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Proposed Balance Model for Card Deck Measurement in *Hearthstone*

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Abstract
Hearthstone is a popular trading card game (TCG) that was released in 2014. Players can build numerous decks in the game, one that offers variety and sophistication to over thirty million players worldwide. The TCG requires players to use their card decks to compete with one other. In this paper, a series of functions that describe the strength of a TCG card is described; and a balance model for *Hearthstone*, which could serve as a basis for many other TCGs, is proposed. The balance model could become a fundamental element for TCG design, one that might enable TCG developers to design cards without making them too powerful. The balance model could also be used in other TCGs including *Shadowverse*, *Magical Card* and *The Elder Scrolls: Legend.*

Keywords TCG · BMV · Balance model · Strategy · Numerical methods

1 Introduction

A trading card game (TCG) is a kind of strategy card game that was created back in 1993. At that time, no one thought it would become the popular gaming genre that it is today. TCGs are now so widespread that one was specifically developed for the 2018 Jakarta Asian Games.

There are two important concepts that pertain to TCG card value and strategy. The first concept is called BMV (Balance Model Value), which is used for measuring the value of a card or ability in a TCG. The other concept is the Balance Model, which is a frame of reference underpinning card designation. These two concepts share a relationship in that a balance model runs on BMV functions. In this paper, it is proposed that BMV functions could be used to determine a card's value; in addition, the importance of a balance model in TCGs is discussed.

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Fig. 1 A standard minion card. In a minion card, it has four major parts: 1. mana crystal cost (top left); 2. attack (bottom left); 3. defense (bottom right); 4. effect including keywords and descriptions (in the middle under the picture). Rarity is in the middle of the card

In this paper, *Hearthstone* is used as a case study as *Hearthstone* is familiar to many TCG players. The proposed Balance Model and BMV in this paper could be used for other TCGs provided some sets in them are modified.

Different TCGs have cards incorporating different features. Throughout a TCG game, a player often can only judge the present situation on the battleground and predict opponents' next turns. However, with *Hearthstone* it is not hard for a professional player to predict what his/her opponent will do in the next turn because the most common decks in the Ranked Play Ladder are almost identical. In *Hearthstone*, there are two major kinds of cards: minion cards, and magical cards. Each type of card has its unique effect in a game, and players need to adopt appropriate strategies.

Minion cards are the basic elements of the TCG, and players use their minion cards on the battlefield to compete with one other by destroying other players' minion cards. A standard minion card is shown in Fig. 1. Magical cards have numerous effects on the battlefield and can interact with minion cards.

Some magical cards have a simple description, while others have vague descriptions, as shown in Fig. 2. When a card has a "random" description, the randomness makes it hard to predict the value of the card. Since luck plays an inevitable role in the game, the *Balance Model* will produce a different *BMV* for a card.

Both magical and minion cards in *Hearthstone* consist of neutral cards (which can be used by all classes) and classical cards. There are nine classes in *Hearthstone*: Shaman, Warlock, Mage, Paladin, Priest, Hunter, Rogue, Warrior, and Druid (Fig. 3). Each class has its unique hero power, and the primitive *Balance Model* is generated from the classes.

The remainder of this paper consists of four sections: in Sect. 2, related research is briefly reviewed; in Sect. 3, the BMV functions for classical cards in *Hearthstone* are proposed; in Sect. 4, a deck builder is designed, and the functions and potential application of the model in other TCGs are discussed; and, in Sect. 5, the arguments presented below are summarized.

Fig. 2 Yogg-Saron, a minion card with much randomness in it. Randomness is hard to have a value in the balance model. It is hard to give Yogg-Saron a vivid value. Even its minimum value seems impossible to measure

2 Related Work

There have been some academic studies into TCGs ever since they became popular last decade. In 2014 when *Hearthstone* was released, Google's engineer, Bursztein (2016), described a statistical learning method based on *Hearthstone*'s playing cards strategy in his paper based on cards from Blizzard's (2018) official website. He also used card values for measuring a deck. However, his work was mainly about players' own playing card strategies and means of predicting opponents' strategies, and he did not discuss using a balance model for *Hearthstone*.

