2. Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC)

The methodology for calculating a weapon or unit's Overall Combat Power Coefficient (OCPC) involves two main steps.

The first step involves calculating the individual weapon's inherent offensive lethality. This is essentially the attack strength of the weapon. At this point, the attack strength of the weapon is unmodified by the transport type, housing, chassis or vehicle that the weapon is on.[1] The weapon is not yet considered to be a complete usable 'weapon system' or 'database unit'. There may be multiple weapons in (or on) any given weapons system or database unit (e.g. a tank with multiple weapons). The **individual weapon's inherent offensive lethality** is termed its **Weapon Combat Power Coefficient,** hence referred to as the weapon's **WCPC**.

The second step is to calculate the weapons system or database unit's OCPC by adding up the individual weapon WCPCs (from above), and then including all other factors relating to the individual weapon system or database unit. This then encompasses all the defensive and offensive aspects of the weapon system or unit such as protection, dispersion and mobility. The multitude of additional factors considered in the second step is detailed in the methodology below. The exact procedure for the second step depends on the category of weapon system or database unit. There are three categories of weapon system or database unit considered in this methodology, which are:

- **Non-mobile weapon systems or squads**. These include weapons that are stationary, towed or carried, with no inherent motorised mobility.
- **Land based motorised Mobile Fighting Machines (MFMs).**
- **Aircraft.**

The methodology presented here is generic in that it is applicable to any weapon system. However it is most suitable for weapon systems from the first half of the twentieth century. The results of applying the complete methodology to each country's available weapon systems and combat units in 1941, are presented in the specific volumes and chapters relating to each country's integrated land and air resource model.

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1) Calculating Individual Weapon Combat Power Coefficients (WCPCs)

The following factors are considered in calculating an individual weapon's WCPC: Rate of Fire (RF), Number of Potential Targets per Strike (PTS), Relative Incapacitating Effect (RIE), Range Factors (RN), Accuracy (A), Reliability (RL), Self-Propelled Artillery Factor (SPA), Aircraft Mounted Weapon Effect (AE), Multi Barrelled Weapon Effect (MBE), and Typical Target Dispersion Factor (TDi).

A weapon's WCPC is given by,

$$WCPC = \frac{RF * PTS * RIE * RN * A * RL * SPA * AE * MBE}{TDi}$$

a. Rate of Fire (RF)

This is the practical number of effective strikes which a weapon, under ideal conditions, can deliver against a target in a given time period. The time period considered is one hour because it permits consideration of sustained rates of fire from large calibre projectile weapons. Logistical ammunition supply constraints are not considered at this point, except for aircraft launched weapons which are limited to one sortie per aircraft per hour.

Rates of fire for non-automatic and non-anti-aircraft (AA) weapons in WWII were principally dictated by the weapon calibre. There were small variations due to breech design, particularly for anti-aircraft weapons, but weapon calibre was by far the dominant parameter. Graph RF shows the relationship between Rates of Fire (RF) (expressed in rounds per hour) versus weapon calibre (in millimetres) for non-automatic and non-AA weapons.[2]

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[1] With the exception of Self-Propelled Artillery Factor (SPA) and Aircraft Mounted Weapon Effect (AE). Refer equations below for calculating an individual weapon's WCPC.

