Force Scoring

Situational Force Scoring (SFS) is a combat model and combat factor methodology developed by RAND and which aimed to "*(1) To improve the representation of ground force close combat in aggregate combat models that use scores of one form or another to compute force ratio, attrition, and movement as a result of combat; and (2) To provide an alternative extrapolation mechanism for use in more-detailed weapon-on-weapon models that depend on data that is available only for a modest number of calibration points."* (Allen, 1992). The main version of SFS had a 20-step process, split over 4 stages, and a simpler unit level version was also produced, and is intended to take the situation (e.g. terrain etc) better into account than (then) existing models. It works on top of an existing combat factor methodology (such as WEI/WUV) and adjusts the starting combat factors by further adjustment factors for:

- Density (based on environment, see Table 6)
- Effectiveness (e.g. training, nationality etc)
- Situation (a 4D matrix of weapon category, role (attacker/defender) engagement type and terrain, see Table 7, with Terrain split out into Table 8)
    - Engagement Type: Breakthrough, Withdrawal, Delay, Hasty Defence, Deliberate Defence, Prepared Defence, Fortified Defence, Static, Meeting);
    - Terrain: Open, Mixed, Rough, Urban, Mountain
    - There is also a numeric adjustment for the days of preparation by the attacker
- Shortages (an adjustment, based on any shortfall against an "ideal" combined arms ORBAT for the situational – degrading scores accordingly – see Table 9).

The weapon categories used are: Tanks, IFVs, APCs, anti-armour weapons, mortars & small-arms, artillery, attack helicopters and air defence. The base case for the factors is a deliberate defense in mixed terrain at a roughly 2.5:1 raw force ratio.

Type of Terrain	Armor	Infantry	Artillery
Open	0.8	0.8	1.0
Mixed	1.0	1.0	1.0
Rough	0.5	0.8	0.8
Urban	0.4	1.2	0.7
Mountain	0.2	0.6	0.4

Table 6: Density Adjustment Factors in SFS

		Category of Weapon					
Type of Battle	Type of Terrain	att Tanks IFVs	att APCs	att LR atgms	att SR atgms	att inf	att arty
Hasty	Open	1.380	0.966	1.277	0.972	0.864	1.320
Hasty	Mixed	1.200	0.840	1.140	1.080	0.960	1.200
Hasty	Rough	1.080	0.756	1.049	1.296	1.152	1.080
Hasty	Urban	0.960	0.960	0.479	1.620	1.440	0.840
Hasty	Mount	0.960	0.672	0.958	1.728	1.536	0.960
Deliberate	Open	1.150	0.805	1.064	0.810	0.720	1.100
Deliberate	Mixed	1.000	0.700	0.950	0.900	0.800	1.000
Deliberate	Rough	0.900	0.630	0.874	1.080	0.960	0.900
Deliberate	Urban	0.800	0.800	0.399	1.350	1.200	0.700
Deliberate	Mount	0.800	0.560	0.798	1.440	1.280	0.800
Type of Battle	Type of Terrain	def Tanks IFVs	def APCs	def LR atgms	def SR atgms	def inf	def arty

Hasty	Open	0.880	0.616	0.756	0.630	0.630	0.880
Hasty	Mixed	0.800	0.560	0.700	0.700	0.700	0.800
Hasty	Rough	0.720	0.504	0.644	0.840	0.840	0.720
Hasty	Urban	0.640	0.640	0.294	1.050	1.050	0.560
Hasty	Mount	0.640	0.448	0.588	1.120	1.120	0.640
Deliberate	Open	1.100	0.770	1.080	0.900	0.900	1.100
Deliberate	Mixed	1.000	0.700	1.000	1.000	1.000	1.000
Deliberate	Rough	0.900	0.630	0.920	1.200	1.200	0.900
Deliberate	Urban	0.800	0.800	0.420	1.500	1.500	0.700
Deliberate	Mount	0.800	0.560	0.840	1.600	1.600	0.800

Table 7: Extract of Situational Factor Table in SFS

Type	Attacker					Defender				
Terrain	Armor	Infty[a]	Arty	Helos[c]	Air Def[c]	Armor	Infty[a]	Arty	Helos[c]	Air Def[c]
Open	1.15	0.90	1.10	1.30	0.80	1.10	0.90	1.10	1.20	0.70
Mixed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rough	0.90	1.20	0.90	0.70	1.20	0.90	1.20	0.90	0.90	1.30
Urban	0.80	1.50	0.70	0.40	1.10	0.80	1.50	0.70	0.50	1.10
Mountain	0.80	1.60[b]	0.80	1.00[d]	1.50	0.80	1.60[b]	0.80	1.00[d]	2.00

[a]For short-range anti-armor systems and small arms; for long-range anti-armor systems, use:

Multiplier = 0.8 * armor-mult + 0.2

In the full spreadsheets, we have separate categories for short-range anti-armor, long-range anti-armor, and small arms. In this abbreviated table, we combined these separate columns into a single column, with exceptions defined by the preceding equation and the following rule: In urban areas, the long-range anti-armor score needs to be further multiplied by 0.5 because long-range anti-armor systems have a minimum arming range that works poorly in urban combat.

[b]Infantry specially trained in mountain warfare should get an additional multiplier of perhaps 1.3 here.

Table 8: Terrain Factors in SFS

	Attacker			Defender		
Terrain	Armor	Soft	Arty	Armor	Soft	Arty
Open	0.2	0.6	0.2	0.4	0.6	0.2
Mixed	0.2	0.6	0.2	0.5	0.6	0.2
Rough	0.6	0.4	0.4	0.7	0.4	0.4
Urban	0.8	0.2	0.6	0.8	0.2	0.6
Mntn	0.8	0.2	0.6	0.8	0.2	0.6
Applied to:	Soft	Armor	Armor Soft	Soft	Armor	Armor Soft

Table 9: Capability Shortage Multipliers in SFS

The SFS model goes on to consider the modelling of attrition and advance rates but that will not be considered here.

As an Annex to the SFS report a “new ground force scoring system” is presented, aimed at replacing WEI/WUV. This was a work in progress but is a useful set of a data (albeit of 1980s vintage) and the summary table is shown in

Group	Category	Score	Group	Category	Score
Tanks	M1-A1	7.5	SP Arty	152+ Hw Good	5.0
Tanks	M1	5.5	SP Arty	152+ Hw Fair	4.0
Tanks	M60-A3	3.5	SP Arty	SP Gun	3.5
Tanks	M60	2.5	SP Arty	122- Hw	2.7
Tanks	M48	1.8	SP Arty	100+ Mortar	1.5
Tanks	M47	1.4	SP Arty	MLRS	10.0
Tanks	T34	1.0	SP Arty	200+ mm MRL	7.5
IFV/AA	M-2	3.5	SP Arty	160- mm MRL Good	5.0
IFV/AA	BMP-1	2.5	SP Arty	160- mm MRL Fair	3.0
ARV/AA	ITV	2.5	Td Arty	122+ mm Gn/How	3.0
ARV/AA	ATGM	1.8	Td Arty	152+ mm How	2.7
ARV/AA	Gun/Armor	1.3	Td Arty	130+ mm Gun	2.5
ARV/AA	Gun/Lgt	1.0	Td Arty	122-130 mm How	1.8
ARV/AA	Lgt Tank	1.5	Td Arty	105- mm How	1.2
LARV	Lgt Veh	0.8	Td Arty	122- mm Gun	1.5
APC	IFV/No AT	1.3	Td Arty	100+ mm Mortar	1.0
APC	APC	1.0	Td Arty	107+ mm MRL	2.5
APC	Half Trk	0.8	At Hel	AH-64	10.0
LRAArm	Imp TOW/Veh	1.5	At Hel	Hind	6.5
LRAArm	TOW/Mln-Veh	1.2	At Hel	AH-1	3.5
LRAArm	Imp Tow/MP	1.2	At Hel	Lgt Attack	2.2
LRAArm	Tow/Mln-MP	0.9	ADef	20+ mm Rad ADA	1.5
LRAArm	Aslt/ATGN Hvy	1.2	ADef	57+ mm ADA	1.0
LRAArm	Aslt/ATGN Lgt	0.8	ADef	20+ mm SP ADA	1.0
SRAArm	Lrg Recoil	1.0	ADef	20-40 mm Td ADA	0.7
SRAArm	Sml Recoil	0.7	ADef	AAMG	0.4
SRAArm	Dragon	0.5	ADef	SA-13	2.5
SRAArm	LAWs	0.25	ADef	SA-8	1.8
SRAArm	Sml LAWs	0.2	ADef	Stinger	1.3
Mortar	SP 81 mm	1.2	ADef	SA-14	0.9
Mortar	81 mm	0.7	ADef	SA-7	0.5
Mortar	60 mm	0.4			
SmArm	Small Arms	0.15			

Table 10: Proposed Ground Force Scoring System

Urban Effects

SFS identifies Urban as one of its 5 terrain types. Relating it primarily to Mixed, and based on the information in the tables above and the rest of the report (all percentages approximate):

- Armour will be less dense (40%) and infantry more dense (20%);
- Tanks and IFVs will be less effective in urban, but APCs more so;
- Long range ATGMs will be significantly less effective (50%) but short range ATGMs more effective (60%)
- Infantry will be more effective in urban (30%-50%)
- Artillery will be less effective in urban (30%)
- A shortage of armour only reduces infantry effectiveness by 20% in urban (c.f. 80% in mixed), whereas a shortage of infantry reduces armour effectiveness by 80% (c.f. 40% in mixed).
- A shortage of artillery reduces armour and infantry effectiveness by 40%, c.f. 80% in mixed.

Blandy (1993)

Also mentioned by Rougier (2025) as an influence on *GLOW* was the work of Charles Blandy who worked for the British Army's Soviet Studies Research Centre and published a report on Calculating Combat Outcomes (Blandy, 1993). However, it has not yet been possible to obtain a copy of this report to review.

Rowland (2006)

David Rowland's The Stress of Battle (Rowland, 2006) looks at both the result of early "laser tag" on field exercises in the 1980s and Historical Analysis, very much in the style of Dupuy, although he does not develop a combat model from them.

The field exercise work focuses on two series, Ex Chinese Eye and Ex Kings Ride, with the latter including 78 section level house clearances (with CCTVs inside the rooms) and 27 company attacks at the Ruhleben urban training centre in Berlin.

Rowland offers little in the way of equivalences, and the only ones mentioned are to assist the analysis (such that 9 rifles = 1 MG, and 1x 81mm mortar = 3 MGs). His focus is more on the "degradation" effects between range and exercise findings and live fire battles, and some of the metrics that emerge from both the field exercises and the historical analysis. Rowland was also particularly interested in participation rates and the role of "heroes". Annex D provides a summary of his findings, notable ones being:

- From FTXs:
    - For company level engagements, duration was 30-60 mins, with 20 mins of hot engagement;
    - Combats typically broke down into a sequence/network of smaller engagements, with ratios ranging from 1:1 to 18:1 (see Figure 6, this is a particularly interesting way to examine a battle and may merit further investigation in wargaming terms)
    - Overkill was a major factor, particularly as the ratio of firepower over available targets increases
    - The net combat effectiveness (vs range work) was 5% for riflemen, 21% for MGs (including a factor for non-participation)
- From Historical Analysis:
    - The net combat effectiveness (vs range work) was 10-12% for riflemen, 17% for MGs (including a factor for non-participation)
    - The presence of tank support reduces MG effectiveness, but is in turn reduced by presence of AT weapons
        - Reduce own cas by ~66% with 1 tank, 90% with 2 tanks (PI attack)
    - Defensive prepared positions increase defense effectiveness by x1.65
    - Typical fighting unit had 18% heroes, 55% normal/degraded (cf. FTX) and 27% zeroes (non-participation)
    - Surprise reduced defence effectiveness by x0.6, effect may be larger at low ratio attacks (and surprise essential at <1:1 ratio for success)
    - Shock from tanks is due to surprise, poor visibility and perceived invulnerability of tanks. Shock from infantry is due to surprise, poor visibility and low morale.
    - Dive bombers/rocket/strafing attacks most likely to cause shock from air attack, not bombs, as seem to be coming straight at you.
    -

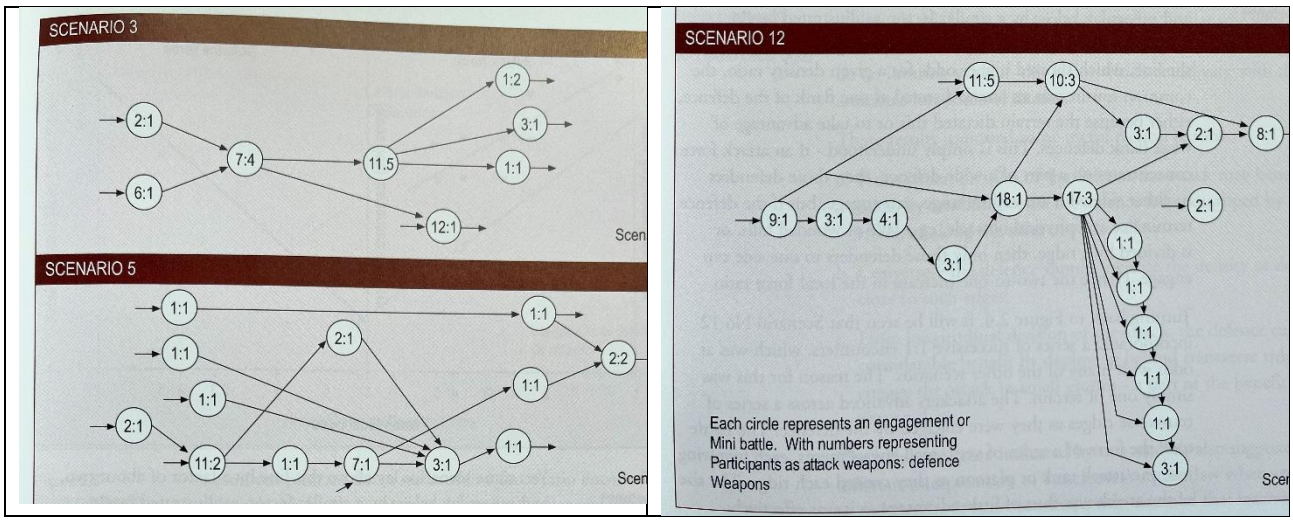

Figure 6: Battles as a network of engagements - showing force ratios (after Rowland, 2006)

Urban Effects

In Rowland, urban effects are reported as follows:

- From FTXs:
  - WARPAC tactics of just fighting through and using tanks/arty to destroy enemy in buildings has same casualty exchange ratios as NATO fire and manoeuvre, but were seem as more effective (faster, simpler).
  - Mini-engagements again seen within each battle: firefights, assaults, house clearances
  - Shorter range actions but longer engagements
  - No evidence of greater ammo use
- From Historical Analysis:
  - Attacker casualties are typically 28% of defenders, no battles above 100% of defender's.
  - Each defender typically inflicts 0.51 casualties
  - Degradation factor in comparison for trials/FTX ranged from x3.8 to x7.2 (i.e only 25% to 7% as effective)
  - Attack cas per Defence MG equiv = 2.07 rural, 0.818 woods, 0.76 urban
  - For defender, the typical casualty mix was 20% killed, 60% wounded/POW, 20% withdrew/ran.
  - Tanks still help with suppression and reducing own losses "urban being 60% less effective with no attacking tanks"
  - Experience effect is significant, with attacker cas per defender dropping from 0.175 to 0.06 after 12 attacks
  - "defence of urban areas is best acheived by light or false defence and by counter-attack and that this practice will be aided by the use or armour in support and training in the attack role" (p.90)
  - The presence of rubble increases defender capability (in casualties caused) by x1.55 (cf x1.6 for prepared positions)
  - Advance is half as fast through rubble
  - Rubble may disorientate and make harder to navigate and identify firer

Hogg (1993)

Hogg's paper *Correlation of Forces: The Quest for a Standardized Model* provides a useful

summary of the state of the representation of combat factors in the US Army in the early 1990s (Hogg, 1993). Correlation of Forces (CoF) refers to the ability to score one fighting force against another so as to provide a predictor of the outcome of any engagement. Hogg notes that "*Currently the United States Army does not have a standardized, realistic methodology for determining the correlation of forces (COF)*" (p.ii). Hogg's research questions are useful as they also to an extent frame the current work:

- How do you measure combat power?
- Is a standardised method needed?
- What should be the structure for that model?
- What about the effects of the environment?
- How do you use the model once it is identified?

Hogg saw that many of the existing methods where subjective, and sought a model that was more objectively based.

Note that whilst Hogg saw resultant force ratios as being essential for the interpretation of the CoF (e.g. 3:1 for a deliberate attack), most of my wargames are not ratio based, instead individual unit engagements are assessed and build to the overall effect, allowing a lower level of granularity to be examined.

Hogg used the US Army's FM100-5 Operations manual definition of Combat Power (or Combat Potential) as being "*the effect created by combining maneuver, firepower, protection, and leadership in combat actions against an enemy in war.*" (*FM 100-5: Operations*, 1986). Whilst the CoF compares just Combat Power, the Correlation of Forces and Means (COFM) includes "*external factors such as surprise, morale, terrain, weather, leadership, etc … which could also effect the combat power of a unit"* (p.6) – and which is derived from Dupuy's work on Soviet COFM.