Machine learning is a good method for making predictions in TCGs, and some researchers have applied it to *Hearthstone*. However, their main focus has been on pitting machine-built decks against human-built decks. Ethan Ham (2010) identified a relationship between a card's rarity and its power. This may be valid for some TCGs such as *Magic: The Gathering*, but for *Hearthstone* and other TCGs a card's rarity does not share a strong relationship with its strength. So, in this paper, it is necessary to explain why rarity is not relevant either to the model or the function. Grad (2017) demonstrated the use of CNN to enable an AI system to play *Hearthstone* cards. Stiegler et al. (2018) reported on a case study on training a bot to play with *Hearthstone* cards. However, none of these researchers developed a balance model for the game. In order for a TCG to be a long-term and profitable franchise, every card design should be based on a balance model: it is therefore important to determine the relationships between cards and the model in a TCG.

Fig. 3 Nine classes' Hero power. Each class has its unique hero power and can be treated equally in a game

3 Balance Model for the Game

The idea that all the TCGs should have a balance model stems from the observation that the hero power of the nine classes has similar effects. These effects can be described by some mathematical functions, which have been termed BMVs

near the beginning of this paper. Therefore, a balance is required as it allows different cards to share a dynamic equilibrium with one other, which could make a TCG more playable and popular over many years.

The conclusion drawn in this paper is based on the following assumption:

Different classes[1] in a TCG have the same competitiveness.

In other words, there is no 'weak' class. Players can win a game by using cards of any class. In *Hearthstone*, it would not be necessary to keep nine classes if there is a weak class among the nine. A card of a weak class would eventually disappear from the game because no-one would play this class.

On a personal note, I have been playing *Hearthstone* for more than 3 years and have attained the legend card back. I have participated in many discussions concerning numerical analyses of TCGs on online gaming communities and on Twitter. However, few people have considered the balance models that underpin the cards. In this paper, I will demonstrate how the balance model can be used to evaluate *Hearthstone* cards and the influence of hero power.

3.1 Balance Model for Hero Power

As mentioned, in *Hearthstone* there are nine classes; each class has its unique hero power. It is important to keep a balance among the nine classes.

The Hunter and Warrior have similar hero powers: one inflicts damage, and the other recovers health. This is the basis of Function 1 described below.

Hero power can be described using the following function (with a variation for the Shaman, Mage, Warlock, and Paladin classes, which relates health/shield (hp) with damage:

$$\varphi = (\mathrm{hp} + \mathrm{a}) + a^* \tag{1}$$

In this function, *hp* represents health, a represents an attack or damage inflicted upon the hero, and a^* represents an additional balance factor used for the Shaman, Mage, Warlock, and Paladin classes. Using a^* is necessary for the function. a^* is used as an adjustment factor to ensure that all card classes have the same competitiveness. This function can be used to describe the balance model for the nine classes.

For example, a Hunter's hero power can inflict 2 points of damage upon its opponent. So, using this function, Hunter's $\varphi = (2 + 0)$. A Druid can gain one attack and one shield from its hero power, so for a Druid, φ is also 2.

For Mage's hero power, although it can only sustain 1 point of damage, it can choose a specific enemy, whereas a Hunter can only attack a hero; and a Mage can attack an enemy hiding behind a Taunt minion (for a minion with keyword "taunt", it is necessary to attack it first before attacking other minions or opponents). Thus,

[1] In *Hearthstone*, these are classes; in *The Elder Scrolls: Legend*, this refers to the decks' colors. For other TCGs, this might refer to games characters.

a Mage's φ can be calculated as $\varphi = (1+0) + a^*$. Therefore, a* can be regarded as 1, and so for a Mage, φ is 2.

A Warlock's hero power is hard to measure because one needs to consider if 2 health points are necessary for the player to obtain an extra card. Players might therefore consider Warlocks to have the best hero power in *Hearthstone*, but when there are many fast attack decks in the environment players need to think twice before they use a Warlock's hero power. So the Warlock's $\varphi = (-2) + a^*$, whereby a^* depends on the drawn card's value.