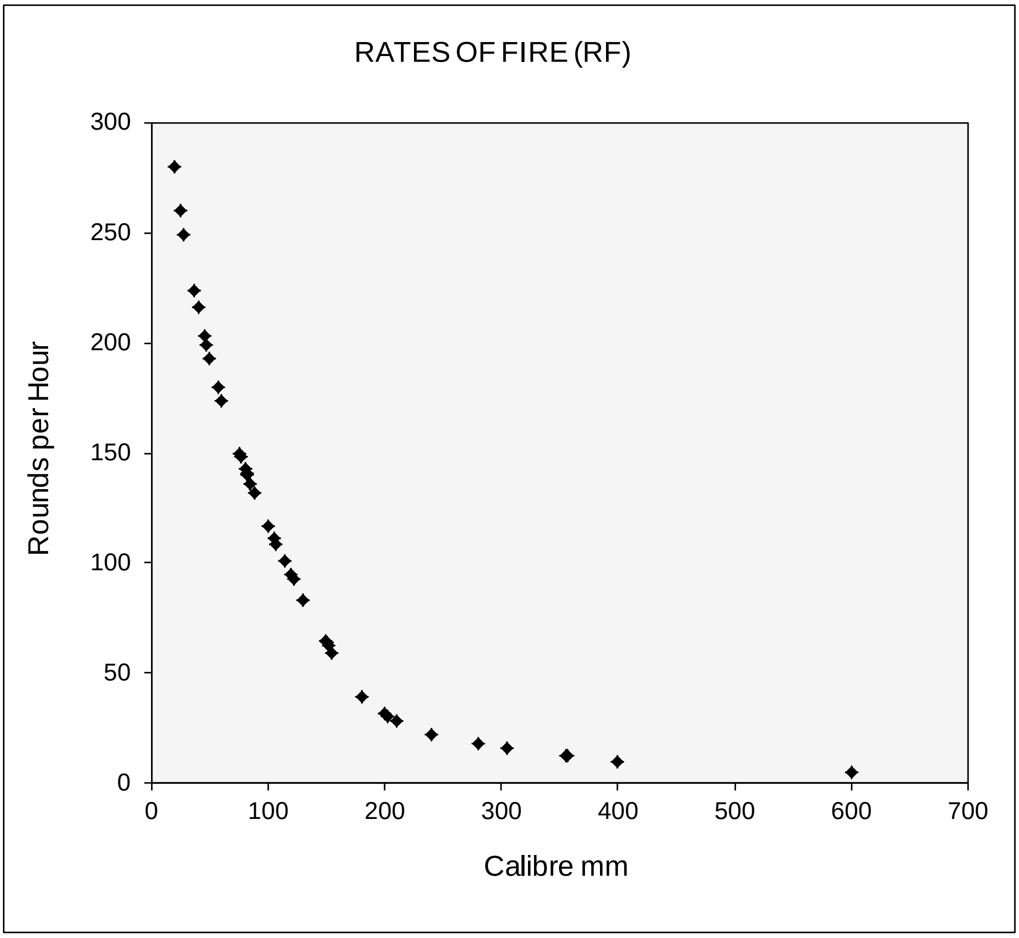
[2] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, p. 192. Note this data doesn't consider higher rates of fire from non-automatic AA weapons, e.g. 75-90mm AA guns.

This data is used to determine the rate of fire for non-automatic and non-AA weapons once the calibre is determined, for calibres down to 20mm.

Graph RF

Calibre mm (x)	Rate of Fire RpH (y)
20	280
25	260
28	249
37	224
40	216
45	203
47	199
50	193
57	180
60	174
75	150
76.2	148
80	143
81.4	141
82	140
85	136
88	132
100	117
105	111
107	109
114	101
120	95
122	93
130	83
149	65
150	64
152	62
155	60
180	39
200	32
203	31
210	28
240	22
280	18
305	16
355	12
356	12
400	10
600	5

Rates of Fire vs Weapon Calibre, for non-automatic and non-AA weapons



To cover other weapon types the following modifications apply:

i. For **Mortars**, RF = 1.2 x RF value determined from Graph RF.

Mortars are not breech loaded and usually had a higher rate of fire than artillery. Mortars in this case only applies to lightweight, smoothbore, muzzle loading weapons firing a fin stabilised bomb.[3]

ii. For **land based AA weapons with calibre < or = 40mm**, RF = 1.4 x RF value determined from Graph RF.