Hogg identifies the three most common approaches to assessing combat power as being:

- Bean counting – just counting the main combat platforms (e.g. MBTs);
- Subjective – taking a reference platform (e.g. Challenger 2) as 1.0, and then expressing other platforms relative to that based on a qualitative assessment; and
- Quantitative – typically also taking a reference platform (e.g. Challenger 2) as 1.0, and then expressing other platforms relative to that based on a quantitative assessment – such as using Standard Units of Armament (SUA – which still has a qualitative element), Weapons Equivalent Weighted Value (WEWV – deprecated even by 1993), or, ideally, field testing.

Hogg examines four existing models: the National Training Center (NTC) model; the Command and General Staff College (CGSC) model; the Theater Analysis Model (TAM); and the Historical Evaluation and Research Organization (HERO) Model (derived from Dupuys's QJM). Annex E details some of the key features of his research, and also reproduces some of the Combat Factors tables from the different models.

Hogg then uses the four different models to calculate the CoF for a US Brigade vs Soviet Brigade meeting engagement scenario, using the same ORBATs in each. The results in terms of the resultant force ratios are shown in Table 11, in each case with the US Brigade predicted to win. The table is useful in showing the wide range of results (from 1.5:1 to 2.41:1) of 4 different combat models, all using broadly the same approach (COF and sum-product). This emphasises the fact that there must be a large qualitative element at play, and that any model derived (or even used) by me for wargames, and particularly without access to the classified information that these models would have) cannot hope to be authoritative – and that the validity of it needs to come from elsewhere.

COF(M) Model	**Force Ratio**
NTC	2.41 : 1.00

CGSC	1.50 : 1.00
TAM	1.72 : 1.00
HERO	2.13 : 1.00

Table 11: Comparison of Four Combat Factor models (after Hogg, 1993)

Across a variety of factors (flexibility, simplicity, definable, 90% solution) Hogg thought that the HERO model provided the best overall solution to COF generation (scoring 29.75 against the next closest, TAM at 25.75, HPS not given), and recommended that is be adopted as a manual process by the US Army, including for "*division and above*" wargaming. Hogg also notes that the two worst performing models (NTC and CGSC) were those then most in use by the US Army!

Urban Effects

In terms of urban Hogg states that HERO has 73 different external variables, which may include elements of urban, but no details available. In TAM though:

- Hasty Attack in urban should multiple CF by 0.4, and 0.6 for Deliberate Attack.
- The Defender should multiply CF by 2.0 for Hasty defence and by 3.0 for deliberate defence. See Figure 12 in Annex F.

Spurlin & Green (2017)

Spurlin & Green (Spurlin & Green, 2017) describe the Correlation of Forces calculator then in use at the US Army Command and general Staff College (CGSC), noting that several versions of such calculators are used by the US Army, typically as Excel sheets, or converted to "Command Post of the Future" apps. They relate the work of Hogg (by then a Lieutenant General), and how the CGSC COF calculator reviewed by him was found outdated when the focus returned to LSCO in the mid 2010s, and their paper describes the derivation of the new calculator – although the calculator itself is classified and not presented. The new calculator used objective values derived from TRADOC Analysis Center derived in turn from studies of NATO and threat systems to build a tool to assist in exercise design. The system presents combat values for units from brigade to company, based on multiplying system quantities by combat potential and summing them. They also revised a set of damage tables based around combat ratios, ranging from 1:4 to 5:1. The problems of asymmetric units (e.g. anti-tank units, anti-aircraft, indirect fires) is also noted, and how it can skew results. Their new calculator took no account of terrain, and a reduction of 25% in effectiveness for night and reduced visibility is suggested. Other warnings about the use of COF calculators are also noted, including engagement direction, mis-matched echelons (>2), and footprint/density.

The Calculator (available in both Engagement and Campaign versions) includes Force Equivalent (combat potential) data for over 150 units, across NATO allies and potential adversaries. Whilst not stated the reference unit (Force Equivalent = 1) is something like a basic leg infantry company. Table 12 shows some selected values (FE = Force Equivalent), with a fuller table in Annex F.

US Unit	**FE**		**UK Unit**	**FE**		**Russian Unit**	**FE**
M1A2 Bde ABCT	248.99		Armoured Inf Bde	272.5		MRR (BMP3/T80U)	269.35
AR CA Bn (M1A2)	37.24		Armd Inf Bn	47.87		MRB (BMP3/T80U)	41.12
Inf Bradley Coy (M2A2)	8.95		Armd Inf Coy	8.05		MR Coy (BMP3/T80U)	8.30
Wpns Coy	4.38		Armd Sp Coy	17.58			
Tk Coy (M1A2)	7.8		Tank Sqn	10.08		Tank Coy (T80U)	6.34
Inf Bn	19.09		Lt Inf Bn	15.25		MR Coy (BTR80)	8.67
M109 Bn	28.13		FA Regt (AS90)	33.42		FA Bn (2S19)	21.42
M109 Bty	5.87		FA Bty	5.59		FA Bty (2S19)	4.26
			GMLRS Bty	6.34			

Table 12: Selected values from the 2017 CGSC COFM Calculator (derived from the Excel code)

COMBAT (1989)

COMBAT was a computer programme developed in the late 1980s to investigate aimed fire attrition equations, allocations of fire and the calculation of weapon scores (Anderson & Miercort, 1989). Several weapon scoring (combat potential) methods are discussed including APP (Antipotential potential – effectively a sum product method), APPVUL (which extends APP to take into account the vulnerability of the firing platform), PEXPOT (Potential Exchange Potential, which also adds vulnerability by basing the score of a weapon is proportional to the rate at which that weapon can kill enemy score divided by the rate at which enemy weapons can kill the friendly score), LEVPOT (Lethality/Vulnerability Potential – a hybrid of APPVUL and PEXPOT), and DYNPOT (Dynamic Potential – which considers a longer engagement time and is a compromise between PEXPOT and LEVPOT. One of the outputs of COMBAT is a Killer-Victim scoreboard, but it admits that its algorithm for that is "rather elementary". The paper does not include any of the weapon scores, but the notions of including both vulnerability and like vs like kill rates are interesting ones.

Russian COFM (2020)

The Russian Army sees (saw) Correlation of Forces and Means (COFM) as a key part of their military planning process.

> *This methodology is the mathematical determination of the combat power of the opposing sides after making mathematical adjustments for differences in combat systems, quantity and quality of systems, quality and training of the forces, terrain, morale, activity (attacking, defending, withdrawing, flanking, etc.), and combat experience. The Correlation of Forces and Means provides the ability to determine a mathematical probability of success, most advantageous avenues of attack or withdrawal and rate of advance in an operation or battle and can be the decisive determinant in the commander's decision.45 Determination of the Correlation of Forces and Means used to be a fairly lengthy mathematical drill, but the methodology has been computerized and upgraded. Mathematical models are also widely used for ammunition, fuel and personnel expenditure rates.* (Bartles & Grau, 2016)

A RAND study (Reach et al., 2020) notes that, as in US, there are different ways of calculating COFM, depending on who is doing the calculation and why. As in the US, the Russians see combat potentials (*boevye potentsialy*) – which they see as the "*relationship of the quantitative measure of combat potential of a given weapon or piece of military equipment to the value of combat potential of a standard [weapon or equipment], conditionally taken as the reference*" (p.19) - as the building blocks of COFM, alongside an assessment of qualitative factors such as training, will to fight and resilience of command and control. Again a simple sum-product approach is applied to the constituent heterogeneous elements of a unit to create a homogeneous combat value. The study identifies a number of different methods that are used to calculate combat potential, including: operation testing, tactical-technical characteristics, historical statistical analysis, ensemble analysis (drawing on multiple methods/studies), modelling and simulation, and expert evaluation and sub-system analysis (potentialometry – *potentsialometriia* in Russian). The Russian approach to combat potential also draws on a long history of qualimetry (*kvalimietriia)* research in the Soviet and Russian armies. Around 2008 the Russians attempted to standardise on the "*Method for Assessing the Combat Potentials of Weapons and Military Equipment and Combat Formations of the Armed Forces and Foreign States*" (known simply as the "Method"), developed by Lev Zakharov in the 1980s, published in 2001, and updated and republished by the Center for Military-Strategic Studies in 2009. The Method appears to be a fairly traditional application of combat potentials, qualimetry and potentialmetry and a sum-product approach, although it is rooted in a qualitative approach and emphasises quality (aggregate of properties) over effectiveness.

Reach et al also examine the evolution of US approaches to combat potentials, including the

development of Weapon Effectiveness Indexes and Weighted Unit Value (see Hogg), Killer-Victim Scoreboards/Matrices and Situational Force Scoring (developed by RAND as a halfway house between WEI and KV).

Annex G reproduces some of the key tables of example Russian COFMs from Reach et al, and Table 13 provides a mid/late 1980s example of the Russian view of the relative combat potential of modern weapon systems – with each category normalised to a reference within the category.

US Equipment	**FE**
M1A1 Abrams	1.08
M2A1 Bradley	1.06
M108 (105mm)	0.51

UK Equipment	**FE**
Challenger CR1?	0.98
Warrior	0.83
Abbot (105mm)	0.54

Russian Equipment	**FE**
T80-UM (reference)	1
BMP3	0.9
Smerch BM-30 (reference)	1

Table 13: Russian Example Combat Potentials (after Reach et al, 2020).

The usefulness of Russian/Soviet approaches to Correlation of Forces and qualimetry in general is shown by the fact that the new Dstl wargame *GLOW* (mentioned earlier) still makes use of a Soviet weight of fires curve for damage from artillery (Rougier, 2025).

Critiques of Combat Models

Stockfisch's differentiates between "detailed" models (for small unit actions) and "aggregative" models (for large, campaigning forces) (Stockfisch, 1975). He notes that detailed models are usually based on kill probabilities, whereas aggregative models mainly rely on firepower scores and force ratios. The paper concentrates on aggregative models and comes to two main conclusions (p.v-vi):

- "*First, the conceptual foundations of firepower indexes (due to what may be described as the weighting problem, by which relative importance is attached to different military specialties such as infantry, armor, artillery, and aircraft) are unsound or questionable. To resolve the weighting problem requires much more knowledge about war than we currently have. To acquire this kind of knowledge at a minimum necessitates much more empirical work*."
- *"Second, although the empirical foundation of the firepower index is logically derivable from the work done in the separate fields of ballistics research and operational testing, including operational research that explicitly tries to employ data and information generated from actual military operations, our conclusions are again twofold. First, the ballistics data employed as inputs to firepower indexes contain major uncertainties. Second, hard operational-testing data are virtually nonexistent. Given these deficiencies, the empirical foundation for existing firepower indexes (or anything that might be substituted for them) is shaky.*"

It might be hoped that since then things improved, but in 1991 Davis wrote, in *The Base of Sand Problem* (Davis & Blumenthal, 1991), that "*the authors had separately concluded that the DoD's approach in developing and using combat models, including simulations and war games, is fatally flawed-so flawed that it cannot be corrected with anything less than structural changes in management and concept*" (p.iii), stating that there was too much interest in implementing the models (particularly for distributed digital wargaming) and not enough interest in the validity of the models themselves. They further state that "*Many models and tools are simply inadequate. Further, they are seldom verified or evaluated well, there is confusion about what the models assume and do, and there have been many wasted efforts and lost opportunities*". They capture

the problems in Figure 7.

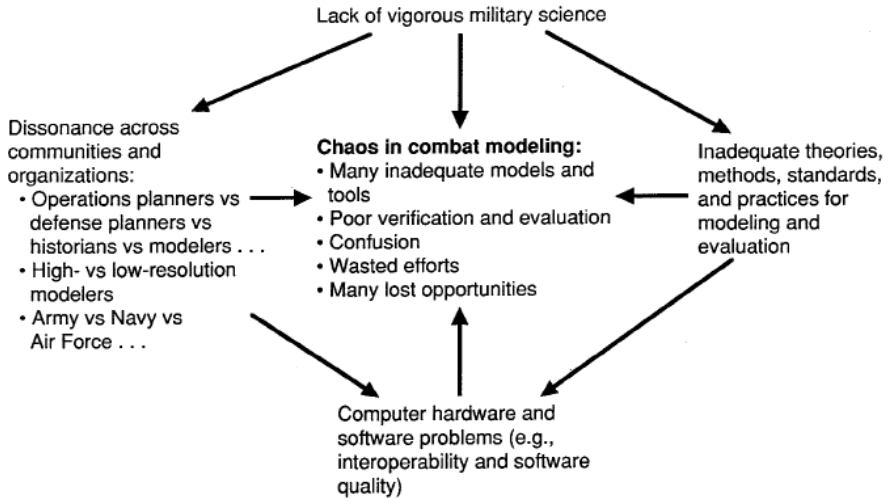

Figure 7: Contributors to the chaos in current combat modelling (Davis & Blumenthal, 1991)

One of their solutions is to more explicitly distinguish between research models (which embody all knowledge and alternative theories) and application models (which can be used to help solve problems or inform decisions). The diagram for a comprehensive approach is (again) remarkably similar to that suggested for developing wargames – which is of course one of the main uses for their models.

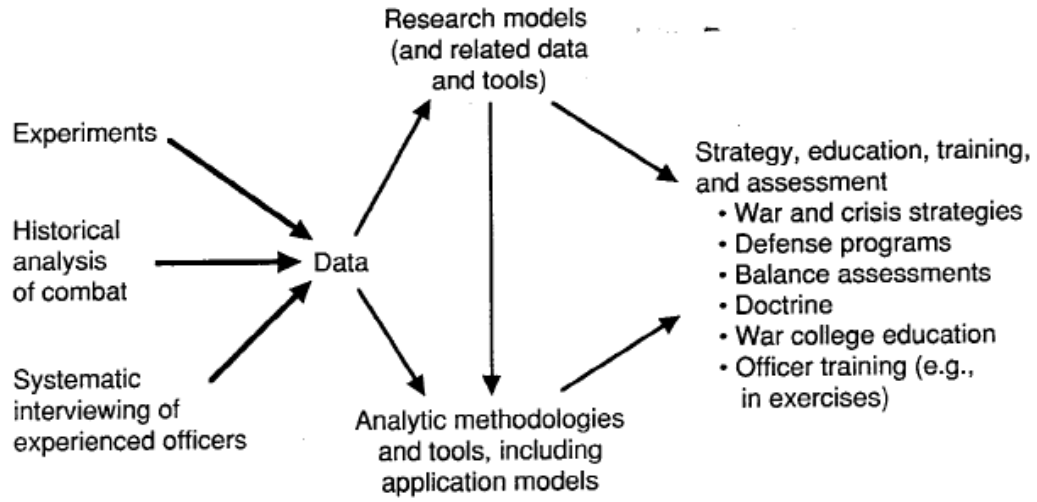

Figure 8: Elements of a comprehensive approach (Davis & Blumenthal, 1991)

Whether the situation has improved since 1991 is probably open to debate, but recent papers might suggest that whilst it has improved it is far from solved (Turnitsa et al., 2021).

Military Heuristics

Whereas most of the models above aspire to be models of combat and used primarily by researchers and strategic planners, there is also an obvious interest in having more pragmatic tools which military staffs can use at a practical level – and which may well draw on some of the models and approaches described above. Some of these are considered below.

US Army FTX Umpire Handbooks (1960s)

During major Field Training Exercises (FTXs) Blue and Red forces deploy onto physical terrain and participate in a relatively freeform exercise. Accompanying units of each side are umpires, and then two opposing nits are about to come into contact the umpires halt the action, use the Umpire Guide to work out what the results of the combat should be, and then let the two side play through the combat to achieve the calculated result, and to suffer the calculated casualties.

The US Army used to have a series of publications called FM105-5 Maneuver Control which included the rules for their FTX "wargames". The latest edition appears to be from 1967, so whilst the data may not be useful the approach is worth looking at. Relevant abstracts are at Annex H, and a summary of key points below.

It's notable that FM105-5 uses a conversion from Firepower ratio to Combat ratio, based on the defender disposition (the means), with the Firepower = Combat for a frontal assault on a hasty defence position. Flank attacks give a x3 advantage to the attacker, defenders in the open give the attacker a 1 step advantage (so 2:1 becomes 3:1), and fortified positions are only an advantage in flank attacks, reducing the expectant flank attack ration by 33%.

Tables are provided for individual weapon Firepower Scores (see Annex H), which are then aggregated up using essentially a sum-product method to Unit Firepower scores, although the manual warns that "*"is not a simple addition of unit firepower scores. Consideration must be given to the type of action and method of force employment.".* Table 14 shows example Firepower Scores. Given the more tactical focus of FM105-5 it is notable that Firepower is expressed at different ranges. It is a pity that no later version or equivalent than 1967 is available, as this would otherwise be very useful data.

