

## Clash Royale Balance Equation

First of all, it's important to understand the peculiarities of Clash Royale vs. "normal" card games like Hearthstone, Magic the Gathering etc.

Unlike standard card games, the deck in CR is infinite - you can never run out of cards to draw, and you always have 4 cards in hand. That makes the concept of card advantage irrelevant in CR - there is only elixir advantage (and card availability - how long do you have to wait until you get again a card that you've just played - but that's a weaker aspect). In most card games cards have intrinsic value - in Hearthstone there are cards that cost 0 mana but have non-zero effect - because when you play cards you pay both their mana price and the price of the card itself. That means that low cost cards usually have "bonus" stats, beyond what you would expect from their mana cost alone. CR works somewhat differently: cards have almost no baseline value.

Another interesting phenomena - that's rare in standard CCGs (collectible card games) is the ability to get a varying number of copies of the *same* creature from playing different cards:

Troop name	Cost	Count	Range
Minions	3	3	2
Minion Horde	5	6	2.5
Musketeer	4	1	6
Three Musketeers	9	3	6
Skeletons	1	4	Melee
Skeleton Army	4	20	Melee

Basically, there is a "mass purchase discount" on troops. You can get 3 minions for 3 elixir - or 6 minions and get a 1 elixir "discount" (and even an extra 0.5 range bonus to boot). Buying 1 musketeer 3 times costs 12 elixir, but buying 3 at the same time saves you a whopping 3 elixir. Skeletons vs. skeleton army shows a similar behaviour.

As we will see later, the balance equation perceives spreading the power over many creatures as a handicap.

There are probably 3 main reasons for this effect. First, you can store only 10 elixir at any time so playing a high cost card leaves you open for a potential counter-push from your opponent while you have very little elixir to defend yourself - which doesn't happen if you build your push mostly from cheap troops since you can stop at any moment and switch to defense and not over-commit. Second, cheap cards allow you to cycle through your deck faster, so you can get your powerful combination of cards easier.

Third, the power of cards in CR is often situational. Would you notice if the skeleton army had 21 skeletons instead of 20? Or even 24? The card would still serve roughly the same purpose, even though it's raw power value would increase by 20%. Minions die to a single arrows spell -

whether you have 3 or 6 of them - so getting a better deal on the extra 3 minions doesn't help at all if the opponent just shoots them down. In general, if a card counters an amount X of some creature, it will usually counter a 2X, 3X or even 5X amount of the same creature - so there is some law of diminishing return on elixir investment.

Another big challenge in analysing CR is that there are very few cards. ~50 cards might seem a lot while you're trying to collect and upgrade them all but for a collectible card game that's a very, very small amount. Hearthstone has more than a 1000, Magic has ~15000. That means any conclusions we draw will be based on a small sample size - so we must be cautious while using them.

Another important choice we must make before we dive into the relation between troop stats and elixir cost is which card levels should we use? In the calculations above I assumed all cards are of the same level - which makes sense for the minion and musketeer cards (as both versions are of the same rarity) but is less likely for the skeletons cards - since the skeleton army is epic vs the common simple skeletons.

The natural choice is to use tournament levels, as this should be the most balanced and "fair" setting. So for all the cards in my analysis I'll use:

	<b>Tournament level</b>
<b>Common</b>	<b>9</b>
<b>Rare</b>	<b>7</b>
<b>Epic</b>	<b>4</b>
<b>Legendary</b>	<b>1</b>
<b>Towers</b>	<b>9</b>

OK - we are now ready to dive in.

Let's start with spells, as there are less of them and the analysis is more straightforward.

## Spells

There isn't much to compare about spells except for damage. Spells like freeze or rage have such unique and situational effects that we have no choice but to accept their value as their elixir cost.

The one stat that's comparable and can teach us something about the game is damage per elixir for spells:

Spell name	Cost	Radius	Damage per Elixir
Zap	2	2.5	84.5
Arrows	3	4	81
Fireball	4	2.5	143
Poison	4	3.5	137.5
Rocket	6	2	205.3
Lightning	6	3.5	144

It's easy to distinguish between 3 categories of damage spells: cheap, medium and expensive. The more you pay, the more "bang for your buck" you get - in a very nonlinear fashion. The exception is lightning, which seems to be in the 4-cost category despite its high price.

It's interesting to note that Arrows - despite being more expensive - has about the same damage per elixir as zap. Arrows has a larger radius but Zap's 1 second stun is more important most of the time. So what's going on? Why is Arrows so popular while seemingly underpowered compared to Zap?