Land based anti-aircraft weapons less than 40mm calibre in WWII, can be considered semi or even fully automatic. However they were still not machine guns. They mostly used small size magazine clips requiring frequent loading and quickly overheated in a sustained fire role. A quick barrel change as used on some MGs was not an option. For this reason they are not considered to be fully automatic weapons, but do get benefit from being semi-automatic. Sometimes heavy machine guns (HMGs) are regarded as anti-aircraft weapons and called anti-aircraft machine guns (AAMGs). These weapons are really machine guns and are therefore treated as land based automatic weapons (below).

iii. For **land based AA weapons with calibre > 40mm**, RF = 1.2 x RF value determined from Graph RF.

[3] Some countries correctly refer to certain types of artillery (those restricted to firing at elevation angles from 45-90deg) as 'mortars'.

Anti-aircraft weapons greater than 40mm calibre usually had semi-automatic breech systems, which enabled faster loading. In addition, they had larger crews for servicing the gun compared to AT guns or artillery of similar calibre.

iv. For **aircraft launched weapons**, RF = the number of bombs or rockets of a particular type, carried on a bombing or ground attack sortie.

v. For **land based automatic weapons**, RF = 4 x cyclic rate per minute x 1.2 (if belt fed) x 1.2 (if water cooled as opposed to air cooled) x 1.33 (if classified as an MMG or HMG with dedicated crew).

Belt fed MGs maintain higher rates of sustained fire when not stopping for reloads with magazine clips. Water cooled MGs maintain higher rates of sustained fire due to more effective barrel cooling and less frequent barrel changes. Medium and heavy machine guns with dedicated crews maintain higher rates of sustained fire over light machine guns (LMGs) in infantry squads. This is due to the larger MG crew and more equipment in the HMG-MMG squad, which results in more rapid barrel changes, fewer stoppages, more spare parts, etc.[4]

vi. For **aircraft mounted automatic weapons**, RF = 2 x cyclic rate per minute.

Generally in WWII, aircraft mounted MGs had a higher cyclic rate of fire than most infantry weapons. For example, the Soviet 7.62mm ShKAS MG (*Shpitalny-Komaritsky aviatsionny skorostrelny* or Rapid-firing Aircraft Gun) had a cyclic rate of fire of 1 800 rounds per minute. This was possibly the highest rate of fire of any WWII MG. Similarly, the 12-13mm HMGs and 15-20mm cannon on aircraft also had higher cyclic rates of fire than equivalent land based weapons. The reason is that aircraft only acquire any target for a few seconds at most, and these weapons need to deliver their 'punch' in that time.

The problem is we are considering sustained rates of fire over a longer time period and aircraft mounted automatic weapons are not designed for sustained fire. Apart from ammunition considerations (considered under Aircraft Mounted Weapon Effects below), these weapons quickly overheat and will likely jam if fired for more than a few seconds at a time. They are fired in shorter bursts suited to AA fire and aerial combat. Coupled with this is the nature of air to ground combat. In order to attack anything the aircraft must sortie, i.e. it spends most of its time getting to a position to sustain a fire rate and then only stays for a short time. Even under the ideal laboratory type environment being considered here (which should be common for all weapons), and at times of maximum contact with the enemy, aircraft spend most of their time flying to and from the target and additional time reloading-refuelling. The net result is overall reduced rates of sustained fire compared to continuously available land based weapons.

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b. Number of Potential Targets per Strike (PTS)

In order to establish a basis for comparison of the relative lethality of all weapons, it is essential to establish a standard of target density. This is because many weapons have the ability to incapacitate more than one enemy per strike (a strike being as defined above). These are often termed area fire weapons as opposed to point fire weapons. A commonly accepted standard for target density is one individual every square metre. Although unrealistic or artificial in terms of battlefield circumstances, this standard allows a comparison to be made of the relative lethality of area fire weapons (mostly using high explosive shells) and point fire weapons (mostly firing non-explosive solid type projectiles).

Individual small arms and light machine guns are limited to one target per strike.

Machine guns with calibre 12-13mm are limited to 1.2-1.4 targets per strike.