US Unit	**FP @ 300m**	**FP @ 1000m**
Inf Bn	2000	700
Inf Coy	540	140
AT Pl	70	70
Mortar Pl	40	40
Tk Bn	2100	1950
Tk Coy	600	550

Russian Unit	**FP @ 300m**	**FP @ 1000m**
Mech Bn	1200	500
Rifle Coy	200	40
AT Pl	40	-
Mortar Pl	-	-
Tk Bn	1200	1000
Tk Coy	350	300

Table 14: Unit Firepower Scores (FM105-5v1967)

It is also noted that:

- 70% of AFV passengers are casualties if an APC is lost.
- AP mines cause 50% casualties within 10m, AT mines cause 30% casualties to those in an APC or truck, plus 70% within 10m
- Blast AT mines cause severe damage to AFVs, penetration mines destroy them and cause 90% casualties inside, but only 10% outside
- Flamethrower casualties are 25% in open (10m x 49m for manpack, 15m x 175m for vehicle), 50% in bunkers etc

Artillery Fire is divided into *first category* for Under Command and Direct Support, and *second category* for those in General Support. *First category* firepower scores are included in the Bde firepower calculations and resolved through that. Artillery support allows an attacker to move an extra 100m in 15 mins, and fire by the defender slows the attacker by 150m in 15 mins. Casualties from second category artillery worked out per battalion volley, and assuming whole unit covered by beaten zone casualty rates are (Fig 28):

- Standing = 10%
- Prone = 6%
- Entrenched = 1%

- In trucks = 6%

There are also useful tables for casualties from, and breaching of, minefields.

Urban Effects

Whilst there are no specific urban factors there is a table for rubble clearance rates per km of rubble (Table 50): 15-18hrs to clear for wheeled (Crawler tractor vs CEV), 1.5 to 2 hrs for tracked.

British Army FTX Umpire Handbooks (1980s)

Having served in the British Army of the Rhine (BAOR) when two such large scale FTXs were held (Ex Spearpoint 1984 and Ex Keystone 1987), I am fortunate enough to have copies of the Umpire Guides that were issued.

It is interesting that whilst the approach in the US FM105-5 is very similar to US boardgames in being all ratios and combat factor based, the approach in the UK umpire handbooks is far more akin to a set of battalion level miniatures rules, talking about sub-units (stands) and casualties. There is no in-built assumption about a 3:1 ratio.

Annex I provides the main relevant tables from Ex Spearpoint Handbook (*Exercise Spearpoint 84: Umpire Handbook*, 1984), and key data is reproduced below.

For direct fire the system used is referred to as the Armoured Vehicle Kill Potential (AVKP), although it applies to both AFVs and infantry – as firers and targets. Although NATO equipment is used for both sides the Orange (as Red was then called) tables are different to the Blue ones, and can be assumed to represent the then current assessment of different capabilities of Blue and Orange. Table 15 shows selected units/equipment from Ex Spearpoint Umpire The 2000m-3000m range category has been omitted as is unlikely in urban.

Side	Unit/Equipment	1000m vs AFVs	2000m vs AFVs	500m vs Personnel
Blue	Tank Tp (3 tanks)(Chieftain)	2	1	6
	Tank Tp (4 tanks) (Chieftain)	2	1	7
	Close Recce Tp (8? Scimitar)	2*	1*	7
	Fd bty	1	0	17
	Swingfire (4 firing posts)	2	1	10
	Rifle Pl (dismounted)	1	0	10
	Mech Pl (in FV432)	1	0	14
	Milan Det (4 firing posts)	2	1	2
	Mortar Pl	1*	1*	14
Orange	Tank Tp (3 tanks)(“T80”?)	3	2	8
	Tank Tp (4 tanks) (“T80”?)	3	2	10
	Fd bty	1	1	24
	LRATGW (4 firing posts)	3	2	15
	Rifle Pl (dismounted)	2	0	15
	Mech Pl (in “BMP”)	2	2	20
	MRATGW det (4 firing posts)	3	1	3
	Mortar Pl	2*	1*	20

* = no MBT casualty awarded

Table 15: Armoured Vehicle Kill Potential (AVKP) from Ex Spearpoint

Whilst the format is not directly comparable with some of the other methods presented here, it is interesting that generally Orange is given more powerful combat factors, although at a resolution of only 1-3 AFV casualties care should be taken about seeing Orange MBTs as 1.5x better than the Chieftain. With the higher numbers for infantry casualties the 50% more effective dismounted orange Rifle Platoon might be more robust, although only a 43% more effective mounted platoon (in BMPs compared to FV432s) seems on the low side. The fact that at short range Swingfire and

Milan are matching the Chieftain launcher for launcher is interesting, with similar matching on the Orange side. The Exercise Keystone 87 Umpire Handbook (*Exercise Keystone 87: Umpire Handbook*, 1987) introduced a table to adjust casualties based on target posture and visibility, which could be useful for establishing wargame norms.

The indirect fire tables could almost have come out of WRG's rules (see below) but are simpler, and could be useful in calculating the reducing effects of artillery fire based on protection, and also the non-linear relationship between rounds and effect.

Urban Effects

In the FTX Umpire Guide for Keystone 87, being in a town reduces direct fire casualties by 75% (i.e. x0.25).

Staff Officer Handbook (1999)

Although the British Army Staff Officers Handbook 1999 (SOHB) (*Staff Officers Handbook*, 1999) includes planning figures for frontages and rate of advance against different opposition ratios it does not include any Correlation of Forces information. It does note that the rate of advance figures come from *Numbers, Predictions and War* (Dupuy, 1979). The SOHB does include useful logistics data and artillery weight of fire data, which will be examined in separate Research Notes.

Professional Wargame Rules

Professional wargame rules are worthy of consideration here as it is hoped that they have been based on sound analysis, and may share sources with some of the heuristics detailed above. Due to access and classification the example are all from the Cold War. This is not to say that some hobby games may not also have useful, and even accurate or valid, data, but rather that it is usually impossible to gauge their provenance.

Annex J provides samples of the relevant firepower sections for the following games:

- The British Army Tactical Wargame (1956)
- Firefight (1976) – a game developed for the US army but released commercially
- Dunn Kempf (1977) – a US Army game, heavily based on the UK's Wargame Research group hobby rules
- First Battle (1979) – a US Army Divisional level game
- Contact! (1980) – a Canadian Army tactical game, again influenced by WRG
- Blockbuster (1984) – A US Army urban specific tactical game
- A Fistful of TOWS (2011) – a hobby/commercial tactical set which has seen significant professional use and adaptation
- Sandhurst Battlegroup Kriegspiel (2016)

It might be interesting to look at the values used in *Battlegroup Clash: Baltics*[1] (Buckley, 2025), but it is not clear to what extent they have changed from the official Battlegroup Wargaming System version.

Comparing the treatment of units and weapon systems between rules and between rules and the models above is problematic since the game mechanics (e.g. how the Combat Factor is combined with or compared to a dice roll) may mask a more direct comparison. As with the models above it may be that the rules provide a sense of what are considered valid differentials between systems and units, and any of my rules should be checked back against such norms.

[1] https://boardgamegeek.com/boardgame/434134/battlegroup-clash-baltics

Applying to My Wargames

This section examines the considerations in applying the models, methods and data presented above to my own games, both heterogeneous (e.g. OPUC and City & CEMA) and homogeneous (City & CEMA and Brick By Bloody Brick) forces to assess a) whether they can be applied (and how easily) and b) to see what variation in combat factors they give – following a similar approach to that of Hogg described above. It should be noted that in both cases there is then a further step to convert the combat factors to numbers which can be used with the chosen game mechanics. These will not be considered here but dealt with in the Designer's Notes or Provenance document for each game.

Heterogeneous Approaches

As an example of the Heterogenous Approach I tried to calculate the Combat Factors for the following units in OPUC using different models presented:

- British Light Role Battalion
- British Boxer Battalion
- British Warrior Battalion
- British Challenger (CR2) Regiment
- British Mech Inf Battlegroup (3x Coy, Sp Coy, 1x Challenger Sqn)
- British 155mm Archer Regiment (18x guns)
- Russian BMP3 Battalion
- Russian T80 Battalion
- Russian 152mm 2S3 Battalion
- Companies for each of the above

Comments on the approach for each of the selected methods is in Table 16, and a comparison of the resultant Combat Factors is in Table 17. Air defence capability has been ignored.

Method	Comment
HERO	Using the OLI tables provided in Hogg (Hogg, 1993). Tables are early 1980s, so only just have SA80, no Warrior (but have MICV80), no CR2 (have CR1), and no Boxer or Archer (have M109). Have BMP2 not BMP3, but have T80.
Belorussian	Only shows AFVs. Close equivalents used (e.g. M1AI for Challenger, M2 for Warrior, M3 for Scimitar, BTR for Boxer)
Raymond	Generated values for Rural and Urban, but data is 1990s era so equivalents again used
SFS	Data is 1990s era so equivalents again used
GCSC2017	Used as is. Mech Inf for Boxer. Bxr BG as Mech Inf Bn + CR2 Sqn
FM105-5v1967	Only US and only 1960s equipment! 300m range used
UK FTX	Good match, but performance is only in tank cas at 1000m, so very low granularity
Firefight	US kit, vs tank at 500m
First Battle	UK kit,CCS+DFS
Sandhurst Kriegspiel	Good as is

Table 16: Comments on Heterogenous Methods

Unit	Composition	HERO-OLI	Belo-rus	CGSC	Raymond (Rural)	Raymond (Urban)	SFS	UK FTX	Fire-fight	Sand-hurst KS
Lt Role Bn	3 x Coy + Sp Coy	2540	22	15	88	167	79	18		19
Boxer Bn	3 x Coy + Sp Coy	2666	24	20	204	329	117	18		19
Warrior Bn	incl 8x Scimitar	5140	49	48	305	494	236		168	25
CR2 Regt	3x Sqn + CR2 (43x CR2)	41796	80	30	603	249	323	26	420	36
Mech Inf BG (3:1)	Boxer Bn + CR2 Sqn	16274	50		400	411	222			
Armd Inf BG (3:1)	Warrior Bn + CR2 Sqn	18748	75		501	575	341			
Archer Regt	24 x Archer 155mm	5352		33	99	149	120	3		
GMLRS Bty	8 x GMLRS			6	135	90	80			
BMP MR Bn	3x Coy + Sp Coy	17487	31	41	243	487	146	23	216	26
BTR MR Bn					141	251	73			
T80 Bn	3xCoy + T80 (31 x T80)	40052	57	19	434	180	171	30	300	33
2S3 152mm Bn	18x 2S3	3888				74	90			

Note: Equivalents have been used where exact equipment not available so interpret with caution!

Table 17: Comparison of Combat Factors in Heterogenous Methods

Table 18 then provides ratio comparisons between the different systems. The number shows how much stronger the Russian unit is than the UK unit.

Comparisons	**HERO-OLI**	**Belo-rus**	**CGSC**	**Ray-mond (Rural)**	**Raymond (Urban)**	**SFS**	**UK FTX**	**Fire-fight**	**Sandhurst KS**
BMP Bn vs Lt Role Bn	6.9	1.4	2.7	2.8	2.9	1.9	1.3		1.4
BMP Bn vs Boxer Bn	6.6	1.3	2.0	1.2	1.5	1.3	1.3		1.4
BMP Bn vs Warrior Bn	3.4	0.6	0.9	0.8	1.0	0.6		1.3	1.0
T80 Regt vs CR2 Regt	1.0	0.7	0.6	0.7	0.7	0.5	1.2	0.7	0.9
2S3/2S19 Bn vs Archer Regt	0.7		0.0	0.0	0.5	0.8	0.0		

Note: Equivalents have been used where exact equipment not available so interpret with caution!

Table 18: Comparison of Combat Ratios in Heterogenous Methods

This shows HERO-OLI as something of an outlier, significantly high rating the Russian units, and it is also the most “bottom-up” model of the set. CGSC also seems to high rate but to a lesser extent, whereas in contrast FM105-5 low rates (which may be right for 1967!). What is interesting is that there does seem to be some sort of consensus between the others, even though they are using different methods.

Finally, Table 19 then repeats the data from Table 17, but normalised to a rifle company. Here we are normalising across categories, so could expect some odd results. As with the previous analysis HERO-CLI is again an outlier, significantly over-rating things, whilst the Belorus data seems to under-rate. There is some reasonable (but by no means complete) alignment between CGSC and SFS, and the Raymond figures seem higher than these for rural, but lower for most urban. The data for the others is too sparse to spot any trends, but they do seem to have quite different numbers to the other – no doubt reflecting the very different methodologies or source data that may have been used.

	HERO-OLI	Belorus	CGSC	Raymond (Rural)	Raymond (Urban)	SFS	FM105-5v1967	UK FTX	Sandhurst KS
Lt Role Bn	6.2	5.2	5.0	5.1	4.1	4.4	3.7	6.0	4.8
Boxer Bn	6.5	5.9	6.7	11.9	8.0	6.5	0.0	6.0	4.8
Warrior Bn	12.6	11.9	15.7	17.9	12.0	13.1	0.0	0.0	6.3
CR2 Regt	102.1	19.4	9.9	35.4	6.1	17.9	3.9	8.7	9.0
Mech Inf BG (3:1)	39.8	12.2	0.0	23.5	10.0	12.3	0.0	0.0	0.0
Armd Inf BG (3:1)	45.8	18.2	0.0	29.4	14.0	19.0	0.0	0.0	0.0
Archer Regt	13.1	0.0	11.0	5.8	3.6	6.7	0.0	1.0	0.0
GMLRS Bty	0.0	0.0	2.1	7.9	2.2	4.4	0.0	0.0	0.0
BMP MR Bn	42.7	7.6	13.5	14.3	11.8	8.1	0.0	7.7	6.5
BTR MR Bn	0.0	0.0	0.0	8.3	6.1	4.0	2.2	0.0	0.0
T80 Bn	97.8	13.9	6.2	25.5	4.4	9.5	2.2	10.0	8.3
2S3 152mm Bn	9.5	0.0	0.0	0.0	1.8	5.0	0.2	0.0	0.0

Table 19: Comparison of Combat Factors in Heterogenous Methods - Normalised to Rifle Company

Heterogenous Combat Factor Guidelines

Based on all of the above, Table 20 presents what seem to be some reasonable guidelines for the comparative values between different unit types in the wargames I develop. Bear in mind that a lot of the sources are for 1970s/1980s era equipment, and so variations since may be expected.

Infantry	• A Boxer Bn should have 50% to 100% the power of a Lt Role Bn (assuming mobility & protection, not firepower effects?) • A Warrior Bn should have ~3x the power of a Lt Role Bn • A Mech Inf BG (e.g. Boxer, at 3 Coy + 1 Sqn) is about 2-3x more powerful than a Lt Role Bn, and 1.5-2x more powerful than a pure Mech Bn • An Armd Inf BG (e.g. Warrior, at 3 Coy + 1 Sqn) is about 5-6x more powerful than a Lt Role Bn, 1.5x more powerful than a pure Armd Bn, and 1.5x more powerful than a Mech Bn • Power in urban should be ~ 30% less that rural for all 3 types, 50% for BGs • A BMP Bn is about 1.3x to 1.4x more powerful than a UK Lt Role Bn or Boxer Bn • A BMP Bn is equivalent or a bit weaker than a UK Warrior Bn;
Armour	• A CR2 regiment should be about twice a Lt Role Bn, but comparison to Warrior Bn ranges from 66% to 200%! Cross category comparisons are always dubious! • A T80 Regiment is weaker (x0.7-x0.9) that a CR2 Regiment – however a CR2 regiment has 43x CR2 against 31x T80, i.e. the T80 regiment is 70% the strength, so tank for tank they are near equivalent).
Artillery	• Comparing indirect fire Arty to direct fire non-Arty units seems a bit problematic, but according to the models the following could be a guide… • A 152mm/155mm bty is roughly equivalent to a Lt Role Bn or possible Boxer Bn

Table 20: Guidelines for the Comparative Values Between Different Unit Types

Homogenous Approaches

As an example of the Heterogenous Approach I compared homogenous weapons ratings and

then tried to calculate the Combat Factors relevant units as might be found in Brick By Bloody Brick or City & CEMA.

Table 21 shows the key weapon systems as rated by the different models and potentially operating in the following homogenous roles:

- Anti-Infantry/Anti-Personnel (AP)
- Anti-Tank/Anti-Armour (AT)

Ideally I would also like to have data for Anti-Structure and Anti-Aircraft but the former is not typically listed in the sources, and the latter is only sporadically available. The following notes apply:

- The copy of HERO available in Hogg only provides data for upto mid 1980s, so few equipments persist. It also does not differentiate between AP and AT capability.
- Whilst FM105-5 v1967, Firefight, Dunn Kempf, Blockbuster and CONTACT! cover a wide range of weapons systems they don't cover the current generation of weapons and at the lowest level aggregate up into squads.
- For Fistful of Tows ROF x Pen has been used for AT fire. For AP the Anti-Infantry (AI) bonus has been used.