First, I believe Zap was indeed underrated for quite a while and only recently gained the popularity it deserves. Second, damage per elixir is not the whole story. Spells are usually used to kill troops - so usually maximizing damage efficiency is not so important. For example - the infamous Princess - which usually drew the use of Arrows from the opponent all by itself. Zap may be more efficient but it would leave the Princess alive - effectively making it useless. To make a truly accurate gauge of power and usefulness of spells - or any other card for that matter - one has to compare its effectiveness against every other card, giving more weight to its performance against the more popular cards in the current meta and arena. A fascinating research in its own right but way beyond the scope of our current effort.

Now for the main goal: troops.

## Troops

When reverse engineering game mechanisms and balance - one must first get a good estimation of the base stats' value - HP, DPS (damage per second) and the basic characteristics (flying, area damage, ranged vs. melee). Only then can we analyse the more unique cards. For this first stage I've used the following cards and data:

Troop name	Cost	Count	Area damage	Ranged	Flying	Hitpoints	DPS
minions	3	3	0	0	1	570	252
minion horde	5	6	0	0	1	1140	504
barbarians	5	4	0	0	0	2544	424

knight	3	1	0	0	0	1272	144
musketeer	4	1	0	1	0	598	160
valkyrie	4	1	1	0	0	1548	140
spear goblins	2	3	0	1	0	330	114
goblins	2	3	0	0	0	507	288
archers	3	2	0	1	0	530	140
skeletons	1	4	0	0	0	252	252
bomber	3	1	1	1	0	318	111
three musketeers	9	3	0	1	0	1794	480
mini pekka	4	1	0	0	0	1056	317
wizard	5	1	1	1	0	598	134
pekka	7	1	0	0	0	3458	332
skeleton army	4	20	0	0	0	800	800
baby dragon	4	1	1	1	1	1064	73

Note that I've intentionally left out all legendaries, all cards that target only buildings and any card that has a special ability except for area damage and flying (even seemingly simple things like the Guards shield). These are the simplest troop combat units - they should give teach us the value of the basic abilities and stats.

Note that the HP and DPS are the *sum* of all deployed troops (unlike what's written in the wiki). I've included "Count" as one of the stats because of our discussion in the beginning - spreading the power over multiple copies of the unit is a disadvantage and should be taken into account. Also, I've ignored troop speed and deploy time for now - assuming their effects are small on the value of the troop and they are chosen by Supercell partially for flavor reasons anyway.

Using Matlab's constrained linear least-squares problem solver (code available on demand), assuming there is some linear correlation between card stats and its elixir cost and rounding to nearest significant digit, I got the **balance equation** for base stats (all values are in units of elixir):

$$\text{Card Cost} = 0.0013 \cdot \text{HP} + 0.0092 \cdot \text{DPS} - 0.2 \cdot \text{Count} - 0.2$$

$$\text{Flying} = +0.25$$

$$\text{Area damage} = +1$$

$$\text{Ranged} = +1.75$$

This equation fits best the actual costs of the basic cards I used.

The predicted “fair” cost of a card is determined, unsurprisingly, by its total HP and DPS - where DPS has ~7 times more weight. When the card’s strength is spread over multiple copies of a creature it makes the card cheaper - as we’ve already discussed.

A more unexpected result is the constant -0.2 elixir every card gets - basically giving every card a little bit of power for free. This is somewhat surprising because cards are endless in CR. 0.2 elixir is a small effect in any case - much less than the ~1.5 mana that a card is worth in Hearthstone.