It is interesting to compare the hero powers of the Paladin and Shaman classes. A Shaman's power is random, and might be useless on the battlefield. By contrast, a Paladin's hero power enables a 1/1 (one attack, one health) minion onto the battlefield. So there is an element of randomness to Shaman and Paladin's hero powers, but both classes can be dictated using the same balance model. ($\varphi = 2$) applies to all the classes; in other words, all the hero power is derived from the same balance model for *Hearthstone*.

3.2 Balance Model for Minion Cards

For minion cards, there are four aspects: mana crystal cost, the attack, health, and keywords in their descriptions. Here are nine examples of keywords for minion cards in *Hearthstone*:

1. Charge: a minion can attack at once.
2. Divine Shield: a minion is immune to one instance of damage
3. Taunt: an opponent must attack or taunt a minion first.
4. Deathrattle: this is triggered when a minion dies.
5. Windfury: a minion can attack twice.
6. Rush: a minion can attack at once, but can only attack the opponent's minion.
7. Poisonous: when a minion sustains damage from another minion, it kills that target minion.
8. Stealth: a minion cannot be targeted by other minions using spells or hero power.
9. Lifesteal: health is gained when a minion makes an attack.

It can be seen that "Charge" is more powerful than "Rush", so if the value given to other keywords is 1, "Charge" should be more than 1. This can be proved using a function called "Discover", whereby a player can discover all the 9 keywords except "Charge", and so can assume that other 8 keywords are of equal value.

Hearthstone has numerous cards in its pool, which cannot easily be described using logic or multi-dimensional vectors. The Bayesian algorithm uses conditional probability that matches a player's deck. Each deck contains 30 cards and there are some duplicate cards in one deck, so one deck can be treated as a set and cards as elements in the set. Researchers have found that some neutral cards can appear in many decks in *Hearthstone*. They have a strong effect on the game, so almost every player likes to have them in his/her deck. For example, Yogg-Saron (shown in Fig. 2) appeared in almost every midrange deck in 2015. The Yogg-Saron card has a

high conditional probability, and *Hearthstone* players are well aware that it is clearly more powerful than other cards. On the other hand, in order to build a deck, a player needs to consider some other cards, except for "high probability cards". Some cards can interact with each other: these are termed "combo cards". This conception is different to Rogue's keyword "Combo" because using "Combo" is mandatory. A player must play a card in order to trigger the "Combo" ability. However, "combo cards" have a high conditional probability of imparting a strong influence on the battlefield, so players prefer to use them together to produce a good effect.

For this study, sophisticated mathematics can only be applied to cards for a small time period. The aim is to find a simpler and more direct description for the value of a card. Choosing basic cards in *Hearthstone* is the most convenient means of illustrating a BMV function because basic cards do not change by different versions in *Hearthstone*.

Here is a *BMV* function for a minion card, which is very similar to the *BMV* function of hero power in Function 1:

$$\varphi = (hp + a + k^*) - C \tag{2}$$

In this function, a represents the attack upon a minion, hp represents the health of the minion, k^* represents the keywords' value of a minion card, and C represents the mana crystal costs of a minion card. Function 2 can be converted into a normalized form for mana crystal costs:

$$\varphi^* = \frac{\varphi + C}{C} \tag{3}$$

By using the normalization equation, the BMV function can omit this effect in the function. Without normalization, it is easy to see (in Table 1) that the higher the mana crystal costs, the higher the value of a minion card. So normalization is necessary for placing every minion card on the same scale in order to compare them to one another.

Using big data statistics, it was demonstrated on April 8 2017 that when a player opened a card pack, he/she had a 71.29% probability of getting a common card, a 23.15% probability of getting a rare card, a 4.51% probability of getting an epic card and a 1.05% of getting a legend card.[2] Ben Brode, the leader of the Hearthstone developer team, once remarked: "Rarity in *Hearthstone* cards serves as a rough indication of quality, but is an inconsistent indication of value in play." He concluded that rarity in *Hearthstone* is a random variable, something that is not considered in the balance model or BMV function. In functions 2 and 3, rarity does not relate to the strength of a card.