Weapon System	**HERO -OLI**	**Belarus**	**SFS**	**FFOT/ AP**	**FFOT/ AT**
UK					
SA80	0.06		}	0/na	
GPMG	0.48		} 0.15	+6	0
UGL	3.9		}	+3	
Sniper Rifle			}		
NLAW			~1.2	+3	14
Javelin			~1.5	+3	16
51mm Mortar	11		~0.4	+4	
81mm Mortar	46		0.7	+6	
Boxer MG	1.85		1	-1	0
Warrior 30mm	52		1.3	+0	24
CR2 120mm			~7.5		51
Russian					
AK74	0.2		}	0/na	
RPK	0.35		} 0.15	+6	
PKM	0.48		}	+6	0
UGL			}	+3	
SVD Sniper Rifle	0.07	0.09	}		
RPG7/16 style		0.09	0.25	+3	10
RPG32 Style			0.5	+3	17
AGS-17				+10	9
82mm Vasilek Mortar	77			+6	
BTR80	5.47		0.8	-1	
BMP3 30/90mm	414	}0.65	3.5?	}	24
BMP3 STABBER			1.2?		14
12.7mm HMG	5.47			-1	3
T72 125mm	977	1.00 (A)			30
T80 125mm	1292	1.85 (UD)			30
T90 125mm					

Table 21: Units and Weapon Categories for Homogenous Analysis

As can be seen there is a real paucity of data to use for any homogenous comparison. One thing that is noticeable is how at the platoon level there is seen as being very little difference between weapon capabilities.

It may be that I need to work up my own homogenous factors from publicly available information such as rates of fire, accuracy, penetration etc – although trying to get consistent and complete information for all the weapon systems I'm interested in is likely to be very hard, if not impossible. The issue then comes as to how to combine these into a single numeric factor, even just for say the anti-tank case. Dupuy appears to use the following formula for his Theoretical Lethality Index (TLI) which is then divided by a Dispersion Index to give his OLI (Dupuy, 1987):

Theoretical Lethality Index (TLI) = Rate of Fire x Reliability x Accuracy x Targets per Strike x Range

However, such a simple multiplication is bound to lead to unrealistic values (e.g. high ROF, small calibre) and includes nothing on killing power or penetration, or, as suggested above, on mobility and survivability of the firing platform. Alternative approaches could include a weighting of factors, and/or a categorisation of factors (high/medium/low), but my expectation is that there would be so many holes in the data as to make such a process impossible, or at least lacking in any robustness.

Homogenous Combat Factor Guidelines

Given the paucity of data there aren't really any guidelines that can be drawn for homogenous combat factors. The data doesn't even seem to follow the "GPMG is half the sections firepower" lesson my Colour Sargeant at Sandhurst kept drilling into us, which in an 8 man section and with a GPMG and loader would make 1 GPMG = 6 x SLR, so if SLR = 1, GPMG = 6. In the data above for HERO the GPMG is 8x the SA80 (which I'd guess is worth more than the SLR), and SFS doesn't even differentiate between small arms!

Conversion to Wargame Unit Combat Factors

Just having a set of combat factors, whether homogenous or heterogenous is just the first step towards having a combat factor that can be given to a wargames unit, since that factor needs to work with the adjudication mechanic being used to tell whether there is a hit or kill or other damage.

The most straightforward method is with ratio CRTs as then all that is required is summing combat factors (such as given above) and then determining a ratio, and then, if desired rolling a dice to introduce some randomness.

In miniatures games and some board games, a target number approach is required, so for instance units hit on 4+. The combat factor in this case needs to be converted to a dice modifier. With a D6 each pip is worth about 17%, so given a reference weapon/unit then for each 17% the firing unit is stronger than the reference it should get a +1 DM. The problem with this is -4 would mean no hits are possible and +3 would mean that 100% of combats are hits.

It is not intended to resolve this issue here, that will be left to the provenance documents for my rules, the point is to highlight that further maths is required to go from a combat factor as described above to a combat factor on a wargame unit.

Other Urban Effects and Reference/Check Points

From an urban point of view several of the works examined provide possible heuristics which at best could inform a set of wargame rules, and as worst provide some guidelines to validate a set of rules against. A summary of the key observations are shown in Table 22.

Category	Observation	Source
Ratios	2.56:1 is enough to guarantee winning in urban, and < 1:1 enough to guarantee losing	Lawrence
Multipliers/Rubble	Rubble increases defender capability (in cas caused) by x1.55 (c.f. x1.6 for prepared positions)	
Multipliers	Urban provides x2 to hasty defence and x3 to deliberate defence and x0.4 to hasty attack and x0.6 to deliberate attack	Hogg (TAM)
Multipliers	Chance of success x0.7 if attacking urban of non-urban probability	BATW
Multipliers	Urban reduces effectiveness to 36% and 46% for infantry and tanks in offence, and 42% and 54% in defence	Raymond
Multipliers	But taken as category multiplier, urban results in x4 for tanks (cf x10 for rural) but x6.4 for IFV mounted section and x3.9 for APC mounted section, cf x4 and x2.8 for rural.	Raymond
Multipliers	Armour is reduced by x0.4 but infantry increased by x1.2 in urban	Allen/SFS
Engagements	Tended to be shorter range but last longer	Rowland
Losses	Attacker loss rate is lower (and c.f. defender) than in rural (but force may be larger).	Lawrence
Losses	Attacker losses ~28% of defender, never >100%	Rowland
Losses	Each defender inflicts 0.51 casualties	Rowland
Advance Rates	Advance rates tend to be lower in urban c.f. rural	Lawrence
Advance Rates	Advance is half as fast through rubble	Rowland
Rubble	It takes 1.5-2hrs to clear 1km of rubble for tracked vehicles, and 15-18hrs to clear for wheeled vehicles.	FM105-5v1967
Exhaustion	Exhaustion does not appear to be a big issue in urban	Lawrence
Consumption	Only MMG/HMG, UGL and light mortar rounds showed higher consumption rates in urban, no other evidence of higher amo use.	Lawrence, Rowland
Consumption	No mention in battle diaries or data/logs of issues with food and water.	Lawrence

Table 22: Possible Urban Heuristics

As mentioned above several of these are challenges to “urban myths” and will be further examined elsewhere in the thesis.

Discussion

The immediate feeling from collecting this information is one of disappointment, it seems like there is no chance of seeing the wood for all the trees! Three major problems in even trying to compare or synthesise a solution from these inputs are that:

- Everyone seems to have slightly different measures and parameters, so direct comparison is problematic.
- In no case is there an unbroken line of evidence from the source data to their conclusions, in most cases the source data is missing (which may be classified in some cases, or is seen as company confidential in other), in others steps in the derivations are opaque or glossed over.
- Where data is available it is often pre-2010, or even pre-1980 and so hard to judge how relevant it might be to a modern game or model.

Reach (Reach et al., 2020) in particular talks about the challenges to COFM models in modern environments, noting the impact of a transition from attrition to non-contact warfare (which seems anyway to have been reversed in the Ukraine, or moved into a new dimension of drone-enabled non-contact warfare), and the increase in network-centric warfare (e.g. EW, cyber).

In terms of urban the following points can be noted:

- Since the focus is often rural, AFVs with ATGMs (e.g. BMP, Bradley) get a big boost, but that may be less relevant in urban where they are firing at short range with only their cannon. Raymond's approach partly addresses this, but then doesn't differentiate between short range AT weapons and longer range ones with greater minimum ranges.
- More significantly, the debate over urban myths that I identified in my historiography looms large here, with Dupuy, Lawrence and even Rowland arguing that urban is nothing particularly special (so calling into question the whole PhD?!), whilst others almost enshrine 3:1 ratios as a doctrine.
- The observation that high ratios are not needed may to an extent be influenced by the fact that commanders went into urban battles having been told that they would need high ratios, and so many urban battles probably had overkill as a result.

There is also the issue that whilst Lanchester uses, many accept, and Dupuy talks about the square law (force strength is proportional to the square of the number of troops/equipments) this is not reflected in any of the military texts - or even QJM - where a linear relationship is used. This seems to be due to Lanchester working in a "perfect" environment (air, sea) where potentially every potential firer can see every potential target in range, but this does not hold in the cluttered land battleground (and even less in urban).

It is interesting though how dominant the sum-product methodology is. Whilst I can see its applicability whilst using like weapons (anti-tank, anti-personnel), it does seem pushed to its limit when it includes anti-aircraft. Knowing which of the fire types to aggregate, and which to disaggregate (or abstract) should be a key game design decision which I need to document. The APPVUL notion of adjusting combat factors based on a systems vulnerability may also be a useful one.

In examining the different sources I must admit to some bias against the Dupuy style work to what appears to be spurious accuracy, with every military activity being definable to 2 decimal places. This doesn't sit well for me with concepts of military friction and the chaotic battlefield, no matter now many battles they are averaged over.

Conclusion

Whilst the sections above have tried to make some sense of the data in terms of my wargames, it seems at the moment that the only real way forward is to have what is sometimes referred to as an "open architecture", so that any combat factor derivation is spelt out in an annex to the rules, or in a separate provenance document, and that as long as it is internally consistent and externally not too out of stepped with perceived norms as presented here then that, for the purposes of this PhD, counts as good enough, and if people disagree with values they can at least see where they came from and change them. The value of the information here seems to be more in establishing some sense of relative impacts and capabilities, between weapon systems and situations, which can then act as a set of potential guard rails to my own values.

It is notable that in a 2020 article for Phalanx (the magasine of the Military Operational Research Society), Maj McCarthy of the Center for Army Analysis and COSAGE Team Chief (COSAGE being the Combat Sample Generator computer simulation systems) reviews many of the same sources as I've looked at in this paper, and notes that "*eventually, most of the combat values were arbitrarily updated or substituted from old combat values from decades prior*" and that even now "*the analytic community lacks a traceable, dynamic system to develop combat values*" (McCarthy, 2020) – so what hope do civilian PhD students have!

Probably the key learning is the recognition that, in Dupuy's terms, every wargame is a combat model, and so how that model was derived needs to be made clear and justified, and fit for the purpose it is being used for. It is then up to others to decide how valid the model, and wargame, is for their needs.

Annexes:

A. Lanchester's Equations
B. Dupuy and QJM
C. Lawrence and TNDM
D. Raymond's Modified WEI/WUV
E. Rowland and "Stress of Battle"
F. Hogg's Combat Models Survey
G. Spurlin & Green Force Equivalent Calculator
H. Russian Correlation of Forces and Means
I. US Army FTX Umpire Handbooks (1960s)
J. British Army FTX Umpire Handbooks (1980s)
K. Professional Wargame Rules

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ANNEX A

LANCHESTER's EQUATIONS

The two equations are, for unaimed fire (the linear law):

$$\frac{dB}{dt} = - B\ r\ R$$

$$\frac{dR}{dt} = - R\ b\ B$$

(where the two sides are Red and Blue, dB/dt is Blue's loss rate and r and b are the rates of fire of Red and Green respectively). This is often used to model artillery fire.

And for aimed fire (the square law):

$$\frac{dB}{dt} = - r\ R$$

$$\frac{dR}{dt} = - b\ B$$

(where r and b are the kills per unit time inflicted by Red and Blue respectively). Note that in aimed fire the loss rate is not dependent on the size of the other force as the fire is being aimed at the survivors (Lepingwell, 1987).

From the aimed fire (square) law we can then derive the following (Lepingwell, 1987):

$$P_{win}(R) = \frac{rR^2(0)}{bB^2(0) + rR^2(0)}$$

From this can be seen that an implication of the square law is that the outcome is more sensitive to force size (since it is squared) rather than to the force's unit effectiveness.

More succinctly, the fighting strength of a force can be expressed as:

$$\text{Fighting Strength} = PN^2$$

Where P= efficiency and N = number fighting (Christian, 2019; Flanagan et al., 2024).

Interestingly Osipov's equivalent equation had $N^{1.5}$ not N^2 (Rowland, 2006) (p.3).

For heterogenous forces (i.e. comprised of a mix of different weapons) the equations were then extended to the sum-product model described above (Farmer, 1980)

$$\text{Fighting Strength} = \left(\sum_{i=1}^{n} \sqrt{P_i}\, N_i\right)^2$$

Where P = probability of hit for weapon type i, and N the number of weapons of type i. Note that P is square-rooted before being squared with N so as to maintain the square law effect on

numbers not efficiency.

But such a breakdown potentially invalidates the core assumptions and expression of the Lanchester equations (Lepingwell, 1987).

Despite being never completely rejected and still influencing military simulations since the 1990s (Dağıstanlı, 2025; Flanagan et al., 2024; Kalloniatis et al., 2021), there are a lot a criticisms of the Lanchester equations including:

- They reflect Napoleonic era land combat and naval and air warfare rather than the empty battlefield and distributed manoeuvre of the modern battlefield (Schneider, 2015);
- Despite repeated attempts it has been hard to match the attrition rates given by the equations to the historical data (Lawrence, 2017);
- Some implementations of the model (e.g. Kaufmann's) include flaws and errors (Lepingwell, 1987);
- *"the literature on Lanchester's laws and equations has been very technical and mathematical, creating a communications gap between professional modelers, the consumers of model results, and academic analysts interested in conventional combat modeling."* (Lepingwell, 1987)*;*
- It reflects an "*impossible to actually achieve upper bound on the level of coordination among weapons*" (Anderson & Miercort, 1989);
- The lack of accommodation for manoeuvre (e.g. trading space for casualties in withdrawal), or for diminishing returns with increasing numbers and force-to-space ratios (Epstein, 1988).

There is a useful set of clarifications and critiques of Lanchester by MacKay (MacKay, 2014).

Indeed Lawrence comments that Lanchester "*has been pretty much discredited and has fallen out of favour*" (Lawrence, 2017)(p.290).

ANNEX B

DUPUY and QJM

Dupuy bases his work on that of Clausewitz, and an implied equation of (Dupuy, 1987)(Ch. 3):

`Outcome Ratio = (Red Number of Troops x Red Circumstance x Red Quality)/(Blue Number of Troops x Blue Circumstance x Blue Quality)`

`Combat Power = Number of Troops(N) x Variable Circumstance (V) x Quality (Q)`

He briefly considers the history of the 3:1 attack ratio, noting that from historical data whilst attacks at 3:1 result in near certain victory for the attacker, and attacks at a 1.5:1 ratio near certain defeat, most attacks are stages at odds within that range (e.g. 2:1) making pure force numbers ratios often useless (Dupuy, 1987)(Ch. 4).

His own theory of combat grew out of the 1977 Leesburg conference, and an invitation to work on the problem from SRI and the US Navy Post-Graduate School. He describes it as an inductive approach, and one that is closely mirrored by the Soviet approach of Correlation of Forces and Means (as described below). (Dupuy, 1987)(Ch. 5 & 6).

The main components of QJM are (Dupuy, 1987)(Ch. 8):

- `Theoretical Lethality Index (TLI) = Rate of Fire x Reliability x Accuracy x Targets per Strike x Range`
    - TLI is assessed for 6 classes of weapon: Infantry, Artillery, Armor, Air Support, Air Defence, Anti-Armour
- `Operational Lethality Index (OLI) = TLI / Dispersion Index (DI)`
    - Where the Dispersion Index reflects the increased dispersion on the battlefield – and hence ability to bring weapons to bear on a target, and which has risen from 3000 in WW2 to 4000 in 1970s, to 5000 in 1980s. There is no explicit derivation for DI, but is seems to come out that DI = sqm per man. (from Lawrence Ch 13 DI of 3000 = 333 men per sq km, Sqrt(3000) = 55m
- `Force Strength (S) = SumProduct of all OLI x Weapon Effect Factor (V or` V_w`) x Number of Weapons per category`
    - Weapon Effect Factors are not explicitly explained, but probably include environmental and operational factors, incl terrain and posture

Within the Clausewitz derived equation (P = NVQ) Dupuy then substitutes his own terms to give:

`Combat Power (P) = Force Strength (S) x Variable Factors (`V_f`) x Combat Effectiveness Value (CEV)`

Where:

- S = W x V_w and W = SumProduct (OLI x Number of Weapons per category)
- Vf includes environmental and posture effects (so some overlap with V_w?)
- CEV is a quality/morale of troops measure, derived by the difference between theoretical and actual outcome (!)

QJM has three main output measures:

- Mission Factor (MF) - was the mission successful;
- Spatial Effectiveness (E_{sp}) – how much ground was gained or held;
- Casualty Effectiveness (E_{cas}) – how efficient in causing casualties (enc cas/own cas).

In further chapters of *Understanding War* there are some indications of typical values for some

of the parameters:

- Defence Factors (in V_f?)
  - Hasty Defence = x1.3
  - Prepared Defence = x1.5
  - Fortified Defence = x1.6
  - Flat terrain in defence = x1.1
  - Rugged terrain defence = x1.3
  - Mountainous terrain = x1.5
  - (It is interesting that these are well down on the bonus that a typical wargame might give)
- Quality Values (CEVs):
  - Early WW2 Germans = 1.2
  - WW2 US Divisions = 0.72 – 1.14 (avg 0.84)
  - WW2 British Divisions = 0.61 – 0.96 (avg 0.76)
  - WW2 Late War German Divisions = 0.82 – 1.49 (avg 1.1)
  - Isreal vs Egyptians = 1.75-1.98
  - Isreal vs Iraqis = 3.43
  - Isreal vs Syrians = 2.44-2.54

Dupuy also updates Lanchester's Square Law in QJM terms to give (for defender)(Ch.16):

$dD/Dt = -C_d (CEV_a)^2 \times S_a$

Where C is a battle or engagement constant (!).