Generally, high explosive weapons are considered to hit one person per square metre within the lethal area of burst. Graph PTS shows the relationship between the number of Potential Targets per Strike (PTS) versus weapon calibre (in millimetres) for weapons using high explosive ammunition.[5] This data is used to determine the PTS value for the weapon once the calibre is determined.

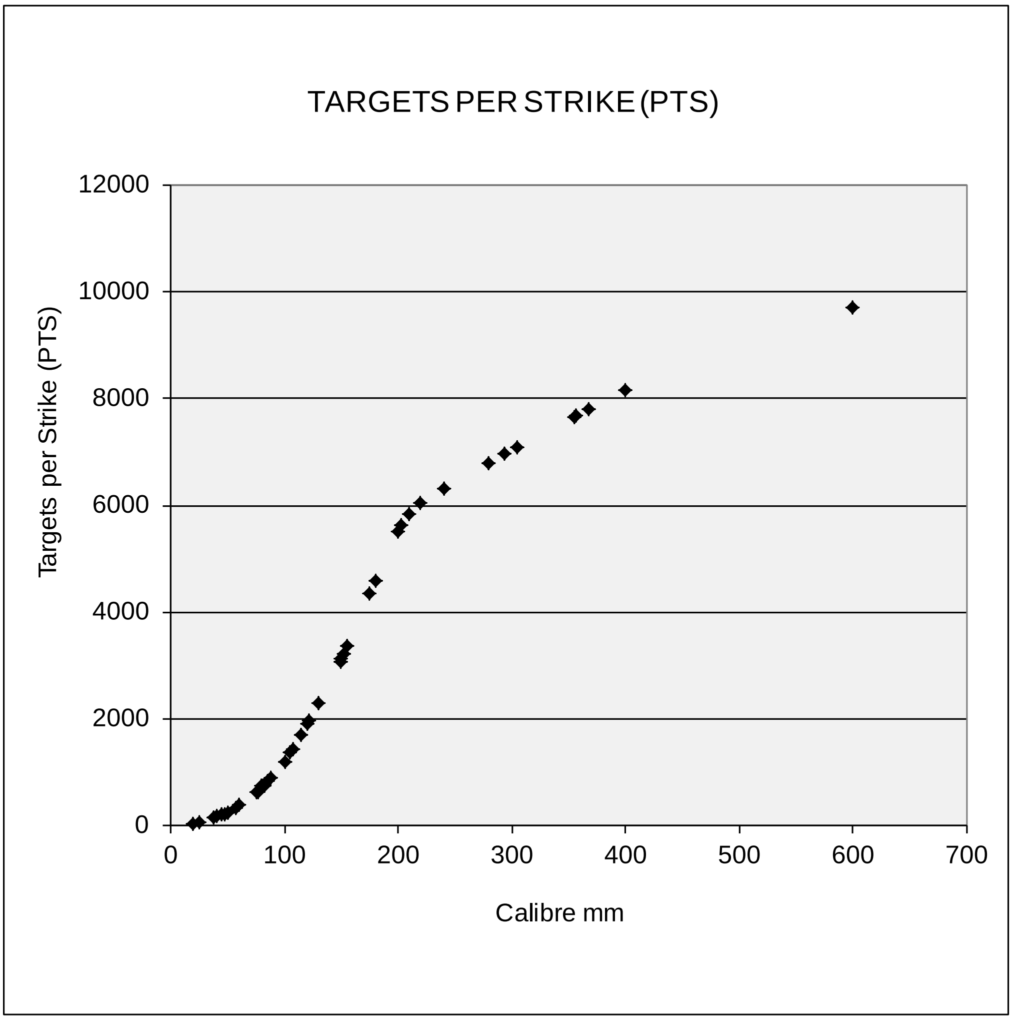
[4] The QJM model also uses cyclic rate per minute x4 for land based automatic weapons and x2 for air mounted automatic weapons. In addition QJM uses x2 for hand or shoulder weapons which is not used here. QJM does not consider any effects due to belt feed, water cooling, or dedicated MMG-HMGs crews over squad LMGs. T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, p. 191.