As well as defining the function of a minion card, it is also necessary to identify a link between card value and mana crystals. Table 1 lists all minion cards worth seven mana crystals or fewer. In the table, *value_1* represents the value calculated

[2] Data available in https://hearthstone.gamepedia.com/Card_pack_statistics.

Table 1 The value of 43 basic cards in Hearthstone

Number	Card's name	Magna crystal	Attack	hp	Key word number	value_1	value_2
1	Elven Archer	1	1	1	1	2	3
2	Goldshire	1	1	2	1	3	4
3	Grimscale Oracle	1	1	1	1	2	3
4	Murloc Raider	1	2	1	0	2	3
5	Stonetusk	1	1	1	1	2	3
6	Voodoo Doctor	1	2	1	1	3	4
7	Acidic Swamp Ooze	2	3	2	1	4	3
8	Bloodfen Raptor	2	3	2	0	3	2.5
9	Bluegill Warrior	2	2	1	1	2	2
10	Frostwold Grunt	2	2	2	1	3	2.5
11	Kobold Geomancer	2	2	2	1	3	2.5
12	Murloc Tiderhunter	2	2	1	1	2	2
13	Novice Engineer	2	1	1	1	1	1.5
14	River Crocolisk	2	2	3	0	3	2.5
15	Dalaran Mage	3	1	4	1	3	2
16	Ironforge Rileman	3	2	2	1	2	1.666667
17	Ironfur Grizzly	3	3	3	1	4	2.333333
18	Magma Rager	3	5	1	0	3	2
19	Raider Leader	3	2	2	1	2	1.666667
20	Razorfen Hunter	3	2	3	1	3	2
21	Shattered Sun Cleric	3	3	2	1	3	2
22	Silverback Patriarch	3	1	4	1	3	2
23	Wolfrider	3	3	1	1	2	1.666667
24	Chillwind	4	4	5	0	5	2.25
25	Dragonling Mechanic	4	2	4	1	3	1.75
26	Gnomish Inventor	4	2	4	1	3	1.75
27	Oasis Snapiaw	4	2	7	0	5	2.25
28	Ogre Magl	4	4	4	1	5	2.25
29	Sen'jin Shieldmasta	4	3	5	1	5	2.25
30	Stormwind Knight	4	2	5	1	4	2
31	Booty Bay Bodyguard	5	5	4	1	5	2
32	Darkscale Heater	5	4	5	1	5	2
33	Frostwolf Warford	5	4	4	1	4	1.8
34	Gurubashi Berserker	5	2	7	1	5	2
35	Nightblade	5	4	4	2	5	2
36	Stormpike Commando	5	4	2	2	3	1.6
37	Archmage	6	4	7	1	6	2
38	Boulderfist Ogre	6	6	7	0	7	2.166667
39	Lord of the Area	6	6	5	1	6	2
40	Reckless Rocketeer	6	5	2	1	2	1.333333
41	Core Hound	7	9	5	0	7	2
42	Stormwind Champton	7	6	6	1	6	1.857143

Table 1 (continued)

Number	Card's name	Magna crystal	Attack	hp	Key word number	value_1	value_2
43	War Golem	7	7	7	0	7	2