Other useful information from *Understanding War* includes:

- Diminishing returns once Combat Power ratio > 2:1
- 26km/d has been average advance rate post WW2, 22km/d in WW2 (cf. 17km in Napoleonic wars)
- Some correlation of ROA with Combat Power (P) ratio, but not with Force Strength (S) or Personnel Strength (N)
- In terms of attrition:
  - Casualty rates lower for victor (but may have more absolute casualties due to higher troop numbers)
  - Improvements in lethality being offset by increased dispersion
  - Divisions in WW2 were getting 1-2% losses per day for winner, and 2-3% per day for loser in intense conflict. Percent losses get higher the smaller the unit.
  - Tank loss rates 5-7 times higher
  - Typical 4:1 wounded to killed ratio
- Suppression is more determined by ROF not calibre (so faster 105mm better than slower 155mm), and can possibly be represented as a temporary reduction in CEV.
- Force Multipliers are seen as a difference between Force Strength Ratio and Combat Power Ratio:
  - Combat Effectiveness Superiority = x1.9 (surely is just CEV ratio?)
  - Mobility Superiority = x1.3
  - Air Superiority = x1.2
  - Surprise = x1.3 – x2.0

For the current task there are 4 potential uses of Dupuy that I can see at the moment:

- For the homogenous case the TLI/OLI values and calculation might be a way of deriving per weapon system combat factors;
- For the heterogeneous case Force Strength (S), or Force Strength x CEV could provide

the basis for unit factors;
- The various variable factors (V_f) could be us use in guiding wargame values; and
- The other Dupuy metrics could be useful to validate wargame models/rules against.

There is a feeling in the lot of the book that the derivation of some of the numbers is a bit soft, and that there are often fudge factors, which are set so that the equation outputs them match the battles they were derived from. The underlying databases and the real detail of QJM are the Dupuy Institutes "crown jewels" and so are not available to independently verify or to check derivations (such as what is in V_w and what is in V_f).

Criticisms in the literature of Dupuy includes:

- An admission apparently by Dupuy himself that QJM was based on "a somewhat messy process of trial and error" (Gowen, 2005)(p.6)
- "*DuPuy can easily be criticized for creating empirical formulae (setting equations to fit the available data) that are not backed by mathematical or scientific theory. Further, DuPuy's Quantified Method is only truly useful for analyzing historical battles. However, he does present at least one example in which he used his methods to analyze the relative force effectiveness of U.S. and Soviet weapon systems.23 An objective analysis of DuPuy's methodology would likely find his theorem to contain only casual relationships too dependent on experiential scenarios. But with all his shortfalls, only time will tell whether DuPuy was a pioneer in scientific discipline of the development of strategy.*" (Gowen, 2005)
- *"Though quantitative in application, deriving the quantities used in comparison still relied on a substantial amount of subjectivity. To mitigate this concern, users of QJM received with the database the values assigned to various factors to ensure transparency and consistency across their assessments"* (Christian, 2019)
- Gerhard Geldenhuys and Elmarie Botha scrutinized the mathematical foundations of the QJM and Dupuy's so-called "new square law" of combat. They identified internal inconsistencies in the QJM's equations, proposed corrections to eliminate these discrepancies, and showed that the new square law fails to satisfy basic requirements of a valid attrition model. Their work concludes that without these fundamental mathematical improvements, Dupuy's formulations cannot reliably predict real-world combat outcomes (cp) (Geldenhuys & Botha, 1994)

ANNEX C

LAWRENCE AND TNDM

Lawrence's *War By Numbers* (Lawrence, 2017) declares in its dedication that it is a "*continuation of his [Dupuy's] life's work*". In particular it has a further development of QJM, called the Tactical Numerical Deterministic Model (TNDM), which incorporates the passage of time (and so returns to differential equations as in Lanchester).

Lawrence refines some of Dupuy's work on force ratios, stating that (Ch 2 & 3):

- Attacks at > x1.2 usually succeed
- Attacks at x2 almost always win
- Attacks at x2.71 attacker never loses and always advances
- Attacker wins 61% of time (regardless of odds, but obviously choses battles!)
- When Defender wins 64% of time attacker is inferior
- When Attacker wins, 24% of time attacker is inferior

On casualty rates (CR), Captured in Action (CIA) and loss ratios (Ch. 8 & 12):

- For WW2
  - For failed attacker, attacker CR=2.98%, defender CR=2.62%, attacker CIA = 0.43%, defender CIA=0.34%
  - For successful attacker, attacker CR = 1.2%, defender CR=2.96%, attacker CIA=0.11%, defender CIA=0.92%
- For post WW2
  - For failed attacker, attacker CR=3.20%, defender CR=2.80%, attacker CIA = 1.28%, defender CIA=0.46%
  - For successful attacker, attacker CR = 1.6%, defender CR=4.83%, attacker CIA=~, defender CIA=1.01%
- Daily engaged casualty rates (WW2 US):
  - Coy - 21%
  - Bn - 9.5%
  - Bde - 2.6%
  - Div - 1%
  - Corps (0.4-0.6%)
- Comparing attacker and defender losses for WW2/Post WW2 LSCO, attacker takes ~12%, defender ~25% (but non-typical engagements)
- - For WW2 Europe,14% attacker, 50% defender, but for 1944 16% attacker, 9% defender
- "There is no direct relationship between force ratios and casualty ratios" - Dupuy
- Loss ratios are 0.5:1 to 2:1 in most cases, some to 6:1, more variable for lower force ratios

On surprise:

- Minor: ~x1.1
- Substantial: ~x1.6
- Complete: ~ 2.2
- Surprise increases chance of success by >50%
- Both attacker and defender show ~50% inc in loss rates if attacker has surprise!

Lawrence reiterates that there is no direct correlation between force ratios and daily advance rates. Seems almost fixed around 1km, with some to 5km or even 10km (cf Dupuy above). Also independent of attacker casualty rates, but is related to outcome (!!)

From Dupuy's *Attrition* (Dupuy, 1990), Lawrence quotes that 20% of cas killed immediately (1:4), 65% survive wounds, 15% die in treatment. There is also a useful table of source of

casualties/deaths by different weapon types:

	Gunshot	Mines	Bombs	Shells	Mortars	Grenade	Bayonet
GE Eastern Front							
British Jun-Jul 1944	31%	4%	4%	39%	21%	1%	
US WW2	32%	3%		53%	2%?		
US Korea	33%	4%		59%	1%?		
US Vietnam	51%	11%		36%	7%?		

He also notes that for gunshots wounded:killed ratio (1/lethality) is 1.56-2.33, whereas for fragmentation weapons it is 2.7-13.

Chapters 16 and 17 are dedicated to urban, and so are considered below.

Whilst Lawrence has some useful metrics to again check wargame results against (assuming that Lawrence's values are valid), there is no useful detail on TNDM itself.

Criticisms in the literature of Lawrence includes:

- *"While TNDM has demonstrated that it can provide a strategic assessment in the form of a probability of success for an overall effort, it has not demonstrated its effectiveness as a tool for operational planners. Moreover, maintaining the accuracy of the TNDM requires an enormous amount of inputs.92 As many of these rely upon difficult-to-obtain information, this requirement incurs a massive amount of lead time. As a result, the TNDM is more frequently used by companies to develop requirements that drive the development of hypothetical weapons more so than operational planners.93 Moreover, it is ineffective in situations where planners or commanders face a large amount of uncertainty"* (Christian, 2019)

<u>Urban Effects</u>

Lawrence devotes two chapters to urban (Lawrence, 2017)(Ch 16 & 17). His view (pointing the finger at Russell Glenn) is that "*The fear of the effects of fighting in cities, or urban warfare, was one of these recent trends. I'm not sure where this trend got started, but it was certainly promulgated by RAND, whose reputation is such that even their bad ideas are given credence.*" p.206. Dupuy Institute produced a 3 part study on urban warfare in 2001 "*with an open mind*", most of which is summarised in *War By Numbers*. Key findings are:

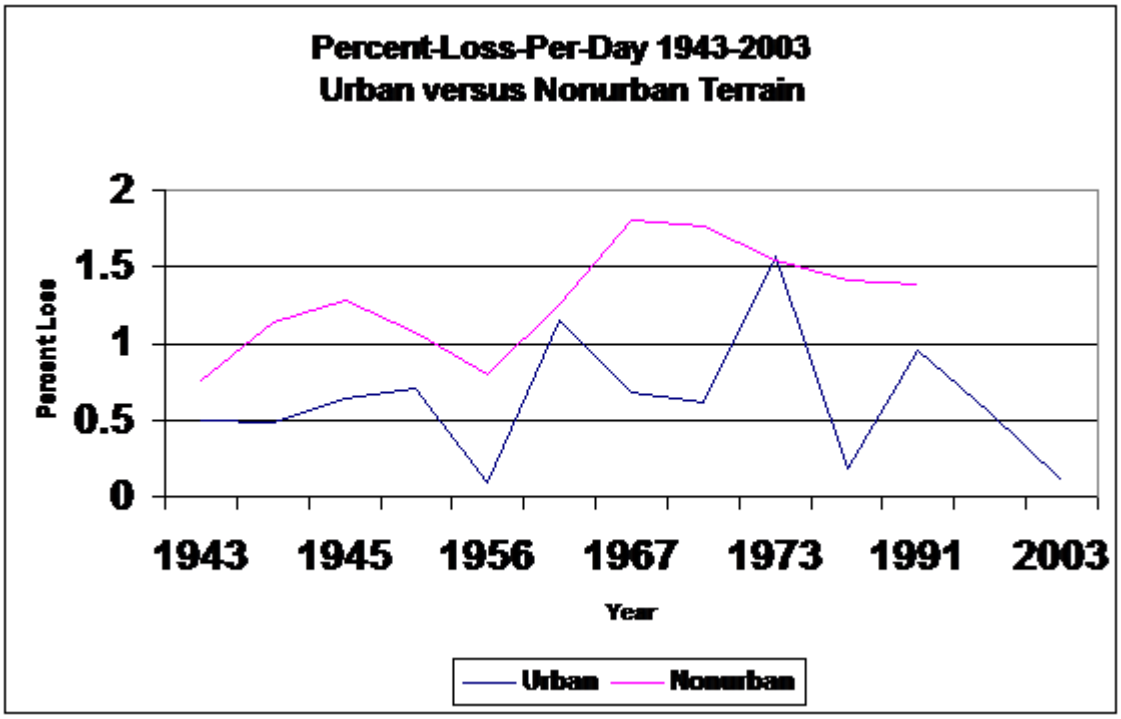
- Average force ratio was twice as high in urban (1944 ETO, c. 140 engagements, 44 urban/conurban)
- All at < 1:1 failed in urban
- None at > 2.56:1 failed (but 20% of rural at that ratio did)
- Force ratio is main predictor of outcome (and outcome is the main driver of casualties)
- Attacker loss rate lower than rural (but higher force ratios)
- Lower advance rates
- Conurban and urban similar
- "terrain [urban or rural type] has no significantly measurable influence on the outcome of the battle"
- "the ratio of attacker to defender casualties is more favourable to the attacker in urban warfare" - may be driven by selection (and force ratios)
- "armor losses were fairly low in most of the urban operations examined" {but cause and effect?}
- There didn't seem to be a link between combat exhaustion and urban (e.g. Brest 4.53%

vs average of 11%), more likely due to poor battle inoculation
- Artillery and small arms data do not show increases in urban (Brest 78x105mm/d cf 242, 43x155mm/d cf 161, 29k small arm at Brest cf 28k/mo). Only big uplift was in 0.5” MG (x4!), grenade projectors (78 cf 17) and 60mm mortar (826 vs 512)
- No mention in battle diaries or data/logs of issues with food and water.

Extending the analysis to both Eastern Front and post WW2 engagements did not contradict, but also did not clarify and if anything made more complex.

His summary was that:

- "*the primary result of urban terrain, according to the data derived from the analysis, is to reduce advance rates significantly, reduce casualties to some extent, and so to extend the duration of the combat.*" p.251
- "the tendency is to weigh one or both flanks and not bother to attack the city until it is enveloped" p.251
- Lack of unbypassable cities results in few urban combats
- Future impact of more effective weapons may result in more dispersal, less time in less protected conurban
- Bigger, taller, denser cities may not lead to a lot of changes, if anything may even have lower PV (eg metal/glass cf stone)
- The revolution in military affairs/information warfare might rebalance attacker advantage, and may allow more rapid isolation, so urban becomes mop-up



ANNEX D

RAYMOND'S MODIFIED WEI/WUV

Table 23 shows a selection of the modified WEI/CW values from Raymond's monograph, derived from an earlier study (Raymond, 1991). The number shown is the Weapon Value (WV, i.e. WEI) x Categoey Weight (CW), where CW has also been adjusted for terrain type.

Weapon System	**WEI (WV)**	**Rural/ Rolling**	**Urban**		**Weapon System**	**WEI (WV)**	**Rural/ Rolling**	**Urban**
MBTs (CW)		*10*	*4*				*10*	*4*
M1A1	1.55	15.5	6.2		T80	1.45	14	5.8
Challenger 1	1.45	14	5.8		T72	1.2	12	4.8
M60A3	1.15	11.5	4.0		T64	1.25	12.5	5
APCs		*2.76*	*3.87*				*2.76*	*3.87*
M113, Spartan	1	2.76	3.87		BTR80	0.95	2.62	3.68
FV432	0.9	2.48	3.48					
IFVs		*4.02*	*6.35*				*4.02*	*6.35*
M2 Bradley	1.3	5.23	8.26		BMP2	1.1	4.42	8.61
Warrior	1.15	4.62	7.3		BMP1	1	4.02	7.83
					BMD	0.65	2.61	5.09
ATWs		*4.96*	*2.18*				*4.96*	*2.18*
Improved TOW	1.15	5.7	2.51		AT-5	1.1	5.46	2.4
Swingfire	1.1	5.46	2.4		AT-3	0.9	4.46	1.96
TOW	1.1	4.96	2.18		AT-2	0.8	3.97	1.74
Milan	0.55	2.73	1.2					
Dragon	0.2	0.99	0.44					
Armd Recce		*2.96*	*2.52*				*2.96*	*2.52*
M-3 Bradley	1.3	3.85	3.28		BRDM2	1	2.96	2.52
Scimtar/Scorpion	1	2.96	2.52					
Attack Helos		*16.71*	*8.24*				*16.71*	*8.24*
AH64	1.3	21.72	10.71		HAVOC	1.2	20.05	9.89
AH1	1	16.71	8.24		HIND	1.1	18.38	9.06
Artillery		*4.13*	*6.22*				*4.13*	*6.22*
155mm SP	1	4.13	6.22		2S7 203mm	1.2	4.96	7.46
					2S5 152mm	1	4.13	6.22
					2S1 122mm	0.85	3.51	5.29
MLRS		13.5	9.01				13.5	9.01
MLRS	1.25	16.88	11.26		BM27	1.0	13.5	9.01
Mortars		*2.86*	*4.12*				*2.86*	*4.12*
81mm (in APC)	0.7(1)	2(2.86)	2.88(4.12)		2S4 240mm	1.5	4.29	6.18
					240mm (tow)	1.25	3.58	5.15
					2S12 120mm	1	2.86	4.12
					120mm (tow)	0.85	2.43	3.50
Inf Pl		*5.68*	*13.71*		**Inf Pl w/tpt**		*5.68*	*13.71*
c. 35 pax, Lt & Med ATGW, Ni Vision	1.1	6.25	15.08		1.3		7.38	17.82
c. 35 pax, Lt & Med ATGW	0.9	5.11	12.34		1.1		6.25	15.08
c. 35 pax, Lt ATGW	0.8	4.54	10.97		1.0		5.68	13.71
c. 35 pax, no AT	0.6	3.41	8.23		0.8		4.54	10.97

Table 23: Modified WEI/CW values (Raymond, 1991)

ANNEX E

ROWLAND AND "STRESS OF BATTLE"

Rowland offers little in the way of equivalences, and the only ones mentioned are to assist the analysis (such that 9 rifles = 1 MG, and 1x 81mm mortar = 3 MGs). His focus is more on the "degradation" effects between range and exercise findings and live fire battles, and some of the metrics that emerge from both the field exercises and the historical analysis.

Urban specific findings are presented further below, but notable rural and general findings are:

- From FTXs:
  - For company level engagements, duration was 30-60 mins, with 20 mins of hot engagement;
  - Combats typically broke down into a sequence/network of smaller engagements, with ratios ranging from 1:1 to 18:1
  - Overkill was a major factor, particularly as the ratio of firepower over available targets increases
  - The net combat effectiveness (vs range work) was 5% for riflemen, 21% for MGs (including a factor for non-participation)
- From Historical Analysis:
  - The net combat effectiveness (vs range work) was 10-12% for riflemen, 17% for MGs (including a factor for non-participation)
  - The presence of tank support reduces MG effectiveness, but is in turn reduced by presence of AT weapons
    - Reduce own cas by ~66% with 1 tank, 90% with 2 tanks (PI attack)
  - Defensive prepared positions increase defense effectiveness by x1.65
  - "Heroes" are vital and account for a significant increase in effectiveness
    - Hero served AT guns hit 0.275 tanks per target, normal crews hit 0.052
    - AT guns in WW2 had a mean T (anti-tank equivalence) of 23, cf typical tanks with 8.4. Heroes could lift T to 90.
  - Typical fighting unit had 18% heroes, 55% normal/degraded (cf. FTX) and 27% zeroes (non-participation)
  - Surprise reduced defence effectiveness by x0.6, effect may be larger at low ratio attacks (and surprise essential at <1:1 ratio for success)
  - Shock from tanks is due to surprise, poor visibility and perceived invulnerability of tanks. Shock from infantry is due to surprise, poor visibility and low morale.
  - Dive bombers/rocket/strafing attacks most likely to cause shock from air attack, not bombs, as seem to be coming straight at you.