[5] T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia 1985, p. 193.

Graph PTS

Calibre mm (x)	PTS (y)
20	40
25	67
37	148
40	170
45	208
47	224
50	250
57	325
60	400
75	620
76.2	640
80	735
81.4	747
82	760
85	832
88	910
100	1200
105	1375
107	1435
114	1690
120	1900
122	1975
130	2300
149	3070
150	3130
152	3220
155	3370
175	4358
180	4600
200	5500
203	5620
210	5850
220	6035
240	6300
280	6800
294	6970
305	7100
355	7660
356	7671
368	7802
400	8150
600	9700

Number of Potential Targets per Strike vs Weapon Calibre



The only major modification to the PTS value applies to mortars, specifically:

i. For **mortars**, PTS = 0.7 x PTS value determined from Graph PTS.

This is because the velocity of impact of mortar rounds is considerably lower than similar calibre artillery rounds, as a result of mortars having lower muzzle velocities and correspondingly much shorter ranges.[6]

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The process for determining the PTS value for rockets and air launched bombs involves an additional step. For rockets the weight of the warhead, and for air launched bombs the total bomb weight, are converted into an equivalent calibre round and then into an appropriate PTS value using Graph PTS.

The Soviet BM-8 and BM-13 rockets have warhead weights of 0.5 and 4.9kgs respectively. These equate to PTS values similar to typical 45mm and 122mm gun-howitzers respectively. The German *Nebelwerfer* 35, *Nebelwerfer* 41 and 28cm *Wurfkorper Spreng* have warhead weights of 2.2, 10 and 61kgs, respectively. These equate to PTS values similar to typical 75mm, 150mm and 305mm howitzers, respectively. Rockets also impact

[6] 'Muzzle velocity' denotes the velocity of the projectile at the moment it leaves the firing weapon's barrel (i.e. velocity at the muzzle).

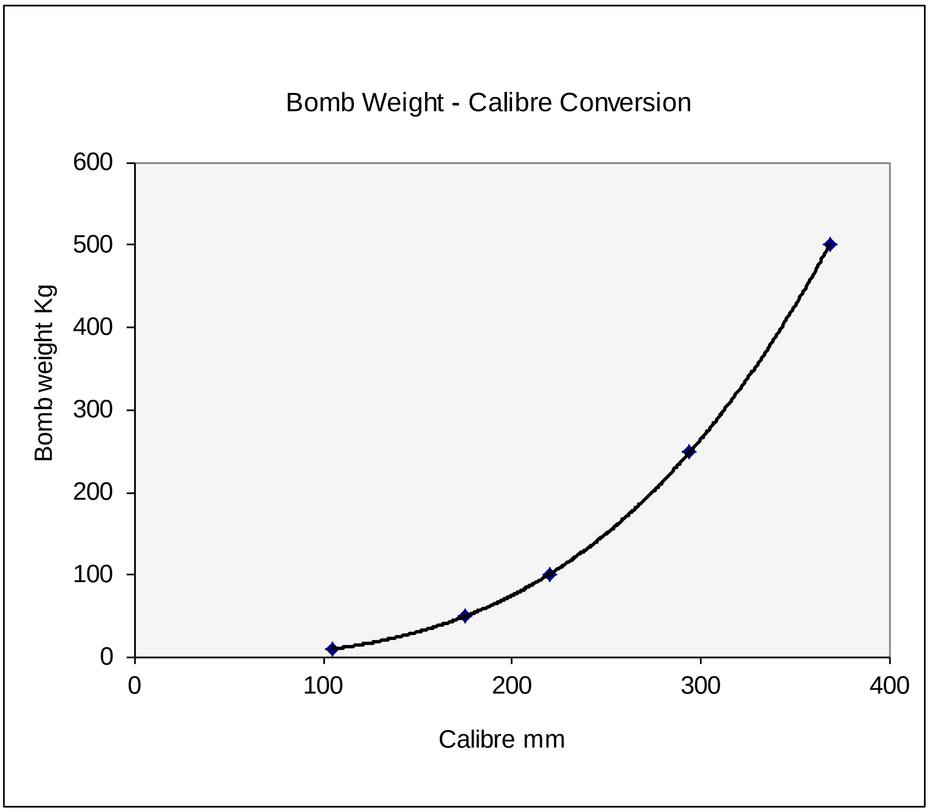
at a lower velocity than artillery rounds, but do not suffer the 0.7 adjustment as for mortars because the rocket's body and unused fuel also contribute to the lethal area burst. Note, the rocket's body and unused fuel are not included in the rocket's warhead weight (above).