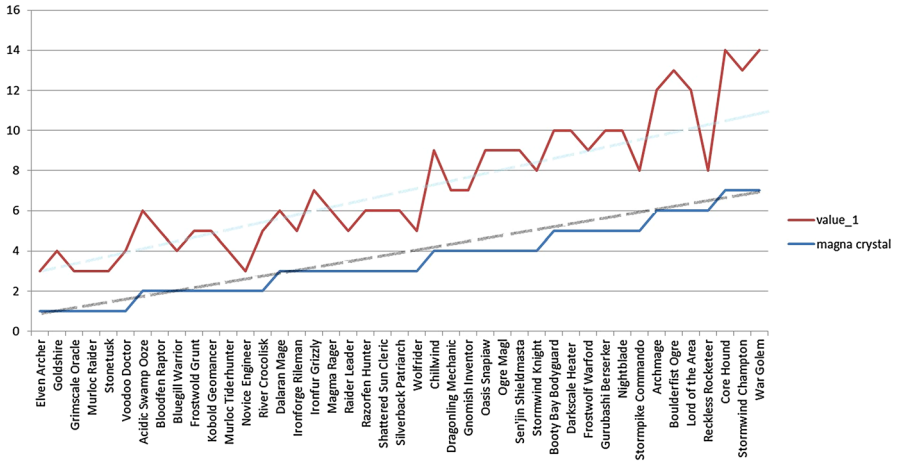

Fig. 4 The relation of mana crystal costs and value_1. The abscissa is cards' name and the ordinate is the value of these cards

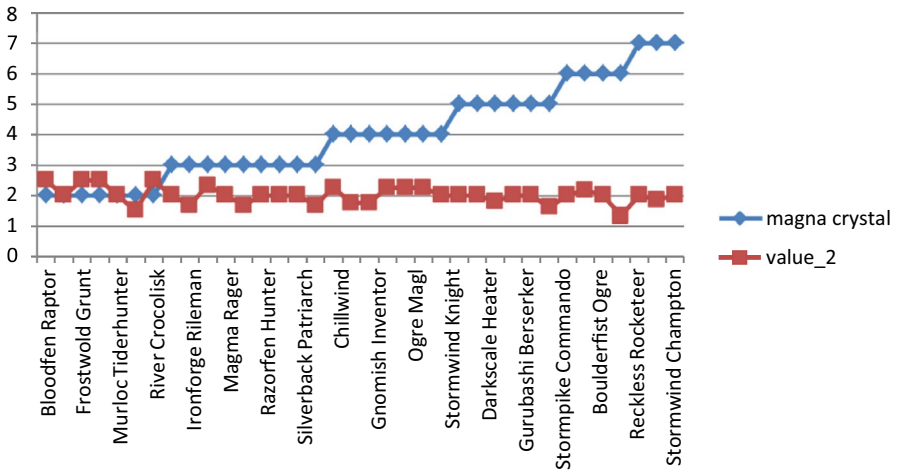

Fig. 5 Normalization of card value (value_2) and mana crystal costs. The abscissa is cards' name and the ordinate is the normalization value of these cards. We can find that the normalization value of a card is around 2

Fig. 6 A standard magical card. This magical card has a simple description while others may have vague descriptions. But they all have three basic parts: damage, health and keyword (other effect). For this card, damage is 6, health is 0 and keyword is null

from mana crystal, attack and health; value_1 can be calculated using the following function:

$$\text{value\_1} = (\varphi + \text{C}) \tag{4}$$

whereby *value_1* is a rough estimate of a minion card, and *value_2* is the normalization of *value_1* by mana crystal cost.

Table 1 lists the 43 basic cards in *Hearthstone*. Basic cards without any keywords are important data for building the balance model for *Hearthstone* because many other cards are based on their designs.

As shown in Fig. 4, Function 5 produces two lines that share a positive linear relationship. The relationship between the mana crystal costs of a minion card and the other three aspects of a card is represented in Function 5, which also explains the positive relationship between the two lines:

$$2\text{C} + 1 = (\text{a} + \text{hp}) + a^* \tag{5}$$

Figure 5 shows normalized values of the basic cards: it can be seen that these are almost static values. This phenomenon indicates that there is a balance model that is used for designing the cards in *Hearthstone*, which is just like the basic model for the design of hero power. The model is used to ensure that no card becomes too powerful in the game.

3.3 Balance Model for Magical and Weapon Cards

It can be inferred from the minion cards that a magical card's value is based on damage (attack), health, mana crystal costs, and keywords. So for magical cards, there is a BMV function. A standard magical card is shown in Fig. 6.