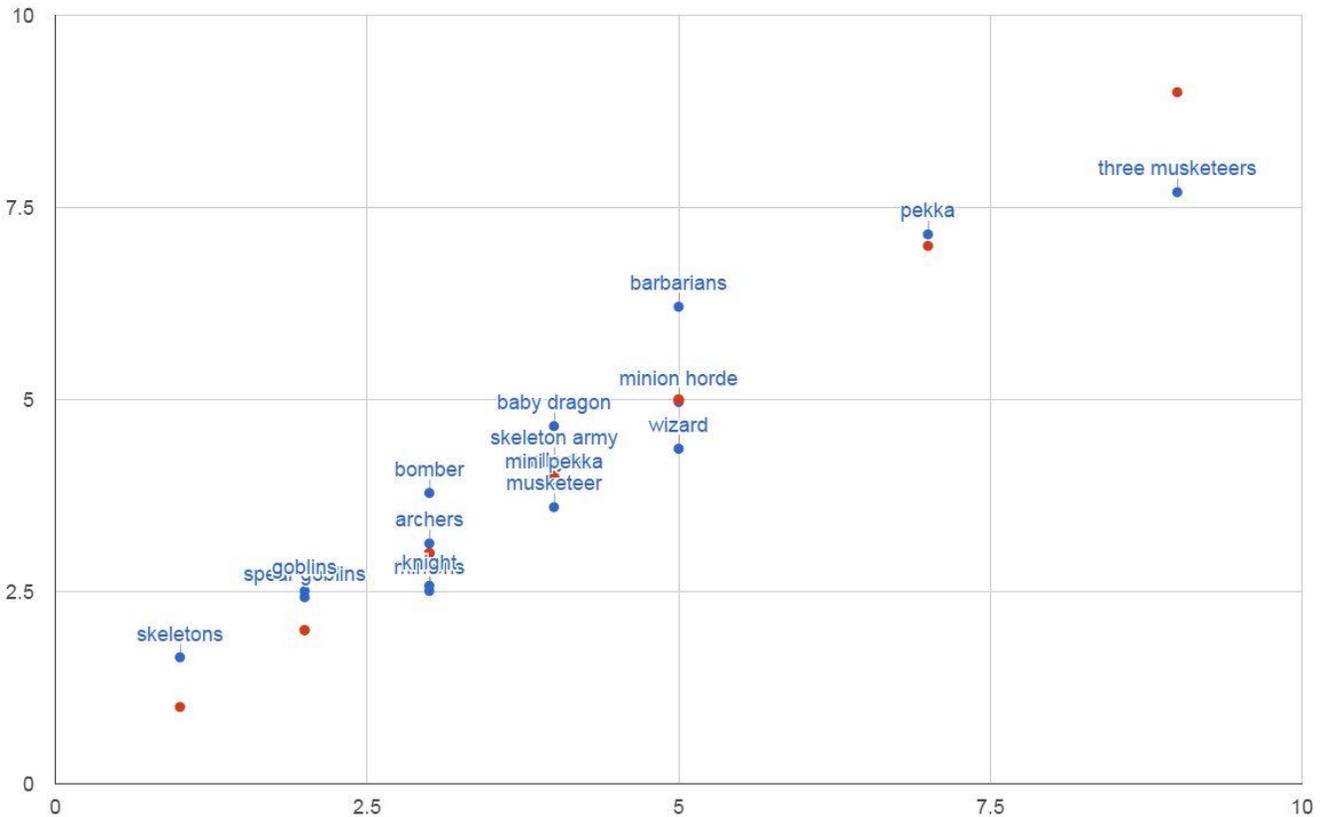
Ranged creatures get a huge additional cost - which makes sense due to tactical placement considerations. Area damage is also a strong ability - as the effective DPS is basically multiplied by the number of targets hit. If the additional targets hit produce an increase of ~110 DPS then the extra cost paid for the ability is already worth it.

Flying is surprisingly cheap according to our calculations. Obviously it’s not as powerful of an ability as area damage so it definitely should be cheaper. Also, don’t forget that we had only 3 flying creatures in our basic set so this value has the least confidence.

Let’s use this equation to see what cards are overpowered and underpowered:

Troop name	Cost	Calculated Value	Value Difference
minions	3	2.51	-0.49
minion horde	5	4.97	-0.03
barbarians	5	6.21	1.21
knight	3	2.58	-0.42
musketeer	4	3.6	-0.4
valkyrie	4	3.9	-0.1
spear goblins	2	2.43	0.43
goblins	2	2.51	0.51
archers	3	3.13	0.13
skeletons	1	1.65	0.65
bomber	3	3.78	0.78
three musketeers	9	7.7	-1.3
mini pekka	4	3.89	-0.11
wizard	5	4.36	-0.64
pekka	7	7.15	0.15
skeleton army	4	4.2	0.2
baby dragon	4	4.65	0.65

A negative value in the right column means an underpowered card, a positive value means an overpowered one. This can be shown in a graph as well:



The red dots mark the 0 difference point for each elixir cost - any card above it is better than the expected power - anything below is underpowered.

Let's discuss some interesting findings we can already see.

First, Three Musketeers is still underpowered even at 9 elixir (which is a pity as this is one of my favorite cards :) ). This is probably since the single musketeer is already somewhat underpowered (-0.4), and they are vulnerable to area damage and spells.

Second, Barbarians are an amazing deal for 5 elixir (+1.2). Indeed, barbs are one of the most popular cards. They are good both on defense and offence, aren't countered strongly by almost anything and in general very cost-efficient.

Third, the 1 and 2 elixir cards seem to be cost efficient. Anyone who ever let Goblins get all the way to his tower already knows this - they do a huge amount of DPS for 2 elixir. Spear goblins do little DPS but are the cheapest ranged unit, so they get the range bonus.

Fourth, the Bomber has a surprisingly high value (+0.78), but that's partially because our calculation didn't take into account the fact that it can only shoot ground troops, unlike other ranged troops, so it has a built in handicap. Nevertheless, I do believe it is currently a slightly underrated card.

Finally, the Baby Dragon is very good (+0.65). It's well rounded, can counter a variety of other troops and it's flying to boot.