<u>Urban Effects</u>

In Rowland, urban effects are reported as follows:

- From FTXs:
  - WARPAC tactics of just fighting through and using tanks/arty to destroy enemy in buildings has same casualty exchange ratios as NATO fire and manoeuvre, but were seem as more effective (faster, simpler).
  - Mini-engagements again seen within each battle: firefights, assaults, house clearances
  - Shorter range actions but longer engagements
  - No evidence of greater ammo use
- From Historical Analysis:
  - Attacker casualties are typically 28% of defenders, no battles above 100% of defender's.
  - Each defender typically inflicts 0.51 casualties
  - Degradation factor in comparison for trials/FTX ranged from x3.8 to x7.2 (i.e only

25% to 7% as effective)
- Attack cas per Defence MG equiv = 2.07 rural, 0.818 woods, 0.76 urban
- For defender, the typical casualty mix was 20% killed, 60% wounded/POW, 20% withdrew/ran.
- Tanks still help with suppression and reducing own losses “urban being 60% less effective with no attacking tanks”
- Experience effect is significant, with attacker cas per defender dropping from 0.175 to 0.06 after 12 attacks
- "defence of urban areas is best acheived by light or false defence and by counter-attack and that this practice will be aided by the use or armour in support and training in the attack role" (p.90)
- The presence of rubble increases defender capability (in casualties caused) by x1.55 (cf x1.6 for prepared positions)
- Advance is half as fast through rubble
- Rubble may disorientate and make harder to navigate and identify firer

ANNEX F

HOGG'S COMBAT MODELS SURVEY

Hogg examines four existing models: the National Training Center (NTC) model; the Command and General Staff College (CGSC) model; the Theater Analysis Model (TAM); and the Historical Evaluation and Research Organization (HERO) Model. The key features of each are shown in

National Training Center (NTC) model	Initially used a bean-count method of tank killing units down to AT-5/TOW level. Then used a relative values approach, with M2 Bradley/BMP2 as 1.00. Example values are shown in Figure 9. No consideration of artillery of air support.
Command and General Staff College (CGSC) model	Uses subjective relative values with a BTR Battalion as 1.0. Force ratios are derived by counting sum-products of units 2DOWN from the main force involved (e.g. companies for a brigade operation). Example values are shown in Figure 10.
Theater Analysis Model (TAM)	TAM is a computer based system which uses a heterogenous model with categories of armour, anti-tank, artillery and infantry systems. Systems are at the vehicle or infantry section level. Each category has its own 1.0 reference system (e.g. M1 for MBTs). System values are subjectively assessed relative to each base. Example values are shown in Figure 11. However, each category is then simply added together, and factors applied for terrain and mission (see Figure 12).
Historical Evaluation and Research Organization (HERO) model	HERO is based on Dupuy's Quantified Judgment Method of Analysis (QJMA) (see below). This uses a Theoretical Lethality Index (TLI) which is a "strictly quantitative approach". The categories used are: armoured weapons, infantry weapons, artillery weapons, air defence, close air support, and antitank weapons. For a mobile unit the TLI is given by: TLI = [rate of fire x targets per strike x relative effect x range factor x accuracy x reliability] x speed x radius of action + the punishment factor (sic) x (rapidity of fire effect x fire control effect x ammunition supply effect x ceiling effect). Only the […] is used for non-mobile weapons. The Operational Lethality Index (OLI) then represents the weapon system's lethality on the battlefield by dividing the TLI by a "dispersion factor" – which is 5000 (!) – but was being reviewed post Desert Storm where 20,000 seemed more applicable to US Forces. Again after the sum product of systems per category there is a simple summation of categories. Hogg notes that QJMA was specifically designed *"for war gaming on a computer to determine the outcome of*

	battles or engagements" (p.21). HERO can take into account 73 different external variables to account for environmental and operational factors.

Table 24: Four Combat Factor models examined by Hogg

NTC CP VALUES

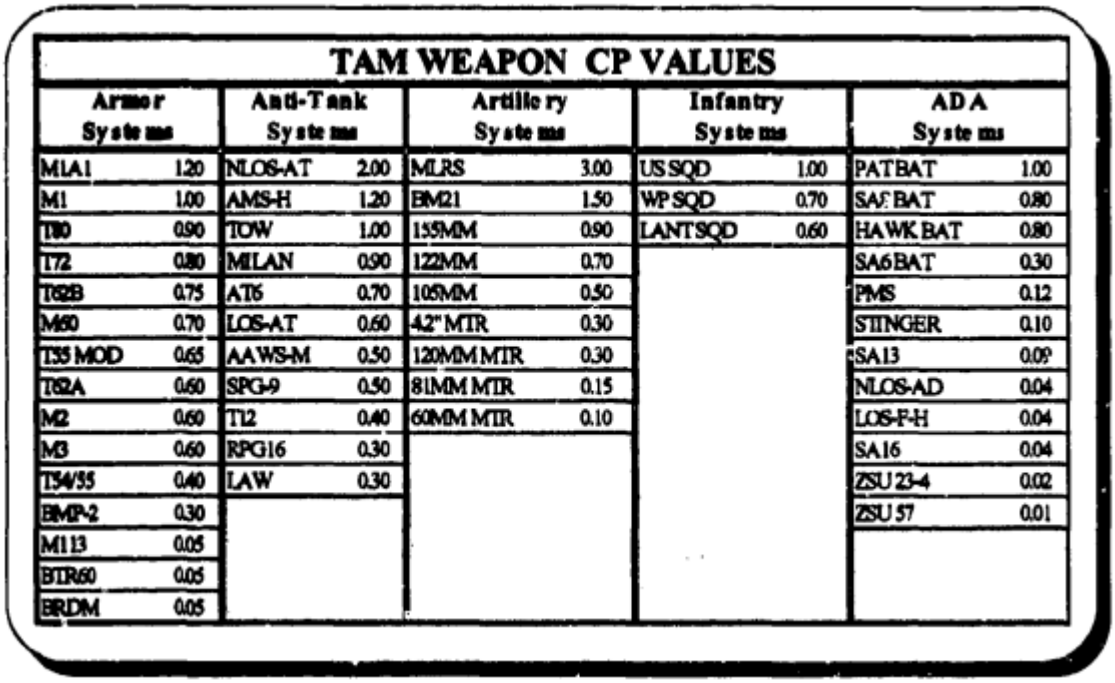
WEAPON	*VALUE*	*WEAPON*	*VALUE*
M1A1	1.4	AT5/TOW	0.8
T80	1.3	BMP1	0.7
M1/T72M1	1.2	AH64	0.7
M2/M3/BMP2	1.1	AH1/HIND	0.4
BMP1IP	0.9	MT12	0.3

Figure 9: NTC Combat Power values (after Hogg, 1993)

CGSC RELATIVE UNIT CP VALUES

US Forces		Krasnovian Forces	
	MANEUVER		
Lt. Inf Bn	0.50	AASLT Bn	0.60
AASLT Bn	0.60	BTR Bn	1.00
M113A3 Bn	1.50	BMP 1 Bn	1.50
M2 Bn	2.00	BMP 2 Bn	1.80
Sep AA Bn	1.00	AT Bn	1.00
M60A3 Bn	2.25	T64 Bn	1.45
M1 Bn	3.00	T72 Bn	1.20
M1A1 Bn	3.15	T80 Bn	1.56
Cav Sqd (Hvy Div)	1.50	Recon Bn	1.60
Cav Sqd (ACR)	4.00		
ACR	16.00		
Atk Hel Bn (AH-1J)	3.00	Atk Hel Sqd (HIND)	3.00
Atk Hel Bn (AH-64)	4.00		
	ARTILLERY		
FA Bn (105mm, T)	0.75	2S1 Bn (122, SP)	2.00
FA Bn (155mm, T)	1.20	D30 Bn (122, SP)	0.80
FA Bn (155mm, SP)	2.50	2S3 Bn (152, SP)	2.25
FA Bn (203mm, SP)	2.75		
MLRS Bty	2.60	MRL Bty	2.50
MLRS Bn (Corps)	6.00	MRL Bn	5.00

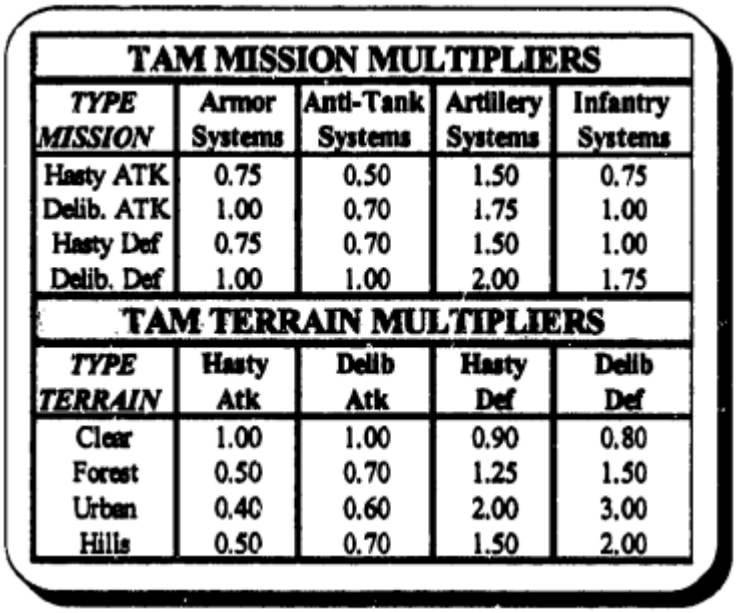
Figure 10: CGSC Combat Power values (after Hogg, 1993)



TAM WEAPON CP VALUES

Armor Systems		Anti-Tank Systems		Artillery Systems		Infantry Systems		ADA Systems	
M1A1	1.20	NLOS-AT	2.00	MLRS	3.00	US SQD	1.00	PATBAT	1.00
M1	1.00	AMS-H	1.20	BM21	1.50	WP SQD	0.70	SAF BAT	0.80
T80	0.90	TOW	1.00	155MM	0.90	LANT SQD	0.60	HAWK BAT	0.80
T72	0.80	MILAN	0.90	122MM	0.70			SA6 BAT	0.30
T62B	0.75	AT6	0.70	105MM	0.50			PMS	0.12
M60	0.70	LOS-AT	0.60	4.2" MTR	0.30			STINGER	0.10
T55 MOD	0.65	AAWS-M	0.50	120MM MTR	0.30			SA13	0.09
T62A	0.60	SPG-9	0.50	81MM MTR	0.15			NLOS-AD	0.04
M2	0.60	T12	0.40	60MM MTR	0.10			LOS-F-H	0.04
M3	0.60	RPG16	0.30					SA16	0.04
T54/55	0.40	LAW	0.30					ZSU 23-4	0.02
BMP-2	0.30							ZSU 57	0.01
M113	0.05								
BTR60	0.05								
BRDM	0.05								

Figure 11: TAM Combat Power values (after Hogg, 1993)



TAM MISSION MULTIPLIERS

TYPE MISSION	Armor Systems	Anti-Tank Systems	Artillery Systems	Infantry Systems
Hasty ATK	0.75	0.50	1.50	0.75
Delib. ATK	1.00	0.70	1.75	1.00
Hasty Def	0.75	0.70	1.50	1.00
Delib. Def	1.00	1.00	2.00	1.75

TAM TERRAIN MULTIPLIERS

TYPE TERRAIN	Hasty Atk	Delib Atk	Hasty Def	Delib Def
Clear	1.00	1.00	0.90	0.80
Forest	0.50	0.70	1.25	1.50
Urban	0.40	0.60	2.00	3.00
Hills	0.50	0.70	1.50	2.00

Figure 12: TAM External Factor values (after Hogg, 1993)

Hogg then uses the four different models to calculate the CoF for a US Brigade vs Soviet Brigade meeting engagement scenario, using the same ORBATs in each. The results in terms of the resultant force ratios are shown in, in each case with the US Brigade predicted to win.

COF(M) Model	Force Ratio
NTC	2.41 : 1.00
CGSC	1.50 : 1.00
TAM	1.72 : 1.00
HERO	2.13 : 1.00

Table 25: Comparison of Four Combat Factor models (after Hogg, 1993)

Across a variety of factors (flexibility, simplicity, definable, 90% solution) Hogg thought that the HERO model provided the best overall solution to COF generation (scoring 29.75 against the next closest, TAM at 25.75, HPS not given), and recommended that is be adopted as a manual process by the US Army, including for "*division and above*" wargaming. Hogg also notes that the two worst performing models (NTC and CGSC) were those then most in use by the US Army!

ANNEX G

SPURLIN & GREEN FORCE EQUIVALENT CALCULATOR

Table 26 shows a fuller set of examples of Force Equivalents from the source data in the Spurlin & Green (Spurlin & Green, 2017) Excel calculator.

US Unit	FE		UK Unit	FE		Russian Unit	FE
Striker Bde BCT	208.61		Armoured Inf Bde	272.5		MRR (BTR80/T72)	274.80
Striker Bn	33.45		Mech Inf Bn	20.41		MRB (BTR80)	42.9
Striker Coy	8.57		Mech Inf Coy	8.81		MR Coy (BTR80)	8.67
M1A2 Bde ABCT	248.99		Mech Inf Sp Coy	4.55		Tank Bn (T72A)	25.47
AR CA Bn (M1A2)	37.24		Armd Inf Bn	47.87		Tank Coy (T72A)	5.22
IN CA Bn (M1A2)	37.69		Armd Inf Coy	8.05		MRR (BMP2/T80U)	251.05
Inf Bradley Coy (M2A2)	8.95		Armd Sp Coy	17.58		MRB (BMP2/T80U)	36.3
Tk Coy (M1A2)	7.8		Lt Inf Bn	15.25		MR Coy (BMP2/T80U)	7.10
Inf Bde IBCT	131.30		Lt Inf Coy	0.84		MRR (BMP3/T80U)	269.35
Inf Bn	19.09		Lt Inf Sp Coy	5.95		MRB (BMP3/T80U)	41.12
Inf Coy	2.70		Tank Regt	41.62		MR Coy (BMP3/T80U)	8.30
Wpns Coy	4.38		Tank Sqn	10.08		Tank Bn (T80U)	28.96
						Tank Coy (T80U)	6.34
						Recon Coy (BMP)	8.87
						Tk Regt (T72A/BMP2)	211.95
						Tk Regt (T80U/BMP2)	222.64
						Tk Regt (T90/BMP3)	230.49
						Tk Bn (T90)	28.01
						Tk Coy (T90)	6.04
M109 Bn	28.13		FA Regt	31.12		FA Bn (2S19)	21.42
M109 Bty	5.87		FA Bty	5.59		FA Bty (2S19)	4.26
			GMLRS Bty	6.34			

Table 26: Selected values from the 2017 CGSC COFM Calculator (derived from the Excel code)

ANNEX H

RUSSIAN CORRELATION OF FORCES AND MEANS

The Russian Army sees (saw) Correlation of Forces and Means (COFM) as a key part of their military planning process.

> *This methodology is the mathematical determination of the combat power of the opposing sides after making mathematical adjustments for differences in combat systems, quantity and quality of systems, quality and training of the forces, terrain, morale, activity (attacking, defending, withdrawing, flanking, etc.), and combat experience. The Correlation of Forces and Means provides the ability to determine a mathematical probability of success, most advantageous avenues of attack or withdrawal and rate of advance in an operation or battle and can be the decisive determinant in the commander's decision.45 Determination of the Correlation of Forces and Means used to be a fairly lengthy mathematical drill, but the methodology has been computerized and upgraded. Mathematical models are also widely used for ammunition, fuel and personnel expenditure rates.* (Bartles & Grau, 2016)

A RAND study (Reach et al., 2020) notes that, as in US, there are different ways of calculating COFM, depending on who is doing the calculation and why. As in the US, the Russians see combat potentials (*boevye potentsialy*) – which they see as the "*relationship of the quantitative measure of combat potential of a given weapon or piece of military equipment to the value of combat potential of a standard [weapon or equipment], conditionally taken as the reference*" (p.19) - as the building blocks of COFM, alongside an assessment of qualitative factors such as training, will to fight and resilience of command and control. Again a simple sum-product approach is applied to the constituent heterogeneous elements of a unit to create a homogeneous combat value. The study identifies a number of different methods that are used to calculate combat potential, including: operation testing, tactical-technical characteristics, historical statistical analysis, ensemble analysis (drawing on multiple methods/studies), modelling and simulation, and expert evaluation and sub-system analysis (potentialometry – *potentsialometriia* in Russian). The Russian approach to combat potential also draws on a long history of qualimetry (*kvalimietriia)* research in the Soviet and Russian armies. Around 2008 the Russians attempted to standardise on the "*Method for Assessing the Combat Potentials of Weapons and Military Equipment and Combat Formations of the Armed Forces and Foreign States*" (known simply as the "Method"), developed by Lev Zakharov in the 1980s, published in 2001, and updated and republished by the Center for Military-Strategic Studies in 2009. The Method appears to be a fairly traditional application of combat potentials, qualimetry and potentialmetry and a sum-product approach, although it is rooted in a qualitative approach and emphasises quality (aggregate of properties) over effectiveness.