The BMV function for magical cards is different from that for minion cards. The BMV function of minion cards is changed slightly to Function 6, which fits the model for magical cards:

$$\phi = \frac{1}{2}(a + hp) + a^* - \xi \tag{6}$$

whereby ξ represents mana crystal costs, a represents attack, hp represents health and a^* represents a parameter associated with keywords. So the BMV function form of a magical card is just like that for a minion card (Function 2); and, its normalization form shown in Function 7 is similar to that for Function 3:

$$\varphi^* = \frac{\varphi + \xi}{\xi} \tag{7}$$

The reason why φ is based on the averaging of attack and health is to make a magical card's value match that of a minion card.

Weapon cards offer duration rather than health; so in the BMV function of a weapon card, duration is substituted for health, whereby d represents the duration of a weapon. Therefore, the BMV function of a weapon card is as follows:

$$\phi = \frac{1}{2}(a + d) + a^* - \xi \tag{8}$$

… and its normalization form is the same as that in Function 7.

4 Practical Application of the Balance Model

The balance model can be used to observe and predict different cards in the game. However, it cannot be used to determine the exact value of the keyword of a card, although it can generate an approximate number.

4.1 The Balance Model in *Hearthstone*

There exists a great degree of randomness in *Hearthstone*. Even the best machine learning methods cannot yield wholly accurate predictions for a *Hearthstone* competition. In the 2016 China–Europe Competition, a player going by the name of *lovelychook* just used Yogg-Saron and turned around *Kolento* in the final battle. During 2016 and 2017, Yogg-Saron frustrated many players, who felt that their strategic efforts were in vain. To date it has been impossible to estimate Yogg-Saron's value in any game as it targets randomly and has random keywords. Therefore, it may be assigned a rough value depending on the number of magical cards in a deck; every *Hearthstone* player should know that luck plays an important role in a TCG.

In Tables 2, 3, and 4, three common decks from the website are provided. Using functions 3 and 7 listed above, players can calculate the value of each deck. In

Table 2 The total value of a Classic Druid deck

Number	Card's name	Magna crystal	Attack	hp	Keyword	value_1	value_2
1	Innervate	0	0	0	1	1	2
2	Innervate	0	0	0	1	1	2
3	Claw	1	2	2	0	1	2
4	Kobold Geomancer	2	2	2	1	1	1.5
5	Kobold Geomancer	2	2	2	1	1	1.5
6	Novie Engineer	2	1	1	1	0	1
7	Novie Engineer	2	1	1	1	0	1
8	Wild Growth	2	0	1	2	0.5	1.25
9	Wild Growth	2	0	1	2	0.5	1.25
10	Wrath	2	3	0	1	0.5	1.25
11	Wrath	2	3	0	1	0.5	1.25
12	Earthen Ring Farseer	3	3	3	1	1	1.333333
13	Harvest Golem	3	2	3	2	1.5	1.5
14	Harvest Golem	3	2	3	2	1.5	1.5
15	Chillwind Yeti	4	4	5	0	0.5	1.125
16	Chillwind Yeti	4	4	5	0	0.5	1.125
17	Keeper of the Grove	4	2	4	3	2	1.5
18	Keeper of the Grove	4	2	4	3	2	1.5
19	Sen'jin Shieldmasta	4	4	5	1	1.5	1.375
20	Swipe	4	9	0	0	0.5	1.125
21	Swipe	4	9	0	0	0.5	1.125
22	Druid of the Claw	5	4	6	1	1	1.2
23	Druid of the Claw	5	4	6	1	1	1.2
24	Boluderfist Ogre	6	6	7	0	0.5	1.083333
25	Boluderfist Ogre	6	6	7	0	0.5	1.083333
26	Ancient of War	7	5	10	1	1.5	1.214286
27	Ancient of War	7	5	10	1	1.5	1.214286
28	Ironbark Protector	8	8	8	1	1	1.125
29	Ironbark Protector	8	8	8	1	1	1.125
30	Cenarius	9	5	8	4	1.5	1.166667
Sum						28	39.62024

today's *Hearthstone* Ranked Play Ladder, Odd Paladin can be regarded as the first team deck, Murloc Paladin as the second team deck, and Classic Druid as the third team deck. It can be seen that the sum of value_2 of a Classic Druid is the lowest; the sum of Murloc Paladin is in the middle; and, Odd Paladin has the highest points. All the three decks have a similar value_1, but this does not mean these decks have the same strength during play.