Now that we have a good idea about the value of base stats, let's apply the formula to the rest of the troops and see what we can learn there:

Troop name	Cost	Calculated Value	Value Difference
minions	3	2.51	-0.49
minion horde	5	4.97	-0.03
royal giant	6	5.67	-0.33
golem	8	5.69	-2.31
giant	5	5.53	0.53
giant skeleton	6	3.87	-2.13
barbarians	5	6.21	1.21
knight	3	2.58	-0.42
musketeer	4	3.6	-0.4
valkyrie	4	3.9	-0.1
spear goblins	2	2.43	0.43
goblins	2	2.51	0.51
archers	3	3.13	0.13
skeletons	1	1.65	0.65
bomber	3	3.78	0.78
three musketeers	9	7.7	-1.3
mini pekka	4	3.89	-0.11
wizard	5	4.36	-0.64
hog	4	3.15	-0.85
prince	5	3.29	-1.71
dark prince	4	3.17	-0.83
pekka	7	7.15	0.15
guards	3	2.08	-0.92
sparky	6	6.3	0.3
balloon	5	4.11	-0.89
skeleton army	4	4.2	0.2

<b>baby dragon</b>	<b>4</b>	<b>4.65</b>	<b>0.65</b>
<b>goblin barrel</b>	<b>4</b>	<b>2.51</b>	<b>-1.49</b>
<b>miner</b>	<b>3</b>	<b>2.12</b>	<b>-0.88</b>
<b>Princess</b>	<b>3</b>	<b>3.05</b>	<b>0.05</b>
<b>Ice Wizard</b>	<b>3</b>	<b>3.65</b>	<b>0.65</b>
<b>Witch</b>	<b>5</b>	<b>3.87</b>	<b>-1.13</b>
<b>Lava hound</b>	<b>7</b>	<b>3.86</b>	<b>-3.14</b>

First, note that our value is calculated only according to base stats and abilities. Cards like Lava Hound, Golem and Giant Skeleton get very negative scores because a significant portion of their power is in their “on death” abilities (spawning additional troops/bomb), not because they are necessarily underpowered.

Now we have the ability to say that the elixir value of the Giant Skeleton’s death bomb is ~2 elixir according to Supercell - and we can decide for ourselves whether it’s worth it (in my opinion - if you can get it near a tower or troops then it’s very cost efficient - so it depends on your opponent’s skill level).

Troop speed (or deployment time) doesn’t seem to contribute to the card value (at least not in a significant enough way for our calculations to see it). If anything, there seems to be a reverse correlation - stronger and bigger cards are usually slower - both for flavor reasons and as a partial balance mechanism.

Let’s take a look at cards that only attack buildings: Giant, Royal Giant, Hog Rider, Balloon, Golem, Lava Hound. Targeting buildings seems to be valued as a positive trait - since the base stats don’t live up to the card’s elixir cost. While Golem and Lava Hound have an alternative explanation, the rest just seem somewhat underpowered - even the popular and feared Hog Rider (-0.85). The ability to focus on the tower objective and get there fast is valued at a premium. The only exception is the Giant that gets +0.5 on stats alone. I suspect part of the reason it’s not overpriced as the rest is because it often dies before ever getting to the tower - so its DPS is sometimes meaningless, unlike Balloon, Hog or Royal Giant that are much harder to stop from reaching at least some building.

Now let’s see about some notoriously dreaded cards. Princess seems balanced (+0.05) *before taking into account her extremely long range* - which she gets effectively for free. Ice Wizard is extremely overpowered, getting +0.65 on stats alone *before taking into account its slowing effect*. The feared new Sparky is only +0.3 on stats - which isn’t that bad actually. I suspect the reason why it feels stronger is because it gets the first hit instantly - Sparky charges to full while it drives over to the opponent’s side - effectively increasing its DPS while in combat.

So far it shouldn't be a surprise - legendary cards are above the power curve isn't a shocker. The surprise is Prince's low value (-1.7). Some of it is in the charge - which gives additional power unaccounted for in the base stats - but the Dark Prince has both a charge and a shield - and is only underpowered by -0.83. Perhaps it gets a bonus for being practically the only card that has high, melee, undistractable, single target damage while being only a single creature itself (the alternative is the Knight which is also underpowered) - but does it explain such a big value discrepancy? Every player should decide for himself, but this result might explain why the Prince is usually seen only in very specific decks once you get to Arena 7 or higher.

A short note about buildings. There aren't enough damage buildings to rigorously compare them, but if we treat them using the same formula as troops we'll see that they are in general somewhat overpowered for their price. Cannon will get +0.9 (but only lives for 30 seconds), Bomb Tower +0.4 etc.

To conclude, we've built the elixir vs. card stats **balance equation**, manually checked that it makes sense for the vast majority of cards and discussed several interesting conclusions.

Until next time,  
Michael Shalyt ([lifeinagraph.shalyt.com](http://lifeinagraph.shalyt.com)).