Reach et al also examine the evolution of US approaches to combat potentials, including the development of Weapon Effectiveness Indexes and Weighted Unit Value (see Hogg), Killer-Victim Scoreboards/Matrices and Situational Force Scoring (developed by RAND as a halfway house between WEI and KV).

Table 27 shows a combat potential table from the Cold War era.

Weapon or Large Unit	Combat Potential
T-55	1.00
T-80 (improved)	2.80
BMP-1	0.80
Leopard-2	2.40
M60A3	1.40
XM-1 (experimental)	2.50
BM-21 "Grad"	0.87
122mm SP Howitzer "Gvozdika"	0.81
"TOW" ATGM	0.95
S-75 [SA-2] (battalion)	4.70
"Hawk" modernized (battery)	12.6
MiG-23M	4.00
Su-24	4.00
F-14	11.90
F-15	9.50
Motorized Rifle Division (T-55, BMP)	1.00
Guards Motorized Rifle Division (T-64A, BMP, SP Artillery)	1.29
U.S. infantry division	0.86
U.S. mechanized division	1.10
U.S. armored division	1.23
U.S. airborne division	0.68

SOURCE: McMahon, 1980, pp. 4–9.

Table 27: Combat Potentials of Selected Weapons and Large Units of the Soviet Union and the "Armies of the Probable Enemy", 1977 (after Reach et al, 2020).

Table 13 provides a later (1980s?) example of the Russian view of the relative combat potential of modern weapon systems.

Category	**System**	**Combat Potential**
MBT	T80-UM (reference)	1
	M1A1 Abrams	1.08
	Challenger CR1?	0.98
	Leclerc	0.99
IFV	BMP3	0.9
	M2A1 Bradley	1.06
	Warrior	0.83
Artillery	Smerch BM-30 (reference)	1
	M108 (105mm)	0.51
	Abbot (105mm)	0.54
	BM-24 (pre BM21)	0.66
Aviation	F-15E (reference)	1
	F-15C	0.93

	Su-24	0.65
	Buccaneer	0.38

Table 28: Russian Example Combat Potentials (after Reach et al, 2020).

Table 29 provides a more comprehensive and slightly later view of combat potentials.

Weapon or Equipment	Combat Potential
Tanks, IFVs, armored personnel carriers (APCs)	
M1 "Abrams"	1.47
M1 A1 "Abrams"	1.87
"Leopard" 1A4	0.88
"Leopard" 2	1.90
"Leopard" 3	2.80
"Chieftain" MK-5	0.92
AMX-30-B2	0.65
"Leclerc" 1	1.80
BMP M2 "Bradley"	0.55
BRM-M3 [armored reconnaissance vehicle]	0.55
BMP "Marder"	0.26
BMP "Marder" A1 (A2)	0.45
"Lux" BTR with ATGM	0.26
BTR without ATGM	0.06
Antitank Weapons	
"Hot"	0.58
"Tow"	0.56
"Milan"	0.46
"Drakon"	0.32
"Vigilant"	0.24
"Iagdpanther"	0.37
120 mm BO [recoilless gun]	0.14
106 mm BO	0.16
90 mm RPTR [reactive antitank gun]	0.07
RPG [handheld antitank grenade launcher] "Panzerfaust" 3	0.20

SOURCE: Valezhanin and Tarchishnikov, 2011.

Weapon or Equipment	Potential
Tanks, IFVs, APCs	
T-64A	0.88
T-64B	1.24
T-72	0.88
T-72A	1.00
T-72B	1.65
T-80	1.06
T-80B	1.65
T-80 UD	1.85
BMP-1	0.47
BMP-2	0.43
BMP-3	0.65
BMGT-T	0.88
BMD	0.47
Antitank Weapons	
"Konkurs" [AT-5 Spandrel]	0.45
"Fleyta"	0.46
"Falanga" [AT-2 Swatter]	0.41
"Malyutka-P" [AT-3 Sagger]	0.39
"Fagot" [AT-4 Spigot]	0.36
"Fagot" mobile	0.32
"Shturm" [AT-6 Spiral]	0.58
100 mm PTP MT-12	0.38
SPG-9	0.15
RPG-7B	0.07
RPG-16	0.09
RPG-7B (with tandem PG)	0.20

SOURCE: Valezhanin and Tarchishnikov, 2011.
NOTE: PG = propelled grenade launcher.

Table 29: Belarussian c.2011 view of Combat Potentials (after Reach et al, 2020).

ANNEX I

US ARMY FTX UMPIRE HANDBOOKS (1960s)

The US Army used to have a series of publications called FM105-5 Maneuver Control which included the rules for their FTX "wargames". The latest edition appears to be from 1967, so whilst the data may not be useful the approach is worth looking at.

Equipments and units are provided with Firepower scores, typically range dependent, and there was a cardboard computer to ease the process of working these out. Ranges were defined as 300, 500, 700 and 1000m. Firepower scores for a unit are combined to give a Combat Power, which *"is not a simple addition of unit firepower scores. Consideration must be given to the type of action and method of force employment. Failure to apply proper tactical principles or to use concealment and cover, and movement through fields of fire without neutralizing the weapons covering the fields of fire result in the assessment of a high percentage of casualties"* (p. 114).

The Firepower ratio is compared to the situation to give an overall Combat ratio (aka combat power), using Table 30. Lookup tables convert the combat ratio to rates of advance.

Firepower ratio (attacker: defender)	1:1		2:1		3:1		4:1		5:1	
	Combat ratio (attacker: defender)									
Direction of attack	*Front*	*Flank*	*Front*	*Flank*	*Front*	*Flank*	*Front*	*Flank*	*Front*	*Flank*
Defender in open	2:1	3:1	3:1	6:1	4:1	9:1	5:1	12:1	6:1	16:1
Defender in hasty defense	1:1	3:1	2:1	6:1	3:1	9:1	4:1	12:1	5:1	16:1
Defender in fortified positions.	1:1	2:1	2:1	4:1	3:1	6:1	4:1	8:1	5:1	10:1

Table 30: Conversion of firepower ratio to combat ratio (FM10505, Fig 25)

Error! Reference source not found. provides examples of weapon Firepower Scores, Table 1 4 of unit Firepower Scores, and .

Weapon	300m	1000m		Weapon	300m	1000m
5.56mm M16	1	-		7.62mm rifle	1	
7.62mm MG	6	6		7.62mm LMG	4	
0.5" MG	10	10		7.62mm HMG	6	4
40mm GL	5			122mm tank gun	34	32
105mm Tank Gun	32	30		120mm mortar		20*
120mm Tank Gun	34	32		122mm Howitzer		20*
81mm Mortar		12*		152mm howitzer		30/40*
105mm Howitzer		20*		140mm MRL		28
155mm Howitzer		50*		280mm MRL		125
175mm Howitzer		75*				
8" Howitzer		100*				

* Indirect fire, to ranges > 1000m

Table 31: Weapon Firepower Scores (FM105-5v1967)

US Unit*	300m	1000m		Russian/OPFOR Unit	300m	1000m
Rifle Squad	24	0		Rifle Squad	10	2
Rifle Platoon	130	10		Rifle Platoon	50	10
Mortar Section	40	40		MG Platoon	40	20

Antitank Section	50	50				
Rifle Company	540	140		Rifle Company	200	40
Battalion Mortar Pl	70	70		AT Gun Platoon	40	
Battalion AT Pl	70	70		RCL Gun Platoon	80	80
Battalion Recce Pl	50	40		AA MG Platoon	130	130
Battalion	2000	700		Mechanised Battalion	1200	500
Tank Platoon	160	150		Tank Platoon	100	80
Tank Company	600	550		Tank Company	350	300
Tank Battalion	2100	1950		Tank Battalion	1200	1000

* Mechanised Bn

Table 32: Unit Firepower Scores (FM105-5v1967)

Casualties are then assessed "*in inverse ratio to combat power*", i.e. a 5:1 superiority in Combat Power implies 1/5th losses. Losses are however capped by typical maximum losses per day (15%) and per hour (1-3%).

There is a useful table for assigning casualties to killed and wounded (Table 33).

	Killed	Wounded
Tank Elements	1	3
Artillery Elements	1	4
Infantry Elements	1	4
Other Ground Force Elements	1	4

Table 33: Casualty Assignment (FM105-5 v1967)

It is also noted that:

- 70% of AFV passengers are casualties if an APC is lost.
- AP mines cause 50% casualties within 10mAT mines cause 30% casualties to those in an APC or truck, plus 70% within 10m
- Blast AT mines cause severe damage to AFVs, penetration mines destroy them and cause 90% casualties inside, but only 10% outside
- Flamethrower casualties are 25% in open (10m x 49m for manpack, 15m x 175m for vehicle), 50% in bunkers etc

There are also some interesting on how much intelligence is available based on time in contact, based on 3 zones (upto 10km from FEBA, 10-20km, beyond 10km). (p.165).

Artillery Fire is divided into *first category* for Under Command and Direct Support, and *second category* for those in General Support. *First category* firepower scores are included in the Bde firepower calculations and resolved through that.

Artillery support allows an attacker to move an extra 100m in 15 mins, and fire by the defender slows the attacker by 150m in 15 mins.

<u>Casualty rates</u>

Small arms inflict casualties at a rate of 1-3% per hour.
Tank losses in meeting engagement are the inverse of number ratio
Tank losses in attack against defending tanks are as per table below:

Combat ratio Attacker	:	Defender	Tank losses (per platoon (5 tanks) per hour) Attacker	Defender
1	:	1	2	1
2	:	1	2	1
3	:	1	1	1
4	:	1	1	2
5	:	1	1	3

Figure 29. Tank losses—exposed attacker versus protected defender.

First category artillery inflict casualties at a rate of 2-5% per hour, depending on number and type of artillery.

Attacker casualties due to artillery and mortars are, per 30 min period:

- On foot, within 500m of FEBA = 6%
- On foot, within 500m-1000m of FEBA = 4%
- On foot, beyond 1000m of FEBA = 1%
- Mechanised = 2%

Defender casualties due to artillery and mortars are calculated as a fraction of attacker casualties based on combat ratio per 30 min period, from 0.33 for 1:1 to 1.66 for 5:1 (linear) (Table 27). Also shown as these percentages:

- 100m – 500m = 2%
- 500m – 1000m = 1%
- Beyond 1000m = 1%

Casualties from second category artillery worked out per battalion volley, and assuming whole unit covered by beaten zone casualty rates are (Fig 28):

- Standing = 10%
- Prone = 6%
- Entrenched = 1%
- In trucks = 6%

Beaten zones for artillery (Fig 27):

- 105mm bn = 200m radius
- 155mm bn = 200m radius
- 155mm bty = 150m radius

Armoured vehs lose 1% per volley (155mm+)
Unarmoured vehs lose 9% per volley
Nice table for air attacks casualties:

Example 18. Nonnuclear Casualties From Airstrikes

Personnel targets	Casualties for initial pass within area of airstrike coverage	Casualties for each additional pass up to a maximum of three additional passes
Marching column (dsmtd)	20 percent	2 percent.
In APC's	70 percent per APC destroyed[a]	10 percent per APC destroyed.[a]
In tanks	2 persons per tank destroyed[a]	1 person per tank destroyed.[a]
In trucks	25% of persons in truck(s) destroyed	1 person per truck destroyed.
Supply convoys	1 person per truck destroyed	1 person per truck destroyed.
In assembly area (dsmtd pers)	10 percent	1 percent.
Deployed for attack	20 percent	2 percent
in defense (foxholes)	0.7 percent	0.7 percent

[a]Determine number of vehicles destroyed in accordance with 36 below.

Minefields

There is a useful table (Table 28) for AP mine casualties, with percentage casualties ranging from 80% for 24 mines per metre, through 50% for 12 mines per metre, to 20% for 2 mines per metre. (density seems excessive!)

Table 45 has AT mine losses for AFVs from 90% at 3 mines per metre (!) through 60% (1 mine per metre) to 10% (1 mine per 5m)

Breaching rates (marking AT, neutralising AP) are 50m per hour, with 1 cas per 100m.

Also has rubble clearance rates per km of rubble (Table 50): 15-18hrs to clear for wheeled (Crawler tractor vs CEV), 1.5 to 2 hrs for tracked.

ANNEX J

BRITISH ARMY FTX UMPIRE HANDBOOKS (1980s)

The following relates to the Umpire Guides for two large scale FTXs: Ex Spearpoint 1984 and Ex Keystone 1987.

For direct fire the system used is referred to as the Armoured Vehicle Kill Potential (AVKP), although it applies to both AFVs and infantry – as firers and targets. Although NATO equipment is used for both sides the Orange (as Red was then called) tables are different to the Blue ones, and can be assumed to represent the then current assessment of different capabilities of Blue and Orange. Table 15 shows selected units/equipment from Ex Spearpoint Umpire Handbook (*Exercise Spearpoint 84: Umpire Handbook*, 1984). The 2000m-3000m range category has been omitted as is unlikely in urban.

Side	Unit/Equipment	1000m vs AFVs	2000m vs AFVs	500m vs Personnel
Blue	Tank Tp (3 tanks)(Chieftain)	2	1	6
1*	Tank Tp (4 tanks) (Chieftain)	2	1	7
0	Close Recce Tp (8? Scimitar)	2*	1*	7
1	Fd bty	1	0	17
	Swingfire (4 firing posts)	2	1	10
	Rifle Pl (dismounted)	1	0	10
	Mech Pl (in FV432)	1	0	14
	Milan Det (4 firing posts)	2	1	2
	Mortar Pl	1*	1*	14
Orange	Tank Tp (3 tanks)(“T80”?)	3	2	8
	Tank Tp (4 tanks) (“T80”?)	3	2	10
	Fd bty	1	1	24
	LRATGW (4 firing posts)	3	2	15
	Rifle Pl (dismounted)	2	0	15
	Mech Pl (in “BMP”)	2	2	20
	MRATGW det (4 firing posts)	3	1	3
	Mortar Pl	2*	1*	20

* = no MBT casualty awarded

Table 34: AVKP from Ex Spearpoint

Whilst the format is not directly comparable with some of the other methods presented here, it is interesting that generally Orange is given more powerful combat factors, although at a resolution of only 1-3 AFV casualties care should be taken about seeing Orange MBTs as 1.5x better than the Chieftain. With the higher numbers for infantry casualties the 50% more effective dismounted orange Rifle Platoon might be more robust, although only a 43% more effective mounted platoon (in BMPs compared to FV432s) seems on the low side. The fact that at short range Swingfire and Milan are matching the Chieftain launcher for launcher in interesting, with similar matching on the Orange side.

For indirect fire, the impact area is standardised at 200m x 200m, which was standard for a battery shoot. Percentage casualty tables are then given for different weights of artillery, and number of rounds fired (total for fire mission). Samples of the tables are shown in Table 35, entries are % casualties even for AFVs/MBTs) and represent Observed fire. Predicted fire is typically shown as only 33% as effective.

Calibre	Rounds	Inf In Open	Softskins	Dug-in, APCs, SPGs	MBTs
105mm/BM21	10	3	2	1	1
	50	21	9	6	3
	100	37	17	1	6
	200	56	31	21	11

152mm/155mm	10	11	5	3	1
	50	39	22	15	7
	100	61	38	26	14
	200	84	60	45	26

Table 35: Indirect Fire tables extracts from Ex Spearpoint

These figures could be particularly useful in calculating the reducing effects of artillery fire based on protection, and also the non-linear relationship between rounds and effect.

The Exercise Keystone 87 Umpire Handbook (*Exercise Keystone 87: Umpire Handbook*, 1987) has the same AVKP table as for Ex Spearpoint, but the Blue figures are now used by both Blue and orange. However, there is now a Direct Fire Adjustment Table to adjust the casualties based on environmental factors. Rows are given for start casualties from 1 to 50, so just selected rows are shown in Table 36.

	Target posture					Visibility			
	Moving /Open	Hasty <2hrs	Improved 2-8hrs	Prepared or Town	Canalised	Day	Smoke/Hvy Rain/Mist	Night Illum	Night No Illum
1	1	1	1	0	2	1	1	1	0
10	10	8	5	3	13	10	8	5	3
25	25	19	13	6	34	25	19	13	6
50	50	38	25	13	64	50	38	25	13

Table 36: Direct Fire Adjustment Table extracts from Ex Keystone 87

Again these tables could be useful to derive different modifiers for different postures and visibility. Note though that the first 4 columns of target posture are the same as for visibility – which seems a bit odd given the numbers involved. The fires are also pretty much linear. The bonus for canalised targets is interesting (about +30%).

The indirect fire tables for Keystone are almost identical to Spearpoint, but the handbook now notes that 100m x 100m is the standard for a single battery shoot.