Table 3 The total value of an Odd Paladin deck

Number	Card's name	Magna crystal	Attack	Hp (duration)	Keyword	value_1	value_2
1	Blessing of Might^	1	3	0	0	0.5	1.5
2	Blessing of Might^	1	3	0	0	0.5	1.5
3	Lost in the Jungle^	1	2	2	0	1	2
4	Lost in the Jungle^	1	2	2	0	1	2
5	Rightous Protector	1	1	1	2	2	3
6	Rightous Protector	1	1	1	2	2	3
7	Divine Favor^	3	0	0	3	0	1
8	Divine Favor^	3	0	0	3	0	1
9	Unidentified Maul*	3	2	2	1	0	1
10	Unidentified Maul*	3	2	2	1	0	1
11	Level Up^	5	2	2	4	1	1.2
12	Level Up^	5	2	2	4	1	1.2
13	Vincecleaver*	7	4	2	4	0	1
14	Vincecleaver*	7	4	2	4	0	1
15	Acherus Veteran	1	2	1	1	1.5	2.5
16	Acherus Veteran	1	2	1	1	1.5	2.5
17	Argent Squire	1	1	1	2	2	3
18	Argent Squire	1	1	1	2	2	3
19	Fire Fly	1	1	2	1	1.5	2.5
20	Fire Fly	1	1	2	1	1.5	2.5
21	Raid Leader	3	2	2	2	1	1.333333
22	Raid Leader	3	2	2	2	1	1.333333
23	Stonehill Defender	3	1	4	1	0.5	1.166667
24	Stonehill Defender	3	1	4	1	0.5	1.166667
25	Fungalmancer	5	2	2	4	1	1.2
26	Fungalmancer	5	2	2	4	1	1.2
27	Corridor Creeper	7	2	5	5	1.5	1.214286
28	Corridor Creeper	7	2	5	5	1.5	1.214286
29	Stormwind Champion	7	6	6	2	1	1.142857
30	Naku the Mooneater	9	7	8	2	0.5	1.055556
Sum						28.5	49.42698

^means this card is a magical card

*means this card is a weapon card

4.2 The Balance Model in other TCGs

The balance model in this paper cannot directly be applied to other TCGs such as T*he Elder Scrolls: Legend* and *Shadowverse* because those are significantly different games in comparison to *Hearthstone*. However, it may be assumed that the same

Table 4 The total value of a Murloc Paladin deck

Number	Card's name	Magna crystal	Attack	hp	Keyword	value_1	value_2
1	Lost in the Jungle^	1	2	2	0	1	2
2	Lost in the Jungle^	1	2	2	0	1	2
3	Rightous Protector	1	1	1	2	2	3
4	Rightous Protector	1	1	1	2	2	3
5	Hydrologist	2	2	2	1	1	1.5
6	Hydrologist	2	2	2	1	1	1.5
7	Divine Favor^	3	0	0	3	0	1
8	Divine Favor^	3	0	0	3	0	1
9	Unidentified Maul*	3	2	2	1	0	1
10	Unidentified Maul*	3	2	2	1	0	1
11	Blessing of Kings^	4	4	4	0	0	1
12	Call to Arms^	5	0	0	4	−1	0.8
13	Call to Arms^	5	0	0	4	−1	0.8
14	Sunkeeper Tarim^	6	3	7	3	2	1.333333
15	Vincecleaver*	7	4	2	4	0	1
16	Murloc Tidercaller	1	1	2	1	1.5	2.5
17	Murloc Tidercaller	1	1	2	1	1.5	2.5
18	Knife Juggler	2	2	2	1	1	1.5
19	Knife Juggler	2	2	2	1	1	1.5
20	Rockpool Hunter	2	2	3	1	1.5	1.75
21	Rockpool Hunter	2	2	3	1	1.5	1.75
22	Coldlight seer	3	2	3	1	0.5	1.166667
23	Murloc Warleader	3	3	3	2	2	1.666667
24	Murloc Warleader	3	3	3	2	2	1.666667
25	Nightmare Amalgam	3	3	4	1	1.5	1.5
26	Nightmare Amalgam	3	3	4	1	1.5	1.5
27	Gentle Megasaur	4	5	4	2	2.5	1.625
28	Gentle Megasaur	4	5	4	2	2.5	1.625
29	Spellbreaker	4	4	3	2	1.5	1.375
30	Fungalmancer	5	2	2	4	1	1.2
Sum						31	46.75833