Graph BW shows the average relationship between air launched bomb weight and weapon calibre. For example, a 100kg bomb (total weight) is equivalent to a 220mm calibre artillery round, so the correct PTS value from Graph PTS is 6 035. Bombs dropped from low altitude would generally have lower impact velocities than artillery, but bombs dropped from medium to high altitude would usually have similar or even higher impact velocities. On balance, air launched bombs do not have the 0.7 adjustment for lower impact velocities.

Graph BW

Average Relationship of Bomb Weight to Calibre.

PTS	Calibre mm (x)	Equiv Bomb Weight Kg (y)
1375	105	10
4358	175	50
6035	220	100
6970	294	250
7802	368	500



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c. Relative Incapacitating Effect (RIE)

Single strikes from some weapons are more likely to be incapacitating than single strikes from others. The Relative Incapacitating Effect (RIE) is the likelihood that a single strike will be incapacitating. RIE is expressed as a percentage probability.

For weapons more powerful than small arms or medium machine guns, the RIE value is always 1. For other weapons the RIE value is as follows:

i. Light and medium machine guns (LMGs and MMGs), and bolt action rifles, RIE = 0.8

ii. Sub machine guns (SMGs), RIE = 0.7

iii. Pistols and revolvers, RIE = 0.6

iv. Hand to hand, RIE = 0.4

Note, hand grenades, flamethrowers and close assault explosive charges are considered to have an RIE value of 1.[7]

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d. Range Factors (RN)

A weapon's effective range clearly has a direct impact on its overall lethality. Longer range gives a weapon more opportunity to be lethal or incapacitating, and enemies within range are forced to take passive and active countermeasures to defend themselves.

There are two basic approaches to calculating Range Factors (RN).

The first is based purely on the maximum effective horizontal range of the weapon. Weapons such as field artillery are designed to take advantage of firing their projectiles at elevated angles (around 45 degrees), to obtain maximum range. These weapons are designed to be used at long range and against targets unseen by the firing weapon (i.e. indirect fire). The RN factor based on maximum effective range is given by,

$$RN(range) = 1 + \sqrt{0.001 * Max\ Effective\ Range} \qquad (1)$$ [8]

where *Max Effective Range* is expressed in metres.

From formula (1) we can see the value of RN(range) is always 1 or greater; 1 being the length of a man's arm or 1 metre.

However many weapons such as AT guns, AA guns and tank mounted guns, are usually used in the direct fire mode. These weapons have high muzzle velocities (significantly higher than most field artillery), and are designed for maximum penetration, flat trajectory and reduced time of flight. Depending on the gun's carriage design, these weapons are capable of similar or even longer ranges than artillery of comparable calibre. However, the weapon data for these weapon types normally lists the 'maximum effective range' to be considerably less than the maximum horizontal range achievable by the weapon if it was firing at elevated angles. This is particularly true for anti-tank (AT) guns which normally fire at very low elevations. The maximum effective range of such weapons is normally considered to be the maximum range that the gun can effectively engage enemy tanks. This 'range' is dependent on muzzle velocity, projectile mass and the optical quality of the gun sight, and is always markedly less than the weapon's maximum horizontal range. Therefore these weapons would be disadvantaged if only formula (1) was used, leading to inconsistent and inaccurate weapon WCPC values.