ANNEX K

PROFESSIONAL WARGAME RULES

The British Army Tactical Wargame (1956)

The British Army Tactical Wargame (1956) (Curry, 2020) is set at the Bde/Divisional level and has Bn/Bde manoeuvre units. Combats are determined based on a look up table of attacker and defender unit types involved (eg bn plus tank troop plus arty bty vs bn only). Separate look up tables are given for a deliberate infantry attack, deliberate combined arms attack, surprise counter attack, fluid encounter battle and hasty attack.. For each combination of attacker and defender the probability of success is given for attack vs a fortified position (> 24 hrs), attack vs a hasty defence (5-23 hours) and attack vs improvised defence (<5 hours). Some example probabilities are given in

Scenario	Attacker	Defender	Vs Fortified	Vs Hasty	Vs Improvised
Deliberate Inf	Bn & Tp	Bn + sp wpns	0.4	0.5	0.6
Deliberate Inf	Bn & Tp	Bn & Bty	0.3	0.39	0.49
Deliberate Inf	Bn, Sqn & Arty Regt	Bn + sp wpns	0.7	0.79	0.87
Deliberate Inf	3 Bns, 3 Sqns, 3 Arty Regts	Bn + sp wpns	0.98	0.99	0.99
Deliberate CA	Bn, Regt & Arty Regt	Bn + sp wpns	0.85	0.91	0.95
Deliberate CA	Bn, Regt & Arty Regt	Bn & Bty	0.65	0.75	0.84
Deliberate CA	2 Bns, Regt & Arty Regt	2 Bns, 2 Sqns, Arty Regt	0.4	0.5	0.6
Deliberate CA	2 Bns, 2 Regts & 1 Arty regt	2 Bns, 2 Sqns, Arty Regt	0.6	0.7	0.79
Surprise CtrAtk	Bn	Bn	na	Na	0.6
Surprise CtrAtk	Bn & Armd Regt	Bn	Na	na	0.95
Encounter	Bn	Bn	Na	na	0.5
Encounter	Bn & Armd Regt	Bn	na	na	0.96
Encounter	Bn & Armd Regt	Armd regt	na	na	0.6
Hasty	Bn	Bn	0.14	0.19	0.25
Hasty	Bn & Armd Regt	Bn	0.29	0.37	0.47

Table 37: Engagement Success Probabilities in the British Army Tactical Wargame

An optional rule is provided that “if attacking a major urban area, the probability should be 70% of that given in the tables – so VERY hard to be successful!

Firefight (1976)

In *The Complete Wargames Handbook* (Dunnigan, 1993), Jim Dunnigan describes how, after designing *Red Star/White Star* for the US Army he was given $25,000 to produce *Firefight* (Dunnigan, 1976), although the US found the resulting game too complicated. Despite that *Firefight* has had a significant impact on the professional and hobby wargaming scene ever since (Curry & Price, 2016). *Firefight* does not have counter stats, but specific lines on the combat charts to give the Attack Rating for a weapon at a specific range, which is then compared to a 2D6 roll on a CRT to give the combat result. Some example ratings are given in

Weapon	Vs Tank @ 500m	Vs Tank @ 1000m	Vs APC @ 500m	Vs APC @ 1000m	Vs Inf @ 250m	Vs Inf @ 500m
M1	10	10	10	10	7	7

M60A3	10	9	9	8	5	5
M2 Bradley	4	-	7	7	8	8
LAW	- (1 @ 400m)	-	- (1 @ 400m)	-		
Dragon	9	9	9	9		
TOW	9	9	9	9		
T80	10	10	10	10	6	6
T62	9	8	9	8	5	5
BMP	6	3	6	3		
SAGGER	7	9	7	9		
RPG7	1	-	2	-		
US Rifle Sqd					6	1
US MG Team					3	3
Sov Rifle Sqd					6	2
Sov MG Team					3	3

Note: There are some real oddities here!

Table 38: Example Combat Ratings from Firefight

The Sandhurst Kriegsspiel (Curry & Price, 2016) includes some notes on the British Army evaluation of Firefight (by Paddy Griffith) from 1977. Some of the key observations were:

- There was (in military terms) little on tactics and doctrine, and game mechanics forced/encouraged non-tactical behaviour (e.g. stacking);
- There was nothing on morale (removed at US Army request from the original draft), training, leadership, command, control or intelligence;
- The scenarios were too unrealistic (too many WARPAC ATGWs, not enough artillery)(but again apparently driven by US Army requirements);
- Cover values, especially for urban, were too low;
- Close combat rules were “ridiculous”;
- The mechanics took too long to learn and play in comparison to a “paper and pencil” wargame on an ordinary map;
- However “the game certainly succeeded in its expressed aim of ‘showing that the lethality and range of modern weapons can destroy a force’ – and hence the need to use terrain, suppressive fire and the combination of arms”;
- It was likely that students playing on their own would learn more about the game’s mechanics than real tactics;
- Hex grid was not liked;
- Long range fights are better modelled than short range ones.

From the perspective of this current paper, the most relevant observation was that “*The technical data … is reasonably sound as far as we could check it in the time*” – except that ATGWs seem overpowered (esp. SAGGER) and tank guns underpowered.

Dunn Kempf (1977)

Dunn Kempf (Dunn & Kempf, 1977) were a set of influential Coy/Bn level wargame rules for 1/300th scale tanks developed by the US Army in the 1970s, and inspired by the Wargame Research Group’s *Wargame Rules: Armour and Infantry 1950-1975* (Barker, 1974). Alongside other changes the US Army replaced the data tables in the WRG edition with actual military (and sometimes classified) data (Curry, 2022). Since Dunn Kempf is essentially a 1 model/stand = 1 vehicle/section set of rules it gives vehicle and weapon specific data, expressed in game terms, as a % chance of a hit (based on range) and then a kill (based on penetration/protection). A more detailed set of tables are also included from a III Corps version of the game. Some sample data from the basic game is in Table 39 (K = auto kill, S= auto-suppression).

Weapon	100m	500m	1000m	Vs T62	Vs BMP	Vs Inf	Vs M60	Vs M113
105mm APDS	13	14	22	36	K	S-51		
TOW	31	26	26	21	21	S-41		
Dragon	41	26	26	21	21	S-41		
LAW	13	-	-	51	31	S-51		
.50 cal	32	43	51	S-56	46	53		
Fireteam	32	52	62	S-65	D-45	42		
115mm APDS	12	12	22			S-51	26	K
73mm (BMP)	21	41	65			43	41	
SWATTER	-	33	31			S-41	31	21
RPG7	12	52				S-43	45	31
12.7mm MG	32	51	61			55	S-54	54
Fireteam	32	52	62			42	S-66	62

Table 39: Sample Dunn Kempf Weapon Data

First Battle (1979)

First Battle (Curry, 2023b) was a US Army set of Divisional level wargame rules with Bn/company-level manoeuvre units. Each unit has a Close Combat Strength (CSS) which was worked out on the basis that 1 CCS = 1x M60 or T62 at 1000m, or 1 infantry squad with supporting mortars. There are then Direct Fire Strengths (DFS) for ranged fires (>1000m). For DFS it was deduced that 2xM60 = 3xM62, and 2xTOW = 3xSAGGER. There is a note to the effect that "*these comparisons are based on the best scientific data available and some estimates about the unquantifiable's involved*" (p.22). For Direct Fire DFS is summed and compared against a D6 on a CRT to give losses. For close combat the ratio of total CCS's is calculated and compared against a D6 on a CRT to give losses to both sides. Example CCS and DFS are given in Table 40. Note that for US forces only some ancillary units are shown in the publicly published version!

Unit	CCS	DFS
Lt Inf Coy	9	1
Mech Div HHC	9	0
Recon Co MRD	7	4
Tk Bn+BMP Coy	41	27
Tk Bn	31	21
MRBn (Res) + Tk Coy	34	22
BMP Bn	33	22
Tk Coy	14	9

Table 40: Example CCS and DFS from First Battle

Being in a prepared position doubles the defenders CCS, but there is no explicit mention of urban.

Artillery units (batteries) are assigned an Indirect Fire Strength (IFS). Examples IFS are:

- 155mm = 6
- 8" (M110) = 8
- 175mm (M107) = 5
- 122mm = 15
- 152mm = 15

- 122mm MRL = 20

It is interesting that whilst Dunn Kempf is very much a miniatures set of rules, First Battle is very much a boardgame set of rules, each adopting the tropes of its relative style.

Contact! (1980)

Contact! (Curry, 2023a), published in 1980 was the Canadian Army's tactical training wargame. Like Dunn Kempf it was significantly influenced by the WRG rules, and designed for use with 1/300th scale models where 1 model = 1 tank and 1 stand = 1 section. In introducing the modern reprint rules the editor (John Curry) notes that hit probabilities were based on operational research (although post-Cold War releases showed the WRG values to be close to the official figures). The indirect fire system also reflected operational research and is seen as a key strength of the game. There is also a useful table on the impact of different sorts of minefields. For direct fire there are separate weapons cards for each weapon type, giving its kill probability at different ranges against different specific target vehicles and infantry dispositions. If within 20 percentage points of a kill then suppression is achieved instead. Table 41 shows some example values at 500m – most weapons showing little variation between 100m and 1000m. The original rules only covered Canadian and WARPAC equipment, but Curry added some UK equipments.

System	**Vs T62**	**Vs T72**	**Vs T80**	**Vs BMP**	**Inf dug in**	**Inf in bldgs**	**Inf halted**	**Inf moving**
Leopard C1	80	80	70	80	30	35	40	50
M60A3	80	80	70	80	30	35	40	50
Chieftain V	80	80	80	80	30	35	40	50
TOW	40	20	10	60	10	15	20	30
MILAN		20	20	40	0	5	0	0
M113 .5MG	0	0	0	10	10	15	20	30
Carl Gustav	20	20	0	30	0	10	10	20
GMPG-SF	0	0	0	40	10	15	20	30
CAN Inf Sect.	0	0	-15	0	5	5	10	20
UK Inf Sect.	0	0	-15	0	10	10	20	30
	Chieftain	**M60A3**	**Leopard**	**M113**				
T80	60	70	80	80	30	35	40	50
T72	60	70	80	80	30	35	40	50
T62	60	70	80	80	20	25	30	40
BMP1	20	20	30	40	20	25	30	40
Soviet Sect.	0	10	20	30	0	5	5	10
SPIGOT AT4	20	20	30	40	-	5	-	-
SPANDREL AT5	20	30	40	50	5	-	-	-
HMG	0	0	0	70	20	25	30	40

Table 41: Example Direct Fire Kill Probabilities from CONTACT! (at 500m)

For Indirect Fire each element in the beaten zone checks against a kill probability PK per battery firing. Beaten zone radii are:

- Mortar = 40m
- 1 battery = 100m
- 2 batteries = 130m

- 3 batteries = 150m
- 2-3 bns = 180m
- MRL = 190m x 510m
- SCATMIN = 200m x 360m per bty

Kill probabilities are shown in Table 42. Roll within +20 gives suppression.

Weapon	Tank	APC	Other Veh	Dug In	Halted	Moving	Bldgs
155mm	1	2	20	3	5	10	3
81mm mortar	0	0	20	5	15	20	2
122mm	2	5	20	5	15	20	3
120mm mortar	2	3	15	15	20	25	10
122mm rocket	3	10	30	5	15	20	3

Table 42: Example Indirect Fire Kill Probabilities from CONTACT!

Blockbuster (1984)

Blockbuster (Curry & Burden, 2023) was a US Army wargame to teach soldiers about the tactics and principles of Military Operations in Urbanised Terrain (MOUT). It has some similarities with Dunn Kempf, but some idea of its approach can be gained form the fact that it claims to enable 15-30 minutes of real action to be played out in 6-8 hours through the wargame! It uses a 30 second turn, and two different ground scales, 1" = 50m in the rural surrounds and 1" = 7m in the urban – which corresponds to the 1/300th models used. Scenarios are typically built around a defending, reinforced US rifle company. For direct fire there is a table for each weapon system showing its probability of a hit (Ph), and then of an absolute kill (K), firepower kill (Kf) or mobility kill (Km) (these sequential, so K, Kf or Km depending on the roll) at different target types and ranges. Extracts are shown in Table 43.

Weapon	Range	Tank Target				APC/IFV Target			
		Ph	K	Kf	Km	Ph	K	Kf	Km
M60A1	500	96	46	58	69	88	51	75	87
M60A1	1000	72	41	54	63	67	53	74	86
T62	500	98	50	57	73	94	11	52	74
T62	1000	71	38	54	63	59	8	51	73

Table 43: Example Weapon Probabilities from Blockbuster

For a set of rules aimed at urban combat it's interesting that the weapon ranges go from 500m to 3000m, with nothing below 500m!

There are also tables for machine gun fire against infantry, for snipers and flamethrowers, for all weapons against troops in buildings, and for close combat assaults.

Most of the weapon tables and many of the combat have not been found to include in the published rules, which limits its usefulness for the current exercise.

A Fistful of TOWS (2011)

A Fistful of TOWs (FFOT) is a set of hobby rules, first released in the mid 1990s and updated a third edition in 2011. Whilst developed as a hobby game the rules have been used, with modifications and different (more realistic) data by several Western militaries. Like Blockbuster they are designed for use with 1/300th miniatures. They use a 1" = 100m or 1" = 250m ground scale and about 12 minutes per turn. Forces are likely to be of company to battalion strength.

Whilst the introductory rules run to only 10 pages the full rules have around 130 pages of rules and 250 pages of army lists and data charts (!), covering weapon systems from 1915 to 2015.

For direct fire, each weapon has Rate of Fire number, and rolls that number of dice looking for 4+ to hit (with a few modifiers). For anti-vehicle fire weapon penetration is compared to armour, and that many dice rolled for each it, with a Kill on a 6, and a Quality Check on 4 or 5. For anti-personnel fire there is a Quality check for each hit. Example stats are in Table 44.

Weapon	**ROF**	**Pen**		**Weapon**	**ROF**	**Pen**
Chieftain Mk10	3	14		T62	2	14
Challenger 2	3	17		T72	2	15
Warrior	4	6		T80-U	2	15
Scimitar	4	6		T80-U msl	1	15
Milan	1	17		T90A	2	15/16
Javelin	1	16		T90A msl	1	15
M60A3	3	14		BMP1 (msl)	2 (1)	11 (12)
M1A2	3	18		BMP3	4 (1)	6 (14)
Bradley	4	7				
TOW	1	15				

Table 44:Example Weapon Stats from A Fistful of TOWs

For infantry the rules provide a method to work up the Anti-Infantry firepower ratings for each stand (typically a platoon) for both ranged and close combat. Key values are shown in Table 45. There is then a further lookup table to convert these to the in-game Anti-Infantry and ROF values.

Base Firepower for Platoon	Pistols	Bolt Rifles	SLRs	Asslt Rifles	SMGs	Grenades	LAWs	ATGMs	Satchel Charges
Ranged	0	27	33	15	0	+0	+0	+3	+0
Close	15	27	33	45	45	+20	+3	+0	+8

(seems to be based on a 27 man platoon with bolt rifles)
(additions are once per pl, assume meets minimum number requirement, eg 2x LAW)

Add per wpn	LMG	MMG (tripod)	HMG (tripod)	GL	AGL	Sniper	Lt Mortar	Med Mortar	Flame-thrower
Ranged	+6	+9	+10	+0	+10	+3	+4	+6	+0
Close	+6	+6	+6	+3	+2	+2	+0	+0	+0

Table 45: Infantry Platoon Firepower Derivation in A Fistful of TOWs

From sight of professional adjustments to data for FFOT it is hard to interpret the way the information is presented, but it seems that whilst armour and penetration values have not been changed, ROF has been significantly reduced to 1 for tanks (from 2) and 3 for BMP2 (from 4).

Sandhurst Battlegroup Kriegspiel (2016)

The *Battlegroup Kriegsspiel* included in *The Sandhurst Kriegspiel* (Curry & Price, 2016) includes stats for a variety of modern units as shown in Table 46. The game is designed to be played on a 1:50,000 map with counters showing unit stats. Combat resolution is via a Combat Factor Ratio vs scenario lookup, which gives a chance of success which is then compared to a D20 roll on a CRT to give the outcome in terms of step losses (most units are 3 or 2 step) and withdrawal. The numbers in Table 46 show the Combat Factor for each level of step loss.

Unit	Combat Factors		Unit	Combat Factors
Challenger/M1 Sqn	12-8-4		T90 Coy	11-9-4
Warrior Coy (mtd)	2-2-2		BMP2 Coy (mtd)	3-2-1
AS90 Bty	10-8-4		D30 Bty	2-2-1
Dismounted Coy	4-3-2		Dismounted Coy	3-2-1
ATGW Platoon?	4-3-1		ATGW Pl?	4-3-1
Mortar Pl	3-2-1		Towed Mortars	4-1-1
Bradley Coy (mtd)	2-2-1			
M113 Coy (mtd)	1-1-1		BTR90 Coy (mtd)	2-1-1
Apache Coy	8-6-2		Hind Coy	

Table 46: Sample Units Stats from the Sandhurst Battlegroup Kriegspiel