^means this card is a magical card

*means this card is a weapon card

assumption specified near the start of Sect. 3—that different classes in a TCG have the same competitiveness—applies to those TCGs. Balance models for other TCGs can be created by making adjustments to the eight functions proposed in the previous section.

For example, *The Elder Scrolls: Legend* also has a minion card with four major parts (mana costs, attack, keywords and health) and magic cards. As

Fig. 7 Samples of *The Elder Scrolls: Legend*'s card. The minion card (left) in *The Elder Scrolls: Legend* also has four parts: mana costs (on the top left); attack (middle left); health (middle right); keywords (in the middle). The magical card (right) has mana costs and keywords

Fig. 8 The magical card in *Shadowverse* (left) has a similar effect and mana costs compared with the *Hearthstone* (right) card

shown in Fig. 7, the minion card from *The Elder Scrolls: Legend* is almost the same as a minion card in *Hearthstone*. So it can be described using a BMV function. It is possible to change k^* in Function 2 to create a unique BMV function for describing a card in *The Elder Scrolls: Legend.*

Figures 7 and 8 shows the similarity among three different TCGs, all of which require the use of magical cards for destroying minions on the battlefield. These three cards have the same mana crystal costs and similar descriptions.

5 Conclusion

Hearthstone can be regarded as a game in which there exists a great degree of probability and arithmetical design. The BMV functions specified above can be applied to most cards in the game. It is essential for a TCG to be dictated by card-designing rules so that no cards become too ubiquitous in the environment.

The assumption that different classes in a TCG have the same competitiveness is not absolute; but if a TCG company expects its product to remain viable over many years, it is important to ensure that no card becomes too powerful. Some "out of model" designs are acceptable for a TCG for several reasons; but they cannot be used to strike a careful balance between different decks. This is akin to the "rock, paper, and scissor game": when there are only a few cards, it is easy to keep a good balance of card decks; but when the pool has more than 1000 cards, it becomes nearly impossible to consider all the situations in the environment. Developers of TCG games therefore should use balance models when designing new cards.

An individual player could apply the BMV functions in this paper for calculating a deck's value when building his/her own deck. Though the BMV functions cannot be used to measure certain cards with a high level of randomness to them, they can be used as a reference or a support tool for a deck builder: a player can calculate his/her deck's value first, and then compare it with a first-class deck on a relevant gaming website and begin to estimate his/her own deck's strength.

Compliance with Ethical Standards

Conflict of interest The author state that there is no conflict of interest regarding the publication of this paper.

References

Blizzard Entertainment. (2018). Hearthstone (official game site). https://us.battle.net/hearthstone/en/.

Bursztein, E. (2016). I am a legend: Hacking Hearthstone using statistical learning methods. In *2016 IEEE conference on computational intelligence and games (CIG)*, 20–23 September, 2016.

Grad, Ł. (2017). Helping AI to play hearthstone using neural networks. In *2017 federated conference on computer science and information systems (FedCSIS)*, 3–6 September, 2017.

Ham, E. (2010). Rarity and power: Balance in collectible object games. *Game Studies Journal*, *10*(1).

Stiegler, A., Dahal, K. P., Maucher, J., & Livingstone, D. (2018). Symbolic reasoning for Hearthstone. *IEEE Transactions on Games, 10*(2), 113–127.