For example, consider the case of the most famous artillery weapon in WWII, namely the German 88mm FlaK 18/36 or simply the '88' as it became known. The 88 was used against all types of aircraft, was lethal against the vast majority of WWII tanks (even at long range), and was sometimes used as field artillery: "anti-aircraft, anti-tank and anti-social!" as one British officer put it. The 88mm FlaK 18/36 had an effective ceiling (against aircraft) of 8000 metres, was able to effectively engage enemy tanks out to 3000 metres (largely due to the outstanding quality of its optical gun sights, designed to engage ground as well as airborne targets), and had an effective horizontal range of 14815 metres. So which 'range' do we use for calculating the 88's Range Factor (RN)? It is unreasonable to use 14815 metres because the 88 was least often used as field artillery. It is unreasonable to use 8000 meters because we are concerned with the 'inherent capability of the 88 to kill personnel, or to make material ineffective in a given time period' and not only its lethality against aircraft. Lastly, it is unreasonable to use 3000 meters because tanks are much harder to destroy than personnel so the previous point applies, and it would be inequitable to use this range whilst allowing field artillery to use effective horizontal range.

It is apparent that the 'maximum effective range' is very subjective for this class of weapon, and we therefore need to change the parameters by which the Range Factor (RN) is calculated. Regardless of the target, or the mode of operation in the example above, the two parameters that remain relatively constant are the weapon's muzzle velocity and projectile mass.[9] This leads us to the second basic approach to calculating Range Factors (RN).

[7] The RIE values used are based on historical experience. T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia 1985, pp. 20 and 26, and figs 2-3, pp. 188-191.
[8] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, pp. 21 and 191.
[9] There is variation in muzzle velocity and projectile mass depending on the ammunition used, which is dependent on the target. However this variation is relatively small, with the exception of 'special' AT ammunition. Thus it is assumed the muzzle velocity and projectile mass of APHE, APCBC, HE and AAHE rounds are similar. APDS, APCR and other special types of armour piercing shot have much higher muzzle velocities. But these rounds also have much less projectile mass, less range, are less accurate at longer ranges and were only available in limited numbers.

For greater consistency of results and increased precision in comparing overall lethality, the RN factor for direct fire, high velocity weapons is based on muzzle velocity and weapon calibre. In this case the RN factor is given by,

$$RN(mv) = 0.007 * Muzzle\ Velocity * \sqrt{0.01 * Weapon\ Calibre} \qquad (2)$$ [10]

where *Muzzle Velocity* is expressed in meters per second, and Weapon Calibre is expressed in millimetres.

To ensure the appropriate formula is applied to any given weapon, the following rules are used.

i. For field artillery, rocket bombardment systems, air launched rockets, hand and rifle grenades, flamethrowers, and AFVs mounting any of these weapons, use RN(range).

ii. For AT guns, AA guns and AFVs mounting any of these weapons, use RN(mv).

iii. For all light and heavy infantry weapons (except those in i. and ii. above), AFVs mounting these weapons, and all aircraft mounted automatic weapons, use an average of RN(range) and RN(mv). These weapon types include HMGs, AAMGs, mortars and infantry guns.

iv. For air launched bombs, use RN(mv), with mv = 250 metres per second.[11]

v. For air launched rockets use the rocket's range in RN(range).

For AFVs it is sometimes unclear what category (as defined above) of primary weapon the AFV carries. Tanks in particular fire at both armoured and non-armoured targets, and some have low velocity high trajectory guns that are still used as AT guns. If unclear, use rule iii. above.

In some cases information is not available for both the weapon's range and muzzle velocity. In these cases use either formula above to calculate RN. Note, the formulas are deliberately designed to not produce widely disparate results. They are there to produce more refined, consistent and precise comparisons of overall weapon lethality.

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[10] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, pp. 21 and 191. The constant 0.007 assures a value comparable to that of the formula based on range.
[11] Ibid, p. 194.